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THE OCCURENCE OF R577X POLYMORPHISM OF *ACTN3* GENE IN A SELECTED GROUP OF ELITE FENCERS

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ABSTRACT

The presented study is focused at identifying the genetic predispositions for anaerobic performance in a group of elite fencers of the Czech Republic. Based on theoretical findings and previous studies, we assume that the identification of genetic coding can help revealing sport talents or recommend to a person interested in sport a suitable branch considering his qualifications. The study concentrates on the comparison of speed-strenght abilities determined by Wingate test performed in the Biomedical laboratory of FTVS at Charles University in Prague and specific speed tests for fencing with R577X polymorphism of *ACTN3* gene in elite fencers of the Czech Republic. By the analysis of buccal smear, we found that 80% of our sample of fencers contains in their genotype at least one R allele of the *ACTN3* gene of the R577X polymorphism and 27% of the whole are homozygotes with RR genotype.

Keywords: speed abilities; fencing; polymorphism R577X *ACTN3*; genetic predispositions; genotype

INTRODUCTION

Sport performance is a broad term covering many agents who are directly or indirectly participating in its level. Environmental factors, such as training and nutrition, are important for the development of the elite athlete, however these factors alone are not enough and most of us can never achieve an elite athlete status no matter how hard we try. Elite sport performance is a complex phenotype of physical capability defined by genetic potential (MacArthur & North, 2005). Phenotype of an individual, which may have a genetic basis for endurance skills, muscle strenght, physiological capacity to

repeat a series in high-intensity or ability of tendons and ligaments to withstand damage, provides us information important for the selection of sport branch (Lippi, Longo, & Maffulli, 2009). Current scientific information suggest that the genetic information in form of several genotypes is an inseparable part of influencing the sport level of every sportsman, and because motoric skills are determined to a greater or lesser extent genetically, it is necessary to take the new molecular genetic research into consideration and involve them in the well-established methods used for predicting of movement abilities (Měkota & Novosad, 2005). Genotype differences, i.e. changes in DNA, can affect a concrete protein function and thus positively or negatively influence some abilities of a given individual. Ahmetov et al. (2012a) in his study states that the most common types of polymorphism variant of DNA sequence are insertion or deletion (I/D) of individual nucleotides. Lippi, Longo, & Maffulli (2009) in their study states that the most commontypes of polymorphism are SNP's (single-nucleotide polymorphism).

Genetic differences can thus influence the amount and the structure of mRNA or protein and therefore may represent major share of genetic factors in the variability of human phenotype. Bouchard, Malina, & Pérussé (1997) in their publication mention another important role of nutritional genomics, in which the normal diet contains a number of bioactive substances which can activate or modulate the transcription of target genes through receptors or directly cause a change of chromatin structure. They represent the next possibility which could be used in the future supplement of the training plans, regeneration methods or convalescence therapies.

According to the existing body of knowledge, the best sportsmen of different specialisations have different share of fibers (Dovalil et al., 2009). The influence of genetic load for a specific physical performance is estimated around 40–50%. The anaerobic performance, in the form of short-term anaerobic action to 10 s, is estimated to be higher than 50% (Bouchard, Malina, & Pérusse, 1997). Měkota and Novosad (2005) reported that the strongest is genetically determined maximal anaerobic alactate performance, which is crucial for the realization of speed-strenght movements. The same argument is also supported by Grasgruber and Cacek (2008), who report as significantly genetically influenced components of sport performance the composition of muscle proteins, blood flow in heart and lungs, as well as the activity of of key enzymes participating in energy production. Havlíčková (2004) states that the speed capabilities are genetically influenced from 65–80%. The simple movement speed is affected the least and we can reach the greatest development of speed capabilities in our school age.

Fencing is a speed-strenght sport, whose energy coverage takes place mainly in the glycidic energy substrate zone. The maximum heart rate during the fight rises on the level of 70–90% of its maximum value. This discipline makes demands on the coordination abilities, dexterity and speed. The basic precondition of a successfull fencer is the prevalence of fast muscle fibers and therefore preconditions to speed abilities rather than endurance movement elements (Jirka, 1995). Factors that may affect the preconditions of the performance in fencing can be observed in the area of anaerobic metabolism measured by Wingate test. The important area for assumption of sport performance in fencing is the level of complex psychomotoric state, such as speed, accuracy and adaptability in motoric learning (Borysiuk & Waskiewicz, 2008). The duration of each fight is influenced by a number of interruptions caused by a referee, that can be used by the fencers as a resting

interval for recovery of the organism. Owing to this fact, the fencers can perform most of the actions which last on average 5–15 s (depending on the type of weapon), in high-intensity load (Lavoie, Léger, Pitre, & Marini, 1985).

Ahmetov, Vinogradova, and Wiliams (2012b) reported that the abilities to perform aerobic and anaerobic exercise differs significantly depending on the composition of muscle fibres. Muscle fibers are classified as type I and type II fibres with subgroups IIA and IIX (IIB). These fibre types differ in maximum shortening speed. Type I fibres show the slowest contractions but high fatigue resistance, and type II fibres, especially type IIX, show the fastest contractions, hence higher maximum shortening speed, larger cross-section area diameter but low fatigue resistance. That means that they can produce substantially greater maximum performance. The data based on metabolic profile of muscle fibers show that type I fibres are rich in oxidative enzymes and suitable for endurance performance. Type IIX fibres are rich in glycolitic enzymatic activity and are adjusted to short exploding high speed and performance. Type IIA fibres have middle activity of enzymatic function and are better adapted for medium anaerobic exercise. Melichna (2004) states that the degree of genetic interdependence limits the range of adaptive plasticity of a given character and thereby limits also the influence of sport training. The smaller the influence of the training is, the higher will be the value of heritability coeficient. This coeficient can be up to 99.6% for the percentage share of fast or slow muscle fibres. This is relatively high genetic interdependence of a character. Conversely metabolic potential of the muscles participating in releasing the energy for muscle function is apparently not unambigously geneticaly dependent.

A significant protein, which is present only in fast muscle fibres (fast twitch – FT fibres, or type IIA and IIX fibres), and to which this contribution is dedicated, is actin-binding protein (alpha-actinin-3 = *ACTN3*). *ACTN3* is always present among the best performative athletes-sprinters (Lippi, Longo, & Maffulli, 2009). Human sarcomeric α-actinin isoforms (α-actinin-2, α-actinin-3) contain a pedominant protein part of sarcomeric Z-line, where it produces a latticed structure, which binds together thin actin filaments and stabilizes muscle contractile apparatus (MacArthur & North, 2004). According to Sovičová (2010), the isoforms of α-actinin are divided into two groups based on the ability to bind calcium. Muscle α-actinins (*ACTN2*, *ACTN3*) are not dependent on calcium to bind aktin. Non-muscle isoforms (*ACTN1*, *ACTN4*) bind actin via calcium. The expression of *ACTN3* gene is limited to a subgroup of two fast muscle fibres. The change of the basis occurs in nucleotide 1747 in exon 16 of *ACTN3* gene, which results in the emergence of R577X polymorphism. Ahmetov et al. (2012) adds that 577X allele contains modified sequences, which can completely prevent the production of a functional protein α-aktinin-3. Sovičová (2010) further states that the presence of *ACTN3* has a beneficial effect on the function of skeletal muscles in creating strong contractions in high speed and thus provides evolutionary advantage in sprint disciplines. Ahmetov et al. (2012b) mention several studies which state that the *ACTN3* RR genotype is over-represented or that *ACTN3* XX genotype is under-represented in strenght and speed athletes compared with control group. Eyon et al. (2009) mention functional polymorphism, which was identified in *ACTN3* gene and can affect the speed performance. This polymorphism encodes the muscle isoform of alpha-actinin-3, which leads to the substitution of arginin (R) with premature stop-codon (X) at 577 amino acid. 577R allele and thus also 577RR genotype

from polymorphism *ACTN3* R577X was found in connection with the highest level of sprinters in wide selection of ethnic groups. Ahmetov et al. (2012a) reported that to date more than 20 genetic variants were connected with strenght and performance-related phenotypes, of which gene polymorphisms *ACE* (angiotensin-converting enzym), *ACTN3* and *PPARA* (peroxisome proliferator-activated receptor α) has been the most studied for for the time being. Our study is based on the knowledge of fencing and genetic encoding of speed abilities and thus we presuppose certain connection between genetic encoding of speed abilities, i.e. R allele *ACTN3* R577X gene polymorphism, and performed tests in a group of elite fencers.

PURPOSE

The aim of this work is to determine the occurence frequency of R577X gene polymorphism in the group of elite fencers and compare these results with applied tests.

METHODS

Fifteen elite and subelite fencers of the average age of 24.9 (± 6.6) participated in the research investigation. The criterion for the selection of the subjects was placing of the fencers in the first twenty percent of the total number of starters in current season 2011/2012. The subjects were instructed to perform all measured attempts at maximum possible speed. The measurement was conducted during May and June, which was the peak of the season.

The level of maximum anaerobic performance and general dispositions for speed were conducted by Wingate load test on MONARK (Sweden) bicycle ergometer in Biomedical laboratory of FTVS of Charles University (Prague). The test started after cca 5 minute warm-up without a load, when the subject reached above the level of 130 beats per minute. The value of heart frequency was monitored by sport-tester POLAR. The actual test was carried out for 30 s with cca 10% resistance of the actual body weight of each subject. Given the focus of our study, we used the maximum number of revolutions (RPT – number of revolutions per 30 s) and the maximum value of power (P_{max}) expressed in watts to compare the results from genetic inquiry.

Another method used was determination of the speed of extension at the elbow joint. The tested subjects had to hit as quickly as possible a hitting target, which was a part of the Fitrosword device for visual stimulus. The target was placed at a height of the tested person's breastbone (*processus xiphoideus os sternum*) in the guard position. After lightin up the red LED diodes, the guard of the used sword left (Uhlmann, Germany) the highly sensitive horizontal obstacle on which was the sword placed in the guard position. Software Sword evaluated the movement time of the hit alone, and thus we excluded the negative intervention of reaction time, which was not the subject of our investigation. The horizontal barrier was placed 125 cm from the target. For the direct hit inquiry we came out of the Wiliams and Walmsley study (2000). Fitrosword device was used again for detection of the lunge speed. In this case, we proceeded as in the previous experiment,

where we separated the reaction time from the overall response time. The lunge's movement distance was determined as the distance between the vertical axis intersecting the vertical line of the centre of the hitting target and the floor. From this point, we measured individual distance considering the height of each subject. The height of the tested person in centimetres was multiplied by 1.5 coeficient (Williams & Walmsley, 2000) and the resulting value was transferred to the floor.

To detect the strenght preconditions, we used digital dynamometer in Biomedical Laboratory of FTVS of Charles University, Prague. The tested subject was in the sitting position and the arm, which held the dynamometer, was freely lowered along the body to the ground. In this position, the test subjects performed three handgrips. The resulting values were averaged.

Another test used was specific shuttle test (Iglesias & Rodrigez, 2008; Tsolakis & Vagenas, 2010). The subjects were to move between two lines that were spaced 5 m, as quickly as possible using the advance and backward, so that the total distance of the shuttle test would be 30 m. The actual test was launched from the guard position on the baseline by START command. The test was terminated as soon as the subject overstepped the start line with his front leg and overcame the mentioned 30 m. The test was conducted three times, with a 30 minute rest interval. The average values of all three tests are shown in the results.

Molecular genetic analysis was performed with DNA samples obtained from epitelial mouth cells using the isolation kits provided by the commercial laboratories Genomac International, s. r. o. (Prague, CR). The smears were made by a special sterile brushes that were after the swabbing put into test tubes with lids. The obtained samples were thoroughly described and taken into the genetic laboratory. The genotypic analysis of R577X *ACTN3* was conducted the above mentioned laboratory.

RESULTS

The results of our study are presented below in Table 1. Due to a low number of tested individuals, we did not statisticaly analyze the results. The resulting values of single variables are always expressed in arithmetic average and standard deviation.

The Table 1 shows that R allele occurs 12× at the investigated group, of which 4× it is in a homozygotous form. The complete absence of the observed allele appeared only in 3 subjects. Certain connection was found between the relevant genotype and the direct lunge movement time, the maximum performance value in Wingate test (Pmax) and the number of revolutions in the maximum 30 second Wingate test (RPT). Subjects with RR genotype, i.e. homozygotes, had the best results in the above mentioned tests. Subjects with XX genotype had the weakest results and the subjects with RX genotype, i.e. heterozygotes, achieved a little weaker results than the individuals with RR genotype.

In the applied tests, in which we investigated lunge movement time, specific shuttle test and handgrip strenght, the resulting values did not meet our assumptions.

It is obvious from Table 1, that R allele, i.e. speed allele, occurs in 80% of monitored fencers.

Table 1. Identified variables in various tests

	Genotype	Subject	PČV [ms]	PČPB [ms]	SČT [s]	HG D [N]	RPT/30s	P_{max} [W]
ACTN3	XX	Subjekt 1	512	207	11.83	55.5	52	938
		Subjekt 2	540	213	10.81	55.1	53	1081
		Subjekt 3	580	197	11.48	46.1	47	749
		Diameter	**544**	**205.7**	**11.4**	**52.2**	**50.7**	**922.7**
		SD	**34.2**	**8.1**	**0.5**	**5.3**	**3.2**	**166.5**
	RX	Subjekt 4	528	178	11.85	41.7	51	876
		Subjekt 5	608	179	12.8	50.3	52	946
		Subjekt 6	453	192	12.51	46.8	45	828
		Subjekt 7	522	174	11.21	42.1	60	1015
		Subjekt 8	455	180	11.92	37.1	54	947
		Subjekt 9	508	141	11.25	41	53	948
		Subjekt 10	483	194	12.08	56.8	50	1115
		Subjekt 11	499	179	12.51	50.4	47	985
		Diameter	**507**	**177.1**	**12.0**	**45.8**	**51.5**	**957.5**
		SD	**49.5**	**16.2**	**0.6**	**6.5**	**4.6**	**86.7**
	RR	Subjekt 12	519	174	10.75	57.5	57	1107
		Subjekt 13	537	184	12.45	34	50	788
		Subjekt 14	552	185	11.85	57.2	50	1072
		Subjekt 15	552	142	11.12	56.1	50	1102
		Diameter	**540.0**	**171.3**	**11.5**	**51.2**	51.8	1017.3
		SD	**15.7**	**20.1**	**0.8**	**11.5**	**3.5**	**153.6**

Legend: PČV – lunge movement times; PČPB – direct lunge movement time; SČT – specific shuttle test; HG D – dominant limb handgrip; RPT/30 s – maximum number of revolutions in 30 s during Wingate testu; P_{max} – maximum value in Wingate test

DISCUSSION

The aim of our study was to determine the occurence frequency of the R577X polymorphism of *ACTN3* gene in a group of elite fencers and to compare these results with the tests used.

For the analysis of speed capabilities, we were looking for suitable tests that would bring specific physical skills and abilities closer to the laboratory conditions. For this reason, we chose a simple movement maneuver in the form of direct hit, lunge and specific shuttle test, in which we examined the movement time or duration of the activity. After the evaluation of the results we discovered that the easiest movement test in the form of direct hit was the most suitable for our research. For tests, such as specific shuttle test and movement time of the lunge, the skill level of tested people, which is associated with learned movement patterns, could have negatively affected the results.

Although fencing is a speed sport where an attack may last only a few seconds, some actions at a high intensity can sometimes during a fight last up to 30 s. These circumstances led us to use Wingate test in determining the performance level of fencers. We selected only the value of the maximum power (P_{max}) and the number of revolutions achieved in 30 s (RPT) from the obtained data.

Due to the fact that the fencers have a weapon in hand during the whole fight which weighs at the most 700 g, we also involved in our study the testing of hand grip strength (so-called handgrip). The results of this testing contained great differences, in which we found that subjects younger than 24 years had significantly lower values.

The results of our study also proved that individuals with XX genotype, i.e. without the presence of "speed allele" had worse values in some tests and in others excelled. We believe that further similar genetic investigations should be directed at a larger number of genes that affect athletic performance and try to give more complex overview of the possible linkages of certain genes and movement skills.

CONCLUSION

Fencing is a speed-strength sport that makes demands on coordination skills, dexterity and speed (Jirka, 1995). In the second half of the 20th century occurred, due to the existence of signaling devices which made decissions easier, an acceleration of the course of the fight. This put greater demands on speed and complex actions became redundant (Trohař, 1973). From this point of view, we decided to perform a study in which we tested 15 elite fencers in several speed tests and DNA tests, where we monitored the frequency of the R577X polymorphism of the *ACTN3* gene. After studying the relevant studies, we assumed that our selected group will have higher occurrence of R allele genotype (RR, RX).

The results of genetic investigations were compared with values from the speed-power tests. We concluded that the simple movement actions are more suitable for determination of the speed level than the complex actions, where the specific and longer-lasting training and final performance with individual skills of the tested individuals must precede.

By the analysis of buccal smear (Genomac International, s. r. o., Prague), we found that 80% of our sample of fencers contains in their genotype at least one R allele of the *ACTN3* gene of the R577X polymorphism and 27% of the whole are homozygotes with RR genotype. Only 20% of our sample has XX genotype. After the comparison with the performative tests, we found that the group with RR and RX genotype had better results than subjects with XX genotype in performative tests, such as the lunge movement time, maximum number of revolutions during Wingate test and the maximum power at Wingate test. In other tests, we found no association between the genotype and the results. We are aware of the low number of observed probands which should be extended in future studies. Yet it is clear from our study that R allele genotype supporting speed capabilities occurs in the group of elite fencers and in the next investigation we want to concentrate on the other possibilities of genetic encoding.

We believe that for the fencing performance are undoubtedly important speed abilities, whose usability during the game is complemented by a composition of other factors (technical, tactical, fitness, somatic, psychological, and so on), which are in mutual interaction (Barth & Beck, 2007; Roi & Bianchedi, 2008). For this reason it is necessary to monitor

the genetic predispositions in other components of sport performance and thus contribute towards the completion of the knowledge of genetic encoding of movement skills.

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REFERENCES

AHMETOV, I. I., GAVRILOV, D. N., ASTRANENKOVA, I. V., et al. (2012a). The association of ACE, ACTN3 and PPARA gene variants with strength phenotypes in middle school-age children. *The journal of physiological sciences* 63(1), 79–85.

AHMETOV, I. I., VINOGRADOVA, O. L., WILLIAMS, A. G. (2012b). Gene polymorphisms and fiber-type composition of human skeletal muscle. *International journal of sport nutrition and Exercise metabolism* 22, 292–303.

BARTH, B., BECK, E. (2007). *The complete guide to fencing*. Oxford: Meyer and Meyer sport (UK).

BORYSIUK, Z., WASKIEWICZ, Z. (2008). Information processes, stimulation and perceptual training in fencing. *Journal of Human Kinetics* 19, 63–82.

BOUCHARD, C. (1997). *Genetics of fitness and physical performance*. Champaign: Human Kinetics.

DOVALIL, J., et al. (2009). *Výkon a trénink ve sportu*. Praha: Olympia.

EYON, N., ALVES, A. J., YAMIN, C., et al. (2009). Is There ab ACE ID – ACTN3 R577X Polymorphisms Interaction that Influences Sprint Performance? *Genetics & Molecular biology* 30, 888–891.

HAVLÍČKOVÁ, L., BARTŮŇKOVÁ, S., DLOUHÁ, R., et al. (2004). *Fyziologie tělesné zátěže I. Obecná část.* Praha: Karolinum.

IGLESIAS, X., RODRIGUEZ, F. A. (2008). *Physiological testing and bioenergetics in fencing.* Presented at 1st International congress on science and technology in fencing, Barcelona.

JIRKA, Z. (1995). Šerm. In J. Melichna, et al. *Fyziologie tělesné zátěže II. Speciální část – 2. díl.* Praha: Karolinum.

LIPPI, G., LONGO, U. G., MAFFULI, N. (2009). Genetics and sports. *British medical bulletin* 93, 27–47.

MACARTHUR, D. G., NORTH, K. N. (2004). A gene for speed? The evolution and function of α-actinin-3. *BioEssays* 26, 786–795.

MACARTHUR, D. G., NORTH, K. N. (2005). Genes and human elite athletic performance. *Human Genetics* 116, 331–339.

MELICHNA, J. (2004). *Aktivní a pasivní pohybový systém.* In L. Havlíčková et al. *Fyziologie tělesné zátěže I. Obecná část.* Praha: Karolinum.

MĚKOTA, K., NOVOSAD, J. (2005). *Motorické schopnosti*. Olomouc: FTK UP Olomouc.

ROI, G. S., BIANCHEDI, D. (2008). The science of fencing: implications for performance and injury prevention. *Sports medicine* 38(6), 465–485.

SOVIČOVÁ, A., BERNASOVSKÁ, J., BERNASOVSKÝ, I., et al. (2010). *Výskyt polymorfizmu r557x ACTN3 génu vo vybraných skupinách športovcov.* In T. Perič et al. *Identifikace sportovních talentů.* Praha: Karolinum.

TROHAŘ, R. (1973). *Základy šermu.* Praha: Olympia.

TSOLAKIS, CH., VAGENAS, G. (2010). Anthropometric, physiological and performance characteristics of elite and sub-elite fencers. *Journal of human kinetics* 23, 89–95.

WILLIAMS, L. R. T., WALMSLEY, A. (2000). Response timing and muscular coordination in fencing: a comparison of elite and novice fencers. *Journal of science medicine in sports* 3(4), 460–475.

YANG, N., MACARTHUR, D. G., GULBIN, J. P., et al. (2003). *ACTN3* genotype is associated with human elite athletic performance. *The American society of human gentics,73*, 267–631.

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EFFECT OF SHORT-TERM BALANCE TRAINING ON POSTURAL STABILITY IN ICE HOCKEY PLAYERS

PAVOL ČECH

ABSTRACT

Postural stability is one of latent factors affecting game performance of an individual to a certain extent. The presented study deals with monitoring changes of postural stability in ice hockey players after eight week's balance training.

The screened sample consisted of junior category ice hockey players divided into experimental (n = 8) and reference groups (n = 8).

Postural stability was measured using a stabilographic method on the AMTI AccuSwayPLUS force platform. The level of postural stability was assessed in three tests, namely bipedal stance with and without sight control and bipedal stance with reduced proprioception using the parameters of 95% confidence ellipse, path of CoP and mean velocity of CoP.

The level of monitored stability parameters did not indicate any significant differences between the groups in any of the tests at the level of significance $\alpha = 0.05$. Comparing postural stability of the experimental group between pre-test and post-test showed significant differences in the test without sight control and the test with reduced proprioception in l_{CoP} and v_{CoP} parameters ($Z = 2.1004$; $\alpha < 0.05$). Regarding the reference group, no significant changes of the level of postural stability between the pre-test and post-test were found in any of the parameters ($Z = 0.3652$ to 1.8257; $\alpha > 0.05$).

Keywords: sport training; balance exercises; posturography; AMTi; CoP

INTRODUCTION

Ice hockey is a fast, dynamic and invasive sport with a broad membership base. Sport performance in ice hockey consists of complex playing and skating skills. Skating in ice hockey is a complex motor skill (Bracko, 2004) and professional coaches, general managers and scouts consider skating skills a significant factor for selection of players for the team (Hansen & Reed, 1979). Skating is characterised by acyclic movement structure which consists of artificial movements (Pavliš & Perič, 2003) in terms of the structure of basic locomotion.

The level of skating skills is determined by mastering skating techniques and the level of stability. Skating in ice hockey is an automatized, subconscious process while consciousness is more involved in searching and assessing an optimal solution of the incurred playing situation. Practising skating technique is a domain of training process starting with children's categories; Pavliš & Perič (2003) suggest that it should account for up to 80% of training time; however, it also is necessary to develop skating technique in further stages of the training process, as well.

The basis of each movement is maintaining posture which the movement stems from (Trew & Everett, 1997; Véle, 1997). Figure skating and ice hockey belong to sports, in which the biomechanic stability required to maintain balance is limited by narrow base of support (Zemková, 2011). In addition, Braco (2004) points out the complexity of ice hockey in terms of high demands on coordination and repeated muscle load with a short rest interval. A narrow blade also causes strenuous eccentric muscle work and proprioceptive control in order to maintain stability (Humble, 2003; Li, 2007).

Equilibrium, postural stability and balance have not been clearly defined yet. A number of ambiguities are connected not only with terminological models but also with diagnostic methods, instrumentation capabilities, data processing and interpretation of results (Čech & Junger, 2012). Balance is often taken for granted and its importance is overlooked, even though it is one of the most important aspects in ice hockey (Stamm, 2001). Available literature provides only limited information on the effect of exercises on dynamic stability (Zemková, 2011) or the effect of balance exercises on motor skills of athletes (Hrysomallis, 2011). Therefore, we believe it is important to deal with the issue of increasing the level of postural stability in the process of sport training outside the ice rink. More and more coaches discuss the possibilities of strengthening deep stabilization and postural systems using balance exercises performed with one's own body weight or with the use of external supplementary resistance. However, in ice hockey theory, we may see a deficit of knowledge in the field of training process.

PURPOSE

The purpose of this study was to assess the effect of eight-week's exercise programme on the level of postural stability in ice hockey players.

METHODS

A total of 40 junior category ice hockey players participated in this research. However, the presented results includes only 16 players as the other players did not complete all measurements due to various reasons (transfer to another club or to another age category, sickness at the time of output measurements).

The research was carried out on a sample of players from HC Košice who won the title of Master of the Slovak Republic in their age category in the previous competitive season. The results of the research are related to performance of the players (n = 16) who completed both input and output measurements. Before exposure to the assigned stimulation,

players were divided in experimental and control groups S1 and S2 according to the head coach's instructions. At the time of the initial measurement, the decimal age of S1 group (n = 8) was 15.8 ± 0.6 years (x ± s), and S2 (n = 8) 15.7 ± 0.4 years. Basic somatic characteristics of both groups are listed in Table 1.

Table 1. Basic somatic characteristics of the screened sample

	Experimental group				Control group			
	Age	**Body weight**	**Body height**	**BMI**	**Age**	**Body weight**	**Body height**	**BMI**
$\bar{x}$	15.8	68.1	177.9	21.5	15.7	70.0	180.5	21.5
S	0.6	4.8	3.8	1.6	0.4	6.6	5.6	1.1

Legend: $\bar{x}$ – mean; s – standard deviation; BMI – body mass index

In terms of the phases of the annual training cycle, research was carried out in the period of intensive fitness training outside the rink. An independent variable affecting postural stability was an exercise programme consisting of dynamic power exercises especially with the use of unstable surfaces (bosu, balance boards, balance pads, overballs, expanders, medicine balls). The exercise programme was completed only by players from the experimental group (S1). Exercises on unstable surfaces represented 20% of net workout time of two training sessions in a week under the guidance of a fitness coach. Participants performed different exercises each week. The members of the control group (S2) practised traditional methods commonly used in the club. Traditional training sessions included exercises in a gym, fitness workouts (spinning, running, inline skating), obstacle courses and imitation hockey exercises.

To assess postural stability, we used a posturography method of measurement on a force platform. Each of the players, regardless of the group which he belonged to, completed three tests of postural stability marked as T1, T2 and T3 in input and output diagnostics. T1 measurement consisted of a bipedal stance with feet together on the force platform with sight control; in T2 participants performed a bipedal stance with the feet as wide as the pelvis with elimination of visual analyser and in T3 a bipedal stance with the feet as wide as the pelvis with reduction of proprioceptive perception and with a sight control (stance on a 10 cm high foam surface). During measurements with sight control (T1 and T3), participants concentrated on a selected visual point located on the wall at the level of their eyes at a distance of four meters. Each of these measurements lasted for 30 seconds and the tested subjects performed them in a row with a rest interval necessary for changing position or preparation of changed conditions, respectively. The level of postural stability was assessed on the basis of parameters related to the Centre of Pressure (CoP). The participants' CoP was measured on AMTI's AccuSwayPLUS force platform (© Advanced Mechanical Technology, Inc., 2002). Digital output from the platform was recorded by AMTI's NetForce software, the recording frequency of which is 50 Hz. The software for identification of CoP location uses algorithms from the related variables, i.e. parameters of forces acting on the platform (Fx, Fy, Fz) and moments of these forces (Mx, My, Mz). The recording was further processed by means of BioAnalysis software which provides not only digital outputs in the form of statistics but also 14 graphical outputs.

To analyse the effect of the intervention programme, out of the spectrum of parameters we selected three basic parameters which characterise the movement of CoP during the measurements; namely path of CoP (l_{CoP}), mean velocity of CoP (v_{CoP}) a 95% confidence elipse ($EA_{95\%}$).

Individual performances of participants from S1 and S2 groups were further processed using both quantitative and qualitative procedures. Data were processed using methods of mathematical statistics in the Statistica 10 programme. From the perspective of the nature of data (low number of subjects, normality of data distribution), for statistical evaluation we selected the median (ME) from the measurements of central tendency and interquartile range (IQR) and quartile deviation (QD) from the measurements of variability. To monitor the effect of intervention on the level of postural stability parameters we used non-parametric methods of mathematical statistics. In the case of evaluation of the statistical significance of differences between S1 and S2 groups we used the Mann-Whitney U test for independent samples. To assess the significance of differences in the level of postural stability between pre-test and post-test within individual groups the Wilcoxon test for dependent samples was used. Subsequently, the results were evaluated at the level of significance $\alpha = 0.05$.

RESULTS AND DISCUSSION

A number of studies dealing with sport performance and training in ice hockey have been published. However, most of them focus on biomechanical parameters of skating (Braco, 2004; Humble, 2003; Maclean, 2012), kinematic analysis (Marino & Drouin, 2000; Upjohn et al., 2008; Stidwill, 2009) or sport performance (Brocherie et al., 2005; E. Maclean, 2012). There is a deficit of knowledge in the field of development of stability in ice hockey even though Zemková (2011) states that fast adaptation of stability in and after sport performance is considered an important skill in sport practice.

Table 2. Descriptive statistics of stability parameters of S1 group (n = 8)

		T1			T2			T3		
		ME	**IQR**	**QD**	**ME**	**IQR**	**QD**	**ME**	**IQR**	**QD**
$EA_{95\%}$	**Pre-test**	0.968	0.937	0.487	2.987	3.712	1.856	2.488	4.038	2.019
	Post-test	0.913	0.281	0.141	2.750	1.322	0.661	2.326	1.218	0.609
v_{CoP}	**Pre-test**	0.950	0.152	0.076	2.917	0.367	0.184	3.146	0.987	0.494
	Post-test	0.921	0.212	0.106	2.671	0.594	0.297	2.942	0.846	0.423
l_{CoP}	**Pre-test**	28.500	4.559	2.280	174.990	22.019	11.010	188.780	59.217	29.608
	Post-test	27.630	6.377	3.188	160.240	35.598	17.799	176.480	50.760	25.380

Legend: T1 – bipedal stance with feet together with sight control; T2 – bipedal stance with the feet as wide as the pelvis without sight control; T3 – a bipedal stance with the feet as wide as the pelvis with reduction of proprioceptive perception; ME – median; IQR – interquartile range; QD – quartile deviation; $EA_{95\%}$ – 95% confidence ellipse; v_{CoP} – mean velocity of CoP; l_{CoP} = path of CoP

Table 3. Descriptive statistics of stability parameters of S2 group (n = 8)

		T1			T2			T3		
		ME	IQR	QD	ME	IQR	QD	ME	IQR	QD
$EA_{95\%}$	Pre-test	1.154	0.844	0.422	2.701	2.472	1.236	2.908	2.339	1.170
	Post-test	0.916	0.457	0.229	2.033	0.354	0.177	2.386	1.218	0.434
v_{CoP}	Pre-test	0.898	0.168	0.084	2.850	0.299	0.149	3.109	0.703	0.352
	Post-test	0.807	0.235	0.118	2.336	0.677	0.339	2.232	0.846	0.241
l_{CoP}	Pre-test	26.913	5.017	2.510	170.970	17.907	8.953	186.540	42.191	21.906
	Post-test	24.197	7.064	3.532	140.060	40.637	20.319	133.910	50.760	14.440

Legend: T1 – bipedal stance with feet together with sight control; T2 – bipedal stance with the feet as wide as the pelvis without sight control; T3 – a bipedal stance with the feet as wide as the pelvis with reduction of proprioceptive perception; ME – median; IQR – interquartile range; QD – quartile deviation; $EA_{95\%}$ – 95% confidence ellipse; v_{CoP} – mean velocity of CoP; l_{CoP} = path of CoP

Table 2 and Table 3 present results of descriptive statistics of the selected parameters characterising postural stability of experimental and control groups. On the basis of these results we can state that the monitored stability parameters improved in both experimental (S1) and reference group (S2) during the training process.

Considerable improvement in stability, in terms of middle values, was recorded in members of the control group (S2). These findings indicate the uselessness of implementation of a short-term balance exercise programme in the sports training of young hockey players. On the other hand, Braco (2004) mentions that if we want to prepare an effective training programme, players should be confronted with such conditions which control their movement during a game, e.g. to include enhancing exercises for stick work technique in the balance exercises as it was in our case.

Analysis of results characterising variability of the measured data (QD, IQR) in l_{CoP} and v_{CoP} parameters indicate that in the case of the reference group (S2) we recorded higher values than in the experimental group. Therefore, we believe that the achieved middle value of ME in the S2 group could have been partially influenced by the extreme performance of participants in terms of greater heterogeneity of performance in post-test measurement or skewness of the measured data distribution (data not published), respectively.

Véle (1997) mentions that exclusion of one of the three main components (visual, vestibular and proprioceptive) providing afferent information on stability for regulatory organs should not be reflected in deterioration of stability. However, research studies confirm crucial importance of proprioception for regulation of stability (Le, 2007), which is in accordance with the results of our study. In the measurement with reduced proprioception perception (T3) we recorded the highest middle values in comparison to other tests, which means deterioration of postural stability.

Table 4. Comparison of the level of postural stability parameters recorded before and after intervention (Wilcoxon test)

	S1					
	T1		T2		T3	
	T	Z	T	Z	T	Z
$EA_{95\%}$	13.0	0.7001	10.0	1.1202	13.0	0.7001
v_{CoP}	14.0	0.5601	3.0	2.1004*	3.0	2.1004*
l_{CoP}	14.0	0.5601	3.0	2.1004*	3.0	2.1004*
	S2					
$EA_{95\%}$	1.0	1.4606	4.0	0.3652	1.0	1.4606
v_{CoP}	4.0	0.3652	1.0	1.4606	0.0	1.8257
l_{CoP}	4.0	0.3652	1.0	1.4606	0.0	1.8257

Legend: T1 – bipedal stance with feet together with sight control; T2 – bipedal stance with the feet as wide as the pelvis without sight control; T3 – a bipedal stance with the feet as wide as the pelvis with reduction of proprioceptive perception; T – Student's T-score; Z – Z-score; $EA_{95\%}$ – 95% confidence ellipse; v_{CoP} – mean velocity of CoP; l_{CoP} – path of CoP; *$p < 0.05$.

Based on results in Table 4, we can conclude that in the case of the control group we did not find any statistically significant changes in the level of the monitored parameters of postural stability between input and output measurements in any of the tests. Statistical analysis further indicated a positive effect of the training process on the performance of participants from the experimental group when in T2 and T3 tests we recorded significant differences in the level of path of CoP (l_{CoP}) and mean velocity of CoP (v_{CoP}). Concerning the third examined parameter $EA_{95\%}$, no significant changes between input and output measurements were recorded. We suppose it can be caused by a high level already achieved in the input measurement (ME T2 = 2.98 cm^2; ME T3 – 2.48 cm^2), which participants managed to slightly improve in the output measurement (ME T2 = 2.75 cm^2; ME T3 – 2.32 cm^2). In T1 no significant changes in the examined parameters of postural stability were found. We think that the reason could be in inadequacy of the motor test.

Table 5 provides the results of statistical significance of differences in the level of postural stability between performances of the experimental and control group. In any of the compared data pairs we did not record significant differences at the level of significance $\alpha = 0.05$.

Based on the structure of the training process which participants completed there are several aspects which could have caused the obtained results. The first is inclusion of imitation skating exercises and obstacle courses in the usually used training model. These methods impose substantial requirements on agility and coordination abilities of athletes which can positively influence stability of the stance.

Table 5. Comparison of the level of postural stability parameters between S1 and S2 groups in input and output measurements (Mann-Whitney U test)

	S1					
	T1		T2		T3	
	T	Z	T	Z	T	Z
$EA_{95\%}$	22.0	0.194	24.0	–0.065	23.0	–0.065
v_{CoP}	18.0	0.711	18.0	0.711	19.0	0.581
l_{CoP}	18.0	0.711	18.0	0.711	19.0	0.581
	S2					
$EA_{95\%}$	1.0	1.461	4.0	0.365	1.0	1.461
v_{CoP}	4.0	0.365	1.0	1.461	0.0	1.826
l_{CoP}	4.0	0.365	1.0	1.461	0.0	1.826

Legend: T1 – bipedal stance with feet together with sight control; T2 – bipedal stance with the feet as wide as the pelvis without sight control; T3 – a bipedal stance with the feet as wide as the pelvis with reduction of proprioceptive perception; T – Student's T-score; Z – Z-score; $EA_{95\%}$ – 95% confidence ellipse; v_{CoP} – mean velocity of CoP; l_{CoP} – path of CoP

Moreover, especially in that period, training sessions focused on development of strength abilities of all muscle groups were applied. Development of strength abilities is, particularly in the older population, considered a suitable means for positively influencing the level of postural stability.

The training programme was applied during eight weeks in the period of intensive fitness preparation when the players performed two-phase training load in 8–12 training sessions during a weekly micro-cycle. The intervention programme made up only 20% of two training sessions. Therefore it is possible that the effect of balance exercises could have been partially affected by inhibited endogenous and exogenous changes caused by other forms of the load applied. Similarly, the length of intervention in the experimental group could be another reason why exercises were not reflected in greater measure. However, authors are not consistent in the opinion on the time interval required to make the independent variable reflect in the improvement of the level of the observed parameters. Zemková (2011) in her meta-analytic study described the usage of 3, 4, 8 and 12 week intervention programmes focused on the development of postural stability.

CONCLUSION

The presented study does not have a character of generalised results as basic requirements for randomness and representativeness of the research group and its size were not met. However, we believe that the results will contribute to enrichment of knowledge in the field of ice hockey and that they will also be usable for sport practice.

Based on the above described results we can state that:

– no statistically significant difference in the level of postural stability between the experimental and control group was found in any of the measurements,

– in the case of the experimental group, after intervention, statistically significant differences in the level of parameters indicating the level of postural stability were observed between the test without sight control and the test with reduced proprioception,
– in the control group, no significant changes in the level of postural stability between pre-test and post-test were detected,
– the performed balance exercises had a positive impact on homogeneity of results of the experimental group.

Ice hockey is a fast, popular sport, performance in which is determined by a number of manifestation and latent variables. Postural stability as one of the main latent variables is thus an important factor influencing not only skating technique; therefore it can also influence individual playing performance to a certain extent. This is the reason why we believe that inclusion of balance exercises in the training process is more than desirable. We do not state that a high level of postural stability is the only crucial factor in the level of player's performance. However, further research in the form of relationship analyses between this latent variable and skating technique or skating speed would certainly enrich not only the theoretical part of science but practice as well.

REFERENCES

Advanced Mechanical Technology Inc. (2002). *AccuSway Plus System Validation*. PA: Watertown.

BRACKO, M. R. (2004). Biomechanics powers ice hockey performance. *Biomechanics* 11(9), 1–7.

BROCHERIE, F., BABAULT, N., COMETTI, G., et al. (2005). Electrostimulation training effects on the physical performance of ice hockey players. *Medicine and science in sports and exercise* 37(3), 455–460.

ČECH, P., JUNGER, L. (2012). Úroveň posturálnej stability v dôsledku zmeny pozície v stoji. In J. Suchý et al. 2012. *SCIENCIA MOVENS sborník příspěvků z mezinárodní studentské konference.* Praha: FTVS UK.

HANSEN, H., REED, A. (1979). Functions and on-ice competencies of a high caliber hockey player – a job analysis. In J. Terauds, H. J. Gros (eds.). *Science in skiing, skating, and hockey. Proceedings of the International Symposium of Biomechanics in Sports.* Del Mar, CA: Academic Publishers, 107–115.

HRYSOMALLIS, C. (2011). Balance ability and athletic performance. *Sport medicine* 41(3), 221–232.

HUMBLE, N. (2003). *Podiatric management in Ice skating*. Retrieved from http://www.podiatrym.com/.

LI, J. X. (2007). *Can proprioreception be improved by exercise?* XXV ISBS Symposium. Brazil: Ouro Preto.

MACLEAN, C. (n. d.). *Biomechanics of ice hockey skating*. Retrieved from http://parispedorthic.com.

MACLEAN, E. (n. d.). *A Theoretical review of the physiological demands of ice-hockey and a full year periodized sport specific conditioning program for the canadian junior hockey player.* Retrieved from http://performancetrainingsystems.net.

MARINO, G. W., DROUIN, D. (2000). Effects of fatigue on forward, maximum velocity in ice hockey skating. *XVIII ISBS Symposium*. China: Hong Kong.

PAVLIŠ, Z., PERIČ, T. (2003). *Abeceda hokejového bruslení*. Praha: Český svaz ledního hokeje.

STAMM, L. (2001). *Laura Stamm's power skating* (3rd ed.). Human Kinetics: Champign.

STIDWILL, T. J. L. (2009). *Comparison of forward hockey skating kinetics and kinematics on ice and on a synthetic surface by means of a customized force measurement system and electrogoniometry*. Kanada: Quebec.

TREW, M., EVERETT, T. (1997). *Human movement, an introductory text* (3rd ed.). New York: Churchil Livingstone.

UPJOHN, T., TURCOTTE, R., PEARSALL, D. J., LOH, J. (2008). Three-dimensional kinematics of the lower limbs during forward ice hockey skating. *Sports Biomechanics* 7(2), 206–221.

VÉLE, F. (1997). *Kineziologie pro klinickou praxi*. Praha: Grada Publishing.

ZEMKOVÁ, E. (2011). Assessment of balance in sport: science and reality. *Serbian Journal of Sports Sciences* 5(4), 127–139

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HERALD OF NEW, HEALTHIER MODE OF LIFE (ACADEMIZATION OF PHYSICAL EDUCATION AND FORMATION OF THE FACULTY OF SPORT IN SLOVENIA)

TOMAŽ PAVLIN, MILAN ŽVAN

ABSTRACT

In the period between the two World Wars, physical education became an important educational sphere in Yugoslavia and Slovenia. At the same time, the process of giving the educational sphere a Slovene character has to be emphasized, which was ensued by the establishment of a new Southern Slav state. In this process, physical education was professionally influenced by Sokol gym and Sokol education. At the same time, the Sokol started the process of the formation of a state regulated short-cycle college of physical education. Behind the action were demands for professional teachers and coaches. The process culminated after the Second World War with the establishment of the Institute of Physical Education in Ljubljana (1953). The Institute adopted Sokol gym as a basic physical activity but it was soon reorganized and renamed 3-year Short-cycle College of Physical Education and finally in 1960, 4-year College of Physical Culture, which was the beginning of the present Faculty of Sport.

This paper discusses the historical progression of physical education to academic science on the basis of the development of the Faculty of Sport and on the basis of available historical primary sources and professional texts.

Keywords: physical education; Sokol; gym; gym courses; short-cycle college; faculty; Slovenia

INTRODUCTION

In practice, the question of the profession and staff arose when physical exercises and gym/gymnastics and later physical education was introduced as a regular subject to the school curriculum in the Austrian part of Austria-Hungary (1869) and when gymnastic societies (first in Slovenia Južni Sokol / South Sokol, 1863) and sports activities in clubs became more and more popular in the second half of the 19th century. The problem was solved by organizing professional and specialist courses, which resulted in setting up short-cycle college study programmes and college study programmes of physical

education. This article describes the process of the establishment of the College of Physical Culture, a predecessor of the present Faculty of Sport of the University of Ljubljana, and the professional contribution of the Sokol movement in the period between both World Wars.

METHODS

The article is historiographic and a historical method of the analysis of primary and secondary sources and interpretation are used.

DISCUSSION

The discussion will focus on three complete chronological periods which are established in historiography and which marked a political and cultural development and consequently also the development of physical culture. These are the Austrian period ending in 1914, the period of old Yugoslavia between 1918 and 1941 and the period of new Yugoslavia after 1945.

Physical activity as school and club activity

In the Austrian period, physical activity was introduced as a compulsory school subject and at national level, a civil society gym movement was organized. In 1869, a school act was passed regulating primary schools and introducing a new curriculum with gym (2 lessons), what later extended also into secondary schools – first into natural science secondary schools and teacher training secondary schools (1870) and finally into grammar schools, where gym was optional at first and became obligatory in the 1909/10 school year. Gym lessons aimed at hygiene and education, enhancing health, strengthening the body, mental fitness as well as building up strength, will and endurance. Legal measures raised a question of a new profession: gym teacher (Turnlehrer). According to the decree of the Ministry of Education (1870), the candidates who wanted to get qualifications in gym or physical education had to pass an exam in front of the commission appointed for this purpose. In 1871, the first professional two-year course was organized in Vienna followed by a theoretical and practical exam. A similar commission and later educational course at university was also established in Graz, in Styria. At the same time, Graz was the academic educational centre nearest to the present-day territory of Slovenia[1]. Many Slovenes from different parts of present-day Slovenia enrolled on the courses. Ulaga and Bergant mention there were 49 candidates in the period between 1875 and 1914; among those who finished the course in Vienna is also Franc Brunet, who taught gym in Ljubljana and published an influential reference book in Slovene entitled *Telovadba v petrazrednih in manj kot petrazrednih ljudskih šolah* (Gym in elementary schools with

[1] The National university was established in Ljubljana after the First World War.

five classes and with fewer than five classes, in 1900; reprint in 1907) (Okoliš, 2009; Stepišnik, 1974; Ulaga & Bergant-Knez, 1992).

As early as the middle of the 19th century, amateur physical activity or gymnastics was spread throughout the bourgeoisie. On the territory of present-day Slovenia[2], two gym societies, i.e., the German Turnverein and the Slovene Južni Sokol, were established in 1862 and 1863 respectively. In the period before the First World War, a mass national and liberal Sokol movement was set up. In Slovene society, the Sokol clubs brought about a new profession, which was spread and developed with the help of publications and courses for instructors. The first professional work *Nauk o telovadbi* (Science of gym) was published as early as 1867 and 1869, but for Sokol professional development, courses for instructors organized by Viktor Murnik after 1896 were of outmost importance. They were based on Tyrš's Sokol system, which became the basis of work in clubs and professional work as well as the basis of contacts with Sokol movements in other countries. Tyrš's system was also adopted by Croats and Serbs and was presented in Montenegro in the late 1910s. As a sign of re-Catholization, the catholic Orel movement was established at the end of the 19th century. Orel, however, was also professionally based on Sokol's profession (Pavlin, 2008).

Sokol character in physical education

At the end of the First World War, Southern Slavs established the Kingdom of Serbs, Croats and Slovenes (from 1929 on, the Kingdom of Yugoslavia), which introduced two physical education lessons in schools. Schools on the territory of present-day Slovenia took on a Slovene character, which was of great importance from the national and cultural point of view (Dolenc, 1996). In the process of giving physical education in schools a Slovene as well as a Yugoslav character, the Sokol movement played the most important professional role. In the middle of 1919, Slovene, Croatian and Serbian Sokols merged into a uniform Yugoslav Sokol organization. The founding general meeting discussed the connection with the school system and laid down a principle called "Sokol and schools" emphasizing the fact that the Sokol and school should be connected reciprocally. As they stressed, the Sokol movement had had a nation-forming task for over 50 years and in the new state, it should therefore penetrate all national schools, secondary moderns, secondary schools and other schools with its spirit and take over physical education in schools. The Sokol movement should play a leading professional role in resolving issues concerning physical education as well as within the framework of the authority structures from the lowest to the highest ones at ministry or government level. The Sokol declaration was taken into account since in January 1920, the government ordered that school gym should be carried out in accordance with the Sokol system. By coming into schools and by introducing Sokol gym and national education, Sokols were – in the catholic part of the country[3] – confronted with the traditional educator, i.e., the Catholic Church, and its intention to use the principles of the catholic Orel in this part of education. This led to an

[2] The lands within Austria with a predominantly Slovene population were: Carniola, southern Carinthia, southern Styria, Görz region, Trieste region with the Karst and northern Istria (or also the Littoral).

[3] Slovenia, Croatia and part of Bosnia and Herzegovina.

eruption of the cultural fight between the Sokol and Orel movements which had a political liberal and catholic background (Dolenc, 1996; Pavlin, 2009).

The Sokols also took care of the professional basis and their 1921 general meeting made an appeal to the Ministry of Education for organizing courses for gym teachers and for employing gym teachers trained according to Sokol principles in all teacher secondary training schools in the country. They also made an appeal to the authorities for special supervisors for physical education. They also proposed that a department of physical education should be established in at least one faculty of arts – in cooperation with the faculty of medicine; lecturers should be established Sokol experts. The Ministry of Health should award grants to young doctors skilled at physical exercises who could specialize as physiologists and develop the physiology of physical education. However, the demands were too radical for new authorities and in practice, the education of staff was based on Sokol professional courses (in Ljubljana, a one-month training course for Sokol instructors was organized as early as autumn 1919; it consisted of 10 lessons every day covering theoretical and practical aspects) which were also recognized in schools as appropriate for teaching physical education. At the end of November 1920, Yugoslav Sokols met with the Czechoslovak Sokols in Ljubljana to establish the Association of Czechoslovak and Yugoslav Sokol Movement. In the declaration, they stressed that one of the central points of Sokol work was a physical rebirth of a nation and education of young generations, that is why both Sokol organizations demanded that the states should pay attention to these issues and they would help them. They also stressed the fact that among the goals of this Association are the commitment to reforming schools and army according to Sokol principles, an obligatory law on physical education of all citizens and the establishment of a college of physical education either in Czechoslovakia or in the Kingdom of Serbs, Croats and Slovenes. Actually, a six-month Sokol school was organized in Prague in the late 1920s where also Yugoslav Sokols were trained. This training, however, was carried out primarily in a civil society manner. On the basis of Sokols' initiatives, the Yugoslav state got involved in solving the problems regarding professionalism in physical education in the late 1920s. In June 1927, it introduced a one-year course in physical education for physical education teachers in secondary schools. At the same time, Sokols emphasized that physical education teachers and professionals in the field of civil physical education should study for two years either at university or teacher training short-cycle college until a suitable short-cycle college of physical education was established (Pavlin, 2009).

Short-cycle College

On 6 January 1929, King Alexander established a dictatorship and dissolved the parliament and national and ideological political parties in order to calm a tense political situation in the country. The Yugoslav Sokols met with King Alexander in March 1929 and prepared a memorandum with a law draft dealing with school youth physical education and a law draft concerning a physical education military school, which would mean that Sokol physical education extended to include the military. They emphasized the general need for physical education and claimed that history taught us that great cultures prospered as long as physical education was a component part of general education. If a country wants to popularize physical education among all strata of the nation, it must

take care primarily of professionalism and suitable infrastructure in schools and in the army as well as of material and moral support of the Sokol movement, which promotes physical education in the civil sphere. The memorandum included a plan for a three-year study programme comprising six semesters and 108 theoretical and practical lessons. The curriculum included 22 theoretical and practical subjects[4] (Memorandum, 1929). At the beginning of the 1930s, the Sokol movement, which made an appeal for a school for professional staff, was supported by the Association of Sports Associations and by sports organizations in general (Stepišnik, 1964). While civil organizations kept demanding and emphasizing the need to establish physical education studies, the latter already existed in many other countries. Consequently, also some Slovenes went abroad. Drago Ulaga[5], for example, graduated from the Berlin College of Physical Education in 1930, the same holds true of Janko Kavčič (who graduated in 1934), whereas Branko Polič graduated from the Warsaw Central Institute of Physical Education in 1934. As a result of numerous initiatives, pressures and finally sports achievments at the Olympics and world championships (i.e., gymnast Leon Štukelj and other Sokols) and probably also as a result of the Slavic examples in Czechoslovakia and Poland, the Ministry of Physical Education of the Nation finally responded and in 1938, the Short-cycle College of Physical Education was established in Belgrade. After the internal political reorganization of the Yugoslav state in 1939/40, a similar school was established in Zagreb. The activities were also performed in Slovenia. Drago Ulaga, a graduate of the Berlin College of Physical Education, prepared plans for the study within the Ljubljana Faculty of Arts shortly before the Second World War but the budget debate and the opposition of the Ministry of Finance as well as the attack on Yugoslavia in April 1941 and the Second World War caused the initiative to founder (Ulaga & Bergant, 1992).

Post-war restoration

After the liberation and establishment of new communist Yugoslavia and pro-Soviet physical culture, there were aspirations in Slovenia as early as October 1945 to establish an academy or an institute where physical education could be studied in combination with another course of study. Jelica Vazzaz was among the main initiators of physical education studies; she was a pre-war Sokol and a student of the Short-cycle College in Belgrade, and after the war, she was assistant for physical education at the Ministry of Education of the People's Republic of Slovenia. The demand for staff was great (in 1946, the physical culture association estimated that around 10,000 professional workers

[4] Practical gym, games, light athletics and sport, fencing, gym systematics and theory, methodology of physical exercises, history and literature of physical exercises, aesthetics of physical exercises, general pedagogy, physics, biology, anatomy and histology with practical classes, anatomy of the appearance of a human being, general physiology with practical classes, general and special physiology of physical exercises, general hygiene, school hygiene and hygiene of physical exercises, physical development and hygiene in pre-school period, anthropometry, orthopaedics, massage and medical exercises, first aid with practical exercises, the building and equipment of gyms and gym facilities.

[5] Drago Ulaga (1906–2000) was a successful gymnast, member of the catholic Orel association, which awarded him a scholarship to study at the end of the 1920s. After graduating in the 1930s, when the Orel already disbanded, Ulaga first acted as a coach in the Ilirija sports club, then he was a teacher outside Ljubljana and from the mid-1930s on, he worked at the Ministry of Physical Education of the Nation in Belgrade. Before the Second World War, he returned to Ljubljana.

were needed for a mass activity). As Edvard Kardelj, one of the leading members of the Communist Party of Yugoslavia, said in a discussion with athletes in 1947, physical culture should obtain a new character after the liberation within the framework of general transformation of the homeland in the course of a democratic revolution. Kardelj also emphasized that liberation fight and revolution were characterized by care for human beings and care for well-being of an individual and nation as well as care for a general rise in physical culture, since there is no quality life without strengthening of the body, health and physical strength of a human being. Correspondingly, physical culture is national and humane and strengthens the human body and mind, thus helping an individual to become a perfect human being (1st congress of the Physical Culture Association of Yugoslavia, 1947). In accordance with this, it was emphasized in Slovenia as early as 1946 that it is necessary to establish a short-cycle college of physical education within the framework of the University of Ljubljana as soon as possible. This institution should educate physical education teachers for primary and secondary schools and for short-cycle colleges as well as experts for organizations of physical culture and professional education (1st meeting of the Physical Culture Association of Slovenia, 1946).

In that period, the politics and the state were preoccupied with solving problems connected with physical education staff and studies according to the state centralist approach, the consequence being the establishment of a central state institution in Belgrade which was founded on the site of the pre-war Short-cycle College. Thus, in 1946, the State Institute of Physical Culture was established in Belgrade and one-year professional courses were organized; later on, secondary schools of physical culture were established in different republics[6]. In Slovenia, the Institute of Physical Culture organized a one-year theoretical and practical course in the 1946/47 school year which was supposed to provide a new "figure of a physical culture teacher, figure of an instructor who should also excel in practical knowledge", since "mastering practice sufficiently … creates conditions for higher-level professional studies". Consequently, a future broadly educated physical culture teacher will not be "a mere expert but also a herald of a new, healthy way of life" as well as an educator (Ulaga, 1947). After that secondary schools of physical culture were organized (1947/48) following the centralist physical culture guidelines, and the grammar school graduates pursued studies in Belgrade. One of the reasons for subjecting to the state centralist model of physical education studies was the fear that there would not be enough graduates of grammar schools and other graduates to enrol on several short-cycle colleges of physical education, since the needs in other academic areas were much higher. On the other hand, the secondary school system and the school system in general were undergoing restoration as well as political and ideological changes in the decade following the Second World War (Okoliš, 2009; Treatise of the College of Physical Education). Despite this, we can agree with Stepišnik that "the first physical culture school was born in Slovenia" with the establishment of secondary schools of physical culture. Although this school was not a short-cycle college, it was a "foundation for the future", since the teaching staff consisted of teachers employed on a permanent basis. In 1950, the school came under administrative control of the Ministry of Education (Stepišnik, 1964, p. 9).

[6] As opposed to old centralist Yugoslavia, new Yugoslavia was a union of republics: Slovenia, Croatia, Serbia, Bosnia and Herzegovina, Montenegro and Macedonia.

Organization of the College

The 1950s represented a new turning point, since these were the post-Cominform years and the years of establishing an autonomous socialist political model typical of Yugoslavia and years of radical reorganization in the area of state schools which also included the question of education of teaching staff. The proposals for the education level of teachers teaching in new uniform eight-year primary schools and four-year secondary schools including grammar schools ranged from a two-year to four-year teacher-training college. The Slovene proposal supported the point of view that future teachers should pursue a four-year course of study, but the introduction of two-degree studies resulted in the title of a teacher and professor (Gabrič, 1992). At the same time, the professional staff still needed the physical culture area and the staff educated within the system of courses. In the 1950s, the problems connected with the physical education staff coincided with school reformism and state and political decentralization. As a result, the physical education study model characterized by the state centralism was abandoned and transformed to the level of the republics. At the beginning of the 1950s, the committee for physical education of the Council for Education and Culture of the People's Republic of Slovenia analysed the situation in the field of physical education and found out that there was a shortage of physical education teachers. That is why it proposed the establishment of an independent college of physical education where physical education could be studied in combination with another course of study. In February 1953, the plan was presented at the University of Ljubljana and an agreement was reached with the University. Then the Council for Education and Culture decided to establish the Institute of Physical Education in Ljubljana in November 1953 as a transitional stage. The Institute carried out a three-year course of study ending with a short-cycle college degree. In the middle of March 1956, the Institute was renamed Short-cycle College of Physical Education. The Institute and later the Short-cycle College accepted candidates who finished grammar school or passed a school-leaving exam at a secondary technical school. The candidates also had to pass the entrance examination and go for a medical check-up. Although the school was officially a short-cycle college, the studies lasted for 6 semesters and the curriculum consisted of the subjects from four subject areas: social sciences and humanities, medicine, physical education and methodology as well as practice. As far as the professional orientation is concerned, the Institute and the Short-cycle College supplemented the theory of physical exercises with the systematization according to the physiological effect of exercises, with the emphasis of exercises that originated from man's and social needs and not from the interests of organizations, thus widening the social usefulness of activities as opposed to that of the Sokol and nation. Interestingly, the heritage criticism did not mention the Sokol movement but emphasized that the Short-cycle College fought against the heritage of German formalism (Spiess's formalism) as well as "for the fact that the primary aim is training for work rather than artistry – and the normal place for taking exercises is nature rather than an indoor place: a playground in the open air, a meadow, forest, water, snow". The criterion for judging new findings was "their scientific correctness and usefulness for man and society" (a new branch of science, a predecessor of kinesiology, was developed at the Institute of Sports Medicine, which was established at the same time). The method of work with the school youth focussed on "concrete aims of physical education:

biological and medical, learning, educational and recreational aims". The research work in the field of methodology of physical exercise, however, showed that "in particular age groups … it is necessary to develop human creative powers" through various motor tasks instead of stylized exercises (Report 1958/59, p. 10).

Between 1953 and 1958, 152 full-time and 37 part-time students enrolled on the study and the enrolment figures were not satisfactory. The education gained and the occupation of a physical education teacher were not stimulating regarding the length of the study, since the same title was obtained by the graduates of the short-cycle teacher training college following a two-year study, while the students studying at the faculties whose study was only one year longer obtained the title of a professor. For the candidates, an increasingly disturbing fact was that the three-year short-cycle college did not develop into a four-year college as planned and as students expected on the basis of promises (Report 1958/59). Consequently, the Committee for Physical Culture at the Executive Council of the People's Republic of Slovenia discussed staff problems at the end of June 1958 and approved the proposal to establish a college. In 1959, a special expert group prepared a draft law. In spring 1960, this draft was authorized by politicians and experts (from the Partizan[7] movement and sports associations) and submitted to the parliament for consideration. At its session on 24 June 1960, the parliament approved the establishment of the specialist College of Physical Culture (CPC) with a two-degree programme for the education of physical education teachers and professors as well as staff needed in physical culture organizations. The organizational and study basis for this course of study was the existing Short-cycle College with its teaching staff (Stepišnik, 1964).

In autumn 1960/61, the first generation enrolled on the CPC. The CPC curriculum was based on the pedagogical and scientific logic of its predecessors and on four subject and expert groups that developed into the departments[8] (CPC Statute).

In 1975, the CPC became member of the University of Ljubljana and in 1982 on the basis of a quality pedagogic and scientific development, it instigated a procedure for the transition into a faculty and its resulting renaming, i.e., Faculty of Physical Culture. In March 1982, the University Council of the University of Ljubljana permitted the

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[7] The Partizan movement was actually a successor to the Sokol movement. When the physical culture model was abandoned after the Comintern in 1948, the gymnasts again organized themselves independently and at the general meeting in November 1951, they proposed the old name Sokol. The proposal was rejected, the reason being that in central and southern Yugoslavia, the majority of the Sokol members either joined the Chetnik movement or the Yugoslav royal army or supported fight against partisans following the Nazi and Fascist occupation in 1941. On the contrary, in Slovenia, the Sokol movement was the founding group of the Liberation Front. To avoid the post-war confrontation, the name Partizan (i.e., partisan) was proposed, since the Second World War and the partisan liberation of Yugoslavia made the partisan "a symbol of heroism, self-sacrifice, altruism, comradeship and love of one's country and freedom, so that the name of a mass gymnastic organization will imply the greatest possible honour and pride, since it is this organization together with the Veterans Association that should continue with the bright educational traditions … of the national liberation fight among its members."

[8] The curriculum consisted of "social sciences" with the subjects the basics of social sciences, history of physical culture, organization of physical culture, general and youth psychology, sports and work psychology, pedagogy, foreign language, building of sports facilities, "biological sciences" with anatomy, physiology, injuries and first aid, biology, hygiene, massage and preventive gymnastics, subjects dealing with theory and methodology of physical education (theory of physical education, methodology with teaching practice, biomechanics of physical exercises, recreation) and practical part containing athletics, sports games, martial arts, elemental games, swimming, gymnastics, rhythmic gymnastics, dances and gym routines, skiing, mountaineering, rowing.

development into a faculty on the basis of the assessment of the past development and reputation in Yugoslavia as well as in Europe (CPC, 1982). In 1990, the Faculty was renamed the Faculty of Sport.

REFERENCES

Archives of the Faculty of Sport

Memorandum on physical education. Yugoslav Sokol Association, Ljubljana, 13 March 1929.

College of Physical Education in Ljubljana. Treatise of the Institute for the School System Progress of the People's Republic of Slovenia, Ljubljana. (undated)

Report on the school activities from the establishment to the end of the 1958/59 school year. (undated)

Treatise of the College of Physical Education. (undated)

Statute of the College of Physical Culture. (undated)

College of Physical Culture in Ljubljana (developmental path, state and some problems), 1982.

Bibliography

I. kongres Fiskulturnog saveza Jugoslavije. Beograd (1947).

DOLENC, E. (1996). *Kulturni boj*. Ljubljana: Cankarjeva založba.

GABRIČ, A. (1992). Šolska reforma. In *Slovenska novejša zgodovina: od programa Zedinjena Slovenija do mednarodnega priznanja Republike Slovenije 1848–1992, Part 2*. Ljubljana: Mladinska knjiga, Inštitut za novejšo zgodovino, pp. 1035–1037.

Iz izkušenj preteklosti – bodoča pot fizkulture. Iz I. redne ustanovne skupščine Fizkulturne zveze Slovenije. Ljubljana (1946).

OKOLIŠ, S. (2009). *Zgodovina šolstva na Slovenskem*. Ljubljana: Slovenski šolski muzej.

PAVLIN, T. (2008). Slovensko sokolstvo je samo po kroju in imenu podobno češkemu … In N. Troha, M. Šorn, B. Balkovec B. (eds.). *Evropski vplivi na slovensko družbo*. Ljubljana: ZZDS, pp. 155–159.

PAVLIN, T. (2009). Zmaga-svoboda. Sokolsko jugoslovaniziranje. In B. Balkovec (ed.). *Jugoslavija v času: devetdeset let od nastanka prve jugoslovanske države*. Ljubljana: Filozofska fakulteta, pp. 213–227.

STEPIŠNIK, D. (1964). Razvojna pot Visoke šole za telesno kulturo v Ljubljani. In *Zbornik VŠTK I.* Ljubljana: VŠTK, pp. 5–16.

STEPIŠNIK, D. (1974). Školsko fizičko vaspitanje na području Slovenije u periodu 1848–1914 (PhD dissertation). Ljubljana.

ULAGA, D. (1947). Zavod za fizkulturo. *Tovariš*, 1947, p. 24.

ULAGA, D., KNEZ-BERGANT M. (1992). Izobraževanje strokovnih kadrov za šolsko športno vzgojo pred ustanovitvijo Zavoda za fizkulturo v Ljubljani. *Šport* 1–2, pp. 3, 54.

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NEW PERSPECTIVES OF CORPORATE IDENTITY IN SPORTS ORGANIZATIONS

JOSEF VORÁČEK

ABSTRACT

This paper deals with the topic of corporate identity in sports. The main objective of this paper is to present new views, trends and tools in building a desirable image for sports organizations using corporate identity tools, including some selected areas relating to the brand. The main points of this paper include corporate design, communication, culture and sports organizations' product. These tools are all linked and transformed into the creation of a cool brand for a new generation of athletes and consumers – the so-called Generation Y of sports. This group is becoming a new economically important group for many companies in sports, as well as many sports organizations. The Sports industry is heavily dependent on the new generation of athletes in all performance levels, and sport fans. Therefore, it is necessary to constantly be innovating new corporate identity tools with a focus on the sports area.

Keywords: corporate identity; brand; Generation Y; sport organizations; image

INTRODUCTION

In the new millennium, marketing has been a dynamically changing sector, where those who are successful are the people who can adapt to these conditions adequately, or change them with new creative ideas, procedures, tools and methods. This trend is also visible within the sports environment. There is an apparent increasing power and influence on the sports market of the new consumer generation, sport companies customers, sportspeople and other interest groups in the sports environment; such as fans, spectators, volunteers, club members etc. This generation had grown up in a colourful marketing environment (Yarrow & O'Donnell, 2009; Van den Bergh & Behrer, 2012) and they are therefore more or less immune to the classical marketing tools and consequently very critical towards them. This new generation is also called "Generation Y" (Bush, Martin, & Bush, 2004; Manpower study, 2007; McCrindle, 2009; Van den Bergh & Behrer, 2012; Vysekalová, 2011; Yarrow & O'Donnell, 2009). A sports environment offers this generation a big

amount of possibilities how to spend their free time, how to have unique experiences, how to evoke strong emotions, and how to tell famous stories. For different sports organizations there has been development of a highly competitive environment where they fight for keeping current members and are engaging new ones from target groups labelled "customers". Sports organizations must constantly come up with new solutions to attract their target groups to differ from competition and to be unique, special, original and attractive. In this respect there is importance in creating a strong brand, which has its own clear identity, and is somehow specific (Quart, 2003; Van den Bergh & Behrer, 2012). It is the corporate identity that sports organisations should focus on in their marketing activity to support and fulfil their aims (Voráček, 2012). Sports organizations will no longer be only "empty" providers of a sports product. The new generations of people do not want to satisfy their basic needs by being connected with the basic form of a product offered any more (Wells, 2011; Quart, 2003; Van den Bergh & Behrer, 2012). Generation Y is searching for more than just physical exercise and activities, sport performance, sports equipment etc. within a sports product. The main aspect for attractive sports products are entertainment, excitement, experience, emotions, story, freedom and sharing these aspect with friends. It is therefore appropriate to link these aspects with a sports organizations' brand and its overall perceived image through the use of corporate identity tools. They increase the chance to make the sports organization interesting and attractive for the younger generation.

Due to a strong tendency to share everything with friends, each satisfied and enthusiastic customer from Generation Y is a bearer and propagator of an organization's image and this contributes to and supports the PR activity of the specific sports organization. This oral communication among people, (also known as: "word-of-mouth", oral propaganda, grapevine, one lady says etc.) or a recommendation or not to a friend, has currently shown as the trustworthiest source of information for new customers (Van den Bergh & Behrer, 2013) which, is entirely for free. This contribution is focused on new trends in the sports organisations corporate identity creation aimed at the new consumer generation of sport products.

This article shows the differences and characteristics of Generation Y and also shows the brand new model (CRUSH) developed by Van den Bergh and Behrer (2012) on the basis of many researches on Generation Y. This CRUSH model is then applied into a sport environment, and sports organisations by the author of this article.

METHODS

This paper is not typically a research paper, but it is theoretical concept developed by the author of the article. Because of that, the basic method for this paper is analysis of literature resources, especially one – Van den Bergh and Behrer (2012, 2013). These authors developed the CRUSH model.

Generation Y

The so-called Generation Y has already been mentioned in the introduction – it is therefore essential to give the basic characteristic of this segment and how it is classified. This generation has not been clearly classified yet. However, it consists of individuals born in the 80s or the 90s of the 20th century. Bush, Martin and Bush (2004) claim that Generation Y is described as anybody born between 1977 and 1994. The Manpower study (2007) according to Morgan shows the generational division of Generation Y, are individuals born between 1976 and 1990. McCrindle (2009) presents in his study, the ABS Census, a source that defines Generation Y, as those who are born between 1982 and 2000. It is therefore a generation of young people who are getting into or have already reached the highly productive age. Van den Bergh and Behrer (2012) state several important characteristics of this generation in relation to a brand creation:

- Members of Generation Y are addicted to stimulation. Their favourite trendy brands appeal to their individual control and immediate satisfaction.
- Generation Y uses technologies to build a social life, never vice versa.
- For them content is the social currency number one.
- Friends are the filter of relevance through which the members of Generation Y perceive the brands messages. Trendy brands use social media and communicate equally with everybody – they do not dictate but engage young people while offering them control.
- Members of Generation Y have a higher confidence in people and social contacts.
- As a result of mamahotels and boomerang returns the members of Generation Y have a higher influence on family purchases.
- Members of Generation Y choose and mix the right pieces for the real moment and purpose. Brands should take care of this range of opportunities and needs and offer a possibility of choice.
- Attraction to brands and identification with them is being created in adolescence in connection with brain development.
- This consumer generation is looking for basic brands which can offer stability, harmony and authenticity.

Vysekalová (2011) characterises Generation Y in the following words:

- Generation Y have been growing up surrounded by modern technologies that are, unlike older generations, natural for them. The world is for these people accessible with "one mouse click".
- They are spoilt children of loving parents, born in a quiet time. They are confident, used to express their opinions also on products about which they discuss on various internet forums.
- High flexibility is typical for them which projects into all spheres of life. As customers they are demanding and want the goods to be accessible anytime and anywhere they need.
- They are different from previous generations. They perceive more incentives at once, listen to music, browse internet websites and discuss things with friends at the same time. They perceive visual incentives more and prefer complex information.

– Social bonds are important for them as well, just as life in a community. Thanks to the internet and social networks they keep these bonds. Peers opinions and the "Word-Of-Mouth" communication are important aspects while choosing products.
– Questions of ecology become more significant. They are sensitive to environmental problems.
– This generation is characterized by its higher loyalty to brands they share with their peers. Not only do they buy a product with a brand but also the overall company image.

The demonstrations and characteristics mentioned are necessary to be considered also within a sports environment, where self-realisation and self-expression not only of members of this generation, are visible through sport performance and the behaviour while doing it. The following tools of corporate identity in sports are adapted to the above mentioned Generation Y.

Corporate identity in sport

Despite the fact that the vast majority of sports organizations in the Czech Republic are nonprofit (only professional football clubs and ice-hockey clubs are the profit sport organisations), it is necessary to realise and implement marketing principles typical of a profit sector. Marketing oriented management is also connected with corporate identity creation, which is then closely connected with establishing a brand. The basic tools of a sports organizations corporate identity are: specific corporate design, communication, culture and obviously the very product, which is the core of the organization activity. Using these tools reflect significantly on the image which is very important in relation to the above mentioned Generation Y. Before mentioning new approaches and trends in individual parts of corporate identity, one must not omit one major initial aspect of sports organizations, their corporate philosophy. Corporate philosophy, expressed by a motto, mission, credo or vision, is always rooted in sports organisations statutes (if it is a civilian association), or in another founding document. This is usually one reference. Therefore there comes the main task for sports organizations chairpeople and leaders to compose this philosophy into the above mentioned corporate identity tools. This is the only way to create a unified, unique and original sports brand focused on the young generation of the sports oriented public.

The main solution to the effective creation of corporate identity focused on Generation Y is implementation of the CRUSH model by Van den Bergh and Behrer (2012) on the corporate identity system of sports organizations as it is mentioned by Voráček (2012). This implementation is illustrated in picture 1.1. CRUSH model includes the following 5 aspects – *cool*, *real*, *unique*, *self-identification* and *happiness*.

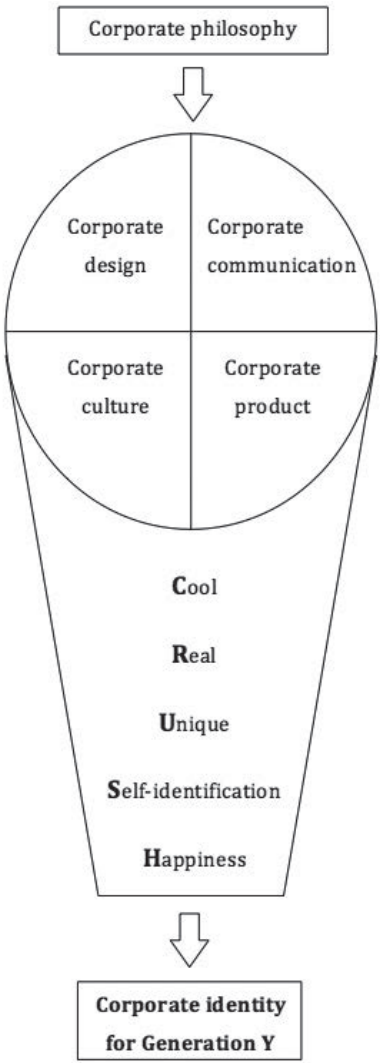

Figure 1. Implementation of the CRUSH model on the corporate identity sports organisations system

Very problematic in this model is the *cool* aspect. According to the authors of this model, Van den Bergh and Behrer (2012), the basic archetypes of what *cool* is are these:

- Be trendy
- High status
- Clean reputation
- Success
- Creativity
- Be entertaining, funny
- Cheerful

– Own style
– Changes a lot
– Luxury
– Clear opinion, posture or position
– Contemporary
– Honesty
– Retro
– Attractiveness
– Originality
– Popularity

However, which archetype a member of the Generation Y deems *cool* in a specific situation is, mostly determined by friends, television or music industry. In the sports environment it can be expected a high influence of sports personalities and events that generally belong to the least significant aspects.

The next aspect of the CRUSH model is *real* (authenticity). For Generation Y Van den Bergh and Behrer (2013) show these meanings and advice for keeping the brand *real*:
– Don't underestimate the power of face-to-face personal contact with Gen Y.
– Brand origin, history and heritage are often not relevant or even not credible for the critical youth.
– This classic interpretation of authenticity should never be shouted (no mass media) but only be whispered and even better: be experienced.
– Authenticity is all about staying true to yourself; not imitating, not faking.
– Keep your brand's vision central but reinterpret the meaning of your brand following changes in tastes, interests or values.
– Honesty means more for a brand than Corporate Social Responsibility programmes or "not lying"; it's about being respectful to youth and youth's life, about listening and discussing with them on the same level, and about sticking to your own ideas.
– Real brands are transparent, open and human: like a friend.

Unique is the third aspect of the CRUSH model. Everyone wants to have something unique, especially the Generation Y. To mark (sports organization) unique, it should prove to find answers to questions that generation Y in relation to this aspect puts according to Van den Bergh and Behrer (2013):
– Who are you?
– What is your unique brand DNA; your identity that makes you stand out from competition?
– What are you?
– What "brand meaning" do you offer me?
– What's your brand vision?
– What do I have in common with the brand?
– What do I feel about you?

Self-identification of consumer with brand (sport organisation) is the one of the main ways to gain brand loyalty consumers. To increase the aspect of *self-identification* includes according to Van den Bergh and Behrer (2013) these activities and facts:

- Identification of tribes, that are relevant for brand positioning.
- Reflection of the passions and interests of selected tribes.
- Consideration Gen Yers as partners in marketing and product design.
- Screaming about that are related to your DNA and facilitate existing passions.
- Showing every day how the brand's vision is related to these passions.
- There's a close fit between online and offline identities of youth. "You are who you know" is not only reflected in friending but also in brand fandom on social networks.

The last but not least aspect of the CRUSH model is *happiness*. According to Van den Bergh and Behrer (2013), happiness seems to be the emotion that has the largest impact on brand leverage. The right ways to tap into emotional branding are connecting with and arousing positive emotions or taking away negative ones. Van den Bergh and Behrer (2013) also state:

- By addressing youth's senses, especially scent, sound and design, a brand puts EQ (emotional quotient) in its offer to Generation Y.
- Gratifications are challenging experiences fuelled by gamification, through different touch points (in-store, online, mobile or at events) that require one's full attention and socially connect Gen Yers to peers.

Corporate design

Generation Y, as it has already been mentioned, perceives more visual incentives and is therefore important to aim their attention to all the details of visual elements of sports organizations corporate design. Some of these elements according to Voráček (2012) are:

- Name of the sports organization, team, club
- Logo as an identification mark
- Colours of team, club
- Printed material
- Merchandising products
- Interior and labelling buildings, stadium, arenas, motorhomes, fanshops and other sport facilities
- Clothes of the organization, club, team members
- Sports equipment
- Means of transport and other technical equipment
- Official websites and other online presentations of the organization, team, club
- Events visual elements
- Expositions on exhibitions and tradefairs
- Sponsorship

Each of these elements should be based on the already mentioned sports organization's philosophy and history. This way the deeper meaning of the design used is supported. Companies in the profit sector innovate their brand design continuously and sports organizations may not overlook new design trends either. In relation to the basic theoretic concept, the visual incentives for the Generation Y remain to be *cool* and *unique*. One of the most precise examples of a successful corporate design in sports in the Czech Republic

is the Olympic collection of the Czech athletes at summer Olympics in London 2012 and also the Czech House. A well-done design will afterwards reflect on another factor, which is *happiness* that in this meaning includes evoking positive emotions and surprise. Even design can be emotional and surprising as it was visible within those examples mentioned.

Corporate communication

Sports organisations have currently focused heavily on the external communication with the public, mainly through massmedia. However, the current sports public has already gotten used to the strategically driven and controlled communication by the sports organizations; whether it be clubs, unions, or individual athletes. In this respect there was one illustration visible in 2012 showing how media are told only the stuff required within a sports organization. This moment happened during a Czech representation press conference where the manager was overheard telling the coach how to answer individual questions. However, this will not be acceptable in the future from the point of view of corporate communication. External communication will become less and less significant and valuable. The result will be clear, characteristic, typical and authentic in style of communication. On the contrary, the meaning of internal communication will grow focused on sports organization members who are the important and loyal bearers of the organization image.

All elements of the CRUSH model play a significant role during the sports organizations communication and mostly in between athletes. The first three (*cool, authenticity, uniqueness*) are typical of this part of external communication. Sports environment are nowadays full of special personalities, athletes, coaches, managers etc. However, a lot of them underestimate the significance and importance of being *cool*, *authentic* and *unique*. The future sports public will accept exceptionally striking sport personalities who are somehow unique. Therefore, sports organizations should put an effort on the personal approach and their own way of communication characteristic for a specific organization, athletes or their members. A good example can be Jaromir Jagr, who is typical for him being on first-name terms, good relationship with media representatives and frequent humour during an interview. In this way he fulfils those three aspects – his is *cool*, *real* and *authentic*, also *special* and *unique*. The aim for other sports organizations and their members are not copying his style but have their own style and way of communication with interest groups in the area of sports.

Other significant factors related to *authenticity,* which are going to become more and more important for communication with the sports public are:

– Transparency
– Confidence
– Honesty

If this is fulfilled during communication, it highly contributes to the growth and support of a specific sports organization and to the athlete's authenticity. Media, are in this respect, strong, in that they can either support this authenticity, or damage it very severely. As an example it is appropriate to mention the cyclist Lance Armstrong who confessed to doping. Obviously his brand including the foundation he established were heavily damaged, however, this may be a very good stepping stone for an even bigger strengthening of his identity and brand. Because this confession, with respect to the above-mentioned

honesty, transparency and confidence, he could use this as a base for creating his brand for fighting against doping in sports.

The future of corporate identity in sports can be seen in the strength of life and sports stories which, thanks to their characteristics are created by the sports themself. Nevertheless, it will be only up to the sports organizations and athletes about how they share their stories with the sports public. Stories have the specific characteristic that they can evoke very strong emotions and therefore support the aspect of happiness (or other emotions such as sadness, surprise, sympathy etc.) They can also involve the sports public into the story itself, which corresponds with the aspect of identification with the brand. Sports are such a colourful area that each sports result of each sportsperson bears a potential life story which is necessary to be told to support their specific identity. Good examples are the stories of significant Czech successes – the fairytale about the last javelin throw of the javelin thrower Barbora Spotakova at the Olympics in Beijing 2008 or the story of Czech hockey players in Nagano 1998 etc. There can obviously be found many examples, however, the perspective for the future is sharing this emotive content and background after each significant sports performance.

Other important areas of corporate communication are internal interest groups, mainly sports organizations members. They are those who will become the most important during the creation of the organization's image. The membership base for sport unions, club and sporting associations is one of the income sources for these sports organizations. These members are not tied with a contract or a condition on which information they can say to the surrounding environment. Especially, in the period of time of social networks and mobile devices enabling a constant contact and sharing information with friends, the right communication is the base for keeping up the desirable organization reputation.

In communication with internal interest groups there are obviously the same communications with the external environment. It is therefore essential to stay transparent, keep confidence and stay honest. This can be quite well ensured via open, detailed communication with all members about how everything is happening within the organization. Thanks to the tools such as various social networks and email, any information can be easily transmitted to all sports organization members. Higher and higher pressure is on the mutuality of communication. Future communication in sports organizations should be based on sharing all information with all members.

Corporate product

Higher and higher influence of sports organization members on the invididual sports product creation will be increasing. Participation on the content of the organizations sports activity is more and more relevant with respect to the extending possibilities for the new generation of future sportspeople. The possibility of participation supports the idea of *identifying with the brand.* The bond of members to the sports organizations will be much higher. The probability of a product evoking positive experiences, emotions, entertainment and *happiness* in sports organization members is much higher. This aspect is currently an important initiator of sports organizations members' behaviour.

Corporate culture

Another significant trend is a bigger need to share sports organization's values, transmission and mainly their advancing and obeying. In this respect the most important person is the organization leader who is the main bearer of these values. These values should correspond with the main message and the sports organization's vision. The vast majority of the sports public does not even know the basic values and messages of their sport organization whose members they are. Corporate culture on the level of a sports organization is quite specific and shows certain positive aspects but is often unrealized and uncontrolled. Here it is necessary to think about all five aspect of the CRUSH model – *cool*, *real*, *unique*, *self-identification*, *happiness*. It is necessary to engage the sports organizations members to all aspects of corporate culture, which are symbols (that are also related to the above mentioned design), rituals, heroes and values. Sharing their opinions while creating and keeping the culture in the organization is the cornerstone for the success at Generation Y.

CONCLUSION

Generation Y has currently become the main target group for sports organizations and therefore it is necessary to get to know it perfectly and use this knowledge as a base during marketing management for a specific sport subject. It includes completely different, innovative tools, mostly with the usage of technological innovations. To create corporate identity that will be respected and positively accepted by this very generation. It is necessary to approach individual tools more creatively and more originally than ever before, mostly with respect to corporate design creations which must be modern (even with emphasis on tradition and history). It is characteristic for Generation Y, within the area of sports and sports brand creation and its identity, to use all technical tools enabling them to be constantly in contact with their social group. This case refers to their friends and other members of sports clubs and organizations. With that said, it is possible to share sport performances, experiences, emotions, tensions, stories and surprise that sport environment can offer. Another important solution is the openness, transparency, honesty and trustworthiness of communication among these young athletes, spectators, fans and sport club members.

Generation Y also highly appreciates their participation in the sport product creation, which obviously includes a whole range of possibilities related to sports, or other areas; e.g. music. This engagement can enable members of sports clubs, organizations and athletes to identify themselves with a certain brand and its identity by which a stronger connection and potentionally higher loyalty are created. This will obviously be shown on the overall image of the sports organization. By the help of the above-mentioned points, there is established a completely unique (conscious or unconscious) culture in sports organizations where everybody shares the same values. This is a very important fact for sports organizations because there is the team spirit in sports and team work is an inseparable, not only of sports success. It is necessary to conclude that supervisors, chairpeople and leaders of sports organizations should realize that for the Generation Y in regards to sports (traditional, but also new, freestyle, extreme etc.) within these CRUSH model aspects are important – be *cool*, *real*, *unique*, enable and support *self-identification* and emphasize and provide *happiness*.

One example of the new and modern corporate identity of sport organisation, focused to Generation Y according to author of this article, could be the Czech Olympic Committee. Design of the last three Olympic collections for Czech athletes, made by AlpinePro was considered successful, original and unique. Communication is actually transparent, quick, with use of modern technologies (mobile application) and social networks. Also the products especially Czech Olympic House in London 2012 and Czech Olympic Park in Prague 2014, includes all the aspects of corporate identity, including culture, for Generation Y. Of course nothing is perfect, but this example shows, that sport organization can be *cool*, *real*, *unique* and increase *self-identification* and *happiness* of the new generation of consumers, Generation Y. At the end it is appropriate to use the claim of one of the marketing communication strategy of Czech Olympic Team: "New generation brings new achievements".

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REFERENCES

BUSH, A. J., MARTIN, C. A., BUSH, V. D. (2004). Sports Celebrity Influence on the Behavioral Intentions of Generation Y. *Journal of Advertising Research* 44(1), 108–118.

Manpower. (2007). *Generation Y in the Workplace Australia*. Australia: Author. Retrieved from http://www.manpower.cz/images/GenerationYintheWorkplace.pdf.

MCCRINDLE, M. (2009). *Understanding Generation Y.* North Parramatta, Australia: Government of South Australia – Department of Education & Children's Services. Retrieved from http://www.learningtolearn.sa.edu.au/Colleagues/files/links/UnderstandingGenY.pdf.

QUART, A. (2003). *Branded: The Buying and Selling of Teenagers*. London: Arrow.

VAN DEN BERGH, J., BEHRER, M. (2012). *Jak cool značky zůstávají hot: Marketing zaměřený na mladou „generaci Y"*. Brno: BizBooks.

VAN DEN BERGH, J., BEHRER, M. (2013). *How Cool Brands Stay Hot: Branding to Generation Y.* London: Kogan Page Limited.

VYSEKALOVÁ, J. (2011). *Chování zákazníka: Jak odkrýt tajemství „černé skříňky"*. Praha: Grada.

VORÁČEK, J. (2012). *Public Relations ve sportovních organizacích*. Praha: Karolinum.

WELLS, T. (2011). *Chasing youth culture and getting it right: how your business can profit by tapping into today's most powerful trendsetters and tastemakers.* New Jersey: John Wiley & Sons.

YARROW, K., O'DONNEL, J. (2009). *Gen BuY: How Tweens, Teens, and Twenty-Somethings Are Revolutionizing Retail.* San Francisco: Jossey-Bass.

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THE EVALUATION OF CHANGES IN THE KNEE MENISCUS IN VIVO AT 3T MRI SCANNER

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ABSTRACT

Noninvasive imagining of the knee meniscus without the use of the contrast agents is more difficult compared to articular cartilage. Despite the lower signal intensity of the knee meniscus, MRI is considered the best non-invasive imaging method. Thanks to the lower water content in the meniscus compared to the surrounding tissues, it can be distinguished from the environment, but the determination of the boundaries is more complicated than in articular cartilage. There are many studies dealing with the MR imaging of the loaded and also unloaded knee, but they have mainly observed quantitative and geometric changes (movement or deformation of tissue), not targeted qualitative changes in the extracellular matrix (ECM). These changes can be evaluated with T2 relaxation times, which are more sensitive to the interaction of water molecules and the concentration of macromolecules and structures of the ECM, especially in the interaction based on the content, orientation and anisotropy of collagen fibers. Fluid and tissues with the higher water content level have long relaxation time T2. In the healthy meniscus these times are shorter; the reason is a highly organized structure of collagen and lower content of proteoglycans. To quantitatively detect changes, it is necessary to assure a sufficiently high resolution of images throughout choosing appropriate pulse sequences. After that, the acquired data can be processed to produce the T2 maps, to portray non-invasive collagen content, architecture of the ROI, changes in the water content (distribution of interstitial water in the solid matrix) and the spatial variation in depth. The aim of this work is firstly to introduce the meaning of T2 relaxation and methods for calculating T2 relaxation times. Further, the aim of this work is to give a brief description of the current pulse sequences used to display menisci.

Keywords: segmentation; T2 relaxation time evaluating; T2 mapping

INTRODUCTION

Meniscus is a structure carrying out several functions in the knee joint. It performs load bearing and so prevents direct contact of the cartilaginous ends of the femur and tibia, reduces stress on the articular cartilage, decomposes evenly pressure on the contact surfaces of cartilages, absorbs shocks and controls external and internal rotation of the tibia. Therefore, it is considered to be a secondary knee stabilizer. Meniscus is a complex hyperviscoelastic biomaterial. Its stiffness is ensured by hydrophilic elements. Their content in meniscus compared to articular cartilage is lower. The permeability of meniscus is affected by the amount, type and arrangement of collagen fibers, mainly represented by the type I. This type of fibers is mechanically much stiffer, able to withstand tension but it has low compressive, flexural and torsional stiffness compared to collagen type II (found eg. in articular cartilage) (Bae, Du, Bydder, & Chung, 2010). That is why meniscus is able to maintain its volume relatively well and shows significant changes of its thickness. Loaded meniscus expands sideways, thus covers still larger area of tibial plateau.

Due to the intra characteristics of the knee joint, the ability to view changes directly in its original position is highly problematic. Magnetic resonance imagining (MRI), an imaging method allowing displaying pathological changes in the human body, is despite the lower signal intensity of the meniscus considered the best non-invasive imaging method (Braun & Gold, 2012). The MR image is formed by the signals from hydrogen protons in water bound to the tissue. The contrast in the MR image depends mainly on the tissue water concentration and its T1 and T2 relaxation times. T1 and T2 relaxation times are influenced by the interaction of the water protons with their surrounding and with each other, respectively, and therefore reflect tissue structure. The values of T1 and T2 times depend on the strength of the magnetic field, e.g. the transition from 1.5 T scanner to 3 T reduce the T2 time to 85% (Stanisz et al., 2005, in Tintera, 2008).

PURPOSE

The aim of this paper is to firstly introduce the basics of MR imaging methods and secondly, to create a brief overview of the current articles dealing with non-invasive imaging of menisci in vivo using MR scanner and using T2 relaxation times to determine the changes in the meniscus.

METHODS

Basic MR imaging measurement sequences and their parameters

Given T1,T2 relaxation times and the concentration of water molecules in the tissue the resulting MR image is highly influenced by type, timing and parameters of the selected measurement sequence (it should be noted that also other tissue parameters such as diffusion or flow influence MR image). Sequence parameters control the image contrast, intensity and

resolution. The most common measurement sequences and dedicated sequences for knee imaging are briefly described below.

Most important parameters of MR imaging sequences

A MR imaging sequence consists of a set of radio-frequency pulses and magnetic field gradients. The selection of the sequence depends on the measured body part and the particular diagnostic question. Sequence parameters control the image contrast, intensity and resolution, therefore, their adjustment plays an important role. Most important parameters of the MR imaging sequence are explained below.

Repetition time (TR) – the time between two consecutive excitation RF pulses. It controls the degree of the image T1 weighting and influences the acquisition time.

Echo time (TE) – the time between the excitation (90°) pulse and the time of the echo occurrence. It controls the degree of T2 weighting. The shorter the time is, the higher the intensity of the echo. However, too short TE causes a loss in the image T2 contrast because tissue T2 curves are too close together. On the contrary, if TE is very long, the echo signal is very weak and the signal to noise decreases.

Field of view (FOV) – represents an imaged area that contains a volume of interest. It is defined as two-or three-dimensional size of the image. With smaller FOV the higher resolution is achieved, however, at the expense of the lower measured signal. The correct choice of the field is important for MR image quality.

Image (acquisition) matrix and resolution – the MRI image is composed of pixels representing signals from tissue volume elements (voxels). The acquisition matrix determines in how many voxels the FOV is divided and, therefore, influences image resolution. Image resolution is of high importance for correct interpretation of MR images. Meniscus, tendons and ligaments have very short T2 times and usually occur in the standard MR image like black areas, which may cause difficulties while evaluating the results. For a reliable in-time diagnosis of lesions ultra structural morphological composition of fibrous tissue high resolution images are essential.

Slice gap (slice spacing) – a distance between two neighboring slices. By reducing the distance between slices it is possible to achieve more precise rendering of the imaged area.

Acquisition time – the time required to gain data from the scanned FOV. This time is restricted due to the patient comfort as well as possible motion artifacts. Acquisition time depends on number of parameters as mentioned before.

Field strength – the strength of the external magnetic field. Scanners can be divided according to the field strength into three groups: low field (0.15 to 1.0 T), medium field (1.0 to 2.0 T) and high field (2.0 to 7.0 T) scanners. The optimal field strength depends on the application**.** As reported by Tintera (2008) “high field systems enable to improve

spatial resolution and fast dynamic examination. On the other hand devices with a weaker field have better tissue contrast. To display cartilage, there has not been demonstrated a clear clinical benefit of field 3 T yet. If the extremely high resolution is required, the time of measurement (without parallel techniques) with no deterioration in quality at 3 T field is about a half compared to 1.5 T for certain sequences."

Open MR devices were developed to monitor tissue in the natural physiological conditions. The devices have magnetic field of lower strength (0.6 T), and so lower image quality and longer acquisition time.

Description of the selected MR imaging sequences

Spin echo sequence, calculation of T2 relaxation time

One of the fundamental pulse sequences used in the magnetic resonance imaging is spin echo sequence (SE) that enables the acquisition of T1, T2 and PD weighted images. The sequence is composed of 90° and the subsequent 180° refocused pulses (Figure 1).

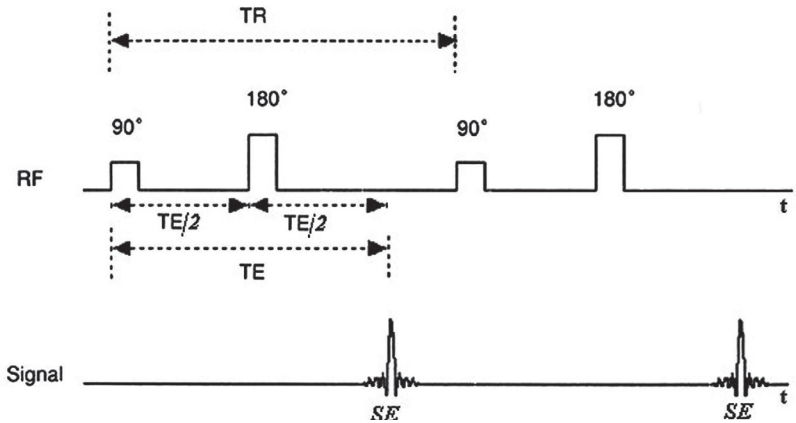

Figure 1. SE sequence consisting of 90° pulse and the subsequent 180° pulse. Figure edited from Fieremans (2009) and subsequently adapted

After the 90° excitation pulse individual protons begin to lose phase coherence by the effect of local inhomogeneities (also called T2* relaxation), resulting in a decrease of transversal magnetization. After some time (TE/2) another, so called refocusing (180°) pulse follows. This pulse causes that the protons start performing the movement with the same precession frequency but in the opposite direction than it was carried before the pulse. As a result, after the period of time equal to TE/2, the protons will be re-phased and restore transversal magnetization. A strong signal which can be detected by the receiver coil at this moment is known as the spin echo (SE). It should be noted that the resulting SE signal is compensated for signal dephasing caused by the external magnetic field inhomogeneity (T2*), however, it is not compensated for T2 relaxation.

In so called multi spin echo sequences several 180° pulses can be employed and multiple echoes recorded. This process can be repeated until the signal decays due to T2 relaxation to zero. The decay of the echo signal S(TE) is exponential as follows
$S(TE) = S(0) * \exp(-TE/T2)$.
Therefore, the acquisition of multiple echoes and the evaluation of measured signals enables the calculation of the T2 time. The calculation is usually performed by the minimization of the square root difference between the measured echo signals and the model function
$S(TE) = A * \exp(-TE/T2) + B$
using Levenberg-Marquardt algorithm.

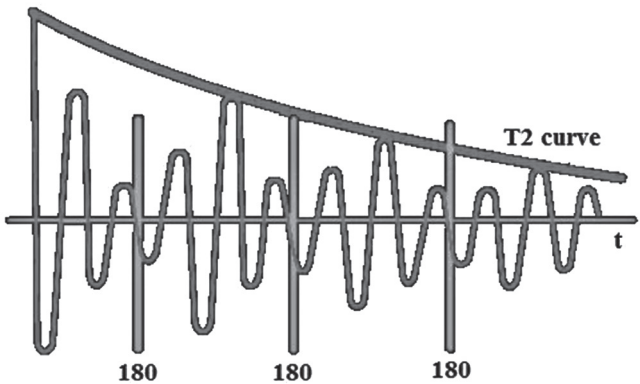

Figure 2. The T2 curve created as a result of the pulse sequence 90°–180°–180°–180°. It shows that the individual echoes are getting gradually lower signal intensity

Turbo spin echo or Fast spin echo (TSE, FSE) – TSE is a modification of the multiple spin echo sequence when the phase encoding gradients are changed for each echo. In this manner the acquisition time can be significantly reduced. This is the reason why these sequences have almost replaced the conventional T2-weighted SE sequences. In T2-weighted TSE images the water and fat appear highly intense.

Gradient echo (GE) – in the gradient echo pulse sequence an additional magnetic field gradient is added to the existing external magnetic field for a very short time. This results in a controlled increase of magnetic field inhomogeneity and a faster decay of the transverse magnetization. After the time TE/2 the polarity of the gradient is reversed. After the next time interval TE/2 an echo, this time called a gradient echo can be observed. GE is similar to the spin echo, however, the echo signal is not T2 weighted but T2* weighted. The longer the TE time is, the more T2* weighted the resulting image becomes.

SPGR (Spoiled Gradient Echo) or FLASH (fast low angle shot) – a gradient echo sequence with a short TR that is mainly used for T1 weighted images (Hashemi, Bradley, & Lisanti, 2012; Mala, 2011). An SPGR sequence spoils the transverse magnetization by semi-randomly changing the phase of the RF pulse (RF spoiling), resulting primarily in

T1 but also PD contrast. For knee imaging a selective radiofrequency (RF) pulse of short-duration (<1 msec) is usually used to excite a slab covering the entire knee joint.

Multiple slice imaging techniques – a concept that can be applied to various MR imaging sequences. The acquisition of a single image may take up to several minutes, depending on the spatial resolution. When searching for pathology, it is usually necessary to obtain several images from different locations. Using conventional approach the acquisition of multiple slices would require multiple repetitions of the whole sequence and in turn very long acquisition time. Multiple slice imaging techniques enable the acquisition of several slices in approximately the same time as required for a single-slice acquisition. During one TR period not only one but several parallel slices are excited and acquired. When TR is longer than TE other slices can be excited and their signal measured while waiting for the recovery of longitudinal magnetization after the signal measurement in the first excited slice. However, neighboring slices acquired during the TR period must be at a sufficient distance from each other so that the excitation of one slice does not affect another slice. It is even possible to measure the whole T2 relaxation curve for the selected slices in a single scan (Herynek, 2013). Although this technique can be used for various pulse sequences it is mostly applied with the SE sequences, because in the SE sequences the TR is much longer than the TE.

There is a limit on the number of slices that can be acquired within a given TR. The limit is given by the time required to excite and collect the echo from each slice: N (max) = TR / (TE + Tc), where N(max) indicates the maximum number of scanned slices and Tc marks the time from the echo peak to the end of the signal (Hendrick, 2008, p. 58).

Ultra short echo time (UTE) sequence – by shortening RF pulses and optimizing the signal acquisition very short TE can be achieved. This is beneficial for imaging structures with very short T2. TE can be up to 100–1000 times shorter in UTE sequences than those used in conventional imaging sequences. As reported by Thakkar, Subhawong, Carrino, and Chhabra (2011) and Qian, Williams, Chu, and Boada (2012), UTE with high resolution allows to display both the surface and the deep layers of connective tissues in the knee. It also displays small structures within the cartilage, meniscus, ligament and patellar tendon. When using high plane resolution (0.28 and 0.14 mm) UTE allows the detection of early damage or fine reparative changes in these tissues. UTE requires a short excitation (0.5 ms) and short acquisition delay (less than 0.2 ms) to reduce TE and thus minimize T2 decay. Since UTE is a relatively new method, research continues to refine 2D and 3D sequences for clinical scanners that would be faster, have better resolution and contrast. For 2D acquisition images with the in plane resolution of 0.3 to 0.8 mm, the slice thickness of 3–5 mm and the total acquisition time 3–17 min have been reported (McWalter, Braun, Keenan, & Gold, 2012). The contrast between the tissue with short T2 relaxation time and surrounding tissues, which may or may not have a short T2 times, can be improved by using several other techniques based on UTE (McWalter et al., 2012).

AWSOS (Acquisition-weighted stack of spirals for fast high-resolution three-dimensional ultra-short echo time MRI) – this sequence based on the spiral data acquisition provides

3D UTE images suitable for knee imaging. It allows the acquisition of 3D images with high resolution (0.28 to 0.14 millimeters) and with the reasonable acquisition time (5–10 min) (Qian et al., 2012).

3D variable TE1 CARTESIAN SPGR – standard Fourier encoded 3D sequences can be adapted to provide the sub millisecond TE using nonselective excitation pulses, highly asymmetric readouts in combination with the variable TE1 along the phase and slice encoding directions. The sequences represent suitable alternative to the morphological musculoskeletal UTE imaging in clinical practice and they have a good potential for biochemical quantification techniques (eg T2* mapping). A minimum TE is typically about 2.8 ms for 0.5 mm in plane resolution in 3D Cartesian scan. The variable TE1 Cartesian methods are fast and flexible and unlike the UTE imaging and provide easy adjustment for the integration of other preparation schemes, such as the suppression of long T2 time components or suppression of the fat signal. (Deligianni, Bär, Scheffler et al., 2012).

T2 relaxation in cartilage and menisci

As stated by Rauscher et al. (2008) in their study, T2 relaxation times reflect more closely the changes in the meniscus compared to the T1 relaxation time, whereas in articular cartilage the opposite is true. Fluids and the tissues with higher water content have long relaxation time T2, which is related to the small size of the water molecules. Their rapid movement causes the time averaging of the local magnetic fields formed by individual water protons. As a result, they do not create significant local magnetic field inhomogeneities that would reduce the T2 relaxation time. In contrast, a mixture of water and organic molecules of greater size (eg. collagen fibers) reduces T2 times. The matrix of the meniscus is composed mainly of highly organized collagen structures in which the most of fibers is oriented in the circumferential direction. Therefore, T2 times in the meniscus are short (Juras et al., 2013; McWalter et al., 2012). T2 times are sensitive to the structure of the ECM, especially on the interaction based on the content, orientation and anisotropy of collagen (Bae et al., 2010; Fragonas et al., 1998; Liess et al., 2002). Damage of the matrix and enhancement of water content in degenerating cartilage can increase T2 relaxation times.

Thanks to the calculation and the display of the T2 maps it is possible to detect the changes in the collagen component of the ECM noninvasive and more precisely to detect the changes in the water content (distribution of interstitial water in the solid matrix) which are not normally visible in conventional MRI images (Nishii et al., 2008; Welsch et al., 2008).

RESULTS

Summary of studies dealing with MR imaging of the meniscus

Described papers were selected using EBSCOhost and Google Scholar services. Also papers found in references of the selected articles were included. The summary of basic information about measurement evaluation methods is provided in the following pages

(Figure 4). Mere comparing the T2 times values stated in individual measurements does not allow making a general conclusion. The reason is that several parameters such as measurement sequence type, final resolution, ROI segmentation technique, the area of interest, age of the subjects, the load history, and the degree of the damage of the meniscus and other differ among individual studies. Moreover, the absolute values of T2 times may depend on the field strength, coil sensitivity, temperature, gradient systems, pulse sequences etc. Therefore the direct comparison of reported T2 relaxation times is problematic. The only correct approach is to compare relative changes in T2 values measured on the same scanner under the same conditions. Generally speaking, T2 relaxation times in healthy meniscus of middle age person range around 11 ms (Rauscher et al., 2008; Stehling et al., 2011; Zarins et al., 2010). Higher values are listed in medial meniscus (Chiang et al., 2013; Subburaj et al., 2012; Tsai et al., 2009; Zarins et al., 2010). Further, T2 times are the lowest in the white zone and they increase in direction to the red zone (Chiang et al., 2013; Tsai et al., 2009).

DISCUSSION

The authors very often use the SPGR pulse sequences to assess the degree of damage. With those sequences they achieve a relatively good resolution (about $0.3 \times 0.3 \times 1$) in a reasonable acquisition time (max. 9 min). 3D SPGR sequences are usually combined with T2 preparation modules. The results show that the lowest acquisition time is around 5 min when using the 3D UTE sequences AWSOS. The segmentation is performed either with a semi-automatic programs written in Matlab or IDL programming languages based on the edge detection or also by the manual detection of the borders. In an effort to reach a low error rate, the measured edges are often completely neglected from the segmentation. T2 relaxation times are mostly calculated using a mono-exponential fitting procedure based on the of the least squares method.

The reason why higher T2 values can been found in the healthy medial meniscus is the different organization of collagen fibers in both parts of the meniscus. In the medial meniscus collagen fibers are more organized, they have higher anisotropy. Also in the full knee extension phase, medial meniscus is loaded by less pressure element in comparison to the lateral meniscus (Athanasiou & Sanchez-Adams, 2009). Because the water is not expelled from the tissue T2 times in medial meniscus are increased.

The reported values indicate also the increase of T2 times depending on the geometric location of the monitored area (red zone – the highest T2 time) and the degree of meniscus damage (the degree of damage increases together with T2). T2 values increase also proportionally to the age. This fact can be explained by increasing free water content and mobility and also by the destruction of the cartilage with increasing age which may in turn lead to changes in meniscus. The studies have also showed that the T2 times in menisci increase after extreme loading. Directly after 30 min running, there are no significant changes in T2 relaxation times in any area of meniscus (Subburaj et al., 2012), however, significant changes were found after 48–72 hours (Stehling et al., 2011). The reason can be that during the resting time, tissue can by swollen by drawing free water into the matrix. Also, released catabolic

substances cause loosening of the collagen network. The permeability of the tissue increases, more interstitial (free) water appears and penetrates into this newly – acquired space.

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REFERENCES

ATHANASIOU, K. A., SANCHEZ-ADAMS, J. (2009). *Engineering the Knee Meniscus* (K. A. Athanasiou Ed. 1st ed.). Rice University. Morgan Claypool Publishers.

BAE, W. C., DU, J., BYDDER, G. M., CHUNG, C. B. (2010). Conventional and ultrashot time-to-echo magnetic resonance imaging of articular cartilage, meniscus, and intervertebral disk. *Top Magn Reson Imaging* 21(5), 275–289.

BRAUN, H. J., GOLD, G. E. (2012). Diagnosis of osteoarthritis: imaging. *Bone* 51(2), 278–288.

DELIGIANNI, X., BÄR, P., SCHEFFLER, K., et al. (2012). High-resolution Fourier-encoded sub-millisecond echo time muskuloskeletal imaging at 3 Tesla and 7 Tesla. *Magnetic Resonance in Medicine* 70(5), 1434–1439.

FIEREMANS, E. (2009). *Validation Methods for Diffusion Weighted Magnetic Resonance in Brain White Matter* (Ph.D. thesis), Gent University, Belgium. Retrieved from: fieremans.diffusion-mri.com/validation-methods-diffusion-weighted-mri-brain-white-matter.

FRAGONAS, E., MLYNÁRIK, V., JELLÚS, V., et al. (1998). Correlation between biochemical composition and magnetic resonance appearance of articular cartilace. *Osteoarthritis and Cartilage* 6(1), 24–32.

HASHEMI, R. H., BRADLEY, W. G., LISANTI, C. J. (2012). *MRI: the basics*. Lippincott Williams & Wilkins.

HENDRICK, R. E. (2008). *Breast MRI: Fundamentals and Technical Aspects*. New York: Springer.

HERYNEK, V. (2013). MR imaging – T1 and T2 relaxation, contrast of MR image, relaxometry. In vivo molecular and cell imaging 2013. Presentation – specialized seminar. ZRIR. IKEM Prague.

CHIANG, S. W., TSAI, P. H., CHANG, Y. C., et al. (2013). T2 Values of Posterior Horns of Knee Menisci in Asymptomatic Subjects. *Plos One* 8(3).

JURAS, V., APPRICH, S., ZBYN, S., et al. (2013). Quantitative MRI analysis of menisci using biexponential T2* fitting with a variable echo time sequence. *Magnetic Resonance in Medicine* 71(3), 1015–1023.

LI, X., MA, B. C., LINK, T., M., et al. (2007). In vivo T(1rho) and T(2) mapping of articular cartilage in osteoarthritis of the knee using 3 T MRI. *Osteoarthritis and Cartilage* 15(7), 789–797.

LIESS, C., LÜSSE, S., KARGER, N., et al. (2002). Detection of changes in cartilage water content using MRI T2-mapping in vivo. *Osteoarthritis and Cartilage* 10(12), 907–913.

MALÁ, A. (2011). Dynamic T1 – contrast enhanced MR imaging. (Master thesis), Masarykova Univerzita, Přírodovědecká fakulta, Brno. Retrieved from: http://is.muni.cz/th/211542/prif_m/dipl_MRI_CA_Mala.pdf.

McWALTER, E. J., BRAUN, H. J., KEENAN, K. E., GOLD, G. E. (2012). Knee. In *Encyclopedia of Magnetic Resonance*.

NISHII, T., KURODA, K., MATSUOKA, Y., et al. (2008). Change in knee cartilage T2 in response to mechanical loading. *J Magn Reson Imaging* 28(1), 175–180.

QIAN, Y., WILLIAMS, A. A., CHU, C. R., BOADA, F. E. (2012). High resolution ultrashot echo time (UTE) imaging on human knee with AWSOS sequence at 3.0 T. *Journal of Magnetic Resonance Imaging* 35(1), 204–210.

RAUSCHER, I., STAHL, R., CHENG, J., et al. (2008). Meniscal Measurements of T1 and T2 at MR Imaging in Healthy Subjects and Patients with Osteoarthritis. *Radiology* 249(2), 591–600.

STEHLING, C., LUKE, A., STAHL, R., et al. (2011). Meniscal T1rho and T2 measures with 3.0T MRI increases directly after running a marathon. *Skeleat Radiol* 40(6), 725–735.

STEHLING, C., SOUZA, R. B., HELLIO LE GRAVERAND, M. P., et al. (2012). Loading of the knee during 3.0T MRI is associated with significantly increased medial meniscus extrusion in mild and moderate osteoarthiritis. *European Journal of Radiology* 81(8), 1839–1845.

SUBBURAJ, K., KUMAR, D., SOUZA, R. B., et al. (2012). The acute effect of running on knee articular cartilage and meniscus magnetic resonance relaxation times in young healthy adults. *The American Journal of Sports Medicine* 40(9), 2134–2141.

THAKKAR, R. S., SUBHAWONG, T., CARRIO, J. A., CHHABRA, A. (2011). Cartilage Magnetic Resonance Imaging Techniques at 3 T: Current Status and Future Directions. *Topics in Magnetic Resonance Imaging* 22(2), 71–81.

TINTERA, J. (2008). MR zobrazování s magnetickým polem 3 T: teoretické aspekty a praktická srovnání s 1,5 T. *Česká Radiologie* 62(3), 233–243.

TSAI, P. H., CHOU, M. C., LEE, H. S., et al. (2009). MR T2 values of the knee menisci in the healthy young population: zonal and sex differences. *Osteoarthritis and Cartilage* 17(8), 988–994.

WELSCH, G. H., TRATTNIG, S., SCHEFFLER, K., et al. (2008). Magnetization transfer contrast and T2 mapping in the evaluation of cartilage repair tissue with 3T MRI. *Journal of Magnetic Resonance Imaging* 28(4), 979–986.

WILLIAMS, A., QIAN, Y., GOLLA, S., CHU, C. R. (2012). UTE-T2* mapping detects sub-clinical meniscus injury after anterior cruciate ligament tear. *Osteoarthritis and Cartilage* 20(6), 486–494.

ZARINS, Z. A., BOLBOS, R. I., PIALAT, J. B., et al. (2010). Cartilage and meniscus assesment using T1rho and T2 measurements in healthy subjects and patients with osteoarthritis. *Osteoarthritis and Cartilage* 18(11), 1408–1416.

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Table 1. The authors who have worked on the visualization of the knee meniscus for last 6 years: a summary of used sequences and procedures, basic imaging parameters and segmentation techniques, method for calculation of T2 relaxation times and their resulting values (sign "?" means that value was not stated in published paper

Author (Year) Object of work	Used sequences and parameters		Number of subjects (N) and Segmentation (S)	Calculation of T2 relaxation times	Making T2 maps, the resulting values of T2 relaxation times ± SD
Rauscher et al. (2008) Sequences according to Li et al. (2007) comparison of T2 times meniscus healthy and those with OA	*SPGR sequences*		N: 23 healthy subjects (age 34.1 ± 10), 27 with mild OA (age 52.5 ± 10.9), and 10 with severe OA (age 61.6 ± 11.6). S: Program in Matlab and use of semi-automated technique based on the edge detection and parametric Bezier curves.	The meniscal segmentations were then resampled and superimposed onto the T1rho and T2 maps to define the ROI for T1rho and T2 assessment.	T2 maps were automatically coregistered to the SPGR images.The selective T2 preparation sequences were added into the SPGR sequences and 3D sagittal T2 maps were created. After segmentation, the meniscus was transformed into a 3D binary mask with isotropic voxels, and T2 maps were reconstructed Values for both menisci: Health 11.4 ms ± 3.9 ms, middle level OA 13.5 ms ± 4.7 ms and a severe OA 16.6 ms ± 8.2 ms.
	TR/TE (ms)	20/7.5			
	FOV (mm)	160 × 160			
	Matrix	512 × 256			
	voxel size	0.293 × 0.293 × 1			
	aq. time (min)	7:37			
	non-selective T2 preparation sequences				
	TR/TE (ms)	2000/4.1; 14.5			
	FOV (mm)	140 × 140			
	Matrix	512 × 512			
	voxel size	0.54 × 0.72 × 3			
	aq. time (min)	10:36			
Tsai et al. (2009) zonal and also sex differences in the back corner of med. and lat. meniscus in 3 zones	*multislice TSE sequences*		N: 10 men and 10 women (age 26.5 ± 2.74). S: ROIs identified on the sagittal MR images of the first echo in the posterior horns of the med. and lat. menisci. To avoid partial volume effects, the upper and lower borders of the meniscus were not selected in the ROIs.	T2 were derived using the least square single-exponential curve-fitting method in the Matlab. Analysis of the T2 values was conducted on a zone-by-zone basis. The mean signal intensities were calculated in the ROIs of the posterior horns of the med. and lat. menisci on each slice of the motion-corrected images.	T2 maps are not produced. Zonal differences found in the back corner of the meniscus: inner white zone T2 = 8.02 ms ± 0.60 ms, white and red T2 = 8.78 ms ± 0.99 ms, outer red zone T2 = 22.12 ms ± 0.92 ms.
	TR/TE (ms)	2500/6.4; 9.4; 12; 15			
	FOV (mm)	?			
	Matrix	258 × 324			
	voxel size	? × ? × 1			
	aq. time (min)	14:40			

Zarins et al. (2010) value of T2 relaxation times in determined part of the meniscus depended on the damage	*3D SPGR*		N: 29 men, 34 women (age 51 ± 13.6). 19 of them without damaging the meniscus 26 with moderate OA and 18 with a severe OA. S: according to Raucher (2008) on the SPGR high-resolution images was performed semi-automatic segmentation at home created software in Matlab based on the edge detection and Bezier parametric curves.	All images were transferred to a Sun Workstation to create the T2 maps. The last T2-weighted image had extremely low signal, therefore, was not used for the reconstruction of T2 map.	Reconstructed by fitting the T1rho and T2 images pixel by pixel using a at home-made LM algorithm. A significant increase of the time in the posterior corners of med. and lat. meniscus at a higher level of damage was founded. Lat. meniscus: a healthy 10.42 ms ± 1.45 ms, higher levels of damage 12.03 ms ± 2.12 ms med meniscus: a healthy 11.26 ms ± 1.51 ms, corrupted 17.89 ms ± 4.51 ms.
	TR/TE (ms)	15/6.7			
	FOV (mm)	140 × 140			
	Matrix	512 × 512			
	voxel size	0.273 × 0.273 × 1			
	aq. time (min)	7:37			
	T2 preparation sequences				
	TR/TE (ms)	9. 3/3.1; 13.5; 23.9; 44.8			
	FOV (mm)	140 × 140			
	Matrix	256 × 192			
	voxel size	0.54 × 0.73 × 3			
	aq. time (min)	11:00			
Stehling et al. (2011) meniscus measured 48–72 h after completing marathon	*SPGR sequences*		N: The experimental group – 8 women and 5 men (age 32.3 ± 5.6), the control group – 4 men and 6 women (age 30.5 ± 5.3 years). S: in-house software developed with an Interactive Display Language (IDL). An IDL routine was used to simplify the drawing of splines delineating meniscal areas.	After the segmentation IDL routine was used to calculate the average T2 values of on the ROI generated maps.	Images were transferred to a remote SUN/SPARC station to create T2 maps. Resulting values: significant changes only in runners before competition 11.15 ms ± 1.46 ms, within 3 days after running 13.36 ms ± 1.27 ms, $p < 0.0001$ and 3 months after the competition 11.47 ms ± 1.42 ms.
	TR/TE (ms)	20/7.5			
	FOV (mm)	160 × 160			
	Matrix	512 × 512			
	voxel size	0.293 × 0.293 × 1			
	aq. time (min)	7:37			
	non-selective T2 preparation sequences				
	TR/TE (ms)	2000/4.1; 14.5; 25; 45.9			
	FOV (mm)	140 × 140			
	Matrix	256 × 192			
	voxel size	0.55 × 0.73 × 3			
	aq. time (min)	10:36			

Qian et al. (2012) Meniscus and its display with the highest possible resolution in a short time till 10 min	*Home developed 3D UTE seq. AWSOS*		N: 7 men and 2 women (age 28.3 ± 5.5), 5 of them asymptomatic and 4 with ACL injury. S: demonstration of the image acquisition with high resolution (0.28 mm) in a relatively short time (5–10 min). Meniscus non-segmented.	T2 times were not calculated.	T2 maps were not created.
	TR/TE (ms)	80/0.6			
	FOV (mm)	140 × 140			
	Matrix	512			
	voxel size	0.28 × 0.28 × 2			
	aq. time (min)	5:12 Spiral readout 16.80 ms			
Subburaj et al. (2012) articular cartilage + meniscus front and back corner after 30 min run	*T2 FSE*		N: 10 men and 10 women (age 22–35). S: from the sagittal SPGR images by using in house-made software based on spline-based semi-automatic segmentation algorithm in Matlab (automatic edge detection and manual correction).	Images were transferred to a workstation HP for the off-line quantification of T2 relaxation times.	T1rho and T2 maps were obtained by a combination of T1rho/T2 quantification sequences during post processing. Home made LM algorithm was used to fit the intensity images into the equation. T2-weighted images with TE = 54.8 ms had a low SNR ratio (SNR; <5), therefore they were not included into the reconstruction. Generally higher T2 values were found in medial anterior horn and medial body. After run, T2 times were increased in all regions except the posterior horn of the medial meniscus, but changes were not significant.
	TR/TE (ms)	4300/51			
	FOV (mm)	140 × 140			
	Matrix	512 × 256			
	voxel size	0.27 × 0.54 × 0.5			
	aq. time (min)	?			
	sag 3D SPGR; combined T1rho/T2 quantification sequences				
	TR/TE (ms)	15/6.7; 0/13.67/27.34/54.68			
	FOV (mm)	140 × 140			
	Matrix	512 × 512; 256 × 128			
	voxel size	0.27 × 0.27 × ?; 0.54 × 1.09 × 3			
	aq. time (min)	9:00			

Stehling et al. (2012) meniscal extrusion by applying loading 50% of body weight	*Sag.+coronal 2D T2-weighted FSE*		N: 10 healthy subjects and 20 with confirmed OA (age less than 40 years).	Qualitative change was not followed, only a shift of the burden meniscus.	Degenerative knee abnormalities demonstrate an increase of meniscal extrusion in a loaded knee joint compared to healthy samples.
	TR/TE (ms)	4000/48; 3000/10			
	FOV (mm)	140 × 140			
	Matrix	384 × 192			
	voxel size	0.36 × 0.72 × 2			
	aq. time (min)	?			
	coronal 3D SPGR				
	TR/TE (ms)	22/7.0			
	FOV (mm)	140 × 140			
	Matrix	512 × 512			
	voxel size	0.27 × 0.27 × 1.5			
	aq. time (min)	?			
Williams, Qian, Golla, and Chu (2012) T2* values of menisci in healthy subjects compared to subjects ACL rupture or both ruptured ACL and meniscus tearing	*AWSOS*		N: 10 healthy subjects, 25 with a ruptured ACL (age 26–77 years). S: manual rendering of the posterior horn of med. and lat. meniscus on the AWSOS sequences obtained at TE = 7 ms, where the contrast between the meniscus and the surrounding tissue was strongest.	Interpolation: Prior to T2 curve-fitting, TE images from the AWSOS sequence collected in vivo were linearly interpolated to a matrix size of 512 (or a pixel size of 273 mm) to permit finer image registration.	UTE-T2* maps were generated with a mono-exponential T2 curve-fit of all 11 echo images using MRI Mapper software. Values T2: in asymptomatic individuals 8 ms ± 2 ms, patients without rupture of the meniscus but ruptured ACL 13 ms ± 5 ms and patients with ruptured meniscus and the ACL 21 ms ± 7 ms.
	TR/TE (ms)	0.6; 1; 2; 3; 4; 5; 7; 10; 20; 30; 40			
	FOV (mm)	140 × 140			
	Matrix	256 × 256 lin. interpolated to 512 × 512			
	voxel size	0.273 × 0.273 × ?			
	aq. time (min)	22:00			

Chiang et al. (2013) Age, sex and zonal differences in the posterior corners of the meniscus	*multislice TSE sequences*		N: 30 asymptomatic men and 30 asymptomatic women (age groups 20–34, 35–49, 50–70 years). S: meniscus was divided into red, white and white-red according to the vascularization. On the omission of partial volume effects, the upper and lower edges were not included in the ROI.	T2 were derived from each image and averaged over all slices in on the ROI on the motion-corrected image. Then T2 values were derived using the least squares method in Matlab. The accuracy of fitting is reported by the R^2 values used in the non-linear curve fitting.	Motion correction: 2D auto-correlation method was used, in which the first image acquired with TE = 6.4 ms was used as a reference image to coregister the other three echo images acquired with TE = 9.4, 12, 15 ms, and between-slice 2D correlation coefficients were calculated. Results: 9.94 ms ± 0.94 ms, 10.73 ms ± 1.55 ms and 12.36 ms ± 2.27 ms for women of different ages. For men: 9.17 ms ± 0.74 ms, 9.64 ms ± 0.67 ms and 10.95 ms ± 1.33 ms.
	TR/TE (ms)	2500/6.4; 9.4; 12; 15			
	FOV (mm)	258 × 324			
	Matrix	?			
	voxel size	?			
	aq. time (min)	14:40			
Juras et al. (2013) T2* times of menisci	*3D vTE Cartesian SPGR sequences*		N: 48 healthy menisci, 12 degenerated and 8 with tears (study includes together 8 men age 34 ± 10 and 9 women aged 36 ± 14). S: ROI were defined on the five successive sections, each section was divided into two regions (white and black).	T2*: Images from the vTE sequence were analyzed using a custom-written script in IDL. A monoexponential as well as a biexponential fitting procedure was employed on all MR data sets on a pixel-by-pixel basis.	Comparison of the ability of monoexponential (Me) and biexponential (Be) T2* fitting to distinguish between healthy, degenerated and torn meniscus. Me: healthy 7.61 ms ± 2.49 ms, degenerated 9.54 ms ± 2.25 ms, meniscal tears 14.59 ms ± 5.24 ms. Be (compare short/long components of T2*): healthy 0.82 ms ± 0.38 ms / 15 ms ± 5.4 ms, degenerated 1.29 ms ± 0.53 ms / 19.97 ms ± 5.59 ms, meniscal tears 2.05 ms 0.73 ms / 26.83 ms ± 7.72 ms.
	TR/TE (ms)	29/0.75; 3.51; 5.87; 8.23; 10.6; 12.96; 15.33; 17.69; 20.06; 22.42			
	FOV (mm)	120 × 180			
	Matrix	256 × 176			
	voxel size	0.47 × 1.02 × 0.7			
	aq. time (min)	12:16			

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ASSESSMENT OF THE QUALITY OF MOVEMENT FOR PATIENTS WITH ADOLESCENT IDIOPATHIC SCOLIOSIS

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ABSTRACT

Goal of the work is to verify if there exists a significant difference in the quality of movement measured via virtual reality (VR) technology between two groups of patients diagnosed with adolescent idiopathic scoliosis (AIS). Grouping is made according to geographic regions; Group 1 is from Zagreb, Group 2 from Vukovar. Another goal of the work is to verify whether there is a significant improvement from initial to final measurements over a one year period in the results of all patients from both groups.

Hypothesis: there is no significant difference in the quality of movement between two groups of patients, as obtained through VR tests. The second hypothesis is that there is no significant difference in the results of specific VR tests for AIS between initial and final measurements of all the examinee; respectively, the conventional therapy program in both groups doesn't produce significant results in the direction of improvement.

The sample: each group is comprised of 5 patients with AIS diagnosis, between the ages of 12–18, of both genders. The patients have a double scoliotic curve with Cobb value between 37 and 46 degrees, and are being treated with classical physiotherapeutic methods for AIS, at clinics in Zagreb and Vukovar.

Methodology: VR tests for assessment of the quality of movement are a part of the *System for Diagnosis and Control in Kinesiology* (SYDACK) constructed at the Faculty of Kinesiology, University of Zagreb, as described in the dissertation: VR in physiotherapy of patients with AIS (Filipović, 2011). SYDACK is an original Croatian product, containing 4 VR tests for evaluating the quality of movement: diagonal sliding to the right, diagonal sliding to the left, sliding and hip elevation.

Results are analyzed via a t-test for small independent samples and a t-test for small dependent samples. In 93.75% cases there is no significant difference between results of the two groups, as obtained by all 4 VR tests. The analysis shows there is no geographical dependence in the quality of motion with AIS, which confirms the initial hypothesis. In 81.25% cases there is no significant difference in the results of specific VR tests between initial and final measurements. In 18.75% cases there is a significant difference in the direction of improvement.

Keywords: SYDACK; assessment; AIS

INTRODUCTION

Adolescent idiopathic scoliosis is represented as pathological postural adaptation of the body through a structural three-dimensional deformity of the vertebral column and the body in process of puberty (Filipović & Ciliga, 2010). Although scoliosis was described in detail by Hippocrates, with this condition there are still many unknowns. Theories about the origin of AIS are different, but there is a consensus about the multi factor etiology. Basic characteristics of pathological pattern of AIS are: postural asymmetry, dysfunction in proprioceptive system and abnormal postural balance. The origin of the problem points to the central nervous system (Zabjek, 2008; Filipović & Ciliga, 2010). Within the population of girls, AIS is 7 times more common than in the boys' population, and girls may be more sensitive to changes in central control during the development of the central nervous system (Lowe, 2000). Girls with AIS have insufficient balance control, which is explained as the problem of motor deficits which follow changes in vertebral torsion and rotational trunk asymmetry in relation to the vertical axis (Dalleau, 2007). Some studies suggest that through the visuomotor coordination and spatial recognition the brain uses abstract spatial information located between the sensory inputs and motor outputs (Veldhuizen, 2000). Huynh (2006) performed biomechanical analysis of patients with AIS and found that asymmetric development of the central nervous system can't be the only factor in the development of this condition since genetic background, growth and development play an important role (Schizas, 1998; Lowe, 2000). In this sense, the family history is positive in 36% of non-identical and 73% of monozygotic twins (Burgoyne, 2001). In choosing a treatment for AIS, it should be emphasized that spine reaches its maturation within 2 years after skeletal maturity (Dickson, 2004). Asymmetry in the paravertebral muscles on convex and concave sides of the scoliosis curve, measured by surface EMG, can be pointed as the central factor responsible for the progression of AIS (Cheung, 2004; Veldhuizen, 2000). However, today the asymmetry in paravertebral muscles as the origin of AIS is rejected and shown as a secondary aspect (Mahaudens, 2005; Weinstein, 2008; Filipović, 2011). The effectiveness of screening and early treatment using orthosis is an issue that is intensively discussed. Orthoses give some common non-operative approach, which has been used for 40 years, but more controlled trials of its effectiveness for AIS are necessary (Stephens Richards & Vitale, 2008; Bunge, 2008). Therapeutic evaluation of children with scoliosis is usually done by radiography. International Society on Scoliosis Orthopaedic Rehabilitation and Treatment (SOSORT) approves the method according to Cobb which is considered as the gold standard in scoliosis assessment. The biggest concern about the radiological assessment is that children at the age when their growing and development are intensive are exposed to radiation. However, Stephens Richards and Vitale (2008) emphasized that exposure to radiographic technology today is significantly lower than in the past. In order to reduce the risk of radiation exposure there are some imaging techniques which measure the deflection of the spine; scoliometry, Moire topography, integrated computer scan systems that use back contour surfaces as points for determining the direction and degree of deformation of the trunk (Mior, 1996). Pearsall (1992) states that the Cobb method does not describe fully three-dimensional deformation of the spine and associated segments. He also points out the lack of a forward bend test which is not sufficiently sensitive in measuring thoracolumbal deformities. Filipović (2003) states that

the Cobb method has no statistical significance in order to assess the function of the spine, where it only indicates the degree of curvature. Dickson (1999) explains that scoliosis is usually estimated by the Cobb method because it simply took root among clinicians, but the disadvantage is its non-linearity compared to increasing the size of curvature. Cobb angle is not an arithmetic size and can't be used as a descriptive statistic, while the reliability of the method according to Cobb, measured by multiple examiners, ranges between 3.2° and 9.6° error (Mior, 1996). However, no better approach was developed for the measurement of scoliosis. Lehnert-Schroth (1992) concludes through empirical research that the degree of scoliosis, measured using radiographs, is less important to patients – they want to see how the hump on their back decreases. Wong and Wong (2008) made a study on the use of "intelligent clothes" in assessing posture. Guided by the principle of therapeutic posture through continuous training and feedback control, and learning good postural habits, these authors constructed special clothing with built-in accelerometers and devices for the detection of postural curvature in the sagittal and coronal planes. Filipović (2006) provides a view of information technology application of virtual reality (VR) in the form SYDACK (System for Diagnosis and Control in Kinesiology), to the functional assessment of AIS, as well as in the physiotherapy for a variety of other disorders of the musculoskeletal system.

PURPOSE

Goal of the research is to verify if there exists a significant difference in the quality of movement measured via VR technology on specific tests named SYDACK between two groups of patients diagnosed with AIS. Another goal of the research is to check whether there is a significant improvement from initial to final measurements over a one year period in the results of all patients from the two groups. Grouping is made according to geographic regions; Group 1 is from Zagreb, Group 2 from Vukovar. Hypotheses are that there is no significant difference in the quality of movement between two groups of patients, as obtained through VR tests and that there is no significant difference in the results of VR tests for AIS between initial and final measurements of all examinee.

METHODS

The examinee sample is comprised of two groups. Each group is comprised of 5 patients with AIS diagnosis, between the ages of 12–18. The first group consists of three girls and two boys from Zagreb, the second of three girls and two boys from Vukovar. The patients have a double scoliotic curve with Cobb value between 37 and 46 degrees, and are treated with classical physiotherapeutic methods for AIS, at clinics in Zagreb and Vukovar respectively. VR tests for evaluating the quality of movement are a part of the SYDACK system constructed at the Faculty of Kinesiology, University of Zagreb, as described in the dissertation *VR in physiotherapy of patients with AIS* (Filipović, 2011). 4 VR tests were applied: diagonal sliding to the right, diagonal sliding to the left, sliding and hip elevation. Assessment of postural status was done once a month during the one year for both groups. All participants took up VR tests for the first time in this study. SYDACK

system is consisted of the following elements: **a)** Animated Avatar head model performs specific physiotherapeutic exercises on the computer screen (Figure 1) which include four VR tests; **b)** A set of two sensors tracks movements of postural segments, shoulder and pelvic girdle, in relation to the x-axis (forward and backward movement) and the y-axis (left and right movement); **c)** SYDACK consists of four applications: a program for viewing therapeutic exercises (continuous red lines on the computer screen), a program for displaying information from sensors that monitor the patient movement (intermittent lines), the application for the registration of data in a database and program for Avatar head model animation. The Avatar animation program is taken as an animation tool with the name Pozer-4, while the animation process is a combination of video recording of the physiotherapist motion and Pozer-4. SYDACK is an original Croatian product and the result of the scientific project VR in kinesiology and scientific research "Virtual reality in physiotherapy for adolescent idiopathic scoliosis" (Filipović, 2006).

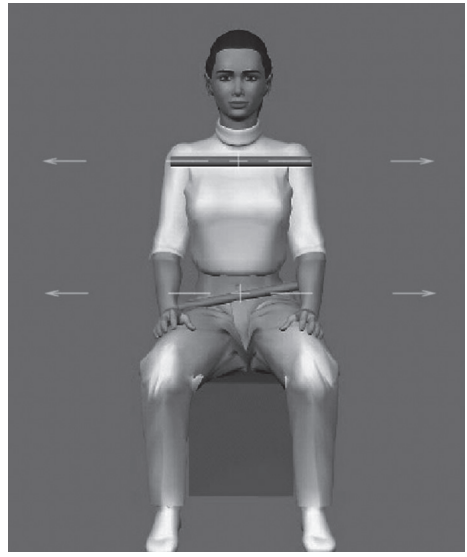

Figure 1. Avatar animated head model (Filipović, 2006)

Data are figures of deviations in angles from zero position to the end range of motion, and these are variances from y-axis and x-axis (the higher the score the higher deviation). Data analysis is based on monitoring and comparing the symmetry or asymmetry of motion in the initial and the final measurement. It analyzes the movements of the shoulder and pelvic girdle and at each there are sensors as labels that record angles in two dimensions (y-axis and x-axis). Analysis of postural status provides conclusions based on the results from analysis of variance of the initial to final measurements of these segments of the body. Therefore, selected shoulder and pelvic girdle movements are followed.

VR tests

Sliding test requires translation of the shoulder girdle in the frontal plane from side to side with a stable pelvis (Figure 2).

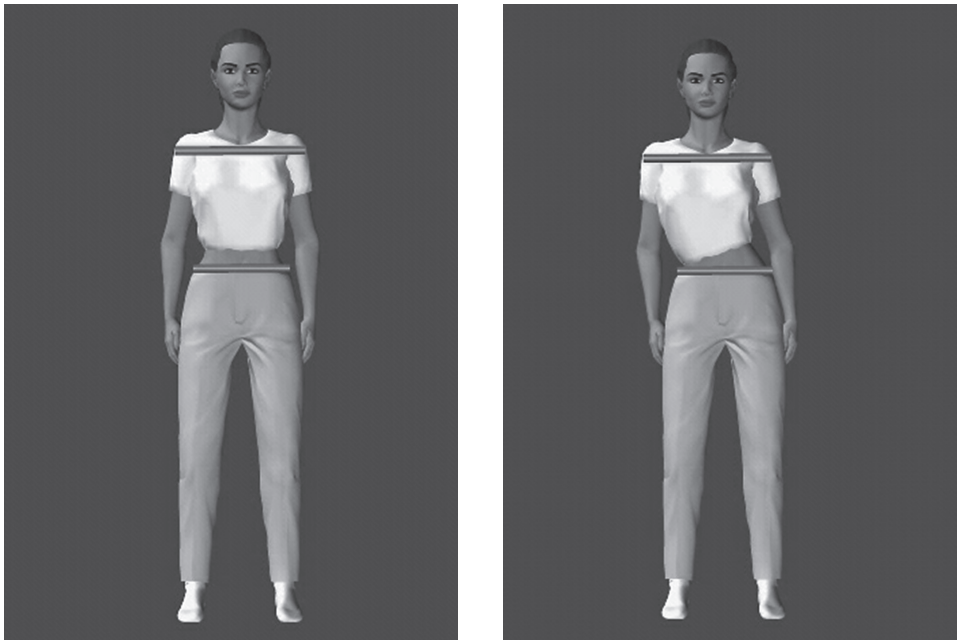

Figure 2. Sliding test (Filipović, 2006)

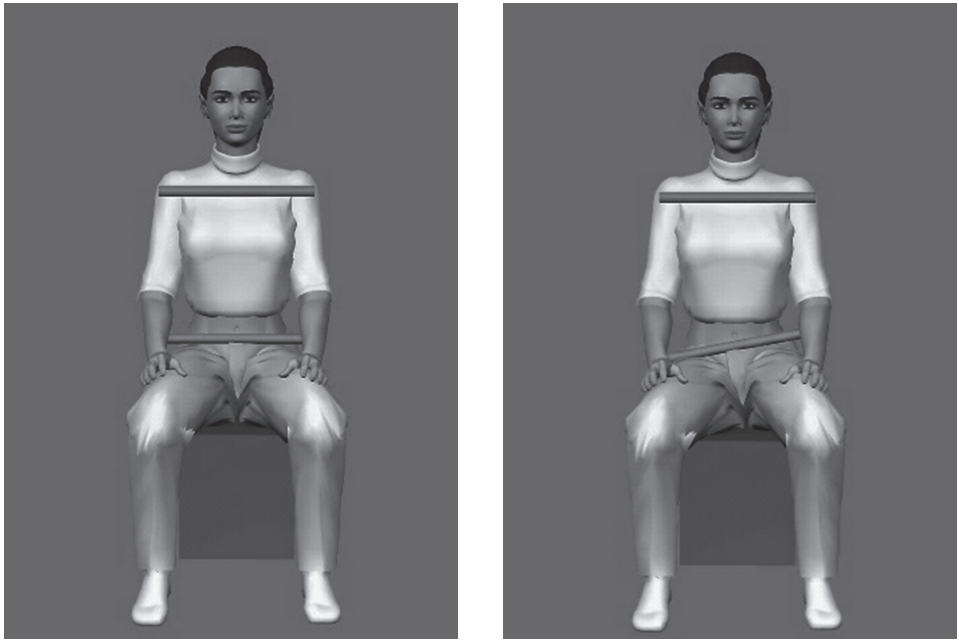

Figure 3. Hip elevation test (Filipović, 2006)

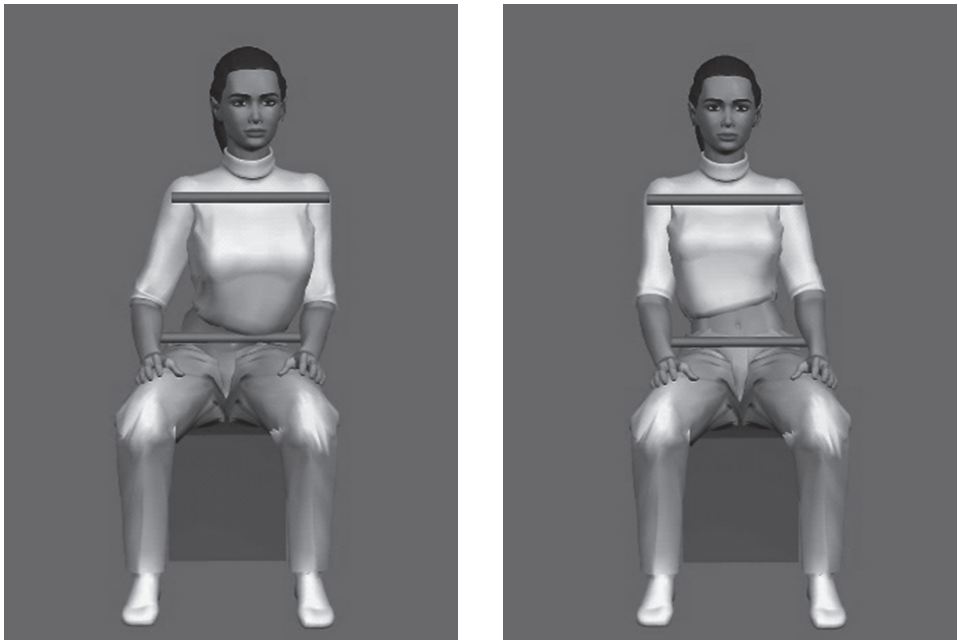

Figure 4. Diagonal sliding to the right test (Filipović, 2006)

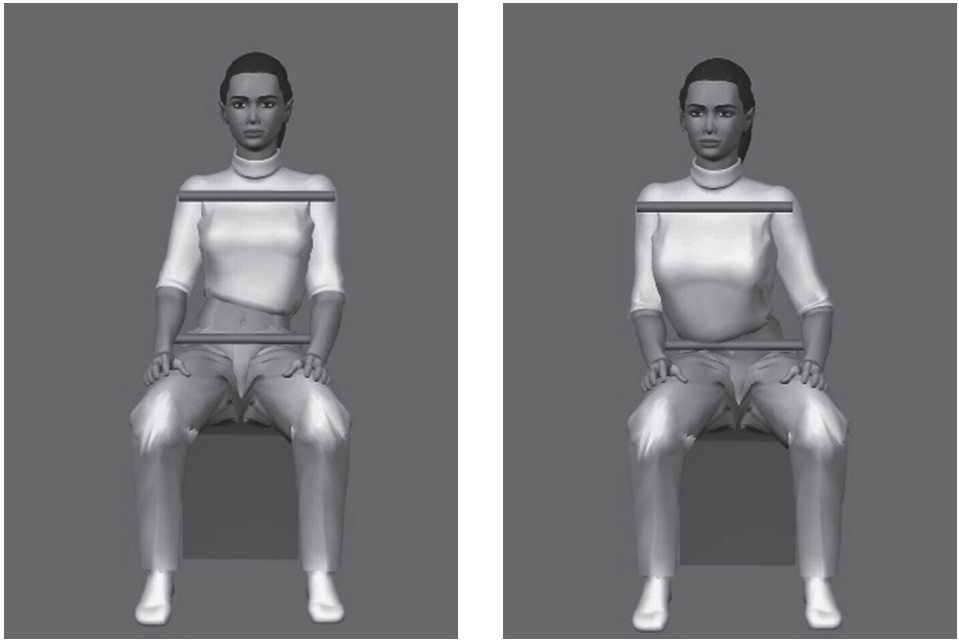

Figure 5. Diagonal sliding to the left test (Filipović, 2006)

Hip elevation test requires an alternating elevation of the pelvis in the frontal plane to the right and left with a stable shoulder girdle (Figure 3).

Diagonal sliding to the right test requires translation of the shoulder girdle and spine in the transverse plane right forward and left back with a stable pelvis (Figure 4).

Diagonal sliding to the left test requires translation of the shoulder girdle and spine in the transverse plane left forward and right back with a stable pelvis (Figure 5).

Each subject was individually assessed using an anamnestic questionnaire with questions on age, gender, city of living, body weight, body height, place and the time of making the AIS diagnosis, possible problems during their mother's pregnancy and their birth, family history and questions about the type and intensity of exercise, school and out-of school activities, and performing sports. Each examination was performed using SYDACK measurement systems and data were recorded on the same computer in the same conditions once a month. Measurement was individualized and continually carried out by the same examiner for a one year period. The first and last measurements were performed in 3 sets of 10 repetitions for each of the 4 VR tests with every subject. From the second to the eleventh measuring session, the participants performed a series of 10 repetitions for each of the 4 VR tests. SYDACK system is tested for its metric properties (Viskić-Štalec, 2006) and as a measuring instrument has high reliability and validity. Results are analyzed via a t-test for small independent samples and a t-test for small dependent samples, in the Statistical Package for the Social Sciences (SPSS), version 15.0.

RESULTS

In order to compare the results of each VR test for the subjects from Zagreb and Vukovar, a t-test for small independent samples was used – between small groups of Zagreb (N = 5) and Vukovar (N = 5) respectively.

Table 1. Comparison of initial and final results of the examinees from Zagreb and Vukovar on each variable of VR tests

	M	SD	t	df	P		M	SD	t	df	P
1axr group1	1.24	2.18	–0.43	8	>0.05	2axr group1	0.78	0.54	–0.5	8	>0.05
1axr group2	1.74	1.35				2axr group2	0.99	0.78			
1axz group1	0.58	0.26	–1.93	8	>0.05	2axz group1	1.42	1.43	–0.4	8	>0.05
1axz group2	2.43	2.13				2axz group2	1.80	1.17			
1ayr group1	2.37	2.01	–0.76	8	>0.05	2ayr group1	3.66	2.27	0.09	8	>0.05
1ayr group2	3.76	3.56				2ayr group2	3.47	3.69			
1ayz group1	2.93	2.45	0.31	8	>0.05	2ayz group1	3.10	2.96	–0.79	8	>0.05
1ayz group2	2.46	2.26				2ayz group2	4.74	3.51			

1bxr group1	2.22	1.47	–0.24	8	>0.05	2bxr group1	1.25	0.53	–0.88	8	>0.05
1bxr group2	2.51	2.27				2bxr group2	1.74	1.12			
1bxz group1	2.01	2.11	–0.62	8	>0.05	2bxz group1	1.33	0.62	–0.65	8	>0.05
1bxz group2	3.07	3.11				2bxz group2	1.82	1.55			
1byr group1	6.22	4.34	0.22	8	>0.05	2byr group1	2.6	2.36	–0.39	8	>0.05
1byr group2	5.67	3.46				2byr group2	2.65	1.58			
1byz group1	2.93	2.14	–2.28	8	>0.05	2byz group1	2	1.71	–1.7	8	>0.05
1byz group2	9.30	5.84				2byz group2	5.14	3.73			
1cxr group1	1.95	1.02	1.03	8	>0.05	2cxr group1	1.58	1.84	0.32	8	>0.05
1cxr group2	1.38	0.69				2cxr group2	1.27	1.02			
1cxz group1	2.71	3.12	–0.23	8	>0.05	2cxz group1	1.85	1.70	–0.15	8	>0.05
1cxz group2	3.06	0.93				2cxz group2	2	1.29			
1cyr **group1**	3.17	1.55	***–2.84***	8	**<0.05**	2cyr group1	4.41	3.51	–1.16	8	>0.05
1cyr **group2**	9.41	4.65				2cyr group2	8.08	6.08			
1cyz group1	1.91	1.41	–1.33	8	>0.05	2cyz group1	2.85	1.63	–2.05	8	>0.05
1cyz group2	5.23	5.35				2cyz group2	5.95	2.95			
1dxr group1	0.93	1.13	–1.26	8	>0.05	2dxr group1	0.32	0.20	–1.85	8	>0.05
1dxr group2	2.05	1.62				2dxr group2	0.97	0.74			
1dxz group1	2.50	3.12	–0.22	8	>0.05	2dxz group1	5.40	2.73	1.03	8	>0.05
1dxz group2	2.85	1.54				2dxzgroup2	3.58	2.82			
1dyr group1	2.43	1.06	–1.51	8	>0.05	2dyr group1	5.83	6.13	0.02	8	>0.05
1dyr group2	5.14	3.85				2dyr group2	5.76	4.28			
1dyz group1	1.68	1.48	–1.06	8	>0.05	2dyz group1	4.62	3.40	0.41	8	>0.05
1dyz group2	2.58	1.16				2dyz group2	3.90	1.89			

Legend: 1 – initial measurement; 2 – final measurement; x – axis with a tilt forward and back; y – axis with a tilt left and right; r – shoulders; z – pelvis; a – sliding test; b – hip elevation test; c – diagonal sliding to the right test; d – diagonal sliding to the left test; M – mean; SD – standard deviation; t – t-test; p – reliability

T-test shows that the difference between the arithmetic mean of the first and second group of patients isn't statistically significant ($p > 0.05$) for all of the variables, except the *1cyr* variable (initial tests measuring diagonally sliding to the right on the y-axis in the shoulder girdle) where a statistically significant difference exists between means ($p < 0.05$). With the exception of the variable *1cyr*, the hypothesis that there is no statistically significant difference in the quality of movement between two groups of patients in specific VR tests for AIS is confirmed. Between 32 analyzed parameters (initial and final tests) 31 didn't show a statistically significant difference in the results (96.87%). Between 16 initial variables, 15 of them didn't show a statistically significant difference in the results (93.75%). It is possible to conclude with statistical significance that there is no geographical and regional dependence between the two groups of patients with the

diagnosis of AIS, according by place of living, in results of 4 VR tests that evaluate the quality of motion of two postural body segments, the shoulder girdle and pelvis.

In response to the second problem including initial and final measurement, a t-test for small dependent samples was used, for all subjects in total (N = 10).

Table 2. Comparison of the results achieved in all patients at each initial and final VR test

	M	SD	t	df	P
pair 1 1axrM – 2axrM	0.60	1.74	1.09	9	>0.05
pair 2 1axzM – 2axzM	–0.10	2.11	–0.16	9	>0.05
pair 3 1ayrM – 2ayrM	–0.49	4.79	–0.32	9	>0.05
pair 4 1ayzM – 2ayzM	–1.22	4.79	–0.80	9	>0.05
pair 5 1bxrM – 2bxrM	0.87	1.86	1.47	9	>0.05
pair 6 1bxzM – 2bxzM	0.96	2.04	1.49	9	>0.05
pair 7 **1byrM – 2byrM**	3.32	4.48	***2.33***	9	**<0.05**
pair 8 **1byzM – 2byzM**	2.54	2.94	***2.73***	9	**<0.05**
pair 9 1cxrM – 2cxrM	0.24	1.24	0.61	9	>0.05
pair 10 1cxzM – 2cxzM	0.96	1.81	1.67	9	>0.05
pair 11 *1cyr*M – 2cyrM	0.04	6.01	0.02	9	>0.05
pair 12 1cyzM – 2cyzM	–0.82	5.17	–0.50	9	>0.05
pair 13 1dxrM – 2dxrM	0.84	1.42	1.87	9	>0.05
pair 14 1dxzM – 2dxzM	–1.81	3.59	–1.59	9	>0.05
pair 15 1dyrM – 2dyrM	–2.01	6.81	–0.93	9	>0.05
pair 16 **1dyzM – 2dyzM**	–2.12	2.07	***–3.24***	9	**<0.05**

There is no significant difference between arithmetic means ($p > 0.05$) in most of the pairs (81.25%). The exceptions are the following tests in which there is a significant difference ($p < 0.05$):

– pair 7 (initial and the final assessment of the *byr* variable: hip elevation on the y-axis of the shoulder girdle),

– pair 8 (initial and the final assessment of the *byz* variable: hip elevation on the y-axis of the pelvis),
– pair 16 (initial and the final assessment of the *dyz* variable: diagonal sliding to the left on the y-axis of the pelvis).

For these pairs, three of them 16 (18.75%) there is a significant difference in the results of specific VR tests assessment between initial and final measurements.

DISCUSSION

The intention of the physiotherapeutic evaluation of patients with AIS measured via VR technology was to check whether there is a significant difference in the results of examinees from Zagreb and Vukovar in the quality of movement. Pathology length in patients from diagnosis to initial measurements using SYDACK system is from 6 months to 2 years. The presence of male patients in the sample confirms the characteristics of AIS by Lowe (2000) although the clinical experience of authors is not 7:1 ratio for girls, but the AIS increases in frequency among boys and the age of the patients decreases. The patient sample has the range of the AIS curve according to Cobb of an angle from 18° to 38°, which means that tested candidates are not in the category suitable for surgery. There was no statistically significant difference between the results of the two analyzed groups measured via VR technology for assessment of the quality of movement. Results of initial tests obtained in 15 of the 16 variables (93.75%) indicate that the groups don't vary in territorial characteristics (lifestyle, environmental conditions, etc.). The only exception is represented by the initial measurement of the shoulder girdle motion through diagonal sliding to the right test, for the y-axis (variable *1cyr*), which shows significant variation in the direction of better results in the first group (patients from Zagreb). The final measurement of the same exercise as well as all other final measured tests, shows no statistically significant difference between two groups. According to these results it is possible to assume that there is no geographical dependence for the obtained results. In tests *1axz* (initial assessment of the exercise-test sliding on the x-axis of the pelvis), *1byz* (initial assessment of the exercise-test hip elevation on the y-axis of the pelvis) and *2cyz* (final assessment of the exercise-test diagonal sliding to the right on the y-axis of the pelvis) the difference is close to significance, also in the direction of better results in the first group. During the assessment some of the patients characteristics were perceived, related with their approach and expectations of the treatment. It has been shown that patients from Vukovar have less opportunity for active exercise, for continuous monitoring of physiotherapist or for sports activities, in relation to patients from Zagreb, who were all involved in an activity and have a wider choice of places and modules for AIS treatment. Through conventional methods of clinical AIS treatment, physiotherapy is limited to an average of 10 sessions and the intensity of the therapy depends on the patients themselves; their parents, motivation, desire, and persistence. Possible relation between patients according to AIS conventional physiotherapy in clinics is determined by chance of choice. The type of sport that the patients are involved in is also very important; how intensely and for how long are they doing it, because some sports activities such as tennis, volleyball, badminton and other sports that use a dominant hand (Gielen & Van der Eede, 2008) adversely affect

the postural pattern and raise progression of scoliosis. Well selected sports significantly increase lung function in patients with AIS. Sports with high axial loads, such as lifting weights or those where there are extreme forms of hyperlordosis, especially those that raise resistance in spastic tissues may be potentially harmful in the treatment of AIS. Negrini et al. (2008) showed that physical therapy exercises can have a positive effect on the function of breathing, strength and postural balance and are useful in reducing the specific difficulties for patients with AIS. They state that specific and personalized treatment could be more effective than conventional physical therapy in order to reduce the progression of scoliosis. A small sample is one of the drawbacks of this research. Difficulty was also in motivating patients to the continuous arrival on examination once a month. Patients were involved in the conventional program for scoliosis physiotherapy at clinics and there is an evident lack of a specific individual therapeutic approach to their treatment. On the basis of these results, possibilities for new research are opening, with larger samples and variables. Possible problems that are imposed here are the psychological characteristics of children with AIS, lifestyle, hereditary factors, timely diagnosis and individualized physiotherapy with the goal of postural reeducation of pathological pattern.

CONCLUSION

Despite various theories about the origin, etiopathogenesis of AIS is not fully evidenced and still remains unknown. There is a consensus about the multi factor etiology of AIS. Comprehensiveness and thoroughness of the assessment is fundamental for any treatment of pathology. The goal of the research is to verify if a significant difference in the quality of movement measured via VR technology on specific tests named SYDACK between two groups of patients diagnosed with AIS exists. Grouping is made according to geographic regions; Group 1 is from Zagreb, Group 2 from Vukovar. Another goal of the work is to verify whether there is a significant improvement from initial to final measurements over a one year period in the results of two groups of patients. The hypothesis is that there is no significant difference in the quality of movement between the two groups of patients, as obtained through VR tests, and no geographical dependence. The second hypothesis is that there is no significant difference in the results of specific VR tests for AIS between initial and final measurements of all patients, from Zagreb and Vukovar; it points that the conventional therapy program in both groups doesn't produce significant results in the direction of improvement. The sample consists of two groups of 5 patients with AIS diagnosis, between the ages of 12–18, of both genders. Subjects were diagnosed with double scoliotic curve with Cobb value between 37 and 46 degrees, and are being treated with classical physiotherapeutic methods for AIS, at clinics in Zagreb and Vukovar respectively. SYDACK system for evaluating and analyzing the postural status was constructed at the Faculty of Kinesiology, University of Zagreb. It consists of four applications: a program for viewing therapeutic exercises, a program for displaying information from sensors that monitor the patient's movement, the application for the registration of data in a database and a program for the animation of the Avatar head model. Results are analyzed via a t-test for small independent samples, in the Statistical Package for the Social Sciences (SPSS), version 15.0. Results obtained in 15 of the 16 variables (93.75%)

indicate that there is no statistically significant difference between patients from Zagreb and patients from Vukovar on specific initial assessment of AIS via VR tests. From a total of 32 analyzed variables (initial and final tests) 31 didn't show a statistically significant difference in the results (96.87%). Results indicate a more favorable initial status of patients from Group 1, and almost negligible significance of differences in the final status. That suggests greater success applying AIS exercises for patients from Group 2. It is possible that the explanation of these indicators lies in the regional conditionality and impact of the social environment. The t-test for small dependent samples in all patients (Group 1 and Group 2 together) for three of the 16 cases (18.75%) shows a significant difference in the results of specific VR tests assessment between initial and final measurements, in the direction of improvement. One of the drawbacks of this research is a small sample. The reason for this is the difficulty of measuring which had to be individualized and continuous over a period of one year, on the same instrument, in the same conditions, and that had to be done by the same examiner. There is a need for new research with the requirement for analysis of psychological, sociological factors of causality and an analysis of individual and targeted physiotherapy for AIS.

REFERENCES

BUNGE, E. M., JUTTMANN, R. E., VAN BIEZEN, F. C., et al. (2008). Estimating the effectiveness of screening for scoliosis: A case-control study. *Pediatrics* 121, 9–14.

BURGOYNE, W., FAIRBANK, J. (2001). The Management of scoliosis. *Current Paediatrics* 11, 323–331.

CHEUNG, J., HALBERTSMA, J. P. K., VELDHUIZEN, A. G., et al. (2005). A preliminary study on electromyographic analysis of the paraspinal musculature in idiopathic scoliosis. *European Spine Journal* 14, 130–137.

DALLEAU, G., ALLARD, M. S., BEAULIEU, M., et al. (2007). Free moment contribution to quiet standing in able-bodied and scoliotic girls. *European Spine Journal* 16, 1593–1599.

DICKSON, R. A. (1999). Spinal deformity – adolescent idiopathic scoliosis. *Spine* 24(24), 2601–2606.

DICKSON, R. A. (2004). Spinal deformity – basic principles. *Current Orthopaedics* 18, 411–425.

FILIPOVIĆ, V. (2003). *Biomehanička analiza lokomocije i posturalnih svojstava kod idiopatskih adolescentnih skolioza*. [Biomechanical analysis of locomotion and of postural characteristics in idiopathic adolescent scoliosis. In Croatian.] (Unpublished Master's thesis, University of Zagreb). Zagreb: Kineziološki fakultet Sveučilišta u Zagrebu.

FILIPOVIĆ, V. (2011). *Virtualna realnost u programu fizioterapije pacijenata s idiopatskom adolescentnom skoliozom.* [VR in physiotherapy of patients with adolescent idiopathic scoliosis. In Croatian.] (Unpublished dissertation, University of Zagreb). Zagreb: Kineziološki fakultet Sveučilišta u Zagrebu.

FILIPOVIĆ, V., CILIGA, D. (2010). Postural adaptation of idiopathic adolescent scolioses (IAS). *Kinesiology* 42(1), 16–27.

FILIPOVIĆ, V., VISKIĆ-ŠTALEC, N., ŠTALEC, J., et al. (2006). SYDACK – System of Diagnosis and Control in Kinesitherapy. 28th Int. Conf. *Information Technology Interfaces ITI 2006*, June 19–22, 2006, Cavtat, Croatia.

GIELEN J. L., VAN DER EEDE, E. (2008). Scoliosis and sports participation. *International SportMed Journal* 9(3), 131–140.

HUYNH A.-M., AUBIN, C.-E., RAJWANI, T., et al. (2007). Pedicle growth asymmetry as a cause of adolescent idiopathic scoliosis: a biomechanical study. *European Spine Journal* 16, 523–529.

LEHRNERT-SCHROTH, C. (1992). Introduction to the three-dimensional scoliosis treatment according to Schroth. *Physiotherapy* 78(11), 810–815.

LOWE, T. G., EDGAR, M., MARGULIES, J. Y., et al. (2000). Etiology of idiopathic scoliosis: current trends in research. *The Journal of Bone and Joint Surgery* 82-A(8), 1157–1168.

MAHAUDENS, P., THONNARD, J. L., DETREMBLEUR, C. (2005). Influence of structural pelvic disorders during standing and walking in adolescents with idiopathic scoliosis. *The Spine Journal* 5, 427–433.
MIOR, S. A., KOPANSKY-GILES, D. R., CROWTHER, E. R., WRIGTH, J. G. (1996). A comparison of radiographic and electrogoniometric angles in adolescent idiopathic scoliosis. *Spine* 21(13): 1549–1555.
NEGRINI, S., ZAINA, F., ROMANO, M., et al. (2008). Specific exercises reduce brace prescription in adolescent idiopathic scoliosis: a prospective controlled cohort study with worst-case analysis. *J Rehabil Med* 40, 451–455.
PEARSALL, D. J., REID, J. G., HEDDEN, D. M. (1992). Comparison of three noninvasive methods for measuring scoliosis. *Physical Therapy* 72(9), 35–44.
SCHIZAS, C. G., KRAMERS-DE QUERVAIN, I. A., STÜSSI, E., GROB, D. (1998). Gait asymmetries in patients with idiopathic scoliosis using vertical forces measurement only. *European Spine Journal* 7, 95–98.
STEPHENS RICHARDS, B., VITALE, M. G. (2008). Screening for idiopathic scoliosis in adolescents. An information statement. *J Bone Joint Surg Am* 90, 195–198.
VELDHUIZEN, A. G., WEVER, D. J., WEBB, P. J. (2000). The aetiology of idiopathic scoliosis: biomechanical and neuromuscular factors. *European Spine Journal* 9, 178–184.
VISKIĆ-ŠTALEC, N., ŠTALEC, J., FILIPOVIĆ, V., VUK, S. (2006). The reliability of the movement measurement quality by SUDIKK system. Suvremena kineziologija. Kupres.
WEINSTEIN, S. L., DOLAN, L. A., CHENG, J. C. Y., et al. (2008). Adolescent idiopathic scoliosis. *Lancet* 371, 1527–1537.
WONG, W. Y., WONG, M. S. (2008). Smart garment for trunk posture monitoring: A preliminary study. *Scoliosis* 3, 7.
ZABJEK, K. F., COILLARD, C., RIVARD, C. H., PRINCE, F. (2008). Estimation of the centre of mass for the study of postural control in idiopathic scoliosis patients: a comparison of two techniques. *European Spine Journal* 17, 355–360.

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HEALTH BEHAVIOURS AND THEIR DETERMINANTS AMONG PHYSICAL EDUCATION AND PEDAGOGY STUDENTS AS WELL AS SCHOOL TEACHERS – A COMPARISON STUDY

IDA LAUDANSKA-KRZEMINSKA

ABSTRACT

The aim of this study is to analyze social and individual determinants of health behaviour. The following factors are evaluated: nutrition, physical activity (PA) and smoking behaviour. The examined determinants of health behavior include: health-specific self-efficacy and health locus of control. Material and Methods: The survey was carried out among 298 students at state and private universities in Poznań and 342 teachers in primary and secondary schools in the Wielkopolska Province in Poland. The author's questionnaire was used to assess nutrition and smoking status and the International Physical Activity Questionnaire (IPAQ) served to evaluate PA. The health related self-efficacy questionnaires and Multidimensional Health Locus of Control Scale (MHCL) were employed. Results and Conclusion: Health oriented physical education studies favour a more healthy lifestyle both during the studies and employment. The worst health behaviour patterns have been found among pedagogy students. The issue of healthy life style should be given more prominence in the curriculum at the undergraduate level to better develop health-sensitive personality in future teachers.

Keywords: health behaviour; self efficacy; health locus of control; students; school teachers

INTRODUCTION

Health behaviour is one of the most significant factors determining health. According to the first indications in this respect, developed in the Lalonde Report (1974), their influence is as high as 53%. Nutrition, physical activity (PA) and smoking play particularly important roles from the point of view of prevention against civilisation related diseases. Each of the areas of behaviour above has been discussed in a number of reports in terms of behaviour patterns beneficial for health or health consequences of not complying with them. Another direction is the analysis of various combinations of accumulation of behaviours, both beneficial and adversely affecting health, which has not got so many reports. Patterns in this respect may be determined by socialising processes related to the direction of education, professional status, age, sex etc.

In the area of health science the issue of psychosocial determinants of specific human behaviour towards health is particularly interesting. Self-efficacy is one of the important determinants of health behaviour. It is used in Social Cognitive Theory explaining the realisation of health behaviour (Bandura, 1977). Many things indicate that in the context of developing health behaviour not only general self-efficacy is important, but rather health-specific self-efficacy (Schwarzer, 1995). This is an individual characteristic which is built on the basis of a person's experience, is a consequence of their personality, education, etc. Thus, it may evolve under the influence of educational activities, hence many educational interventions (programmes) relating to health behaviour are directed to improve self-efficacy (Łuszczyńska, 2007). In respect to various types of health behaviour it may have a varied degree of predictiveness (Von Ah, 2004; Łuszczyńska, 2004). Many studies indicate that the feeling of self-efficacy is related to undertaking and continuing health behaviour, such as prevention of uncontrolled sexual behaviour, undertaking regular physical exercise, controlling weight and nutritional behaviour, prevention and quitting of smoking and other addictions (AbuSabha, 1997; Schwarzer, 2007).

Health locus of control (HLC) informs about the role a person allocates to himself/herself and external factors (authorities or coincidence) in responsibility for his/her health. People are categorised as "external" or "internal" depending on how they perceive the effect of external (e.g. powerful others, chance, God etc.) or internal (e.g. the self) factors on their health (Wallston, 1978a). It is generally assumed that people with an internal health locus of control have better health habits (Norman, 1998) than people with an external locus of control. Its relations to health behaviours are not as strong as self-efficacy, although worth attention. In particular for health educator they may mark the direction of necessary educational activities.

PURPOSE

The aim of this study is to analyse the patterns of coexistence of the three main health behaviours (PA, nutrition, smoking) among physical education and pedagogy students as well as school teachers. The social and individual determinants of health behaviour will also be investigated. The examined determinants of health behaviour include: health-specific self-efficacy and health locus of control. We are looking at differences between university students, studying to be teachers in the future, and actual working school teachers.

MATERIAL AND METHODS

Study participants

The survey was carried out among 298 students at state and private universities in Poznań and 342 teachers in primary and secondary schools in the Wielkopolska Province in Poland. There were 126 Physical Education (PE) students and 172 Pedagogy (P) students, 95 PE teachers and 247 Other Subjects (OS) teachers. The stratification of the participants is presented in Table 1.

Table 1. Description of the study samples

n		All	PE teachers	OS teachers	PE students	P students
		640	95	247	126	172
age	$\bar{x}$ ± SD	31.9 ± 11.8	39.5 ± 9.0	41.2 ± 9.8	21.6 ± 1.4	22.8 ± 4.8
gender	♀ n (%)	499 (78)	56 (59)	213 (86)	84 (67)	146 (85)
	♂ n (%)	141 (22)	39 (41)	34 (14)	42 (33)	26 (15)

MEASURES

The author's questionnaire pool was used to assess nutrition and smoking status. The nutrition status was calculated as a mean of answers to 12 questions relating to the number and quality of meals rated on the scale from 1 (unhealthy behaviour) through 2 (moderate) to 3 (healthy behaviour). Smoking status was evaluated in two categories: as currently smoking or as non-smoking respondents (used to smoke or never smoked). The International Physical Activity Questionnaire (IPAQ) (Biernat, 2005) was used to assess the respondents' physical activity. Metabolic Equivalents (METs) values per week were calculated for individuals and the respondents were divided into three categories of PA (law, moderate, high). We also used two Schwarzer's (2000) questionnaires: the Nutrition Self-Efficacy Questionnaire and the Physical Exercise Self-Efficacy Questionnaire, Velicer and others'(1990) Smoking Self-Efficacy Questionnaire; to assess the health locus of control we used the Multidimensional Health Locus of Control Scale (Wallston, 1978b; Juczyński, 2001: 79–86).

Statistical analyses

The data were analysed using STATISTICA 10.0 software (StatSoft Inc., Tulsa, OK). Statistical significance was defined as $p \leq .05$. One way analysis of variance (ANOVA) was used to compare the analysed groups for PA, nutrition, smoking. The eta-squared ($\eta 2$) effect size was calculated. The effect size indicates the percent of variance explained by the particular effects of the dependent variable. To compare the average values of mean health behaviour Tukey HSD test detailed post hoc comparisons were conducted. Cluster analysis was used to group the individuals with the similar behaviour (healthy or unhealthy). Forward stepwise regression was used to find psychological variables related to nutrition and PA. The logistic regression and Pearson's correlation coefficient were calculated for smoking status and psychological variables.

RESULTS

The findings from the analysed behaviour are reported in Table 2. There are significant differences in smoking status between the analysed groups ($p = .012$). The P students

significantly more often smoke cigarettes than Other Subjects teachers (p = .026). There are significant differences in nutrition behaviour (p < .0001). Pedagogy students have the worst nutrition habits. Other Subjects teachers, PE teachers and PE students have better nutrition behaviour than Pedagogy students (p = .054, p = .001, p < .0001, respectively). PE students have better nutrition than Other Subjects teachers (p = .016). PE students have the highest score of PA. They differ significantly from Pedagogy students (p < .0001) and Other Subjects teachers (p < .0001). The PE teachers also have a better score than Pedagogy students (p = .018) in reference to PA.

Table 2. F statistics for differences among analyzed groups

		OS Teachers	PE Teachers	P Students	PE Students	F (p)	η2
		$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD		
Nutrition (score)		2.38 ± .27	2.46 ± .25	2.31 ± .26	2.49 ± .28	12.41 (.000)	.06
PA (METs)		4367 ± 4250	5944 ± 5115	3979 ± 4083	6778 ± 6556	8.66 (.000)	.05
		% (n)	% (n)	% (n)	% (n)		
Smoking	yes	14 (35)	14 (13)	26 (45)	21 (25)	3.66 (.012)	.02
	no	86 (205)	86 (78)	74 (125)	79 (93)		

METs – Metabolic Equivalent minutes per week

Two clusters of individuals were identified in each of the analysed groups (see Figure 1 and Figure 2). The descriptive characteristics of the clusters are presented in Table 3. PA and nutrition behaviour are the significant factors of differentiation for the clusters identified among Other Subjects teachers. Cluster 1 is characterised by higher PA and better nutrition and it contains 50% of Other Subjects teachers. Cluster 2 is characterised by less healthy behaviour and it contains 50% of Other Subjects teachers. Nutrition behaviour and smoking status are significant factors of differentiation for the clusters identified in the group of PE teachers. As previously, cluster 1 is characterised by healthier behaviour (better nutrition, no smoking) and it includes 80% of PE teachers. Cluster 2 is characterised by unhealthy behaviour and it includes 20% of PE teachers.

Smoking status is a significant factor (only statistical tendency was noted for nutrition) for the clusters identified in the group of Pedagogy students. Unfortunately, both clusters show unhealthy behaviour (low PA, unhealthy nutrition) and non-smoking status for cluster 1 or smoking cigarettes for cluster 2. The clusters include 73% and 27% of Pedagogy students, respectively. Nutrition behaviour is the significant factor (only statistical tendency was noted for smoking) for the clusters identified in the group of PE students. Cluster 1 is characterised by healthy behaviour (better nutrition, non-smoking) and it includes 67% of PE students. Cluster 2 is characterised by unhealthy behaviour and it includes 33% of PE students.

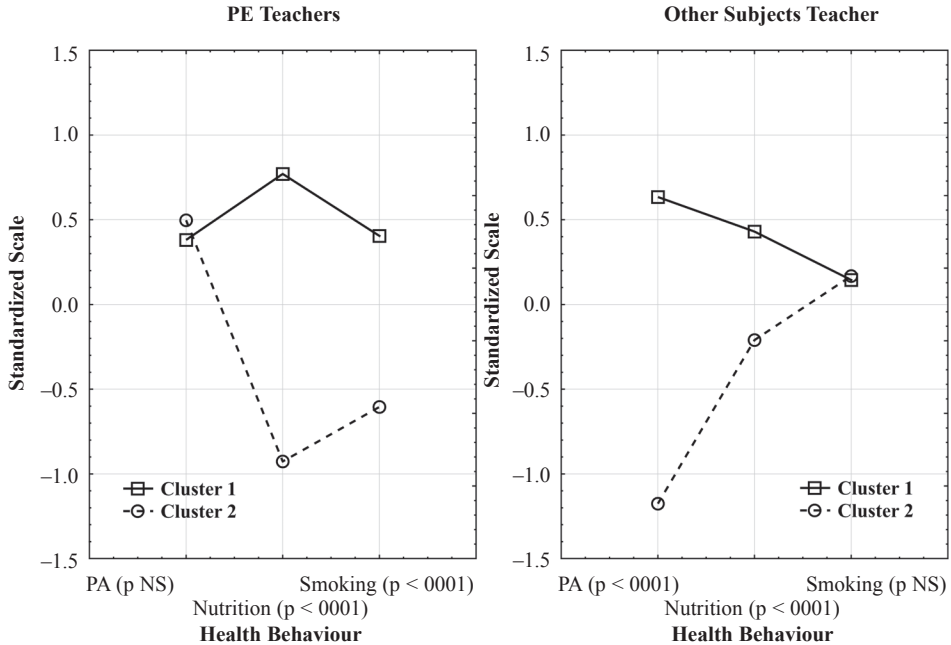

Figure 1. Cluster analysis diagrams for PE teachers and Other Subjects teachers

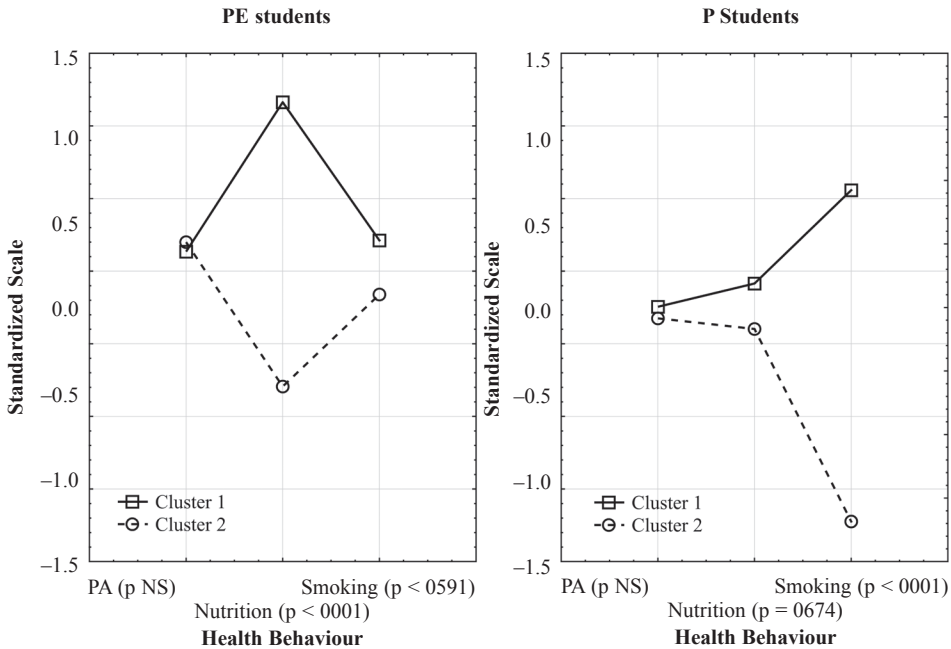

Figure 2. Cluster analysis diagrams for PE students and Pedagogy students

Table 3. Descriptive characteristics of the clusters for analyzed groups of respondents

		OS Teachers		PE Teachers		P Students		PE Students	
		cluster 1	cluster 2	cluster 1	cluster 2	cluster 1	cluster 2	cluster 1	cluster 2
		% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
PA	low	–	75 (79)	11 (7)	6 (1)	29 (33)	38 (16)	24 (17)	21 (7)
	moderate	26 (28)	25 (26)	23 (15)	25 (4)	40 (45)	29 (12)	19 (13)	21 (7)
	high	74 (79)	–	66 (42)	69 (11)	31 (35)	33 (14)	57 (40)	58 (20)
Smoking	yes	17 (18)	14 (15)	5 (3)	50 (8)	–	100 (42)	16 (11)	32 (11)
	no	83 (89)	86 (90)	95 (61)	50 (8)	100 (113)	–	84 (59)	68 (23)
		$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD
Nutrition (score)		2.47 ± .27	2.29 ± .25	2.56 ± .18	2.10 ± .14	2.33 ± .26	2.24 ± .23	2.66 ± .11	2.14 ± .19

Forward stepwise regression was used in order to find the most significant factor related to nutrition and PA (Table 4). Models significant for predicting almost all behaviour in all groups were found (except PA in the group of Pedagogy students). Significant prediction was established for daily physical activity among Other Subjects teachers ($F_{(2,210)} = 5.65$, $p = .004$, $R^2 = .05$), among PE teachers ($F_{(3,81)} = 3.01$, $p = .035$, $R^2 = .10$), and among PE students ($F_{(1,120)} = 26.29$, $p < .001$, $R^2 = .18$). Similarly, there is significant prediction for nutrition habits among Other Subjects teachers ($F_{(3,189)} = 3.39$, $p = .019$, $R^2 = .05$), among PE teachers ($F_{(2,72)} = 4.20$, $p = .019$, $R^2 = .10$), among Pedagogy students ($F_{(2,137)} = 3.77$, $p = .026$, $R^2 = .05$) and among PE students ($F_{(2,103)} = 5.46$, $p = .006$, $R^2 = .10$). Health specific self-efficacy was the most important factor of each health behaviour. It was positively associated with PA among Other Subjects teachers

Table 4. Forward stepwise regression for health locus of control (HLC) dimension, self-efficacy and health behaviours

	OS Teachers		PE Teachers		P Students		PE Students	
	PA (METs) β	Nutrition (score) β	PA (METs) β	Nutrition (score) β	PA (METs) β	Nutrition (score) β	PA (METs) β	Nutrition (score) β
Self-Efficacy	.19**	.10	.14	.22*	.11	.12	.42***	.24**
HLC Internal	.10	.07	.13	–.25*		.19*		
HLC Powerful Others								
HLC Chance		–.17*	–.22*		.11			–.16

Legend: β – standardized regression coefficient; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

($p < .01$) and PE students ($p < .001$) and with nutrition behaviour among PE teachers ($p < .05$) and PE students ($p < .01$). In reference to the health locus of control variables "internal control" is negatively associated ($p < .05$) with nutrition behaviour among PE teachers and positively associated among Pedagogy students ($p < .05$). There is also negative association between "chance control" and PA among PE teachers ($p < .05$) and between "chance control" and nutrition among Other Subjects teachers ($p < .05$).

Additionally correlation coefficients between smoking status and psychological variables were calculated (not shown in tables). There are significant positive associations between self-efficacy and non-smoking status in all research groups (from $r = .64$, $p < .05$ to $r = .85$, $p < .05$). In reference to the health locus of control variables "chance control" and "powerful others control" are positively associated ($r = .26$, $p < .05$ and $r = .35$, $p < .01$, respectively) with smoking habits in PE teachers. The results of logistic regression were not significant for prediction of psychological variables on smoking status among research groups.

DISCUSSION

The results of analyses indicate that health oriented physical education studies favour a more healthy lifestyle both during the studies and after starting employment. Higher physical activity related to the major of studies of PE students or profession of PE teachers is not surprising (Dinger, 1999; Chevan, 2010; Stera, 2010). The studied physical education specialists were characterised by a moderately low percentage of current smokers. The difference is particularly visible between PE and Pedagogy students. Similar differences between students of health-related majors and non health-related ones in the structure of smoking are noted by D'Abundo (2009). This may indicate that students of health-related majors have greater awareness in this respect and that physical activity and athletic participation may protect against the uptake and progression of smoking behaviours (Patterson, 2004; Emmons, 1998; Seo, 2007). In the current study we noted also a significant intergenerational differences in terms of smoking cigarettes. The percentages of smoking teachers are lower than those of smoking students. This confirms that in spite of a falling trend in smoking cigarettes it is still a cause for concern in young people (Choi, 2003; WHO, 2010).

The studied physical education specialists were also characterised by better eating habits, although they are far from ideal. The problem of deteriorating eating habits is noted among American students (La Fountaine, 2006) and among Turkish students (Karadağ, 2010). Huang (2003) found in their research that most students do not follow proper dietary guidelines, which increases the incidence of obesity in this population and Boström (2006) reported that 18–29 year-olds Swedes are the group who eats very little fruit and green vegetables. Also university students from South Africa were observed not to follow healthy dietary habits (Kazi, 2006).

Physical education specialists and school teachers are socially perceived as potential promoters of positive health behaviour. Hence it is important that their behaviour is in line with the educational message. Memis (2010) indicates that teachers in Turkey usually

meet this condition better than nurses. On the other hand, head start teachers in Texas carrying out nutritional education in the USA, need many changes in their life style first (Sharma 2013). The cluster analysis revealed differences in accumulation of health behaviour in the studied groups of respondents. For physical education teachers and students nutrition patterns and, to a slightly smaller degree, smoking cigarettes are significantly differentiating behaviours. This allows, to put it simply, to divide them into two clusters: (1) physically active, with good nutrition, rather non-smoking, and (2) most of whom are physically active, with definitely worse nutrition, more often smoking. The cluster analysis indicated that physical education students and teachers are differentiated in a similar way within the studied health behaviours. The picture of pedagogy students and teachers of other subjects is not as clear. Different health behaviours are differentiating for these groups. For teachers – physical activity and nutrition, and for pedagogy students – smoking. Here we cannot point out similarity in differentiation of both groups. This indicates that health education or health advice is necessary in all majors of studies, not only those with a health focus and that its content and methodological approach has to be fundamentally in order to meet various expectations of the groups it is meant for.

In the analysis of psychological variables it was shown that health related self-efficacy is a significant predictor for PA, nutrition almost in all studied groups (except for Pedagogy students). Also a high correlation was demonstrated between health related self-efficacy and non-smoking. The respondents who presented a higher level of self-efficacy in the area of analysed behaviour, presented at the same time more beneficial indicators. The predictiveness of self-efficacy is reference to health behaviour is indicated in literature (Luszczynska, 2004) and used in constructing educational intervention (Luszczynska, 2007).

Health locus of control dimensions (especial "internal control") have also appeared in predicting health behaviour models in the studied groups. Usually higher feeling of "internal control" favours more beneficial health behaviour (Steptoe, 2001; Badr, 2005). We note a reverse situation among the studied physical education teachers in reference to nutrition. Comparable to the results of Grotz (2011), the findings highlights that the chance dimension is significantly associated with unhealthy behaviours. We also note that their PA increases with the decrease of the role ascribed by them to coincidental, external factors in maintaining health.

CONCLUSION

The analysis indicates that the studied groups of current and future educators, including health educators, have different health behaviour profiles. It means that they also have different educational needs in this respect, which are not commonly diagnosed at Polish universities. We also noticed a generation gap between students and teachers manifested by worse health behaviour (especially smoking) of current students. All teachers (especially PE teachers) are responsible for health education in Polish schools. They should be deliberately involved (also during study) in activities promoting health-related skills and behaviours. This will allow them to be more effective role models for their students and create their own health potential more competently. Promotional and intervention

programmes could use social-cognitive strategies to increase psychosocial skills and competences like self-efficacy or locus of control.

REFERENCES

ABUSABHA, R., ACHTERBERG, C. (1997). Review of self-efficacy and locus of control for nutrition-and health-related behavior. *Journal of the American Dietetic Association* 97(10), 1122–1132.

BADR, H. E., MOODY, P. M. (2005). Health locus of control beliefs and smoking among male Kuwaiti government employees. *Eastern Mediterranean Health Journal* 11(1–2), 137–145.

BANDURA, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review* 84, 191–215.

BIEMAT, E., STUPNICKI, R. (2005). An overview of internationally applicable questionnaires designed for assessing physical activity. *Physical Education and Sport* 49, 32–42.

BOSTRÖM, G. (2006). Habits of life and health. *Scandinavian Journal Of Public Health* 34 (Suppl 67), 199–228.

CHEVAN, J., HASKVITZ, E. M. (2010). Do as I do: exercise habits of physical therapists, physical therapist assistants, and student physical therapists. *Physical Therapy* 90, 726–734.

CHOI, W. S., HARRIS, K. J., OKUYEMI, K., AHLUWAILA, J. S. (2003). Predictors of smoking initiation among college-bound high school students. *Annals of Behavioral Medicine* 26(1), 69–74.

D'ABUNDO, M. L., MARINARO, L. M., FIALA, K. A. (2009). An online survey of cigarette use in college students: Using demographic information to influence health education, prevention and intervention efforts. *ICHPER – SD Journal of Research in Health, Physical Education, Recreation, Sport & Dance* 4(2), 6–9.

DINGER, M. K. (1999). Physical activity and dietary intake among college students. *American Journal of Health Studies* 15(3), 139–148.

EMMONS, K. (1998). Predictors of smoking among US college students. *American Journal of Public Health* 88(1), 104–107.

GROTZ, M., HAPKE, U., LAMPERT, T., BAUMEISTER, H. (2011). Health locus of control and health behaviour: Results from a nationally representative survey. *Psychology Health & Medicine* 16(2), 129–140.

HUANG, T. T., HARRIS, K. J., LEE, R. E., et al. (2003). Assessing overweight, obesity, diet and physical activity in college students. *Journal Of American College Health* 52(2),83–86.

JUCZYŃSKI, Z. (2001). *Narzędzia pomiaru w promocji i psychologii zdrowia*. Warszawa: Pracownia Testów Psychologicznych Polskiego Towarzystwa Psychologicznego.

KARADAĞ, M., YILDIRIM, N. (2010). Health behaviors in health sciences university students in Turkey. *Social Behavior & Personality: An International Journal* 38(1), 43–52.

KAZI, H. A., COOPOO, Y. (2006). Selected morphological and lifestyle profiles of a cohort of South African university students. *Bulletin for academic staff and students* 16(1), 65–76.

LA FOUNTAINE, J., NEISEN, M., PARSONS, R. (2006). Wellness factors in first year college students. *American Journal of Health Studies* 21(4), 214–218.

LALONDE, M. (1974). *New perspective on the health of Canadians: a working document.* Ottawa: Information Canada.

LUSZCZYNSKA, A., GIBBONS, F. X., PIKO, B. F., TEKOZEL, M. (2004). Self-regulatory cognitions, social comparison, and perceived peers' behaviors as predictors of nutrition and physical activity: a comparison among adolescents in Hungary, Poland, Turkey, and USA. *Psychology and Health October* 19(5), 577–593.

LUSZCZYNSKA, A., TRYBURCY, M., SCHWARZER, R. (2007). Improving fruit and vegetable consumption: a self-efficacy intervention compared with a combined self-efficacy and planning intervention. *Health Education Research* 22(5), 630–638.

MEMIS, E., SANLIER, N. (2010). Analysis of Nutrition Habits of the Teachers and Nurses. *Pakistan Journal of Nutrition* 9(12), 1176–1182.

NORMAN, P., BENNETT, P., SMITH, C., MURPHY, S. (1998). Health locus of control and health behaviour. *Journal of Health Psychology* 3(2), 171–180.

PATTERSON, F., LERMAN, C., KAUFMANN, V., et al. (2004). Cigarette smoking practices among American college students: Review and future directions. *Journal of American College Health* 52(5), 203–210.

SCHWARZER, R, FUCHS, R. (1995). Self-efficacy and health behaviours. In M. Conner, P. Norman (eds.) *Predicting Health Behaviour: Research and Practice with Social Cognition Models*. Buckingham: Open University Press.

SCHWARZER, R., RENNER, B. (2000). Social-cognitive predictors of health behavior: Action self-efficacy and coping self-efficacy. *Health Psychology* 19, 487–495.

SCHWARZER, R., SCHÜZ, B., ZIEGELMANN, J. P., et al. (2007). Adoption and maintenance of four health behaviors: theory-guided longitudinal studies on dental flossing, seat belt use, dietary behavior, and physical activity. *Annals of Behavioral Medicin* 33(2), 156–166.

SEO, D. C, NEHL, E., AGLEY, J., MA, S. M. (2007). Relations between physical activity and behavioral and perceptual correlates among Midwestern college students. *Journal Of American College Health* 56(2), 187–197.

SHARMA, S., DORTCH, K. S., BYRD-WILLIAMS, C., et al. (2013). Nutrition-related knowledge, attitudes, and dietary behaviors among Head Start teachers in Texas: A cross-sectional study. *Journal of the Academy of Nutrition & Dietetics* 113(4), 558–562.

STEPTOE, A., WARDLE, J. (2001). Locus of control and health behaviour revisited: a multivariate analysis of young adults from 18 countries. *British Journal Of Psychology* 92, 659–672.

STERA, T., WOJTAS-ŚLUBOWSKA, D. (2010). Effect of physical education studies on selected aspects of preparation of university students for implementation of health education in polish schools. *Studies in Physical Culture And Tourism* 17(1), 55–62.

VELICER, W. F., DICLEMENTE, C. C., ROSSI, J. S., PROCHASKA, J. O. (1990). Relapse situations and self-efficacy: An integrative model. *Addictive Behaviors* 15, 271–283.

VON AH, D., EBERT, S., NGAMVITROJ, A., et al. (2004). Predictors of health behaviours in college students. *Journal of Advanced Nursing* 48(5), 463–474.

WALLSTON, B. S., WALLSTON, K. A. (1978a). Locus of control and health – review of literature. *Health Education Monographs* 6(2), 107–117.

WALLSTON, K. A., WALLSTON, B. S., DEVELLIS, R. (1978b). Development of Multidimensional Health Locus of Control (MHLC) Scales. *Health Education Monographs* 6(2), 160–170.

WHO, Ministry of Health (2010). *Global Adult Tobacco Survey Poland 2009–2010.* Available from http://www.who.int/tobacco/surveillance/en_tfi_gats_poland_report_2010.pdf

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BODY COMPOSITION AND HYDRATION STATUS IN YOUNG ELDERLY WOMEN AFTER 6 WEEKS' MONAVIE JUICE SUPPLEMENTATION

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ABSTRACT

This study was designed to determine the influence of 6 weeks' MonaVie juice supplementation on body composition and hydration status in young elderly physically active women. Sixteen women, students of University of Third Age, were recruited for this study. All women were physically active (daily energy expenditure 1681.8 ± 297.6 kcal/d). Women were divided into 2 groups: 8 of them applied a supplement MonaVie juice (100 ml/d) (S) for 6 weeks, while the eight other women were allocated to the control group (C). There were measured: BW, Fat%, TBW, Hb, HCT and erythrocyte indices: RBC, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC). Based on Hb and HCT were calculated changes: blood (del BV%), plasma (del PV%) and cell (del CV%) volumes in C and S group. Before experiment all body components and hematologic indices were similar in C and S group. After 6 weeks of MonaVie supplementation no significant changes in body composition but significant decrease: (MCH), (MCHC) and an increase cell volume CV% + 2.89 ± 1.24% were found. In control group after 6 weeks period there were no significant changes in body components and hematological indices. These observations suggest that MonaVie supplementation does not induce significant changes in body composition and hydration status in young elderly women, however causes an increase of cells volume and a decrease of mean corpuscular hemoglobin concentration.

Keywords: body composition; total body water; women; supplementation; MonaVie juice

INTRODUCTION

The aging process is associated with several physiological and biochemical changes that may affect one's ability to maintain water balance and body composition. These changes

involve: the loss of fat free mass (FFM) and increase of body fat (FM). Increase of body fatness in aging process is associated with a decrease of the basal metabolism as the result of sedentary life style (Evans, 1992; Chernoff, 2005; Roberts & Rosenberg, 2006) whereas the decline of fat free mass (FFM) is accompanied by a decrease of total water (TBW) content (Chumlea et al., 1999).

Many studies provide evidences, that body hydration status (cellular water content, TBW, FFM hydration) is not stable and decreases during aging process (Schoeller, 1989; Visser et al., 1997; Baumgartner et al., 1991). In addition to above information, others changes as: a decrease in sensation of thirst (Kenney & Chiu, 2001; Chernoff, 2005), alterations in plasma vasopressin effectiveness and concentration, a reduction of fluid intake (Elmadfa & Meyer, 2008), and a shift in the operation points for control of body fluid volume and composition (Mack et al., 1994; Sawka et al., 2007) were observed. Limited information is available on water intake, excretion and retention in older humans. Bossingham et al. (2005) indicated that healthy old women have maintain of water input, output and water equilibrium capable to younger adults and have no apparent changes in hydration status until 60 years of age (however TBW starts to decline after approximates 60 years of age) (Schoeller, 1989).

Fluid retention in the body depends on many factors. In the presence of sufficient substrates consumption and adequate amount of ingested drinks, body hydration remains at the relatively stable level in healthy people (under normal climate conditions and at the defined level of physical activity). The restoration of fluid balance following exercise induced dehydration is slower in older humans and depend on the electrolytes content in the drinks and solid foods consumed (Kenney & Chiu, 2001) after the exercise. Therefore, the addition of sodium and potassium to the ingested drinks and solid foods may be another important factor in the restoration of fluid balance following exercise induced dehydration.

It is known that the diets rich in fruits and vegetables may have beneficial effect on many physiological and biochemical processes. Less information is available on influence some fruits on changes in body composition and hydration in women after 60 years of age. In younger and older adults, fluid intakes, including water consumption ad libitum, depends on the fluid taste and feelings of thirst. Therefore interesting was determine the effects of fruit juice supplementation on a possibility of keeping water balance and proper hydration of body tissues in older women.

The MonaVie juice is a popular nutritional supplement prepared from the Acai berries. Acai provides many vitamins, minerals, antioxidant polyphenolics (primarily from anthocyanin) (Mertens-Talcott et al., 2008) and other nutrients necessary for health and cells regeneration. Xie et al. (2011) found that Acai diet, did not change body composition, despite a significant gain in body weight, and alter total cholesterol in ApoE deficient mice.

PURPOSE

The aim of this study was to determine the influence of 6 weeks of MonaVie juice supplementation on body composition and hydration status in young elderly physically active women.

MATERIAL AND METHODS

Sixteen women, students of The University of Third Age, were recruited for this study (age 61.11 ± 5.48 yr, height 156.33 ± 10.27 cm, body mass 70.45 ± 12.08 kg). Women were divided into 2 groups: 8 of them applied a supplement MonaVie juice (100 ml/d) (S) for a period of 6 weeks, while the eight other women were allocated to the control group (C).

Assessments of body components

Before and after 6 weeks in each group body mass and body composition were measured. There are various methodologies for determining changes in body components. Among them the hydrodensitometry (direct) method has been suggested as a gold standard for body composition assessments, however other methods as the bioelectrical impedance measurement methods BIA are also commonly used. BIA methods are applied not without objections, but are simple and not expensive to assess body composition (Heitmann, 1994), and can be performed across a wide range of subjects with regard to age, and body shape. In particular multi-frequency BIA (MF-BIA) method was described as a tool able to precise assessment of body components as: TBW, ICF and ECF (Volgyi et al., 2007). However, single-frequency BIA method (Tanita), incorporates age into their estimation of body composition and it is an alternative available option which has been used for estimating body components in young elderly women. Body mass and body composition: as: body fat (Fat %, Fat kg), fat free mass (FFM, kg), total body water (TBW kg, TBW/BM %) and body mass index (BMI) were assessed using bioelectrical body impedance (BIA) method, according to Tanita SC330 (Japan) system. Tanita SC330 body composition analyzer is a single- frequency BIA device that uses 4 polar electrodes. This device uses single-point load cell weighting system in the scale platform. An algorithm incorporates impedance, age and height is use to estimate body components. Body mass (BM) was measured to the nearest 0.1 kg.

Assessments of hydration status

The single frequency bioelectrical impedance assumes full hydration and so is unable to assess hydration status, therefore the total body hydration status was estimated on the basis of biomarkers of hydration status: urine specific gravity (USG) and total body water content (TBW) (Bossingham et al., 2005; Sawka et al., 2007). To evaluate a hydration of fat-free body mass the ratio (TBW/FFM) was calculated. In this study fasting blood were collected on day before and at the last day of 6-week's period. In the blood samples: hemoglobin (Hb), hematocrite (HCT), erythrocytes (RBC) and erythrocyte indicators: mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC) were measured, while in the urine samples the specific gravity was determined. Based on Hb and HCT values, changes: the blood (del BV%), the plasma (del PV%) and cells (del CV%) volumes, in C and S group, were calculated (according to the Dill and Costil formula 1974). Based on the ratio (del PV% / del CV%) the relative shift water for ECF and ICF space was calculated, for each tested group.

Assessment of physical activity

Daily physical activity was recorded by an accelerometer Actigraph GT1M (Manufacturing Technology Inc., FL, USA) worn for 7 days. For physical activity classification, healthy step goal 10,000 steps per day (Hatano, 1993) and more detailed Tudor-Locke and Bassett steps/day recommendation were used: <5000 steps/day – sedentary lifestyle index; 5000–7499 steps/day – low active; 7500–9999 steps/day – somewhat active; ≥10,000 steps/day – active; and >12,500 steps/day – highly active. Total daily energy expenditure was calculated according to the method prepared by manufacturer.

Statistics

The statistical package Statisica 9 (Stat Soft, 2009) was used for data analysis with significant level set at $p < 0.05$. Statistical analysis was performed with a one-way analysis of variance for determine differences between groups and pre- and after 6 weeks period in each group. Statistical significance was identified according to the Bonfferoni post-hoc test.

RESULTS

The analysis of subject's characteristics indicated that there are no significant differences in body mass and body composition before and after 6 weeks period between C and S group. According to definition BMI for older adults, only 5 women were optimal weight, while 4 were overweight, and 7 were obese (Table 1). The ratio of TBW/FFM was similar in all women (0.731 ± 0.01) and did not change after 6 weeks period.

There were no significant differences in body mass and biomarkers of the body hydration status: TBW, USG (<1.020 g/dm3) after 6 weeks in C and S group (Table 1), however supplemented women had a higher of TBW/BM, greater of D TBW% (+0.76 ± 0.22%), FFM and lower BMI (Table 1) after 6 weeks.

There were no significant changes in body mass and hydration status biomarkers after 6 weeks period in control group, however in C women was found a decrease of D TBW% (−0.54 ± 0.91%). Compared with C group supplemented S women had significant higher D TBW% after 6 weeks period ($F = 15.67$, $p < 0.05$).

Analysis of hematological indices revealed, that 6-week of MonaVie juice supplementation induces a small increase of RBC ($p > 0.05$) but a significant decrease: of (MCHC%) and an increase cell volume CV% +2.89 ± 1.24 % (Table 2). After 6 weeks MCHC% was significantly lower in S than C group of women (Table 2).

There was a significant difference in the relative ratio of water shift (del PV% / del CV%) to ECF and ICF space after 6-weeks between supplemented (0.60 ± 1.17) and control group (1.35 ± 1.79), ($F = 10.98$, $p < 0.01$).

According to daily activity monitoring, all women were moderately active per day (daily energy expenditure 1681.8 ± 297.6 kcal/d). Based on steps/day classification (Tudor-Locke & Bassett, 2004), one woman was classified as low active, nine women as somewhat active, four women as active and two as highly active. There was no significant

difference between average steps/day values achieved by supplemented group (M ± SD = 9041 ± 1895) and control group (M ± SD = 9570 ± 1597).

Table 1. Subject's characteristics recorded before and after 6-weeks period in control and supplemented group of women

Characteristics	Women (n = 16)	Supplemented Group (N = 8)	Control Group (N = 8)
Age (y)	64.11 ± 5.48	61.85 ± 1.34	65.56 ± 7.45
Height (cm)	156.33 ± 10.27	158.86 ± 2.67	158.31 ± 2.91
Body mass (kg)	70.45 ± 12.08	69.34 ± 14.31[a] 68.87 ± 14.31[b]	71.82 ± 11.38[a] 71.46 ± 10.84[b]
Body Fat (kg)	27.59 ± 9.11	24.91 ± 9.73[a] 25.50 ± 9.98[b]	29.94 ± 8.82[a] 29.41 ± 8.80[b]
FFM (kg)	43.95 ± 5.26	44.43 ± 5.51[a] 43.37 ± 5.38[b]	41.88 ± 4.18[a] 42.04 ± 2.88[b]
TBW/BM (%)	44.94 ± 5.26	46.35 ± 6.16[a] 46.95 ± 5.31[b]	43.08 ± 4.52[a] 43.62 ± 4.83[b]
TBW (kg)	31.44 ± 3.09	32.74 ± 3.73[a] 31.71 ± 3.93[b]	30.55 ± 0.48[a] 30.76 ± 1.97[b]
BMI (kg/m^2)	28.65 ± 5.02	29.31 ± 5.93[a] 27.65 ± 4.94[b]	28.78 ± 5.00[a] 28.71 ± 5.01[b]

Legend: a – before experiment; b – after 6-week's period; FFM – fat free mass; TBW/BM – total body water / body mass; TBW – total body water; BMI – body mass index

Table 2. Changes in blood (BV%), plasma (PV%) and cell (CV%) volume, the number of erythrocytes (RBC) and erythrocyte indicators: mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC) before and after 6-weeks period in control and supplemented group of women

Hematologic characteristics	Women (n = 16)	Supplemented Group (N = 8)	Control Group (N = 8)
RBC	4.71 ± 0.28	4.61 ± 0.31[a] 4.82 ± 0.29[b]	4.70 ± 0.29[a] 4.75 ± 0.23[b]
Hb (g/dl)	140.09 ± 7.81	139.75 ± 6.27[a] 140.09 ± 8.58[b]	139.75 ± 9.07[a] 140.75 ± 8.63[b]
HCT (%)	41.61 ± 2.57	40.87 ± 1.9[a] 42.28 ± 2.28[b]	42.12 ± 2.1[a] 41.25 ± 3.0[b]
MCV (fl)	88.75 ± 2.91	90.25 ± 2.60 [a] 88.42 ± 1.71[b]	89.56 ± 2.83[a] 86.73 ± 3.32[b]
MHC (pg)	30.64 ± 0.93	30.61 ± 1.24[a] 29.39 ± 0.76[b]	30.06 ± 0.59[a] 29.73 ± 0.61[b]
MCHC (%)	21.07 ± 0.53	21.37 ± 0.32[a]⇓∞ 20.59 ± 0.31[b]	20.81 ± 0.37[a]⇑∞ 21.45 ± 0.60[b] **
MPV (fl)	9.50 ± 1.07⇑	8.88 ± 0.96[a]⇑∞ 9.01 ± 0.90[b]	9.67 ± 0.81[a] 10.42 ± 0.38[b]

Δ BV (%)	–0.18 ± 3.47	0.31 ± 3.98$^{a–b}$	–0.68 ± 3.06$^{a–b}$
Δ PV (%)	–0.20 ± 3.41	–0.89 ± 3.68$^{a–b}$	0.49 ± 3.20$^{a–b}$
Δ CV (%)	0.001 ± 3.55	+2.89 ± 1.22$^{a–b\ ⇑}$	–2.53 ± 2.53$^{a–b}$ ***

Legend: * – Significantly different between S and C group ($p < 0.05$); ** – $p < 0.001$; *** – $p < 0.0001$; ∞ – Significantly different between a and b ($p < 0.05$), ∞∞ ($p < 0.001$), ∞∞∞ ($p < 0.0001$); a – before experiment; b – after 6-week's period; Hb – hemoglobin; HCT – hematocrite; RBC – erythrocytes; and erythrocyte indicators: mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), changes in blood (D BV%), plasma (D PV%) and cell (D CV%) volumes

DISCUSSION

This study aimed to investigate the impact of 6 weeks of MonaVie juice supplementation on body composition and hydration status in young elderly women. Several body direct (BM, FFM, FAT, TBW, BMI) (estimated via BIA method) and indirect (TBW/BM, Δ TBW%, TBW/FFM – calculated), compounds were chosen to identify the influence of MonaVie supplementation. We indicated that MonaVie juice supplementation for 6 weeks did not influence on body mass and BM, FFM, FAT, TBW, BMI in young elderly women. Based on steps/day classification (Hatano, 1993), only 37.5% of women accomplished recommended 10,000 steps/day. Moreover, daily total energy expenditure level of the study participants (M ± SD = 1681.8 ± 297.6 kcal) was lower compared to 60–70 yr women in Johannsen et al. (2008) study (TEE ~ 2200 kcal/d).

In connection with aging process, many questions concern the tissue hydration stability (Wang et al., 1999) and maintain a proper body composition in elderly humans. Older humans are generally adequate hydrate but they are more susceptible on dehydration, because they have a slower water and sodium excretion and have a lower thirst (Sawka et al., 2007). It is know that the total amount of water in the body (TBW) is essential to a full description of humans body composition (Wang et al., 1999). If TBW values are available (by assuming that TBW is constant), estimation can be made for various body components including FFM, FM.

The fat-free body mass (FFM) hydration (TBW/FFM) is remarkably stable at 0.73, but may be decreased in elderly and in obese humans (Visser & Gallagher, 1998; Waki et al., 1991; Wang et al., 1999). The results of our study showed that regardless of apply a dietary of MonaVie juice supplementation or not, 65 years women had comparable body composition, fat-free body mass hydration before and after 6 weeks period.

Water is the most abundant ingredient in the humans body and it plays an essential role in the regulatory of cell volume, nutritional transport, waste removal and thermal regulation. Daily water balance depends on the net differences between water gain and water loss. Water gain occurs from consumption and production (metabolic water) while water loss occur from respiratory, gastrointestinal, renal and sweat losses (Sawka et al., 2007). Activation of homeostasis mechanisms to maintenance of body hydration usually occurs in stressful conditions. The stability of body weight for 6-weeks in both groups of women suggests, that supplementation not changes total body water content and body hydration

status significantly, but may influence on a time course of rehydration and expansion of extracellular or intracellular fluid volume.

In many studies TBW has been expressed as the sum of water distributed in intracellular (ICW) and extracellular (ECW) space. The distribution of body fluid within the intracellular and extracellular compartments determines proper physiological processes. We indicated that 6-weeks MonaVie juice supplementation resulted in a significantly increase of TBW (+0.75% vs −0.54%, $p < 0.001$) and a significant increase of cellular volume (D CV%), and decrease of mean corpuscular hemoglobin concentration (MCHC%) and greater shift of water into cellular than extracellular space (D PV% / D CV %).

Changes of MVC (CV), MCHC and RBC may be good parameters to analyze quantify of RBC damage. It is known that older RBC with smaller size and higher hemoglobin concentration (MCHC) are destroyed faster than younger RBC with larger size and lower hemoglobin concentration. RCB cells deformability decides on their sensitivity to subhemolitic injuries associated with oxidative stress. Therefore, the results of the present experiment provide evidences that the MonaVie juice supplementation may induces some changes in the sensitivity of erythrocytes to harmful factors (preventing them from damage).

An important observation of the present study was to show the increase of cellular (del CV%) volume in women after 6 weeks of MonaVie juice supplementation. Fruit and vegetables are rich in potassium. The MonaVie juice is a supplement prepared from the Acai berries. Acai berries provide many vitamins, minerals, antioxidants. In 100 g Acai there is 932 mg potassium, 56 mg sodium and 1.02 g anthocyanins (Mertens-Talcott et al., 2008). It can be assumed that an increase of cell volume may be caused by the high potassium and antioxidants content in the MonaVie juice. Potassium is the major ion in the intracellular fluid and Maughan et al. (1997), Demigne et al. (2004) postulated that the inclusion of potassium into drinks consumed after sweat loss may aid in rehydration by enhancing the retention of water in the ICF space. On the other hand, a high content of antioxidants in the MonaVie juice could have a beneficial effect on cell volume by enter antioxidants to cells and better protect of cells from oxidative damage (Holderness et al., 2011). It may be suggested that increase of cellular volume (del CV%) and decrease MCHC% after the MonaVie supplementation in S women, similar as in Holderness et al. (2011) studies, indicated an improvement of protection erythrocytes from damage.

However, it is worth mention that low sample size tested women not allowing generalizing results of this study to whole population of young elderly women.

CONCLUSION

The results of this research suggests that 6-weeks of MonaVie juice supplementation did not influence body composition and total hydration status in young elderly women, however had an impact on cell volume (CV) and mean corpuscular hemoglobin concentration (MCHC). The increase of RBC, CV and decrease of MCHC observed after the 6 weeks of MonaVie juice supplementation in young elderly women causes changes in the characteristics of red blood cells, which provides evidences that cell (erythrocyte) protection has been improved.

REFERENCES

BAUMGARTNER, R. N., STAUBER, P. M., MCHUGH, D., et al. (1995). Cross-sectional age-differences in body composition in person 60+ years of age. *J Gerontol* 50, M307–M316.

BOSSINGHAM, M. J., CARNELL, N. S., CAMPBELL, W. W. (2005). Water balance, hydration status, and fat-free mass hydration in younger and older adults. *Am J Clin Nutr* 81, 1342–1350.

CHERNOFF, R. (2005). Micronutrient requirements in older women. *Am J Clin Nutr* 81, 1240S–1245S.

CHUMLEA, W. C., GUO, S. S., ZELLER, C. M., et al. (1999). Total body water data for white adults 18 to 64 years of age: the fels longitudinal study. *Kidney Int* 56, 244–252.

DEMIGNE, CH., SABBOH, H., REMESY, CH., MENETON, P. (2004). Protective effects of high dietary potassium: nutritional and metabolic aspects. *J Nutr* 134, 2903–2906.

DILL, D., COSTIL, D. (1974). Calculation of percentage changes in volumes of blood, plasma and red cells in dehydration. *J Appl Physiol*. 37, 247–248.

ELMADFA, I., MEYER, A. L. (2008). Body composition, changing physiological functions and nutrient requirements of the elderly. *Ann Nutr Metab* 52 (suppl. 1), 2–5.

EVANS, W. J. (1992). Exercise, nutrition and aging. *J Nutr* 122, 796–801.

HATANO, Y. (1993). Use of the pedometer for promoting daily walking exercise. *ICHPER* 29, 4–8.

HEITMANN, B. L. (1994). Impedance: a valid method in assessment of body composition? *Eur J Clin Nutr* 64, 228–240.

HOLDERNESS, J., SCHEPETKIN, I. A., FREEDMAN, B., et al. (2011). Polysaccharides isolated from Açaí fruit induce innate immune responses. *PLOS ONE* 6(2), e17301.

MACK, G. W., WESEMAN, C. A., LANGHANS, G. W., et al. (1994). Body fluid balance in dehydrated healthy older men: Thirst and renal osmoregulation. *J Appl Physiol* 76(4), 1615–1623.

MAUGHAN, R. J., LEIPER, J. B., SHIRREFFS, S. M. (1997). Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. *Br J Sports Med.* 31, 175–182.

MERTENS-TALCOTT, S. U., RIOS, J., JILMA-STOHLAWETZ, P., et. al. (2008). Pharmacokinetics of anthocyanins and antioxidant effects after the consumption of anthocyanin-rich Acai juice and pulp (Euterpe oleracea Mart.) in human healthy volunteers. *J Agric Food Chem* 56, 7796–7802

JOHANNSEN, D. I., DELANY, J. P., FRISARD, M. I., et al. (2008). Physical activity in aging: Comparison among young, aged, and nonagenarian individuals. *J Appl Physiol* 105, 495–501.

KENNEY, W. L., CHIU, P. (2001). Influence of age on thirst and fluid intake. *Med Sci Sports Exerc* 33(9), 1524–1532.

ROBERTS, S. B., ROSENBERG, I. (2006). Nutrition and aging: changes in the regulation of energy metabolism with aging. *Physiol Rev*. 86, 651–667.

SAWKA, M. N., BURKE, L. M., EICHNER, E. R., et al. (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. *Med Sci Sports Exerc*. 39(2), 377–390.

SCHOELLER, D. A. (1989). Changes in total body water with age. *Am J Clin Nutr* 50, 1176–81.

TUDOR-LOCKE, C., BASSETT, R. (2004). How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Med* 34(1), 1–8.

WAKI, M., KRAL, J., MAZARIEGOS, M., et al. (1991). Relative expansion of extracellular fluid in obese vs nonobese women. *Am J Physiol (Endocrinol. Metab)* 261, E199–E203.

WANG, Z., DEURENBERG, P., WANG, W., et al. (1999). Hydration of fat-free body mass: new physiological modeling approach. *Am J Physiol (Endocrinol. Metab)* 276, E995–E1003.

VISSER, M., GALLAGHER, D., DEURENBERGER, P., et al. (1997). Density of fat-free body mass: relationship with race, age, and level of body fatness. *Am J Physiol*. 272, E781–E787.

VÖLGYI, E., TYLAVSKY, F. A., LYYTIKÄINEN, A., et al. (2008). Assessing body composition with DXA and bioimpedance: effects of obesity, physical activity, and age. *Obesity* 16(3), 700–705.

XIE, CH., KANG, J., BURRIS, R., et al. (2011). Acai juice attenuates atherosclerosis in ApoE deficient mice through antioxidant and anti-inflammatory activities. *Atherosclerosis* 216, 327–333.

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DEVELOPMENT OF THE MOTOR FUNCTIONS IN 7–15-YEAR-OLD CHILDREN: THE CZECH NATIONAL STUDY

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ABSTRACT

The aim of the national study was to assess the development of motor functions in the population of the Czech children. A Czech representative sample of 7–15-year-old children (n = 1076) was assessed on fine manual coordination, gross motor coordination and balance using the Movement Assessment Battery for Children-2 (MABC-2). Concurrently, the cross-cultural validity of the MABC-2 was examined on a basis of the comparison of results of the testing to the test performance reported for the United Kingdom sample.

Unimanual and bimanual coordination, and visuomotor coordination associated the aiming and timing interceptive tasks improved up to 12–15-year-old children. The Czech girls demonstrated the mature static balance at the age of 7 years, while the Czech boys by two years later. The study showed that the MABC-2 can be a valid method for assessment of gross motor coordination in the Czech children. Before use of this test battery in research and educational and clinical practice in the Czech Republic, an adjustment of the norms of the manual dexterity and balance tests is needed.

Keywords: coordination; manual dexterity; aiming; catching; balance; test

INTRODUCTION

The national surveys of physical competency of the Czech children done during the last three decades were focused primarily on physical performance while motor development assessment with larger cohorts were not carry out in the Czech Republic (CR). The physical fitness test systems as the Eurofit (Council of Europe, 1993) and Unifittest (Měkota & Blahuš, 1995) can provide information on some health-related components, however performance demonstrated in these tests is usually affected by anthropometric measures of a child (Milanese et al., 2010). Besides the physical fitness testing, assessment of child's motor development by the movement coordination tests can serve as the useful indirect indicator of a level of the motor functions.

In a current population of the children increased prevalence of the specific developmental disorders including motor difficulties was reported (Boyle et al., 2011). Then the knowledge on typical patterns of development of motor functions seems to be very useful for the diagnostical puposes. Therefore the first aim of the study was to describe the level of motor coordination in the Czech children of different age.

Motor coordination assessment in children is carried out by professionals in physical education and sport, child psychology, special education and pediatrics. However, in the CR no broadly used diagnostic tool for motor coordination assessment of children exists. On the basis of considerable structural and content changes of the Movement Assessment Battery for Children (Henderson & Sugden, 1992), the new version of this battery was developed – the MABC-2 (Henderson, Sugden, & Barnett, 2007). This battery enables assessment of overall motor coordination and separately fine motor coordination (manual dexterity), gross motor coordination (aiming and catching) and balance.

To use the MABC-2 in the population of Czech children, the cross-cultural validity of the battery should be examined. The previous studies focused on examination of the MABC in some European countries concluded that the battery can be a useful tool for assessment of motor development, however after relevant adjustment of the norms (e.g. Ellinoudis, Kourtessis, & Kiparissis, 2008; Ruiz, Graupera, Gutiérrez, & Miyahara, 2003). Therefore the second aim of the study was to examine the cross-cultural validity of the MABC-2 for the Czech children.

METHODS

Design and subjects

The MABC-2 was used in the Czech sample of 7–15-year-old children (n = 1076) formed by a random selection of 20 primary public schools from all the geographical regions of the CR (a sample size of each age and gender group – see tab. 1–4). Children with physical and other neurological disabilities were not tested. Raw scores were used to analyse the significance of the age factor on motor test performance. The assessment of cross-cultural validity of the MABC-2 was based on comparison of the motor tasks performance in the Czech sample and the United Kingdom (UK) standardisation sample of the same age (n = 741) reported in the MABC-2 Examiner's Manual by Henderson et al. (2007).

Procedures

Before testing, pilot verification of the tests in the 7–15-year-old children (n = 32) was completed. On the basis of the verification, the formulation of verbal instructions to children was specified. Fifteen trained testers with a university master's or Ph.D. degree in physical education, adapted physical education or kinanthropology, performed the testing with the children.

The children were tested in the classrooms and gyms during morning hours. Testing was always running with a group of the 5–8 children going from one station to another one. The study had been approved by the Ethical committee of the faculty and by the

Czech Science Foundation. The study was conducted in accordance with the Declaration of Helsinki. Testing was completed in the schools after receiving the informed consent of parents of the children and the school principals.

Motor asssessment

Two age-adjusted test sets of the MABC-2 – for the age band of 7–10 years (AB2) and 11–16 years (AB3) used contained:

1) three tests of manual dexterity – placing pegs (MD 1), threading lace (MD 2), drawing trail (MD 3) in the AB2; turning pegs (MD 1), triangle with nuts and bolts (MD 2) and drawing trail (MD 3) in the AB3;

2) two tests aiming & catching – catching with two hands (AC 1) and throwing beanbag onto mat (AC 2) in the AB2; catching with one hand (AC 1) and throwing at wall target (AC 2) in the AB3; 3);

3) three balance tests – one-board balance (Bal 1), walking heel-to toe forward (Bal 2) and hopping on mats (Bal 3) in the AB2; two-board balance (Bal 1), walking toe-to-heel backwards (Bal 2) and zig-zag hopping (Bal 3) in the AB3.

Scoring of test performance and convertion of raw scores to the standard scores (SS) was completed according to the MABC-2 Examiner's Manual (Henderson et al., 2007). Reliability and objectivity of the MABC-2 AB3 was reported as intraclass correlation 0.62–0.92, and 0.92–1.00. The stability of SS of three motor components and total test score (TTS) was assessed with SEM = 1.20–1.56 SS (on the scale 1–19 SS, with M ± SD 10 ± 3 SS) (Henderson et al., 2007).

Data analysis

The significance of age on the test performance was analysed using the Kruskal-Wallis test followed by post-hoc multiple comparison test ($\alpha = 0.05$). The differences of test performance between the Czech and UK samples were analysed by the Cohen's effect size coefficient d with pooled SD. The values $d < 0.50$, $d = 0.50–0.80$ and $d > 0.80$ were interpreted as a small, medium and large effect of age, respectively (Cohen, 1988). The difference was finally interpreted as significant if the practical difference $d \geq 0.50$ was confirmed by the two-tailed z-test as statistically significant ($\alpha = 0.05$). For the analyses the NCSS Statistical Software version 2007 (Kaysville, Utah, USA) was used.

RESULTS

Age variations of the motor performance

Manual dexterity performance in the MD 1 and MD 2 tests improved during the prepubescence (7–10 yrs.) and pubescence (11–15 yrs.) in both genders, with statistical significance of the age factor ($\alpha = 0.05$). On the other hand, age wasn't found as a significant factor of a number of errors in drawing trail (MD 3) in both boys and girls (tab. 1–4).

Table 1. Performance in the MABC-2 tests in the 7–10 years old boys (n = 251)

MD 1 pref. hand (s)				MD 1 non-pref. hand (s)				MD 2 (s)				MD 3 (n. of errors)			
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**
7	32	23	39	**7**	36	29	47	**7**	32	23	50	**7**	0	0	2
8	29	19	41	**8**	32	0	42	**8**	28	18	41	**8**	0	0	2
9	26	20	38	**9**	30	20	36	**9**	22	15	36	**9**	0	0	4
10	25	16	46	**10**	**29**	**18**	**58**	**10**	22	15	56	**10**	0	0	3
p = 0.0000				**p = 0.0000**				**p = 0.0000**				**p = 0.8211**			
7 vs 9, 10; 8 vs 9, 10				7 vs 9, 10; 8 vs 10				7, 8 vs 9, 10							
AC 1 (n. of catches)				**AC 2 (n. of hits)**				**Bal 1 better leg (s)**				**Bal 1 other leg (s)**			
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**
7	6	0	10	**7**	6	2	9	**7**	23	4	30	**7**	22	3	30
8	8	1	10	**8**	7	1	10	**8**	20	2	30	**8**	20	2	30
9	7	0	10	**9**	8	0	10	**9**	30	3	30	**9**	21	3	30
10	9	0	10	**10**	8	1	10	**10**	30	5	30	**10**	30	3	30
p = 0.0023				**p = 0.0008**				**p = 0.0000**				**p = 0.3648**			
7 vs 10				7, 8 vs 10				8 vs 10							
Bal 2 (n. of steps)				**Bal 3 better leg (n. of jumps)**				**Bal 3 other leg (n. of jumps)**							
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**				
7	15	8	15	**7**	5	1	5	**7**	5	0	5				
8	15	3	15	**8**	5	1	5	**8**	5	1	5				
9	15	3	15	**9**	5	2	5	**9**	5	1	5				
10	15	4	15	**10**	5	4	5	**10**	5	1	5				
p = 0.0241				**p = 0.0102**				**p = 0.0910**							

Legend: Mdn – median; Min, Max – minimum and maximum value; p = a significance level in the Kruskal-Wallis test; 7 vs 9 – significant difference between two age groups in the post hoc comparison test (α = 0.05)

Age was found the significant factor of performance in the aiming and catching tests (AC 1, AC 2) in the prepubescent and pubescent children of both genders (tab. 1–4), with exception no significant effect of the age on the number of hits in throwing at wall target (AC 2) in the 11–15-year-old girls (tab. 4).

Table 2. Performance in the MABC-2 tests in the 11–15 years old boys (n = 310)

MD 1 pref. hand (s)				MD 1 non-pref. hand (s)				MD 2 (s)				MD 3 (n. of errors)			
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**
11	21	16	34	**11**	23	16	36	**11**	41	21	70	**11**	0	0	4
12	19	15	70	**12**	22	16	50	**12**	38	24	79	**12**	0	0	3
13	19	14	25	**13**	21	15	27	**13**	35	24	68	**13**	0	0	4
14	19	13	27	**14**	22	13	30	**14**	39	23	48	**14**	0	0	3
15	19	16	23	**15**	22	16	27	**15**	35	25	48	**15**	0	0	1
p = 0.0310				**p = 0.0192**				**p = 0.0205**				**p = 0.1479**			
11 vs 12, 13				11 vs 13				11 vs 13							
AC 1 pref. hand (n. of catches)				**AC 1 non-pref. hand (n. of catches)**				**AC 2 (n. of hits)**							
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**				
11	8	0	10	**11**	7	0	10	**11**	6	2	10				
12	9	0	10	**12**	7	0	10	**12**	6	1	10				
13	9	2	10	**13**	9	0	10	**13**	6	1	10				
14	9	0	10	**14**	8	0	10	**14**	7	4	10				
15	10	4	10	**15**	9	2	10	**15**	7	3	10				
p = 0.0003				**p = 0.0000**				**p = 0.0034**							
11, 12 vs 15				11 vs 13, 15; 12 vs 14, 15				11 vs 14							
Bal 1 (s)				**Bal 2 (n. of steps)**				**Bal 3 better leg (n. of jumps)**				**Bal 3 other leg (n. of jumps)**			
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**
11	30	2	30	**11**	15	2	15	**11**	5	1	5	**11**	5	1	5
12	30	2	101	**12**	15	0	15	**12**	5	0	5	**12**	5	1	5
13	30	3	30	**13**	15	1	15	**13**	5	4	5	**13**	5	1	5
14	30	4	30	**14**	15	2	15	**14**	5	3	5	**14**	5	5	5
15	30	2	30	**15**	15	3	15	**15**	5	5	5	**15**	5	5	5
p = 0.7103				**p = 0.1122**				**p = 0.8294**				**p = 0.0565**			

Legend: Mdn – median; Min, Max – minimum and maximum value; p = a significance level in the Kruskal-Wallis test; 11 vs 12 – significant difference between two age groups in the post hoc comparison test (α = 0.05)

Significant improvement of balance performance of boys was found only during the prepubescent (7–10 yrs.) stage, but static and dynamic balance performance in the Bal 1 and Bal 3 test, respectively, was not significantly affected by age (tab. 1).

In the prepubescent girls, age was the significant factor of one-board balance with both better and other leg (Bal 1), and hopping on mats with better leg (Bal 3) (tab. 3). In the pubescent girls, age-improved performance in walking toe-to-heel backwards (Bal 2) and zig-zag hopping with a better leg (Bal 3) was confirmed statistically as the age factor was found as significant (tab. 4).

Comparison of the AB2 (7–10 yrs.) motor test performance of the Czech a UK samples

Of the all manual dexterity tests, only mean performance in the MD 3 test was significantly higher in Czech children (in five Czech age/gender groups) in comparison to the UK sample (tab. 5). Results of the aiming and catching tests achieved in the Czech sample were not significantly different across the age and gender groups in comparison to performance of the UK children. The majority of the age/gender groups of the Czech children showed significantly higher performance in the balance tests than the UK sample (tab. 5).

Table 3. Performance in the MABC-2 tests in the 7–10 years old girls (n = 236)

MD 1 pref. hand (s)				MD 1 non-pref. hand (s)				MD 2 (s)				MD 3 (n. of errors)			
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**
7	31	22	42	**7**	35	21	50	**7**	30	17	42	**7**	0	0	2
8	27	21	41	**8**	30	22	41	**8**	26	16	39	**8**	0	0	3
9	27	19	38	**9**	30	37	30	**9**	22	15	31	**9**	0	0	2
10	25	16	46	**10**	28	21	48	**10**	21	14	78	**10**	0	0	2
p = 0.0000				**p = 0.0000**				**p = 0.0000**				**p = 0.4147**			
7 vs 8, 9, 10				7 vs 8, 9, 10				7 vs 8, 9, 10; 8 vs 9, 10							
AC 1 (n. of catches)				**AC 2 (n. of hits)**				**BAL 1 best leg (s)**				**BAL 1 other leg (s)**			
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**
7	6	0	10	**7**	6	3	10	**7**	30	3	30	**7**	18	3	30
8	7	0	10	**8**	6	3	10	**8**	30	3	30	**8**	28	4	30
9	6	0	10	**9**	7	0	10	**9**	30	3	30	**9**	30	3	30
10	8	0	10	**10**	7	1	10	**10**	30	6	30	**10**	30	3	30
p = 0.0011				**p = 0.0093**				**p = 0.0178**				**p = 0.0006**			
7, 9 vs 10				8 vs 10								7 vs 9, 10			
Bal 2 (n. of steps)				**Bal 3 best leg (n. of jumps)**				**Bal 3 other leg (n. of jumps)**							
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**				
7	15	12	15	**7**	5	1	5	**7**	5	0	5				
8	15	3	15	**8**	5	5	5	**8**	5	0	5				
9	15	4	15	**9**	5	4	5	**9**	5	4	5				
10	15	13	15	**10**	5	4	5	**10**	5	0	5				
p = 0.3279				**p = 0.0751**				**p = 0.0140**							

Legend: Mdn – median; Min, Max – minimum and maximum value; p = a significance level in the Kruskal-Wallis test; 7 vs 8 – significant difference between two age groups in the post hoc comparison test (α = 0.05)

Table 4. Performance in the MABC-2 tests in the 11–15 years old girls (n = 279)

MD 1 pref. hand (s)				MD 1 non-pref. hand (s)				MD 2 (s)				MD 3 (n. of errors)			
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**
11	20	14	27	**11**	22	15	31	**11**	43	25	93	**11**	0	0	2
12	19	14	28	**12**	23	14	32	**12**	38	14	58	**12**	0	0	3
13	18	13	27	**13**	21	16	33	**13**	39	26	66	**13**	0	0	5
14	19	14	25	**14**	20	15	28	**14**	36	24	69	**14**	0	0	1
15	16	7	23	**15**	18	7	26	**15**	36	22	58	**15**	0	0	1
p = 0.0000				**p = 0.0000**				**p = 0.0000**				**p = 0.1363**			
11, 12, 13, 14 vs 15				11, 12, 13 vs 15				11 vs 12, 13, 14, 15							
AC 1 pref. hand (n. of catches)				**AC 1 non-pref. hand (n. of catches)**				**AC 2 (n. of hits)**							
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**				
11	7	0	10	**11**	6	0	10	**11**	5	1	9				
12	8	0	10	**12**	6	0	10	**12**	6	1	10				
13	8	0	10	**13**	7	0	10	**13**	5	1	9				
14	9	1	10	**14**	8	0	10	**14**	6	1	9				
15	9	1	13	**15**	9	1	10	**15**	6	1	10				
p = 0.0191				**p = 0.0000**				**p = 0.4934**							
11 vs 15				11, 12, 13 vs 15; 11 vs 14											
Bal 1 (s)				**Bal 2 (n. of steps)**				**Bal 3 best leg (n. of jumps)**				**Bal 3 other leg (n. of jumps)**			
age	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**	**age**	**Mdn**	**Min**	**Max**
11	30	3	30	**11**	15	1	15	**11**	5	5	5	**11**	5	4	5
12	30	3	30	**12**	15	2	15	**12**	5	4	5	**12**	5	1	5
13	30	9	30	**13**	15	2	15	**13**	5	5	5	**13**	5	1	5
14	30	2	30	**14**	15	2	15	**14**	5	0	5	**14**	5	0	5
15	30	5	30	**15**	15	5	15	**15**	5	5	5	**15**	5	4	5
p = 0.3374				**p = 0.0590**				**p = 0.0451**				**p = 0.3924**			

Legend: Mdn – median; Min, Max – minimum and maximum value; p = a significance level in the Kruskal-Wallis test; 11 vs 15 – significant difference between two age groups in the post hoc comparison test ($\alpha = 0.05$)

Table 5. The MABC-2 tests which showed significantly different performance of the 7–10-year-old Czech boys (B, n = 251) and girls (G, n = 236) in comparison to performance of the United Kingdom standardisation sample

test	gender	age	d	z-value	test	gender	age	d	z-value
MD 3	B	7	0.72	2.870*	Bal 2	B	10	0.57	5.835**
	G	7	1.89	11.794**		G	10	1.00	9.164**
	B	8	0.50	4.202**	Bal 3	G	8	1.23	9.734**
	G	8	0.65	5.025**		B	9	0.70	5.969**
	G	10	0.57	5.395**		G	9	2.00	14.945**
Bal 1	B	7	0.70	2.658*		B	10	1.14	10.772**
	G	7	1.04	5.983**		G	10	0.94	8.293**
	B	8	0.54	4.487**					
	G	8	1.10	8.567**					
	B	9	0.52	4.316**					
	G	9	1.12	8.551**					
	B	10	0.77	7.552**					
	G	10	1.17	10.512**					

Legend: d – Cohen's effect size coefficient; * – $p < 0.05$; ** – $p < 0.001$

Comparison of the AB3 (11–15 yrs.) motor test performance of the Czech a UK samples

Mean performance of all the Czech age/gender groups in the MD 3 test was significantly higher than the MD 3 performance in the age-relevant UK groups (tab. 6). In a case of the MD 2 test, significantly lower performance was found only in the 14-year-old Czech boys and 15-year-old girls as compared to the UK sample (tab. 6).

The Czech sample demonstrated no significant differences in performance in the aiming and catching tests in comparison to the UK sample (tab. 6). Among 15 age/tender comparisons of the balance test performance in the girls, 6 Czech groups achieved signficantly higher performance than the UK girls of the relevant age (tab. 6).

Table 6. The MABC-2 tests which showed significantly different performance of the 11–15 years old Czech boys (B, n = 310) and girls (G, n = 279) in comparison to the performance of the United Kingdom standardisation sample

test	gender	age	d	z-value	test	gender	age	d	z-value
MD 1	B	15	0.67	3.496*	**AC 1**	B	15	0.60	2.778*
MD 2	B	14	0.55	4.756**	**Bal 1**	G	11	0.52	4.636**
	B	15	0.57	2.498		G	12	0.54	4.851**
	G	15	0.64	3.561*		G	13	0.58	7.814
MD 3	B	11	1.00	11.611**		G	15	0.70	3.922**
	G	11	1.32	17.600**	**Bal 2**	G	15	0.78	9.000**
	B	12	0.87	10.151**	**Bal 3**	G	13	0.50	8.058**
	G	12	1.20	13.233**		B	14	0.60	9.200**
	B	13	0.88	8.925**		B	15	0.67	NC
	G	13	1.30	16.273**		B	15	0.67	NC
	B	14	0.68	5.781**					
	G	14	0.90	12.014**					
	B	15	0.77	5.400**					
	G	15	0.78	7.000**					

Legend: d – Cohen's effect size coefficient; * – $p < 0.05$; ** – $p < 0.001$, NC – no calculation due to SD = 0

DISCUSSION

Age variations of the motor functions

The tasks of placing and turning pegs (MD 1 tests) represent unimanual coordination, while threading lace and constructing of a triangle by connecting strips with bolts and nuts in MD 2 tests require bimanual coordination. Found significance of the age factor on performance in these tasks within the both age bands suggested improving in uni- and bi-manual coordination during both the prepubescent and pubescent stage. These findings are relevant to the general meaning that between age of 6–12 years children typically master basic fine motor coordination (Forssberg, 1998).

Although the drawing trail task (MD 3 test) requires unimanual (hand-eye) coordination as the MD 1 test task, no age-related improvement in drawing was observed. The median of number of errors in the drawing task was zero in all age groups of both genders. These results suggested mature graphomotor skills already in the 7-year-old children. However, these findings suggested a methodological problem of the ceiling effect and thus poor sensitivity of the MD 3 test for identification of the developmental improvement of visuomotor functions connected with precise movements with a hand and fingers.

The aiming and catching tasks in the MABC-2 have been considered the indicators of gross motor coordination (Henderson et al., 2007). Performance in the both tasks

significantly improved with age of the Czech children within the prepubescent and pubescent stage. There is opinion that fine and gross motor coordination develop together (Hendesron et al., 2007). Concurrent improvement of performance in manual dexterity tasks and aiming & catching tasks of the MABC-2 observed in the Czech children could result from improved visuomotor coordination of the hand-eye system which underlies performing both small and gross movements (Forssberg, 1998).

Development of static balance is considered a basic characteristic of motor development (Geuze, 2003). The Czech prepubescent boys and girls demonstrated improvement of static one-leg balance (Bal 1), even though significant improvement of balance on a worse leg was observed in boys till at age of 10 years. The maximal score of maintaining static balance position 30 s with better leg was observed as early as at the age of 7 years in girls and 9 years in boys. Maturation of the static balance on a non-dominant leg in this task was delayed by 1–2 years in comparison to the balance on a dominant leg. The dynamic balance demonstrated in the tasks of walking and jumping in the Bal 2 and Bal 3 tests seemed to be mature as early as at the age of 7 years in both genders. However, the problem of the ceiling effect of these tests has to be again considered when 15 steps and 5 jumps, respectively, are the maximal raw scores fot these tests.

Comparison of motor performance in the MABC-2 between the Czech and UK sample

The unequivocal significant tendency of higher performance in the Czech children in the drawing trail test (MD 3) was found in comparison to performance of the UK sample, with exception of the 9-year-old Czech children. The assessment of gross motor coordination with the aiming and catching test of the MABC-2 showed to be valid for the both prepubescent and pubescent Czech children.

Besides the manual dexterity test MD 3, performance in the static balance test Bal 1 showed the largest differences (higher scores) in comparison to the mean performance of the UK standardisation sample. The similar problem with cross-cultural validity of the norms was also found in the case of the dynamic test Bal 3 (jumping), with exception for the 7 and 12-year-old subjects.

Prevalence of developmental motor difficulties in the Czech children

Total test score TTS ≤ 5th percentile denoting having a significant motor difficulties was found in the 0.6% of the prepubescents and 1.4% of pubescents. The prevalence of developmental coordination disorder among the European and north-american populations of children was estimated as 2–4% (Barnhart, 2003). A little lower incidence of motor difficulties found in the study could be partly explained by using various diagnostical tools in the studies, but also by the fact that the Czech sample originated from the public schools and do not included the subjects from schools providing educational programs for the children with severe developmental disorders.

CONCLUSION

Unimanual and bimanual coordination in the tasks requiring both speed and accuracy, and visuomotor coordination used in the aiming tasks and timing interceptive tasks can improve up to 12–15 years-old children. The Czech girls demonstrated the mature static balance at the age of 7 years, while the Czech boys by two years later. The study showed that the MABC-2 can be a valid method for assessment of gross motor coordination in the Czech prepubescent and pubescent children. Before use of this test battery in research and educational, psychological and clinical practice in Czech Republic, an adjustment of the norms of the manual dexterity and balance tests for the relevant age groups are needed.

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REFERENCES

BARNHART, R. C., DAVENPORT, M. J., EPPS, S. B., NORDQUIST, V. M. (2003). Developmental coordination disorder. *Physical Therapy* 83(8), 722–731.

BOYLE, C. A., BOULET, S., SSCHIEVE, L. A., et al. (2011). Trends in prevalence in the developmental disabilities in US children, 1997–2008. *Pediatrics* 127(6), 1034–1042.

COHEN, J. (1988). *Statistical power analysis for the behaviour science*. 2nd ed. New York, NY: Lawrence Erlbaum Associated.

Council of Europe. (1993). *Eurofit tests of physical fitness*. 2nd ed. Strasbourg: Council of Europe.

ELLINOUDIS, T., KOURTESSIS, T., KIPARISSIS, M. (2008). Suitability of the Movement Assessment Battery for Children in Greece: Comparison between a Greek sample and the North-American normative sample of 9 and 11 years old children. *International Journal of Health Science* 1(4), 132–137.

FORSSBERG, H. (1998). The neurophysiology of manual skill development In K. J. Connolly (ed.), *The psychobiology of the hand* (pp. 97–122). London: Mac Keith Press.

GEUZE, R. H. (2003). Static balance and developmental coordination disorder. *Human Movement Science* 22(4–5), 527–548.

HENDERSON, S. E., SUGDEN, D. A. (1992). *Movement Assessment Battery for Children.* London: The Psychological Corporation.

HENDERSON, S. E., SUGDEN, D. A., BARNETT, A. L. (2007). *Movement Assessment Battery for Children-2.* London: Hartcourt Assessment.

MĚKOTA, K., BLAHUŠ, P., et al. (1995). Unifittest (6–60). Tests and norms of motor performance and physical fitness in youth and in adult age. *Acta Universitatis Palackianae Olomucensis Gymnica* 1 (Suppl.), 1–108.

MILANESE, C., BORTOLAMI, O., BERTUCCO, M., et al. (2010). Anthropometry and motor fitness in children aged 6–12 years. *Journal of Human Sport and Exercise online* V(II), 265–279.

MIYAHARA, M., TSUJII, M., HANAI, T., et al. (1998). The Movement Assessment Battery for Children: A preliminary investigation of its usefulness in Japan. *Human Movement Science* 17, 679–697.

RUIZ, L. M., GRAUPERA, J. L., GUTIÉRREZ, M., MIYAHARA, M. (2003). The assessment of motor coordination in children with the Movement ABC test: A comparative study among Japan, USA and Spain. *International Journal of Applied Sports Sciences* 15(1), 22–35.

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EFFECT OF MAXIMUM HEART RATE ON ACCURACY OF FIRE

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ABSTRACT

In today's world, when many offenders are well-equipped with firearms and ready to use them to avoid their apprehension, when the threat of a terrorist attack is high, when war conflicts are increasingly conducted within city borders (urban warfare), the skill of precise and quick elimination of an enemy is vital for members of law enforcement agencies operating in physically demanding situations.

The goal of this paper is to examine the effect of maximum heart rate on the pistol shooting performance by analyzing precision target shooting data of a set of 8 participants all coming from the ranks of the Police of the Czech Republic. This paper represents an empirical descriptive study. In order to find out statistical significance, we used the statistical method of a paired two-sample t-test. We organized the collected data by comparing arithmetic means. For grouping and interpretation of target shooting data, we utilized the method of finding the central point of shots at a target. The *Sport tester*, a monitoring device, helped provide the values of maximum heart rate. Based on the data collected, we conclude that maximum heart rate has a statistically significant effect on precision of target shooting. This precision was defined by the average distance of individual shots at a target from the central point of impact. We also found that the size of this distance before and after intense physical activity can be influenced sport activities that respondents perform as their hobbies.

Keywords: shooting; physical activity; resting heart rate; relaxed state heart rate; maximum heart rate

INTRODUCTION

In today's world, when many offenders are well-equipped with firearms and ready to use them to avoid their arrests, when the threat of a terrorist attack is high, when war conflicts are increasingly conducted within city borders (urban warfare), the skill of precise and

quick elimination of an enemy is vital for members of law enforcement agencies operating in physically demanding situations.

In the Czech Republic, this phenomenon relates to troops of the Czech Armed Forces operating in foreign deployments and specialized units concerned with fighting organized crime, terrorism and arresting dangerous individuals within the borders of the Czech Republic. These units include local municipal police departments, the Rapid reaction unit – an elite Anti-Terrorist Unit of the Czech Police, and specialized bodies such as Customs Service of the Czech Republic and Prison Service of the Czech Republic.

To carry out their work, these specialized units are quite flexible in operations and utilize the element of surprise in their tactics. The surprise aspect is significantly related to a quick approach to the target which with weapons and additional equipment can be compared to a moderate-intensity endurance performance such as a 400 m sprinting event or one lineup change in ice hockey. However, if we take into account that this kind of performance is concluded with point shooting, in other words "target focused shooting", it is necessary to pose the following question: Will the shooting be executed precisely enough? In this aspect we have to consider that shooting which follows intense physical activity can present a certain level of variance from shooting in relaxed state. This variance can be attributed to a short-term physical fatigue impairing the brain's motor centers and hence effecting fine motor skills necessary for the upcoming shot.

The aforementioned conditions for shooting will be simulated by physical activity during which the heart rate of tested individuals will be reaching maximum values. We then assess their shooting performance for preciseness during a normal resting heart rate (phase 1 of the trial) and the maximum heart rate (phase 2 of the trial).

The findings of this analysis can find application within the framework of developing firearms skills in the context of physical training not only in the Czech Army but also in the above mentioned law enforcement units of the Czech Republic.

METHODS

Research participants

The research group (Table 1) consists of 8 participants with the mean age of **30.3 ± 3.5**. As members of the Rapid reaction unit of the Czech Police operating in Prague, they all participate in a minimum of 6 intensive rounds of shooting practice each month. The ammunition used starts with the minimum of 2000 bullets per person per month.

Table 1. Participant characteristics

	Participant No. 1	Participant No. 2	Participant No. 3	Participant No. 4	Participant No. 5	Participant No. 6	Participant No. 7	Participant No. 8
Age	31	34	35	28	26	31	33	25
Height [cm]	186	191	187	179	186	163	177	184
Weight [kg]	81	98	92	81	88	70	83	84
Expected max heart rate [min]	189	186	185	192	194	189	187	195
Physical fitness back-ground	Crossfit Climbing Shooting Cycling	Martial Arts Crossfit	Boxing Crossfit Power-lifting	Triathlon Collective sports	Martial Arts Athletics Cross Country Skiing Cycling	Crossfit Martial Arts	Climbing Tenis	Athletics Martial Arts Cycling

Legend: Physical fitness background – physical activity which participants engage in in their free time

Measuring

The measurement was conducted by using a modified physical stress test to achieve maximum heart rate as published in Macek and Radvansky (2011) and Shephard (1987). The observation took place in an indoor shooting range STVS MO in Praha-Ruzyne on April 19, 2013 at 11:00 a.m. The subjects were introduced to and familiarized with the Czech Army's official safety rules for using firearms as well as the facility safety rules and regulations of the shooting range. Because of limited capacity, the group of 8 subjects was divided into two groups – each group consisting of 4 participants. The first phase of measuring started with the first group of 4 firing at a target during a normal resting heart rate at 11:08 a.m. The same group was then exposed to physical exertion which was followed by the second phase of shooting at 11:15 a.m. The last participant finished his shooting round at 12:15 a.m. Each trial was in compliance with the official legislation of the Czech Armed Forces related to firearms (Vsevojsk 4–2) and the facility safety rules and regulations of the shooting range STVS MO Praha-Ruzyne. The medical emergency personnel from Medical Emergency Service were on site at the time.

Shooting test

The standard distance from the firing line to the target was shortened in our test to the distance of 15 m. Each subject used 10 bullets. The time limit for each shot fired was 2 s. The total time for each round was 20 s. The schematic diagram of the shooting test can be seen in Figure 1. For our test, we chose the Glock 17 pistol which is a standard weapon used by the Rapid reaction units in all Regional Directories of the Police of the Czech

Republic. In order to remove another research variable represented by weapon modification, we consciously decided to use only one type of a handgun design.

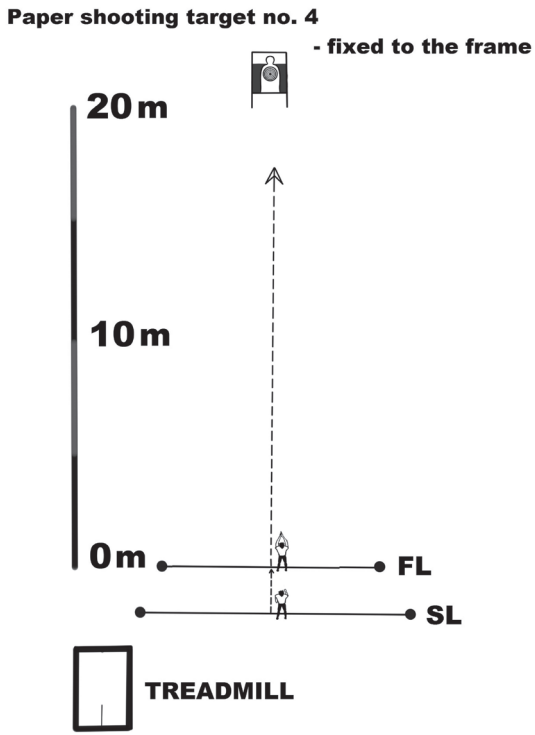

Figure 1. Schematic diagram of test
Legend: SL – starting line; FL – firing line

As Table 2 shows, we utilized the 9 × 19 mm Luger Parabellum cartridge which has also been adopted as standard ammunition by the Police of the Czech Republic and the Czech Army. The bullet is of FMJ (full metal jacket) type which means that a lead core is jacketed with an alloy of copper and zinc content.

Table 2. Technical data of LUGER 9 mm ammunition

Ammunition	Bullet type	Cartridge length [mm]	Cartridge weight [g]	Bullet weight [g]	Muzzle velocity [m*s^{-1}]	Muzzle energy [J]
9 mm Luger	FMJ	29.69	12.15	7.5	390	**570**

Figure 2 represents the shooting target selected for our study. We chose a standard bullseye shooting target No. 4 also used for developing handgun skills based on the Czech Army's Vsevojsk 4–2 regulations.

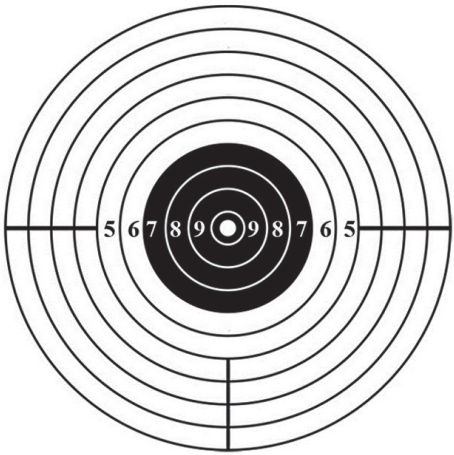

Figure 2. Shooting target number No. 4

Physical stress test

For reaching the maximum heart rate, we used the means of a modified version of the physical stress test which is described both in the Czech and foreign research literature Macek and Radvansky (2011) and Shephard (1987). In accordance with Macek and Radvansky (2011), we decided to take advantage of a treadmill ergometer which engages more muscle groups of its user as opposed to the cycle ergometer. Hence, the treadmill exercise better simulates the real-life physical intensity tested in our study.

The physical stress test began with a treadmill warm-up of light intensity, at the speed of 5.5 km/h. Conditions were changed after 2 minutes and speed went up to 10 km/h. The intensity of exercise was then continuously increased by +2 km/h every minute until each participant refused to continue. Each physical activity took on average 7.5 ± 0.58 min. The test administrators used Garmin Forrunner 310XT Sport tester to monitor reaching the maximum heart rate of each participant.

Data analysis

All shots were recorded and their values analyzed based on the distance of each hit from the centre of the hit and their mean was calculated. The collected data of both sets – before the physical stress test (relaxed state) and after the physical stress test (maximum heart rate) – was statistically compared by means of calculating the arithmetic mean, then the standard deviation, statistical dispersion, and finally evaluating the level of statistical significance using a paired two-sample t-test. In the test, we use the pairwise differences of measured values for the comparison of variational series. We test the hypothesis that the mean value of the measurements before and after the experiment is equal to 0 (difference in mean value of pairwise measurements is equal zero.) The sample was tested for normal distribution by statistical program as part of the

t-test. All statistical calculations were performed using adequate functions of Microsoft Excel 2010 program.

RESULTS

Using the statistical method of a paired two-sample t-test, we apply the collected data to tests our *null hypothesis* **H0 : μ1 = μ2** with an alternative hypothess **H1 : μ1 < μ2**. The level of significance for our data is set at 5%. The value $\alpha = 1.95471783903802 \times 10^{-6}$ ($p < 0.05$) is statistically significant (see Table 5). So, we reject the null hypothesis (H0 : μ1 = μ2: The results of shooting before and after physical activity are the same. We accept the alternative hypothesis (H1 : μ1 < μ2): The results before and after physical activity are different. The distance between hits before and after physical activity has significantly **increased from the mean of 3.211 cm** from the target's centre to **5.560 cm**.

The representation of data in Table 3 and 4 shows that physical activity intensity reaching maximum heart rate has negatively affected the results of shooting of each study participant in the form of increased distance average of hits from the centre point.

The greatest average drop is demonstrated among the participants who performed best i.e. had the lowest average distance in the first phase of measuring that is before the physical test (participants 1, 2, 6). Participant No. 1 shows the exact difference of 2.53 cm, participant No. 2 shows the difference of 2.83 cm, and the participant No. 3 the difference of 2.85 cm. Participants No. 1 and 2 each exhibit more than 100% increase of average distance.

Despite this relatively significant drop, the average results before and after physical activity is still the lowest of the entire set. By analyzing the subject's physical fitness background, we found that participant No. 1, who achieved the best results, engages in firearm shooting in his spare time. Based on the same analysis, we can also speculate that the rest of the participants No. 3–8 who mainly engage in power training rather than aerobic exercises did not adapt well to shooting after physical activity.

On the hand, the lowest difference is found with participant No. 5, specifically 1.499 cm. These participant's hobbies range from power training to endurance activities which can positively effect his adaptation to anaerobic exercise with lactate threshold reaching the maximum heart rate. The second lowest difference of 1.96 cm was achieved by participant No. 8. This participant, just as participant No. 5, is interested in power training and endurance training. As mentioned above, these activities can effect one's adaptation to moderate intensity physical activity for reaching the maximum heart rate. Participant No. 3 achieved the greatest average distance of hits before and after physical activity. Specifically, the average before was 3.86 and after 6.27. This participant is also involved in power training which can influence his poor results after physical activity. When interviewed, this participant revealed that he is quite new at the Rapid reaction unit. Therefore, it is likely that his handgun skills are worse than those of the rest of the study participants.

Table 3. Arithmetic mean distance ($\bar{x}$) from the target centre values [cm] hit [x1 – x10] shooting in relaxed state

HIT	Participant No. 1	Participant No. 2	Participant No. 3	Participant No. 4	Participant No. 5	Participant No. 6	Participant No. 7	Participant No. 8
x1 [cm]	2.9	4.0	3.3	1.4	0.9	3.2	0.6	4.0
x2 [cm]	0.7	0.6	3.7	1.3	1.2	2.7	2.1	3.4
x3 [cm]	1.2	1.3	1.4	5.2	4.6	2.7	4.4	4.2
x4 [cm]	2.4	3.3	2.3	3.7	5.7	3.4	3.2	0.8
x5 [cm]	3.5	1.6	5.1	5.0	3.2	3.3	5.1	4.8
x6 [cm]	4.3	3.0	5.5	4.3	4.4	2.4	4.2	3.5
x7 [cm]	1.8	2.3	4.7	3.9	4.7	1.5	4.6	1.3
x8 [cm]	1.6	1.8	3.3	5.1	5.4	4.3	3.9	1.9
x9 [cm]	1.3	2.4	3.6	4.5	4.1	1.8	2.8	3.7
x10 [cm]	1.7	4.0	5.7	4.0	3.5	4.6	3.2	4.9
$\bar{x}$ [cm]	**2.14**	**2.43**	**3.86**	**3.84**	**3.77**	**2.99**	**3.41**	**3.25**

Table 4. Arithmetic mean distance ($\bar{x}$) from the target centre values [cm] hit [x1 – x10] shooting after physical activity

HIT	Participant No. 1	Participant No. 2	Participant No. 3	Participant No. 4	Participant No. 5	Participant No. 6	Participant No. 7	Participant No. 8
x1 [cm]	4.6	0.9	2.5	2.1	1.2	2.4	3.2	0.6
x2 [cm]	5.7	4.6	1.6	4.2	3.4	2.3	2.7	1.8
x3 [cm]	4.4	7.2	6.8	3.3	5.4	5.2	2.2	5.6
x4 [cm]	4.8	6.4	7.4	3.8	7.2	5.3	6.1	3.8
x5 [cm]	2.4	6.8	5.0	7.6	6.1	7.3	9.8	5.4
x6 [cm]	3.3	5.2	8.2	5.8	9.3	8.5	9.7	1.1
x7 [cm]	4.5	3.2	7.6	6.5	7.6	5.7	1.0	4.8
x8 [cm]	6.7	4.3	8.2	10.1	6.1	4.8	6.1	7.3
x9 [cm]	5.2	6.2	7.1	8.3	5.3	9.8	8.3	10.3
x10 [cm]	5.1	7.8	8.3	9.2	1.09	8.1	8.6	11.4
$\bar{x}$ [cm]	**4.67**	**5.26**	**6.27**	**6.09**	**5.269**	**5.94**	**5.77**	**5.21**

Table 5. T-test calculation ($\bar{x}$ X arithmetic mean values in relaxed state, $\bar{x}$ Y arithmetic mean values after physical activity)

SUBJECT	$\bar{x}$ X [cm]	$\bar{x}$ Y [cm]
1	2.14	4.67
2	2.43	5.26
3	3.86	6.27
4	3.84	6.09
5	3.77	5.269
6	2.99	5.94
7	3.41	5.77
8	3.25	5.21
$\bar{x}$	**3.21125**	**5.559875**
STANDARD DEVIATION	0.609947487	0.507786972
T-TEST	**$1.95471783903802 \times 10^{-6}$**	
SIGNIFICANCE	$p < 0.05$	

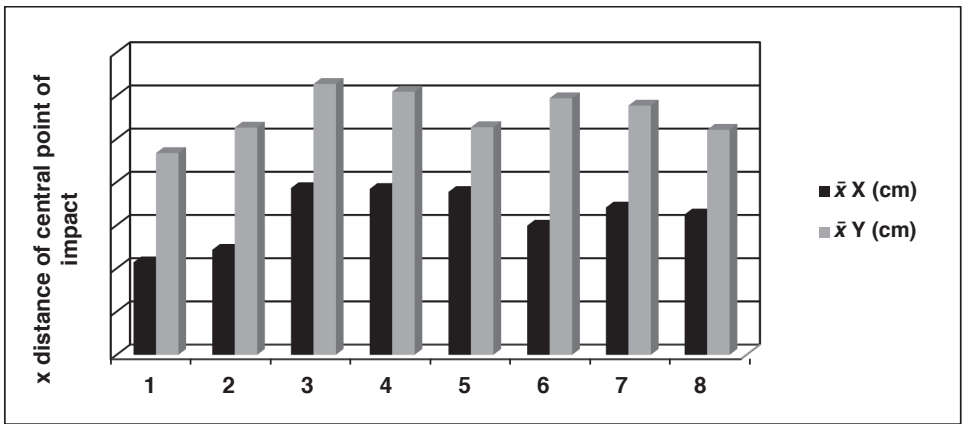

Figure 3. Comparison of arithmetic mean values of distance from the target centre in relaxed state ($\bar{x}$ X) and after physical activity ($\bar{x}$ Y).

DISCUSSION

The goal of this paper was to assess the effect of physical activity which reaches the values of maximum heart rate and which is simulated by a physical stress test using gradually increasing levels of speed on a treadmill ergometer until voluntarily aborting the exercise. For our research we selected from the members of the Rapid reaction unit of the Czech Police operating in Prague who have handgun shooting experience. The intended output of the test was to find statistical differences and statistical significance between

values measured before and after physical activity. To evaluate the statistical difference between shots fired, we took advantage of a ballistics method of ***determine the central point of impact*** which is a point surrounded by evenly scattered points of impact (hits) executed under the same conditions. (Plihal et al., 2011; Kneubüehl et al., 2008). We then determined and compared the arithmetic means of distances of each shot at a target. The method of a paired two-sample t-test allowed us to calculate the statistical significance of the phase 1 and 2 measurements (Navaro, 2007). ***Student's t-test*** is a commonly used and popular parametric test used to test if two sets of data have significantly different mean values μ. The concept of statistical significance testing the difference of mean values helps us consider the effect of the experimental intervention (Brainina, 2013; Chrázka, 2007). The test confirms that the probability that observed differences occur by chance alone is less that 5%. In other words, ***it works with a 95% certainty***. In our study, we tested the null hypothesis **H0 : μ1 = μ2** and the alternative hypothesis **H1 : μ1 < μ2** at the 0.05 level of significance. The value $\alpha = 1.95471783903802 \times 10^{-6}$ ($p < 0.05$) was statistically significant (see Table 5).

In this case we have to reject the null hypothesis (H0 : μ1 = μ2): The results of target shooting before and after physical activity are the same. **We accept the alternative hypothesis (H1 : μ1 < μ2):** The results of target shooting before and after physical activity are different. We then conclude that physical activity which reaches the values of maximum heart rate has an effect on the precision of target shooting.

The negative effect of physical exertion demonstrated in all 8 participants a greater average distance of fired hits from the central point. Second participants whose hobbies range from power training to endurance activities posted the lowest difference of values. One participant who has less firearms experience than others in the group, posted poor results although they were not significantly worse. The best result was registered by a participant who practices his firearms skills outside of work as well.

Our hypothesis assumed that the average distance of shots around the central point would increase after a level of physical exertion. Having conferred our measured data and results, we come to the conclusion that our hypothesis confirms with all participants.

In conclusion, we would like to point out that the highest average distance was 6.27 which is enough to hit a 12.5 diameter circle from a 15 m distance. Also the values of dispersion from the central point of shots was insignificant in comparison to values measured before physical activity. Although statistically significant, the value differences will most likely not influence the factual success of eliminating the target. The shooting ability of all members of the Rapid reaction unit was in all cases correct and clustered. For the next steps of this research, the administrators should measure the values of less and more experienced shooters and compare problematic areas and their causes should be analyzed, and evaluated for their elimination.

CONCLUSION

Based on the data collected from the members of the Rapid reaction unit of the Czech Police operating in Prague and its statistical analysis, we can make the following conclusion. The measuring output was statistically significant. This means that physical exertion

which reaches the values of maximum heart rate has an effect on the precision of target shooting. The null hypothesis of the t-test was rejected and our alternative hypothesis was accepted. We also found worse results for all participants, in other words, the increase in the average distance of shots around the central point after a level of physical exertion. We also noted that for some participants, different kind of physical movement had a level of influence on their shooting performance. Those who do power training and endurance activities of cyclical character registered the lowest difference in comparison to the rest. The same thing happened in one participant which is dedicated in firearms skill training outside of work (better results) and another participant without shooting experience (worse results).

Nevertheless, it is necessary to note that our participant sample size was too small to make generalizations about the population. However, this paper offers certain trends related to further research in this area.

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REFERENCES

ANDĚL, J. (2007). *Základy matematické statistiky*. 2nd ed. Praha: Matfyzpress.

BRAININA, S. I. (2013). *Probability Characteristics of Random Processes. Application of Random Process Excursion Analysis.* Elsevier.

ČELIKOVSKÝ, S., et al. (1979). *ANTROPOMOTORIKA pro studující tělesnou výchovu*. 3rd ed. Praha: SPN.

DOVALIL, J., et al. (2002). *Výkon a trénink ve sportu*. Praha: Olympia.

HELLER, J., VODIČKA, P. (2011). *Praktická cvičení z fyziologie tělesná zátěže*. Praha: Karolinum.

HENDL, J. (2004). *Přehled statistických metod*. Praha: Portál.

HYNOUŠ, J. (1980). *Teorie střelby*. Praha: Univerzita Karlova.

CHRÁSKA, M. (2007) *Metody pedagogického výzkumu*. Praha: Grada.

KITTNAR, O., et al. (2011). *Lékařská fyziologie*. Praha: Grada.

KNEUBÜEHL, B. P., COUPLAND, R. M., MARKUS, A. R., MICHAEL, J. T. (2008). *Wound Ballistics, Basic and Application*. Berlin Heldelberg: Springer.

KRUTECKIJ, V. A. (1972). Problema formirovanija i razvitija sposobnostej. *Voprosy psychologii* 2, 3–13.

KRYL, L. (1979). *Fyziologie sportovní střelby*. Praha: ÚV Svazarmu.

MARQUES, J. P. (2007). *Applied Statistics Using SPSS, STATISTICA, MATLAB and R*. 2nd ed. Berlin: Springer.

MORAVEC, R., et al. (2004). *Teórie a didaktika športu*. Bratislava: Fakulta tělesnej výchovy a športu Univerzity Komenského Bratislava.

NAVARO, M. (2007). *Pravděpodobnost a matematická statistika*. 1st ed. Praha: Nakladatelství ČVUT.

PERIČ, T., DOVALIL, J. (2010). *Sportovní trénink*. Praha: Grada Publishing.

PLÍHAL, B., et al. (2011). *Balistika*. Brno: Univerzita obrany.

SCHMIDT, R. A. (1991). *Motor learning and performance. From principles to practice*. 2nd ed. Champaign (IL): Human Kinetics.

SCHNABEL, G., THIES, G. (1993). *Lexikon Sportwissenschaft. Leistung, Training, Wettkampf*. Berlin: Sportverlag.

SHEPHARD, R. J. (1987). *Exercise Physiology.* B.C. Decker INC.

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CHANGES OF RHEOLOGICAL PROPERTIES DURING VARIOUS DEGREES OF KNEE FLEXION AFTER MENISCECTOMY

ANETA VRÁNOVÁ, MONIKA ŠORFOVÁ, PETR KUBOVÝ

ABSTRACT

Aim of this article is to find out if there is any difference in rheological properties in various degrees of flexion in the knee with meniscal tear and compare the results with measurement after physical activity. Experimental measurements were done by using the method of biorheometry which detects the passive resistance of the knee in movement from flexion to extension. We found changes of rheological properties in higher degrees of knee flexion with typical rising followed by fall of biorheogram around flexion of 80°. They were more remarkable after physical activity. Changes of rheological properties were more expressive in patients who have undergone meniscectomy a few years ago than changes in patients with recent meniscectomy.

Keywords: meniscus; knee joint; biorheometry; rheology; meniscectomy

INTRODUCTION

The meniscus is an important multifunctional component of the knee joint and is considered to be a complex biomechanical system. It has a role in load transmission, shock absorption, proprioception, improvement of stability and lubrication (Bartoníček, 2004; Vedi et al., 1999). Menisci also transmit between 30% and 70% of the load applied across the joint (Guerrero, 2008).

Biorheometer is a measuring equipment which has been constructed in "hidden for review purposes". It is focused on determination of rheological properties of the knee joint. In our study we were going to find out if there is any difference in rheological response during various sequences of knee flexion in patients who have undergone meniscectomy and compare these results after physical activity (50 squads).

PURPOSE

Meniscal tear is one of the most common knee joint injuries. The purpose of this study is to find out if there is any difference in rheological properties in various degrees of flexion in the knee with meniscal tear and compare the results with measurement after physical activity. Then we wanted to compare changes of the rheological properties of patients who have experienced meniscectomy a few years ago to patients with recent meniscectomy.

METHODS

Biorheometer

Biorheometer measures *in vivo* the overall mechanical impedance of the knee-joint. The mechanical impedance is the ratio of complex stress to complex strain. This is measured by the biorheometer at fixed frequency and the corresponding hysteresis-curve is obtained. The hysteresis-curve gives some insight in the viscoelastic properties of the knee-joint. This hysteresis-curve is called a **biorheogram** (Riha, 2012).

It measures the resistance to passive flexion and extension of a leg which is fixed by a socket to the drifter arm above the subject's ankle (Figure 1).

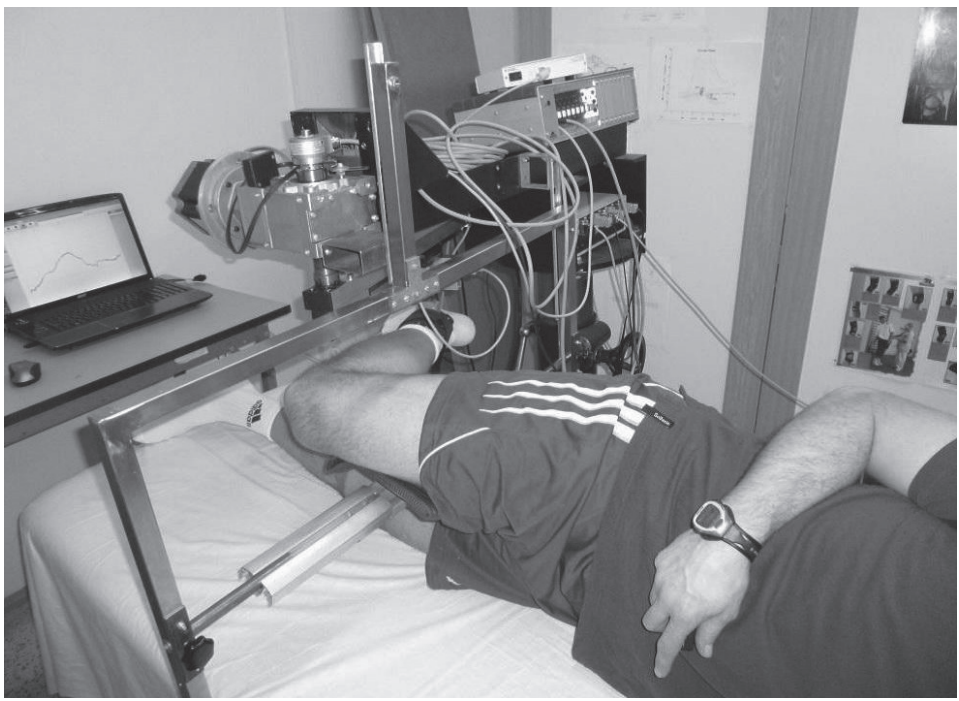

Figure 1. Biorheometry measuring in Department of Anatomy and Biomechanics, Faculty of Physical Education and Sport, Prague

Measuring

We recruited 6 subjects with meniscal tear, all were treated surgically. Subjects with meniscal tear together with ACL lesion were excluded. All subjects suffered from several discomforts while doing sports or activities of daily living. All subjects were injured on their medial meniscus, and were competitive sportsmen, aged 24–45.

All volunteers experienced case history questionnaire and completed WOMET (Western Ontario Meniscal Evaluation Tool). It is a disease specific quality of life measurement tool for patients with meniscal lesions. It consists of three sections: physical symptoms, sports/recreation/work/lifestyle and emotions.

Measuring was done at first on injured limb. Initially, we measured first cycle with angular amplitude of 90 degrees (20 to 100 degrees exactly). Then we used two shorter distances with angular amplitude of 40 degrees (20 to 60 and 60 to 100 degrees). The same was repeated on subject's healthy lower limb. After that subjects had to undergo the physical activity, which consisted of 50 squads. Then we gave them some time (around 10 minutes) to relax and the measurement proceeded again from the beginning with both injured and healthy limbs.

From hysteresis-curve we counted several specific parameters which helped us to determine viscoelastic properties of the knee joint. In our study we were interested in these parameters: stiffness, dissipation energy and local maximums and minimums of the curve.

RESULTS

Results of the WOMET questionnaire in 4 patients showed that the quality of life with their limb after meniscectomy is worse than with the other healthy limb. Only in 2 patients the results were worse in their healthy limb. This may be caused by a pain which could be connected with unrecognized soft tissue injury in their healthy knee (Figure 2).

We divided results of the biorheometry into four sections: we focused on comparison of hysteresis-curves depending on physical activity, healthy and injures lower limb, various degrees of knee flexion (shorter distances 20 to 60 degrees and 60 to 100 degrees) and the year of meniscal injury.

Knees with meniscal tear in history have worse viscoelastic properties than healthy knees. These phenomenons could be caused by the hamstring hyperactivity or structural changes of the knee cartilage.

Results after physical activity vary in specific parameters. This can be caused due to various severity of each meniscal tear.

In short distances from 20 to 60 degrees the changes were less obvious and there were nearly no differences between injured and healthy knees (Figure 3 and 4).

Patients were divided into two groups – first group were volunteers with meniscal tear older than five years, second group were patients with recent meniscal tear (1 year after meniscectomy). We found typical biorheogram rising in angle around 70 degrees in all patients with older meniscal tear. This rising is followed by biorheogram fall which is more obvious after physical activity.

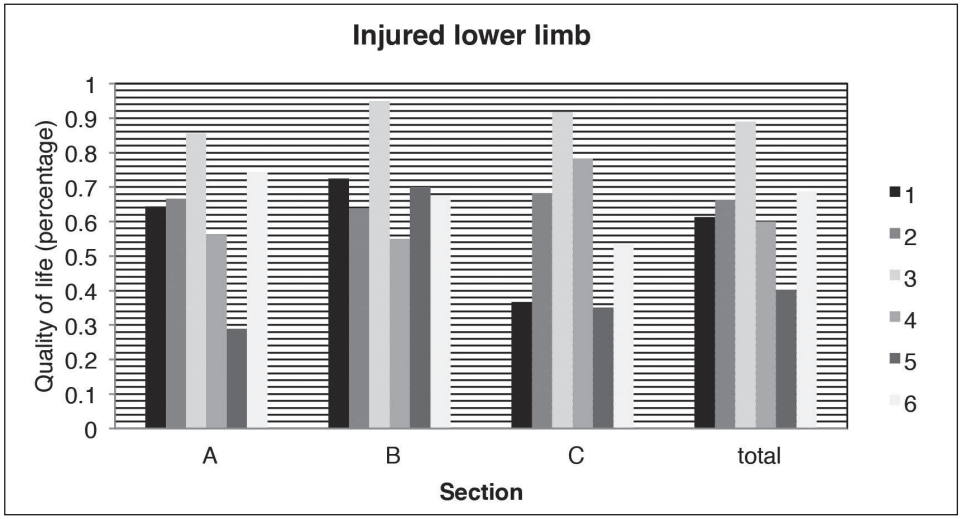

Figure 2. WOMET questionnaire results of injured lower limb. Numbers 1–6, as seen on the right side of graph, are numbers of patients. A – section concerning physical symptoms, B – section concerning sports/recreation/work/lifestyle and C – section concerning emotions. The last part explains total score of each patient's injured lower limb.

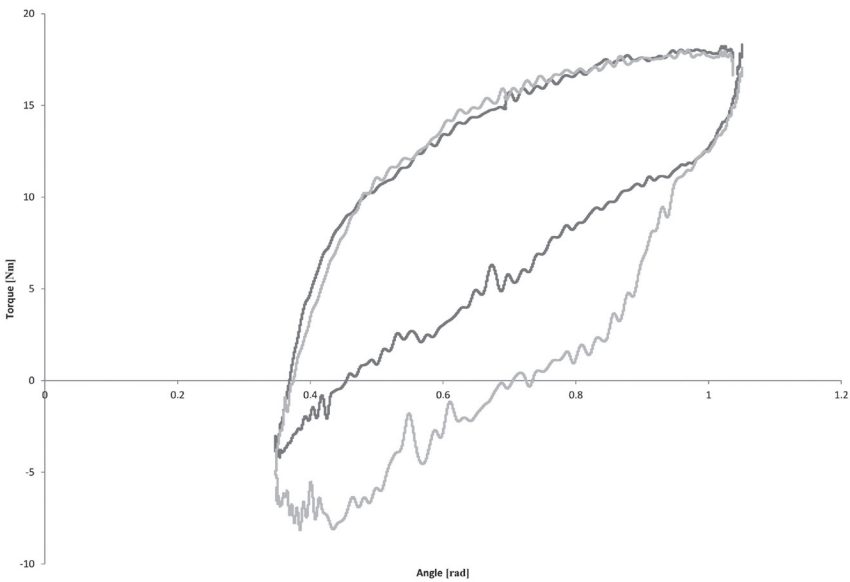

Figure 3. Example of hysteresis-curve in short distance from 20 to 60 degrees in a patient after meniscectomy (dark gray is biorheogram before physical activity, light gray is biorheogram after physical activity)

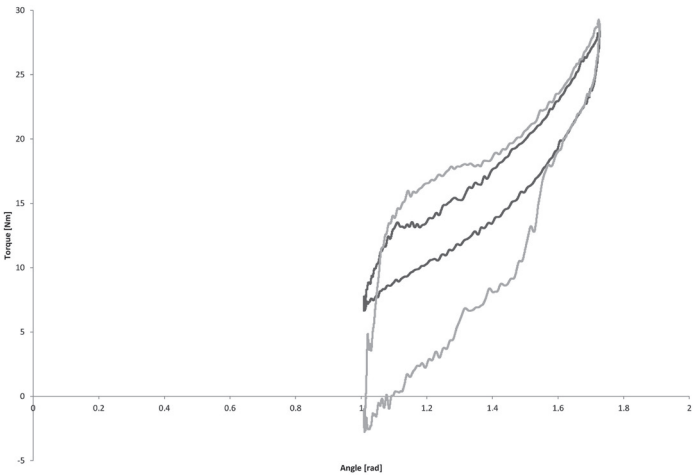

Figure 4. Example of hysteresis-curve in short distance from 60 to 100 degrees in a patient after meniscectomy (dark gray is biorheogram before physical activity, light gray is biorheogram after physical activity)

In second group with recent meniscectomy the rising of hysteresis-curve was present as well, but the following fall was small or wasn't evident at all (Figure 5 and 6). We suppose this could be due to increasing contact pressure and abrasions of the knee cartilage. These rheological changes occur more frequently after longer period of time after meniscectomy.

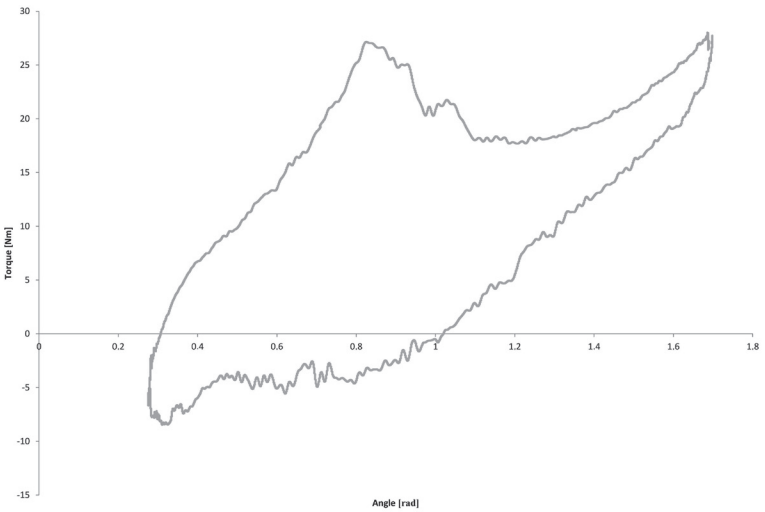

Figure 5. Typical hysteresis-curve rising and fall of patient from group 1 with older meniscectomy (5–7 years old) which had been recorded after physical activity

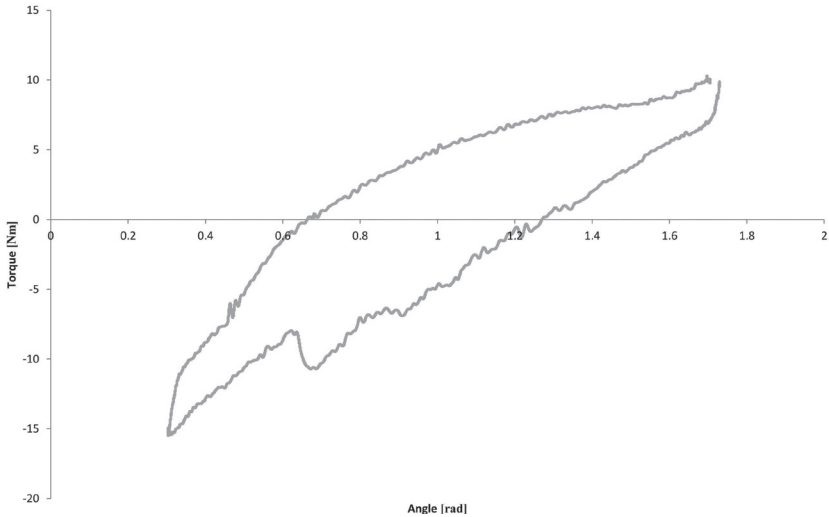

Figure 6. Hysteresis-curve of patient from group 2 with recent meniscectomy (1 year) which has been recorded after physical activity. Typical hysteresis-curve rising and fall, which is obvious in figure 5, is not present here.

DISCUSSION

Results of the WOMET didn't answer to results of biorheometry in two patients, because they had unknown clinical symptoms in their relatively healthy knee.

Vedi et al. (1999) says that meniscal movement turns up with increasing knee flexion. In Guerrero's study (2008) there is a typical medial meniscal translation in 70 degrees, when the posterior horn is gripped firmly between the posterior flare of the femoral condyle and the tibial plateau. After dividing hysteresis-curve into two small sequences, in section 20 to 60 degrees we found sheer increase of the curve which responses to increasing growth of resistance. In section from 60 to 100 degrees there was typical decreasing of the curve after 80 degrees. These changes were more remarkable after physical activity. This can correspond to meniscal translation mentioned above.

Biorheometer measures viscoelastic properties of the entire knee joint, so the result can be influenced by changes is articular capsule, ligaments or menisci.

The most important result of our study was that we found out typical sheer increase followed by decrease of biorheograf in angle around 70 degrees in group 1. The group contained patients with meniscectomy older than 5 years. This change of the hysteresis-curve wasn't present in patients from group 2 with recent meniscectomy. Difference can be caused by presence of rheological changes in knee joint after meniscectomy. As an example could be mentioned increasing contact pressure or abrasions of the knee cartilage.

Williams et al. (2007) found degenerative changes on MRI in knee joint after meniscectomy 5 years after surgery. Degenerative changes and local cartilage abrasion were present in people after meniscectomy.

Englund (2009) found out that meniscal tear is potential risk factor for developing osteoarthritis.

This study is suitable for another research, because we could use only 6 patients after meniscectomy. The verification of typical changes of hysteresis-curve after meniscectomy is obvious only in 3 patients.

Biorheometry is a non-invasive method for detection viscoelastic properties of the knee joint.

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REFERENCES

BARTONÍČEK, J., HEŘT, J. (2004). *Základy klinické anatomie pohybového aparátu*. 1st ed. Praha, Maxdorf.

CHIVERS, M. D., HOWITT S. D. (2009). Anatomy and physical examination of the knee menisci: a narrative review of the orthopaedic literature. *J Can Chiropr Assoc*. 53(4), 319–333. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2796951/ [2013-09-19].

ENGLUND, M., LOHMANDER, L. S. (2005). Patellofemoral osteoarthritis coexistent with tibiofemoral osteoarthritis in a meniscectomy population. *Ann Rheum Dis*. 91(5), 361–365. Available from: http://www.ncbi.nih.gov/pubmed/15843446 [2013-09-14].

GUERRERO, J. G., FOIDART-DESSSALE, M. (2008). *Kinematics of normal menisci during knee flexion*. Department of physical medicine, University Hospital Centre, Liege. Available from: http://www.uv.es/~revfisio/kinematic.pdf [2013-09-19].

KIRKLEY, A. GRIFFIN, S. *WOMET (Western Ontario Meniscal Evaluation Tool). A disease specific quality of life measurement tool for patients with 87 meniscal lesions* [online]. Available from: http://www.banffsportmed.ca/sites/default/files/bp_attachments/WOMET.pdf [2013-09-19].

ŘÍHA, M. (2012). *Effect of femoropatellar joint morphological changes on the rheological response of the knee joint*. (Ph.D. thesis). Prague.

VEDI, V., et al. (1999). Meniscal movement. *The journal of bone and joint surgery* 81(1), 37–41.

WILLIAMS, R. J., et al. (2006). MRI evaluation of isolated arthroscopic partial meniscectomy in patients at a minimum 5-year follow-up. *HSS Journ* 3(1), 35–43. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18751768 [2013-09-19].

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