

2.1 Statistical Analysis

Data analyses were performed using the statistical program SPSS for Windows version 18.0 (SPSS, Inc., Chicago, IL, USA). The calculation of sample size was carried out with $\alpha = 0.05$ (5% chance of type I error) and $1 - \beta = 0.80$ (power 80%), and using the results from our preliminary studies that showed significant differences in agility times between children of different ages [6]. This provided a sample size of 42 for this study. In our preliminary testing age, height, gender, and interactions thereof were included as possible predictors. Height was the most discriminative variable for children of 7 to 9 years of age and demonstrated the highest explained variance ($R^2 > 0.72$) in regression with agility performance. Therefore, the mats located in the four corners outside of a 0.8 m square in the original version of the test were adjusted to fit a 0.55 m square. This allowed the subjects to perform multi-choice stepping reactions to visual stimuli.

The agility data from each of the 553 participants were first tested for normality. The normality of the distribution was investigated using the Kolmogorov-Smirnov test with the Lilliefors correction. Sex data, determined to be normally distributed, were analyzed using the independent samples t-test to examine differences in agility times between boys and girls. A series of one-factor ANOVAs were used to determine within-subject and between-subject differences. The Tukey post-hoc test was used to examine differences in agility time between age groups. The criterion level for significance was set at $p \leq 0.05$. Also, the coefficients of variation (CV) for the agility times (RT) were calculated for each age group to estimate their variability in performance. Additionally, Z-scores were calculated to show how many standard deviations an observation is above or below the mean. Descriptive data for all variables were expressed as the mean and standard deviation (SD).

3. Results

As previously shown, no significant gender effects were found in this study. Using the distance of 0.55 m between mats, no interactions between agility time and height were observed.

Agility time in children decreased with increasing age up to early maturity (Table 2). This decrease in agility time was divided into three phases. There was a rather steep decrease in agility time from 7 to 10 years of age (27.1 %) and from 10 to 14 years of age (26.5 %). Afterwards, there was a slow decrease during the puberty, from 14 to 18 years old (16.5 %). More specifically, agility time decreased at a rate of approximately 241.4 ms/year in the first period, 172.1 ms/year in the second period, and 78.7 ms/year in the third period (Figure 2).

To estimate within-subject variability, the coefficient of variation of agility time was calculated for all of the children and adolescents (measured over all three trials). The within-subject variability was highest among the youngest children and diminished with age ($F_{11,550} = 9.2, p < 0.001$). Mean coefficients of variation (CV) were 9.7% (95% CI, 8.1% to 13.1%) in 7- to 10-year-old subjects, 8.8% (7.4% to 12.1%) in 11- to 13-year-old subjects, 7.9% (95% CI, 6.9% to 9.8%) in 14- to 16-year-old subjects, and 6.9% and 6.2% (95% CI, 4.7% to 8.3%) in 17- and 18-year-old subjects. However, significantly greater intraindividual variability for females than for males in 4-choice agility time was observed in the last period from 14 to 18 years of age (7.9% and 6.3%, respectively).

On basis of the obtained data, a plot illustrating the agility times in each of the age groups was provided (Figure 3) as reference data enabling comparisons to be made with an individual's data and their changes from childhood up to maturity.

Table 2: Agility time (mean ± SD) and inter-difference matrix between agility times of examined groups

Age (years)	Agility time (ms)	7	8	9	10	11	12	13	14	15	16	17	18+
7	891.0 ± 85.4	—											
8	815.7 ± 80.1	≤.05	—										
9	732.0 ± 70.7	≤.01	≤.05	—									
10	649.6 ± 64.4	≤.01	≤.01	≤.05	—								
11	617.3 ± 57.0	≤.01	≤.01	≤.01	n.s.	—							
12	571.7 ± 49.6	≤.01	≤.01	≤.01	≤.05	n.s.	—						
13	526.2 ± 45.3	≤.01	≤.01	≤.01	≤.01	≤.05	n.s.	—					
14	477.5 ± 38.7	≤.01	≤.01	≤.01	≤.01	≤.01	≤.05	n.s.	—				
15	460.5 ± 36.5	≤.01	≤.01	≤.01	≤.01	≤.01	≤.01	n.s.	n.s.	—			
16	450.3 ± 34.9	≤.01	≤.01	≤.01	≤.01	≤.01	≤.01	≤.05	n.s.	n.s.	—		
17	426.1 ± 29.4	≤.01	≤.01	≤.01	≤.01	≤.01	≤.01	≤.01	n.s.	n.s.	n.s.	—	
18+	398.8 ± 24.7	≤.01	≤.01	≤.01	≤.01	≤.01	≤.01	≤.01	≤.05	n.s.	n.s.	n.s.	—

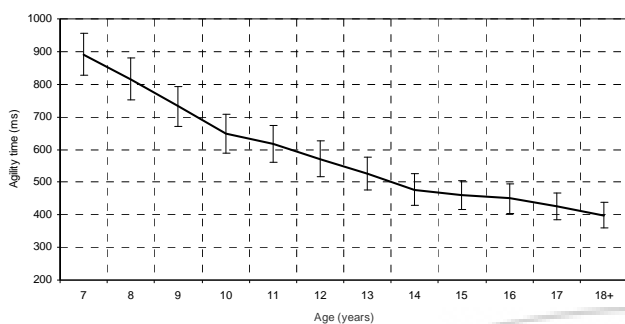


Figure 2: Agility times and SDs in subjects of different ages

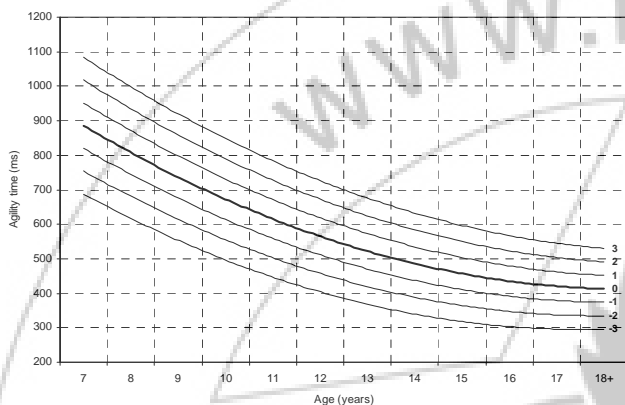


Figure 3: Agility times for age z-scores in subjects from 7 to 18 years old

4. Discussion

A decrease in agility time toward adult age has been found. However, the decrease in agility time was rather steeper from ages 7 to 10 (27.1 %) and from ages 10 to 14 (26.5 %), followed by a relatively slow component during the puberty from 14 to 18 years of age (16.5 %). The obtained data can be used as a set of reference values for comparison with individual subjects when testing agility skills using the Reactive Agility Test. Note that when using this test for the evaluation of agility skills in children, the distance between contact mats should be adjusted in accordance with their height.

This finding is in agreement with other authors [7] who have measured reaction time in young subjects. Kail [8] found that childrens' and adolescents' RTs increase linearly as a function of adult RTs under corresponding conditions and that the size of the increase becomes smaller with age in a manner that is well described by an exponential function. These results are consistent with the view that age differences in processing speed reflect some general (i.e., non-task-specific) component that changes rapidly during childhood and more slowly during adolescence. The commonly reported pattern of decreasing RT mean and variability in childhood and adolescence, followed by an increase in mean and variability through adulthood and into old age, was also confirmed in a study by Dykiert et al. [9]. Greater intra-individual variability for females in simple RT and 4-choice RT was observed in adults but not in children. Males had significantly faster mean simple RTs than did females across their entire life

span, but there were no sex differences in mean 4-choice RTs.

A new approach in the functional diagnostics of children and youth in physical education and sport is the testing of agility skills under simulated competitive conditions. It has been found that agility time is better when the agility test is performed in simulated competitive (Agility Dual) rather than in non-competitive conditions (Agility Single) [10]. An agility test in the form of a simulated competition should be preferred for children and young athletes in order to enhance their levels of arousal and motivation. Such exercises may also represent an appropriate method for agility training, especially in young athletes.

Recently, Kovačiková [11] evaluated the changes in reaction time and speed after 8 weeks of agility training under simulated competitive and non-competitive conditions. A group of 22 fit young men, divided into two experimental groups, underwent the same agility training (2-times/week, 30 minutes). However, while experimental group 1 (ES1) performed the training in the form of a simulated competition (i.e., in pairs and in a group, respectively), experimental group 2 (ES2) performed the same training under non-competitive conditions. Prior to and after the training, agility times in the tests of Agility Single (performed individually) and Agility Dual (performed in pairs in the form of a simulated competition) were measured. Additionally, simple reaction time, multi-choice reaction time, maximal velocity of step initiation, movement frequency of the lower limbs, power in the concentric phase of take-off in a 10-second test of repeated jumps, and jump height and contact time after a drop jump were measured. After 8 weeks of agility training, more pronounced improvements were found in the agility times of the test of Agility Dual in the group trained in the form of a simulated competition than in the agility times of the group which carried out the same training, but without competitive components (18 % and -0.6 %, respectively). There were no significant differences in the changes in other parameters of reaction and speed abilities after the training under simulated competitive and non-competitive conditions. These findings indicate that agility training performed in the form of simulated competition represents a more effective means for the improvement of disjunctive reaction-speed abilities than the same training performed under non-competitive conditions. However, such training does not contribute to more pronounced improvements in other reaction and speed abilities. These findings indicate that better agility times can be obtained in the test in the form of a simulated competition. Similarly, including a competitive component in agility training may make it more efficient in terms of the improvement of agility performance as compared to the same training under non-competitive conditions. Such exercises may also represent an appropriate means for agility training, particularly in young athletes. They may be implemented in teaching, learning, and performing agility skills.

Since agility skills represent a crucial part of performance in many sports, their assessment should be considered an integral part of functional testing in young athletes [12]. To evaluate the efficiency of the agility training, the proposed

Agility Test can be used. The test has been found to be sufficiently sensitive to discriminate between groups of athletes of different sport specializations [13-15]. The best agility times have been found in athletes of racket sports, followed by competitors in combat sports with reactions to visual stimuli, then players of ball sports, and finally competitors in combat sports with reactions to tactile stimuli. These data on agility time in different sports can be used as a reference for the decision-making process in related sports, enabling comparisons to be made with an individual athlete's data and their changes during the training. Taking into account the significantly better agility times in athletes responding to visual rather than to tactile stimuli, this agility test may be recommended primarily for athletes accustomed to responding to various forms of visual stimuli (e.g., the ball).

The agility test complemented with measurements of simple and multi-choice reaction times and movement times may provide additional information on agility performance in young subjects who intend to participate in a particular sport. In the Reaction Test, the participant may respond to either one (simple reaction time) or more stimuli of different forms or colors (multi-choice reaction time). Decision time has a strong influence on total agility time and therefore perceptual skills should be addressed in agility testing and training. Young & Willey [16] found that of the three components that make up the total time, decision time had the highest correlation ($r = 0.77$, $p = 0.00$) with the total time. This correlation with total time was greater than for response movement time ($r = 0.59$) or for tester time ($r = 0.37$), indicating that decision time was the most influential of the test components in explaining the variability in total time. The decision time component within the reactive test condition also revealed that highly-skilled players made significantly faster decisions than lesser-skilled players [17]. Also, the results of Gabbett & Benton [18] demonstrate that decision and movement times on the Reactive Agility Test were faster in more highly skilled players, without compromising response accuracy. Therefore, assessing the perceptual components of agility performance is of practical significance.

5. Conclusions

Agility time decreases with increasing age up to early maturity. Such a decrease in agility time can be divided into three phases. There is a rather steep decrease in agility time from 7 to 10 years of age (27.1 %) and from 10 to 14 years of age (26.5 %). Afterwards, there is a slow decrease during puberty, from age 14 to 18 (16.5 %).

Since this is the first study testing agility skills by means of the Reactive Agility Test, the obtained data can be used as a set of reference values for comparison with subjects of particular ages. Although in some sports the information on reaction and/or agility times may be useful for the selection of young sports talent, one has to be careful using such "norms" for this purpose. The accuracy of measurement of sensorimotor parameters may be influenced by several factors (e.g., motivation, incentive, attentiveness) which are difficult to control in young individuals.

Acknowledgments

This study was supported through a Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences (No. 1/0373/14).

References

- [1] Eurofit, Eurofit Tests of Physical Fitness, 2nd Edition, Strasbourg, 1993.
- [2] J.M. Sheppard, B. Young, Agility literature review: classifications, training and testing, *Journal of Sports Sciences*, 24 (9), pp. 919–932, 2006.
- [3] J.M. Sheppard, W.B. Young, T.L. Doyle, T.A. Sheppard, R.U. Newton, An evaluation of a new test of reactive agility and its relationship to sprint speed and change of direction speed, *Journal of Science and Medicine in Sport*, 9 (4), pp. 342–349, 2006.
- [4] E. Zemková, Assessment of agility skills in sport and physical education, In *Proceedings of the International Forum of Physical Education and Sports Science*, Chandigarh, Panjab University, p. 15, 2012.
- [5] E. Zemková, D. Hamar, Test disjunktívnych reakčno-rýchlostných schopností dolných končatín [Test of disjunctive reaction-speed abilities of lower limbs], In *Proceedings of the Scientific Conference*, Olomouc, Palacký University, pp. 178–181, 1998.
- [6] E. Zemková, Agility u detí [Agility in children], *Tělesná výchova a sport mládeže*, 73 (2), pp. 38–39, 2007.
- [7] J.R. Thomas, J.D. Gallagher, G.J. Purvis, Reaction time and anticipation time: effects of development, *Research Quarterly for Exercise and Sport*, 52 (3), pp. 359–367, 1981.
- [8] R. Kail, Developmental change in speed of processing during childhood and adolescence, *Psychological Bulletin*, 109 (3), pp. 490–501, 1991.
- [9] D. Dykiert, G. Der, J.M. Starr, I.J. Deary, Sex differences in reaction time mean and intraindividual variability across the life span, *Developmental Psychology*, 48 (5), pp. 1262–1276, 2012.
- [10] E. Zemková, T. Vilman, Z. Kováčiková, D. Hamar, Reaction time in the Agility Test under simulated competitive and non-competitive conditions, *Journal of Strength and Conditioning Research*, 27 (12), pp. 3445–3449, 2013.
- [11] Z. Kováčiková, Zmeny reakčno-rýchlostných schopností po rôznych formách agility tréningu [Changes of reaction-speed abilities after different forms of agility training], Bratislava, Comenius University, Faculty of Physical Education and Sports, 2012.
- [12] E. Zemková, D. Hamar, *Toward an understanding of agility performance*, Boskovice, Albert, 2009.
- [13] E. Zemková, D. Hamar, Disjunktívne reakčno-rýchlostné schopnosti u športovcov rôznych špecializácií [Disjunctive reaction-speed abilities in athletes of different specializations], In *Proceedings of the scientific conference*, Nový Smokovec, Slovak Society of Sports Medicine, p. 13, 1998.
- [14] E. Zemková, D. Hamar, Disjunktívne reakčno-rýchlostné schopnosti v úpolových športoch [Disjunctive reaction-speed abilities in combat sports], In *Proceedings*

of the Scientific Conference, Košice, Technical University, pp. 112–117, 1998.

- [15] E. Zemková, D. Hamar, Disjunktívne reakčno-rýchlostné schopnosti u športovcov rôznych špecializácií [Disjunctive reaction-speed abilities in athletes of different specializations], Slovenský lekár, 9 (4-5), pp. 145–146, 1999.
- [16] W.B. Young, B. Willey, Analysis of a reactive agility field test, Journal of Science and Medicine in Sport, 13 (3), pp. 376–378, 2009.
- [17] D. Farrow, W. Young, L. Bruce, The development of a test of reactive agility for netball: a new methodology, Journal of Science and Medicine in Sport, 8 (1), pp. 52–60, 2005.
- [18] T. Gabbett, D. Benton, Reactive agility of rugby league players, Journal of Science and Medicine in Sport, 12 (1), pp. 212–214, 2009.

Authors Profiles



Erika Zemková, Ph.D. is a professor in the Department of Sports Kinanthropology, Faculty of Physical Education and Sport, Comenius University in Bratislava. She completed her Masters Degree in Professional Coaching in 1994, and Doctoral Degree in the scientific and academic branch of Sports Kinanthropology in 1999. In 2007, she became Associate Professor of Sports Kinanthropology, and in 2013 Full Professor of Sports Kinanthropology. In 2008, she graduated at the Institute of International Relations and Law Approximation, Faculty of Law. In 2012 she became a vice-director of the Hamar Diagnostic Center.



Dušan Hamar, MD., Ph.D. is a professor in the Department of Sports Kinanthropology, Faculty of Physical Education and Sport, Comenius University in Bratislava. He graduated in 1976 with a medical degree (MD) from the Medical Faculty of Comenius University in Bratislava. In 1980, he received a specialization in internal medicine and in 1985, a specialization in sports medicine. He received his PhD in Sports Medicine in 1985, became Associate Professor of Sports Medicine in 1992, and a Full Professor of Sports Kinanthropology in 2000.