Age-Related Changes in Agility Time in Children and Adolescents

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Abstract: ***This study compares agility times in groups aged from 7 to 18 years. Altogether 553 subjects performed an agility test. Their task was to touch, as quickly as possible, with either the left or the right foot, one of four mats located in the four corners outside of a 0.55 m square. The mats had to be touched in accordance with the location of a stimulus in one of the corners of a screen. The result was a sum of 32 multi-choice agility times, in four directions, measured by means of the computer-based system FiTRO Agility Check. A decrease in agility time from childhood to adult age has been found. 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 puberty, from age 14 to 18 (16.5%). It may be concluded that agility time decreases with increasing age up to early maturity. 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.***

Keywords: age, agility time, Agility Test, children, youth

1. Introduction

Fitness testing is a common part of the curriculum in many schools. There are a few testing programs that have been developed for school-age children, with tests designed to be appropriate for those ages. The Eurofit Physical Fitness Test Battery is a set of nine physical fitness tests covering flexibility, speed, endurance and strength [1]. The standardized test battery was devised by the Council of Europe for children of school age and has been used in many European schools since 1988. This series of tests are designed so that they can be performed within 35 to 40 minutes, using very simple equipment.

The following 10 tests from the Eurofit Manual are the standard tests recommended for testing school-age children: 1) Anthropometry - height, weight, BMI, and %body fat from skinfold thickness; 2) Flamingo Balance Test - single leg balance test; 3) Plate Tapping - tests speed of limb movement; 4) Sit-and-Reach - flexibility test (using 15 cm at the level of the feet); 5) Standing Broad Jump - measures explosive leg power; 6) Handgrip Test - measures static arm strength; 7) Sit-Ups in 30 Seconds - measures trunk strength; 8) Bent Arm Hang - tests muscular endurance/functional strength; 9) 10 x 5 meter Shuttle Run - measures running speed and agility; and 10) 20 m Endurance Shuttle Run – tests cardiorespiratory endurance.

A 10 x 5m shuttle run is a test of speed and agility. The procedure is as follows: marker cones and/or lines are placed five meters apart. The subject starts with a foot at one marker. When instructed by the timer, the subject runs to the opposite marker, turns and returns to the starting line. This is repeated five times without stopping (covering 50 meters total). At each marker both feet must fully cross the line. This is a pre-planned, change-of-direction speed test evaluating the ability to execute fast movements and to stop and restart rapidly.

Recently, however, agility has been redefined as a rapid whole-body movement with a change of velocity or direction in response to a stimulus [2].

To test this ability, new Reactive Agility Tests that also include anticipation and decision-making components in response to the movements of a tester have been designed. These tests are characterized by three information-processing stages, namely stimulus perception, response selection and movement execution. The use of agility tests that combine change of direction, speed and cognitive measures in practice is encouraged. One of the reasons for this recommendation is their better sensitivity. This may be corroborated by a study by Sheppard et al. [3] which found that the Reactive Agility Test distinguishes between players of differing performance levels in Australian football, while traditional closed-skill sprint and sprint-with-direction-change-tests did not.

Therefore, Reactive Agility Tests that can be carried out on a playing field or in a gym are also preferred for testing children and youth [4]. However, contrary to pre-planned agility tests, for these tests there is no information on agility times in subjects of different ages. Such information on age-related changes in agility time may be useful for comparison with the agility performances of school-age children. Therefore, the aim of this study was to evaluate changes in agility time in children and adolescents.

2. Methods

2.1 Participants

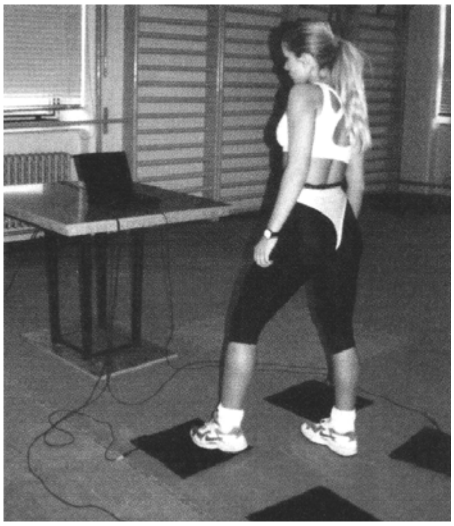
A total 553 subjects from 7 to 18 years old participated in the study (Table 1). There were approximately equal numbers of girls and boys in each age group. All children and their parents and teachers were informed of the procedures, which were in accordance with the ethical standards on human experimentation stated in compliance with the Helsinki Declaration.

Table 1: Characteristics of examined groups (mean ± SD)

Age (years)	*n (1)*	*Height (cm)*	*Weight (kg)*
7	46	175.0 ± 4.8	85.7 ± 7.8
8	48	173.9 ± 5.6	80.2 ± 8.8
9	44	177.1 ± 5.4	76.7 ± 6.5
10	47	186.9 ± 6.2	74.0 ± 5.4
11	45	179.7 ± 4.7	70.8 ± 4.9
12	45	175.4 ± 5.1	71.1 ± 5.1
13	45	177.0 ± 5.4	77.8 ± 6.4
14	47	175.9 ± 5.7	68.4 ± 7.2
15	46	172.8 ± 3.8	68.7 ± 6.5
16	48	175.4 ± 4.1	65.1 ± 6.6
17	46	176.5 ± 3.8	64.7 ± 5.7
18+	46	172.8 ± 2.9	64.1 ± 5.4

2.1 Experimental Protocol

Prior to the study, participants attended a familiarization session during which the testing conditions were explained and trial sets carried out. Each participant was given 1 practice attempt before performing the test. This allowed the tester to provide extra instructions when needed. Afterwards they performed the Agility Test (Figure 1a). Their task was to touch, as quickly as possible, with either the left or the right foot, one of four mats located in the four corners outside of a 0.55 m square. Mats had to be touched in accordance with the location of at stimulus in one of the corners of at screen. The test consisted of 60 visual stimuli with random generation of their location on the screen and time generation from 500 to 2500 ms (Figure 1b). The result was a sum of 32 agility times taken from the better of two trials.



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MOVEMENT DIRECTION	N (#)	BEST (ms)	WORST (ms)	AVERAGE (ms)	SD (ms)
rear left	15	511	1236	654,3	175,5
rear right	15	497	1197	665,8	206,0
front left	15	486	1336	586,9	203,7
front right	15	432	1267	609,8	188,3
** TOTAL **	60	432	1336	629,2	196,4

Figure 1: Agility Test (a) and summary report of the test (b)

2.1 Power Assessment

Agility time was measured by means of the computer-based system FiTRO Agility Check (FiTRONiC s.r.o., SK). The reliability of the test procedure was previously verified and the testing protocol was standardized by the examination of 196 participants [5]. Analysis of repeated measures showed a measurement error of 7.1%, which is within at range comparable to common motor tests. The mean of the best 8 agility times in each direction has been found to be the most reliable parameter of the test, which consists of 3 sets of 60 stimuli (15 in each direction) with random generation of their localization. This is because when the same protocol (i.e., the same location of stimuli in each trial) was used, the agility time significantly decreased after each trial. Participants were most likely able to remember the position of the initial stimuli, which contributed to their better results in successive trials. Therefore, the result of the agility test is a sum of 32 multi-choice agility times, in four possible directions, as a response to stimuli generated by the computer in one of the corners of the screen.

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 ($R2 > 0.72$) 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 ($F11,550 = 9.2$, $p < 0.001$). 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.	__

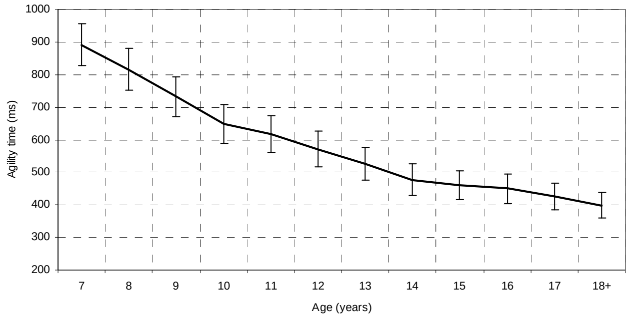

Figure 2: Agility times and SDs in subjects of different ages

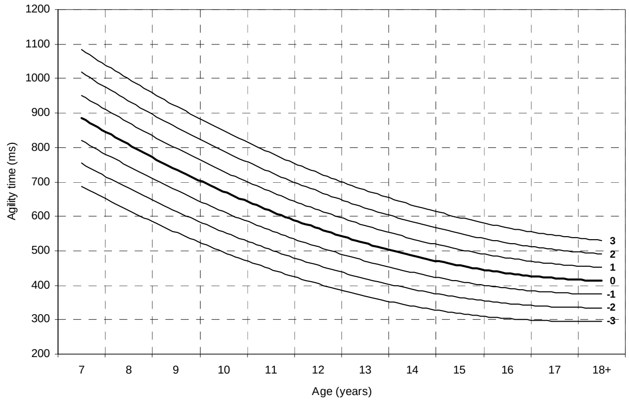

Figure 3: Agility times for age z-scores in subjects from 7 to 18 years old

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 meant 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, Kováčiková [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 a10-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 raquet 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.

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