

Analysis of the dynamics of non-reactive agility under the influence of various structures (ladder and cones) in university students: a longitudinal study

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Abstract

Background and Study Aim Agility is a component associated with skill-related fitness in physical activity. It is required in tasks that involve rapid changes in movement direction. Although various exercise methods are used to develop this ability, their application in university physical education remains a subject of practical interest. The purpose of the research is to design, implement, and verify the utility of a non-reactive agility development programme for university students with non-sports specialization.

Material and Methods The study employed a single-group repeated-measures design with three assessment points: pretest, mid-test, and post-test. The investigated group consists of 572 subjects (315 males and 257 females) from the 1st and 2nd undergraduate years. The average duration of applying the exercises using ladders and cones was 20–25 minutes (8–10 minutes for ladders and 12–15 minutes for cones). Two structures from each category were used in most lessons. The heterogeneity of the students' physical preparation required differentiation of the demands and data analysis. Physically active subjects had longer routes, a greater number of sets, and more repetitions of the exercises, with shorter breaks compared to sedentary subjects. Nine non-reactive agility tests were applied (Hexagon, Fan test, T test, Illinois/primary outcome, 5–10–5 Pro-Agility, Edgren, 10 × 5 m Shuttle, Compass Drill, and Box Drill).

Results The F values for repeated-measures ANOVA and χ^2 values for the Friedman test correspond to statistically significant thresholds ($p < 0.05$) for most tests. The η^2_p and Kendall's W results indicate very strong effects of the proposed experimental programme. The exceptions are the weak effects for sedentary males in the T test ($\eta^2_p = 0.031$) and Compass Drill ($\eta^2_p = 0.055$). Moderate effects were observed for physically active males in the Hexagon test ($\eta^2_p = 0.061$), Fan test ($\eta^2_p = 0.115$), and Illinois test ($\eta^2_p = 0.130$). The differences between the data pairs according to the three test moments indicate a significant improvement in performance ($p < 0.05$) between the initial testing (T1) and the final testing (T3) for both genders and levels of physical activity in all agility tests. Some isolated insignificant differences ($p > 0.05$) are reported between the initial testing (T1) and the intermediate testing (T2), and between the intermediate testing (T2) and the final testing (T3) (for example, the Edgren test for physically active females, and the T test and Compass Drill for sedentary males).

Conclusions Statistical indicators confirm the usefulness of the experimental programme proposed to university students. The programme aims to improve non-reactive agility indicators for both genders and levels of physical activity. The use of diversified exercise structures based on ladders and cones increases the level of student involvement in the lesson. It also facilitates significant progress throughout the academic year for most of the applied tests. The results obtained are similar to those reported in other investigations on university students, but they are obviously lower compared to performance athletes of the same age range.

Keywords: non-reactive agility, university students, ladder and cone exercises, utility, physical education

Introduction

The development of motor abilities is a component of physical education programmes for university students. Among these abilities, agility reflects the capacity to perform rapid and controlled changes of direction during movement.

This capacity depends on the interaction of several physical and coordination factors, including speed, balance, and movement control. The level of agility influences the execution of tasks that require quick transitions between movement directions and stable body control.

Change of Direction Speed (CODS or non-reactive agility) is associated with sports performance. Analysis of studies that investigated over 30,000 athletes from 12 different sports (team sports and

individual sports) indicates higher results for subjects classified as elite level compared with beginners and sub-elite athletes, who show similar performances [1]. Agility is related to the performance of athletes in team games. Those classified as higher level are approximately 7.5% faster than those classified as lower level. Perceptual skills and speed of decision-making contribute to differences between players. Even though the reliability level for agility tests is generally good, this aspect may vary at younger ages [2]. Many team games and field sports involve changes in movement speed and multiple changes of direction to solve tasks. Analysis of the results for CODS and reactive agility (change of direction to stimuli), tested on the same route with four changes of direction (Hungarian football players from leagues 3 and 4, age 24.1 years), indicates better results for the CODS route. The correlation between the two tests is weak and insignificant. This indicates that reactive agility is conditioned by cognitive factors, and different strategies are required for the development and testing of this skill [3]. Developing agility (as a factor involving speed, balance, and coordination) at the level of primary school students creates opportunities to identify and guide students who show higher results in these tests towards practicing various sports games [4].

CODS is particularly associated with muscle strength values, whereas reactive agility (RAG) is also associated with and depends on the cognitive abilities of the test subjects. The evaluation of the two forms of agility in groups of Bosnian children in the pubertal stage (14.86 years) indicates differences between genders. Boys rely mainly on strength gains, whereas girls rely more on cognitive abilities [5]. Recent investigations on Italian amateur university athletes (football, volleyball, martial arts, swimming) have determined associations between explosive strength, reactive strength, and agility. All these complex psychophysical abilities are decisive in achieving sports performance [6]. Other studies address the importance of muscle strength and agility in volleyball and handball [7, 8, 9], or the variations determined by body composition [10]. Another study conducted on Croatian pubertal students found that cognitive abilities cannot be considered a good predictor of reactive agility. In contrast, speed and muscle strength are strongly associated with the values of non-reactive agility tests, especially for boys with above-average motor development. CODS is a good predictor of reactive agility, especially for girls [5]. Similarly, recent research on early pubertal children showed that anthropometric characteristics are weakly related to reactive agility performance, whereas motor abilities such as change of direction speed and explosive leg power significantly contribute to the prediction of reactive agility in both boys and girls [11]. Strong associations between CODS

and acceleration capacity over distances of 10–30 m, explosive strength, and reactive power of leg muscles (jumping ability) are analyzed in [12]. It is recommended to choose agility tests according to the requirements of the sport played. The tests should reflect the specific movement variants, total distances, and changes of direction characteristic of these activities.

Other factors that should be taken into account are gender differences, body mass index, and years of practice [12]. Testing young football and handball players (12–13 years, pubertal stage) with the T and Illinois tests supports their superior reliability in measuring agility. These variants are also good indicators for measuring sprinting ability and jumping ability (muscle power). These abilities can be approached as similar motor skills for athletes involved in these sports games [13]. Investigations on university students with sports specialization and football players of similar age indicate better values for football players in reactive and non-reactive agility tests. Males also have significantly better results than females, especially for reactive agility. These values indicate the need for separate assessment and diagnosis of agility according to gender and through exercises or structures specific to each sport [14]. Another factor influencing the results of CODS tests is the quality of running technique. Technique optimization (4 weeks × 2 sessions) facilitated significant improvements for young soccer players (U11, U13, and U18) in the Pro-Agility test (5-10-5) [15]. A study analyzing agility scores using the T-test for Junior Hapkido athletes in West Sumatra identified poorer values for both genders compared to national standards [16].

An analysis of investigations that addressed different training methods aimed at improving the ability to CODS indicates that the most effective solution is sprinting, followed by plyometric exercises, resistive training, and the combined application of these variants [17]. The integration of plyometric training in the training process of adolescent soccer players in Turkey (6 weeks) ensures a significant increase in performance for lower limb muscle strength (vertical jump variants) and for non-tactile agility (T-test). However, no significant differences were reported between the control group and the experimental group for 30 m acceleration [18]. Plyometric programmes applied in the training of Belgian adolescents practicing recreational basketball (4–8 weeks) have positive effects on vertical jump (CMJ) values and agility. The use of specially designed footwear (elevated forefoot platforms that keep the heels on the ground) provides a superior increase in performance compared to the use of regular sports shoes [19]. Other studies focus on optimizing coordination processes and motor skills in sports games (rugby and soccer), where agility is important [20, 21].

Another investigation notes the beneficial effect of Small Sided and Conditioning Games (SSG) in increasing agility results, aerobic capacity, and anaerobic power. Better effects related to technical-tactical skills are also reported. The use of these exercises in the training of futsal players (18.6 years) has similar effects to the traditional generic fitness training (GFT) version [22]. For young female soccer players at the high school level in Nigeria, the use of a training programme aimed at optimizing fitness indicators (12 weeks × 3 sessions) significantly increases agility (Illinois test) performance and aerobic capacity, but not leg strength values [23]. Other researchers recommend the use of exercises based on the BlazePod device (6 weeks × 3 sessions × 90 minutes) as a solution for increasing agility and reaction speed performance in female handball players [24]. Recent studies emphasize the use of CODS tests, especially those of reactive agility (based on stops, accelerations, and decelerations at light signals). Their advantage is related to the differentiation of athletes of different levels and age stages, and to the predictive nature regarding potential injuries [25].

Exercises based on eccentric contractions have positive effects on improving performance in agility tests. In football, basketball, hockey, and handball, the eccentric variant is involved in the braking phase of movements and in increasing performance in the speed of changing direction [26]. Lateral movements, agility, and acceleration capacity are priority skills for primary school students (10 years). The implementation of special exercise programmes (6 months) for these qualities ensured significant progress in performance in six classic non-reactive agility tests [27]. The implementation of programmes based on coordination and agility exercises facilitates the improvement of nine specific fencing skills for Iraqi students. The progress is explained by the general adaptation syndrome theory (GAS). Physiological demands force the muscles to adapt to new tasks and increase motor performance [28]. The rapidity of badminton-specific actions requires special training. The use of combined exercises using plyometrics and ladder drills ensures the optimization of agility (T-test), explosive leg strength, and speed for young badminton players (12–16 years) in Indonesia [29]. For visually impaired goalball athletes in Thailand, the development of agility is facilitated by using a smart ladder drill prototype, with training planned for 8 weeks. Significant differences are found between the initial and final testing. For agility exercises, distances of 5–10 m and movements between three and five targets are recommended [30]. The combination of short-distance accelerations and structures based on zig-zag movements is effective for performance in speed and agility tests for Indonesian students [31]. Developing agility

through Speed, Agility, Quickness (SAQ) training is more effective than using traditional methods. The application of this solution for eight weeks in Chinese university students is characterized by attractiveness, flexibility, and multilateral effects. Significant progress was noted in the ability to change direction [32].

Analysis of research findings has shown that agility and change-of-direction speed are associated with multiple physical and coordination factors and are influenced by different types of training methods and exercise structures. Researchers emphasize that agility performance depends on the interaction of speed, strength, balance, coordination, and cognitive processes involved in movement control and decision-making. At the same time, the practical application of agility-oriented exercise structures in the context of university physical education requires consideration of the characteristics of students with non-sports specialization and the conditions of regular educational activities. These aspects create a context for analyzing the effectiveness of structured exercise programmes aimed at developing non-reactive agility within university physical education. Most investigations address the development of non-reactive agility through various training programmes with a priority orientation towards performance sports. However, in university physical education the successful involvement of students in lesson activities that require rapid changes of direction is associated with the level of agility indicators. The purpose of the research is to design, implement, and verify the utility of a non-reactive agility development programme for university students with non-sports specialization. It is estimated that the application of this experimental programme will lead to an improvement in non-reactive agility indicators during an academic year.

Materials and Methods

Participants

The study initially included 603 university students with non-sports specialization from the 1st and 2nd undergraduate years of study. The subjects were recruited through randomized cluster selection (different study programmes): Medicine, Dental Medicine, Computers and Automation, Electrical and Electronic Engineering, History and Philosophy, Public Administration, Sciences and Environment, Economics, and Business Administration. Students who did not participate in all non-reactive agility assessment tests, those who did not participate in at least 85% of the scheduled teaching activities, or those who, for various reasons, withdrew from the study (31 cases) were not included in the statistical analysis of the data. A total of 572 subjects (315 males and 257 females) remained for the processing of the obtained data. Most students who did not

meet the lesson engagement criterion ($\geq 85\%$) were also absent from one or more evaluation moments. The results collected from these cases were eliminated from the statistical analysis. Each gender was analyzed according to the level of involvement in physical activities (physically active students involved in physical activities at least three times a week versus sedentary students). The sample size was calculated with G*Power 3.1.9.7 for Windows ($f=0.25$, $1-\beta=0.95$, $\alpha=0.05$). The calculation indicated a minimum of 44 subjects for each gender. The studied groups numerically exceeded this determined threshold. All students were informed about the purpose of the study. Informed consent for participation was obtained. The requirements for investigations involving human subjects according to the Declaration of Helsinki [33] were respected. The study received approval from the Ethics Committee of the educational institution (No. 134/18.04.2024).

Table 1 summarizes the main characteristics of the investigated group. It should be noted that the number of physically active females compared to sedentary females is very small. Only one in ten studied females is physically active. In comparison, one in three studied males is physically active.

Research Design

The study employed a single-group repeated-measures design with three assessment points: pretest, mid-test, and post-test. The research was conducted in the 2023–2024 academic year. Nine non-reactive agility tests were applied (Hexagon, Fan test, T test, Illinois, 5–10–5 Pro-Agility, Edgren, 10×5 m Shuttle, Compass Drill, and Box Drill).

Testing was repeated three times: in weeks 1, 12, and 27.

Given the complex nature of agility, the Illinois Agility Test was designated as the primary outcome of the study. This choice is based on its high representativeness and its extensive use in the international literature. The Illinois test was considered the most appropriate for evaluating the overall impact of the intervention programme. It integrates a wide range of specific demands: explosive accelerations, controlled decelerations, meandering running (slalom), and changes of direction at different angles.

The other agility tests were treated as secondary outcomes. Their role was to provide a detailed perspective on the specific components of agility (segmental coordination, lateral speed, and dynamic balance).

1. Hexagon Test.

The test assesses speed, agility, and the athlete's ability to start, stop, and maintain balance during rapid movements over short distances with departures and returns in all directions. The hexagon consists of six sides, each measuring 60.5 cm. The athlete jumps from the center of the hexagon to the outside of each side and immediately returns to the starting position after each jump. The direction of rotation can be chosen by the subject. Landing on the lines is not allowed. Three complete cycles are performed, which corresponds to 18 round-trip jumps [34].

2. T Agility Test.

The tested subject runs along a T-shaped route marked by four cones (A, B, C, D). The movement

Table 1. Descriptive statistics for the tested groups (male sedentary = 210, male active = 105, female sedentary = 236, female active = 21).

Variables	Gender	Group type	Minimum	Maximum	Mean	Std. Deviation	Std. Error
Age	Male	sedentary	19	35	20.809	3.041	0.209
		active	19	30	20.383	2.112	0.206
	Female	sedentary	18	32	21.103	3.199	0.208
		active	18	25	20.728	1.767	0.386
Weight	Male	sedentary	45.00	128.00	77.824	16.129	1.113
		active	49.00	104.00	74.619	11.904	1.162
	Female	sedentary	38.00	105.00	61.275	12.051	0.784
		active	43.00	75.00	59.523	8.812	0.386
Height	Male	sedentary	156.00	200.00	179.171	7.407	0.511
		active	143.00	197.00	178.257	8.434	0.823
	Female	sedentary	150.00	181.00	164.631	6.282	0.409
		active	158.00	182.00	168.381	6.289	1.372
BMI	Male	sedentary	15.40	41.50	24.151	4.511	0.311
		active	15.50	38.20	23.527	3.794	0.370
	Female	sedentary	14.00	40.00	22.534	4.253	0.277
		active	16.20	26.35	20.976	2.804	0.612

sequence is as follows: from A to B while touching cone B, from B to C while touching cone C, from C to D while touching cone D, returning to C, and then moving backward to A. On the segment B–C–D–B the movement is performed with lateral steps. One yard equals 0.9144 m. Excellent results are considered to be less than 9.5 s for males and less than 10.5 s for females [34].

3. Illinois Agility Test.

The participant runs a course consisting of eight markers, including slalom movement between the central markers. The test begins from a prone or squat starting position. The participant runs the prescribed route as quickly as possible. An excellent score is considered to be under 15.2 seconds for males and under 17 seconds for females [34].

4.5-10-5 Pro-Agility Test (5-10-5 Shuttle).

The participant runs along a course marked by three parallel lines positioned 5 yards apart (right, center, and left). The sequence of movement is as follows: sprint 5 yards to the right, sprint 10 yards to the left, and then sprint 5 yards back to the center line. During each change of direction, the athlete must touch the line with the foot [34].

5. Edgren Side Step Test.

Five cones or floor markers are placed 1 m apart, creating a 4 m route for one full movement. The participant starts at the center marker and performs lateral movements to the right until the last cone, which must be passed with the outside foot. The participant then moves laterally to the opposite side. The movement continues for 10 seconds. The number of correctly passed cones or the distance covered in meters is recorded. Crossing the legs is not allowed and the torso must remain facing forward [34].

6. 10 × 5 m Shuttle Test.

Two parallel lines marked by cones are placed 5 m apart. The participant starts with one foot behind the starting line and runs back and forth between the lines ten times (five round trips). Each turn requires crossing the line with both feet. The total distance covered is 50 m [34].

7. Compass Drill (Agility Cone Drill Test).

Five cones are arranged in the pattern of the cardinal points of a compass. Cone 1 is placed in the center, while cones 2–5 are positioned 3 m from the central cone. The participant starts next to the central cone facing cone 5. At the signal, the participant moves to cone 2 and returns to cone 1, then to cone 3 and back, then to cone 4 and back, and finally sprints to cone 5 to finish. The route is repeated in the opposite direction after a three-minute break. The two results are averaged. The cones must be touched with the hand at each movement [34].

8. Box Drill Fitness Test.

Participants run a square-shaped course marked by four cones. The side of the square measures 10 yards. The starting point coincides with the finish line. Movement is performed along the outer sides of the square: side 1 sprint forward, side 2 lateral movement, side 3 backward movement, and side 4 sprint forward to the finish [34].

9. Evantai Test (Romanian Tennis Federation) [35].

The test evaluates tennis-specific movement speed, coordination, and the ability to accelerate and decelerate over short distances in multiple directions. The athlete must sprint to collect and place five balls positioned on the tennis court at the starting point. Movement may be performed facing the running direction during both the outward and return phases, except after collecting ball number three, when the movement must be performed backward toward the deposit point. The tennis court dimensions used in the test are: court width between points 1–5 equal to 8.23 m and rectangle length between points 1–2 or 4–5 equal to 5.485 m.

The activities aimed at influencing the ability to change direction were planned within the facilities of the Faculty of Physical Education and Sports in Galați. They were applied in each lesson immediately after the warm-up session. The frequency of applying agility exercises was one session per week. The average duration of exercises using ladders and cones was 20–25 minutes (8–10 minutes for ladders and 12–15 minutes for cones). Two structures from each category were used in most lessons. The exercise planning and the approximate duration of the recovery breaks between sets and repetitions are presented in Table 2. The intensity of the exercises was 75–95%. The emphasis during execution was placed on a low body position and good movement control. Feedback was provided to correct technique and prevent injuries. The exercises were changed or diversified from one lesson to another to provide new stimuli and increase attractiveness. The distances used for the ladder exercises were 8–15 m, and for the cone structures 10–25 m. The heterogeneity of the physical preparation of the students required differentiation of the demands. Physically active subjects had longer routes and a greater number of sets and repetitions of the exercises, with shorter breaks compared to sedentary subjects. The dosages presented in the tables are indicative for the average fitness level of the participants. The values may increase or decrease depending on the perceived level of effort (RPE, Rate of Perceived Exertion).

Statistical Analysis

The statistical calculation of the recorded data was based on the application of parametric ANOVA tests with repeated measures, conducted separately by gender and level of physical activity. The sphericity conditions were met in few cases. As

Table 2. Annual Agility Program (20-25 minutes/lesson)

Week	Ladder drills exercises	Dosage Ladder (S x R)	Recovery (rep; set)	Cone drills exercises	Dosage Cone drills (S x R)	Recovery (between repetitions; between sets)
1.	Testing 1/Initial - October					
2.	Forward step + Sidestep	2 x 3	30''; 60''	5x5 m square + Triangle	2 x 3	30''; 60''
3.	Bunny hops + Forward step	2 x 3	30''; 60''	Triangle + 5x5 m square	2 x 3	30''; 60''
4.	Sidestep + Side run	2 x 3	30''; 60''	X drill + L drill	2 x 3	30''; 60''
5.	Forward + Straddle hops	2 x 3	30''; 60''	Triangle + Zig-zag	2 x 3	30''; 60''
6.	Side run + In and out	2 x 3	30''; 60''	X drill + Sprint 45° cut	2 x 3	30''; 60''
7.	Straddle hops + Forward step	2 x 3	30''; 60''	L drill + Y drill	2 x 3	30''; 60''
8.	In and out + Twist hops	2 x 3	30''; 60''	Zig-zag + I-of-pain drill	2 x 3	30''; 60''
9.	Side run + Ali shuffle	2 x 3	30''; 60''	Sprint 45° + Staggered shuttle	2 x 3	30''; 60''
10.	Twist hops + Bunny hops	2 x 3	30''; 60''	I-of-pain drill + Triangle	2 x 3	30''; 60''
11.	Ali shuffle + Sidestep	2 x 3	30''; 60''	Staggered shuttle + X drill	2 x 3	30''; 60''
12.	Testing 2/Intermediate - December					
13.	Twist hops + Ali shuffle	2 x 3	30-40''; 60''	I-of-pain drill + Cone Cone Alley v1	2 x 3	45''; 90''
14.	River dance + Ickey shuffle	2 x 3	30-40''; 60''	Two-track + W drill	2 x 3	60''; 90''
15.	River dance + Forward step	2 x 3	30-40''; 60''	W drill + Cone Cone Alley v1	2 x 3	40''; 75''
16.	Ickey shuffle + In and out	2 x 3	30-40''; 60''	Cone Cone Alley v1 + 1-2-3 back	2 x 3	45''; 90''
17.	River dance + Ickey shuffle	2 x 3	30-40''; 60''	1-2-3 back + Cone Alley v2	2 x 3	45''; 90''
18.	Ali shuffle + Bunny hops	2 x 3	30-40''; 60''	Cone Cone Alley v1 + Zig-zag	2 x 3	45''; 90''
19.	Forward step + In and out	2 x 3	30-40''; 60''	Cone Alley v2 + Run-shuffle-run	2 x 3	45''; 90''
20.	Ali shuffle + Ickey shuffle	2 x 3	30-40''; 60''	Zig-zag + L drill	2 x 3	45''; 90''
21.	Mix 3 exercises + Side run	2 x 3	30-40''; 60''	Cone Alley v2 + X drill	2 x 3	45''; 90''
22.	Bunny hops + Straddle hops	2 x 3	30-40''; 60''	Run-shuffle-run + Triangle	2 x 3	45''; 90''
23.	Sequence 3 exercises	2 x 3	40-45''; 60''	Circuit L drill + X drill	2 x 3	90''; 120''
24.	Mix 3 exercises	2 x 3	40-45''; 60''	Triangle + 1-2-3 back	2 x 3	90''; 120''
25.	Mix 4 exercises	2 x 3	40-45''; 60''	Cone Alley v1 + Shuttle	2 x 3	90''; 120''
26.	Complex circuit (4-5 ex.)	2 x 3	45-60''; 90''	Agility circuit (4structures)	2 x 3	120''; 120''
27.	Testing 3/Final - May					

a result, the Greenhouse-Geisser correction factor (for $\epsilon < 0.75$) and Huynh-Feldt (for $\epsilon > 0.75$) were applied. The results for the values of F, effect size (Partial Eta Squared, with control of other factors influencing the results), the values of Sig., Noncent. Parameter, and Obs. Power were synthesized in tables. The Bonferroni correction factor was applied in the comparison of pairs of results. The confidence interval was set at 95%. For the group of active females (N = 21), the non-parametric Friedman test was used, with the calculation of χ^2 , Kendall's W, and Adj. Sig. (Bonferroni, $p = 0.0167$).

Results

Tables 3 and 4 summarize the main indicators resulting from the application of ANOVA with repeated measures, conducted separately by gender and categories of physical activity. It is observed that the F values correspond, in all cases, to statistical significance thresholds ($p < 0.05$). This confirms the usefulness of the motor structures used to improve agility indicators. However, the η^2p values indicate very weak effects in the case of sedentary students for the T test (male), where only 3.1% of the variance of the result is explained by the implemented programme, and for the Compass Drill (male), where

Table 3. Results of Mauchly's Test of Sphericity and ANOVA with repeated measures for agility tests (sedentary students: Male = 210, Female = 236)

Test	Group	Mauchly's Test		Correction factor	df	Error df	F	Sig.	η^2p	Noncent. Parameter	Obs. Power
		Sig.	ϵ								
Hexagon	Male	0.000	0.765	Huynh-Feldt	1.531	319.968	181.112	0.000	0.464	277.273	1.000
	Female	0.000	0.642	Greenhouse-Geisser	1.284	301.696	238.736	0.000	0.504	306.493	1.000
Fan test	Male	0.000	0.623	Greenhouse-Geisser	1.246	260.449	275.179	0.000	0.568	342.919	1.000
	Female	0.000	0.565	Greenhouse-Geisser	1.130	265.477	213.452	0.000	0.476	241.135	1.000
T test	Male	0.000	0.526	Greenhouse-Geisser	1.052	219.966	6.635	0.010	0.031	6.983	0.742
	Female	0.000	0.573	Greenhouse-Geisser	1.145	269.140	222.180	0.000	0.486	254.458	1.000
Illinois	Male	0.000	0.571	Greenhouse-Geisser	1.142	238.659	600.255	0.000	0.742	685.437	1.000
	Female	0.000	0.608	Greenhouse-Geisser	1.216	285.820	815.297	0.000	0.776	991.609	1.000
5-10-5 Pro-Agility	Male	0.000	0.675	Greenhouse-Geisser	1.350	282.075	65.338	0.000	0.238	88.183	1.000
	Female	0.000	0.701	Greenhouse-Geisser	1.403	329.667	698.382	0.000	0.748	979.714	1.000
Edgren	Male	0.000	0.927	Huynh-Feldt	1.855	387.686	366.637	0.000	0.637	680.096	1.000
	Female	0.076	0.987	Sphericity Assumed	2	470	318.997	0.000	0.576	637.994	1.000
10 x 5 m Shuttle	Male	0.000	0.709	Greenhouse-Geisser	1.417	296.161	184.409	0.000	0.469	261.314	1.000
	Female	0.010	0.971	Huynh-Feldt	1.942	456.294	2810.765	0.000	0.923	5457.592	1.000
Compass Drill	Male	0.000	0.587	Greenhouse-Geisser	1.174	245.262	12.119	0.000	0.055	14.222	0.958
	Female	0.000	0.619	Greenhouse-Geisser	1.238	291.041	717.795	0.000	0.753	888.970	1.000
Box Drill	Male	0.000	0.656	Greenhouse-Geisser	1.311	274.085	1307.932	0.000	0.862	1715.236	1.000
	Female	0.000	0.723	Greenhouse-Geisser	1.446	339.742	2383.522	0.000	0.910	3445.885	1.000

Table 4. Results of Mauchly's Test of Sphericity and ANOVA with repeated measures for agility tests (physically active students Male = 105, Female = 21)

Test	Group	Mauchly's Test		Correction factor	df	Error df	F	Sig.	η^2p	Noncent. Parameter	Obs. Power
		Sig.	ϵ								
Hexagon	Male	0.000	0.505	Greenhouse-Geisser	1.011	105.099	6.722	0.011	0.061	6.793	0.732
	Female	0.000	0.508	Greenhouse-Geisser	1.016	20.324	12.641	0.002	0.387	12.846	0.925
Fan test	Male	0.000	0.511	Greenhouse-Geisser	1.022	106.294	13.452	0.000	0.115	13.749	0.956
	Female	0.000	0.627	Greenhouse-Geisser	1.253	25.064	272.261	0.000	0.932	341.198	1.000
T test	Male	0.000	0.793	Huynh-Feldt	1.586	164.930	1407.859	0.000	0.931	2232.682	1.000
	Female	0.025	0.805	Huynh-Feldt	1.611	32.213	290.929	0.000	0.936	468.578	1.000
Illinois	Male	0.000	0.507	Greenhouse-Geisser	1.015	105.508	15.548	0.000	0.130	15.774	0.975
	Female	0.733	1.000	Sphericity Assumed	2	40	586.410	0.000	0.967	1172.820	1.000
5-10-5 Pro-Agility	Male	0.606	1.000	Sphericity Assumed	2	208	388.258	0.000	0.789	776.516	1.000
	Female	0.100	0.887	Huynh-Feldt	1.774	35.478	139.117	0.000	0.874	246.780	1.000
Edgren	Male	0.153	0.983	Sphericity Assumed	2	208	123.932	0.000	0.544	247.863	1.000
	Female	0.710	1.000	Sphericity Assumed	2	40	20.240	0.000	0.503	40.479	1.000
10 x 5 m Shuttle	Male	0.000	0.699	Greenhouse-Geisser	1.398	145.381	1189.665	0.000	0.920	1663.023	1.000
	Female	0.001	0.665	Greenhouse-Geisser	1.330	26.597	96.842	0.000	0.829	128.785	1.000
Compass Drill	Male	0.000	0.884	Huynh-Feldt	1.769	183.962	890.093	0.000	0.895	1574.455	1.000
	Female	0.000	0.533	Greenhouse-Geisser	1.067	21.335	9.425	0.005	0.320	10.054	0.849
Box Drill	Male	0.000	0.684	Greenhouse-Geisser	1.368	142.236	1042.38	0.000	0.909	1425.620	1.000
	Female	0.312	0.979	Sphericity Assumed	2	40	292.268	0.000	0.936	584.535	1.000

the explained variance is only 5.5%. In the other cases, all values are above the threshold of 0.14. This indicates very strong effects for the applied tests. For example, Box Drill (female) explains 91% of the variance, Box Drill (male) explains 86.2% of the variance, and 10 × 5 m Shuttle (female) explains 92.3% of the variance. For students in the physically active category, the η^2p values indicate moderate effects only in three situations: Hexagon (male) with 6.1% of the variance, Fan test (male) with 11.5% of the variance, and Illinois (male) with 13% of the explained variance. The other values confirm very strong effects of the experimental programme. For example, Illinois (female) explains 96.7% of the variance, Fan test (female) explains 93.2% of the variance, 10 × 5 m Shuttle (male) explains 92% of the variance, and T test (male) explains 93.1%

of the variance. The high values of the Noncent. Parameter for most of the applied tests indicate that the proposed agility programme has clear, strong, and detectable effects on the obtained results. Obs. Power scores indicate, in most situations, values above the threshold of 0.8. This means that there is a probability of over 80% of detecting significant improvements in agility performance. It also indicates correct detection of differences between the three applied test moments and reduced risks of committing a Type II statistical error.

Tables 5 and 6 present the dynamics of performance in agility tests and the comparison of the significance of differences across data points for sedentary students. For males, significant performance improvements are identified in most situations. However, two exceptions were identified.

Table 5. Average results and pairwise differences for the three agility assessments (sedentary males, N = 210)

Test	Mean	SE	T1-T2	Sig.b	T2-T3	Sig.b	T1-T3	Sig.b	95% CI		d
									Lower	Upper	
Hexagon T1	16.530	0.174									
Hexagon T2	16.466	0.173	0.064*	0.000	0.076*	0.000	0.140*	0.000	0.121	0.157	1.069
Hexagon T3	16.390	0.172									
Fan test T1	20.212	0.148									
Fan test T2	20.138	0.149	0.074*	0.000	0.065*	0.000	0.139*	0.000	0.133	0.144	3.412
Fan test T3	20.073	0.148									
T test T1	12.549	0.098									
T test T2	12.541	0.103	0.008	1.000	0.083*	0.045	0.091*	0.000	0.078	0.103	1.001
T test T3	12.458	0.098									
Illinois T1	19.613	0.124									
Illinois T2	19.541	0.123	0.072*	0.000	0.077*	0.000	0.149*	0.000	0.138	0.159	1.963
Illinois T3	19.463	0.123									
5-10-5 Pro-Agility T1	6.262	0.038									
5-10-5 Pro-Agility T2	6.243	0.038	0.019*	0.000	0.034*	0.000	0.053*	0.000	0.042	0.064	0.657
5-10-5 Pro-Agility T3	6.209	0.039									
Edgren T1	16.076	0.146									
Edgren T2	16.448	0.142	-0.371*	0.000	-0.495*	0.000	-0.867*	0.000	-0.920	-0.813	2.205
Edgren T3	16.943	0.138									
10 × 5 m Shuttle T1	20.556	0.116									
10 × 5 m Shuttle T2	20.487	0.116	0.069*	0.000	0.082*	0.000	0.151*	0.000	0.134	0.167	1.244
10 × 5 m Shuttle T3	20.405	0.115									
Compass Drill T1	7.831	0.071									
Compass Drill T2	7.794	0.073	0.037*	0.029	0.023	0.384	0.061*	0.000	0.050	0.070	0.824
Compass Drill T3	7.770	0.070									
Box Drill T1	12.587	0.111									
Box Drill T2	12.542	0.111	0.045*	0.000	0.048*	0.000	0.093*	0.000	0.088	0.097	2.831
Box Drill T3	12.494	0.110									

Note. * - The mean difference is significant at the 0.05 level; b - Adjustment for multiple comparisons: Bonferroni.

Table 6. Average results and pairwise differences for the three agility assessments (Sedentary females, N=236)

Test	Mean	SE	T1-T2	Sig.b	T2-T3	Sig.b	T1-T3	Sig.b	95% CI		d
									Lower	Upper	
Hexagon T1	17.563	0.152									
Hexagon T2	17.510	0.153	0.053*	0.000	0.071*	0.000	0.124*	0.000	0.110	0.137	1.156
Hexagon T3	17.439	0.153									
Fan test T1	22.358	0.128									
Fan test T2	22.282	0.127	0.076*	0.000	0.072*	0.000	0.147*	0.000	0.142	0.152	3.786
Fan test T3	22.210	0.128									
T test T1	14.329	0.086									
T test T2	14.289	0.086	0.040*	0.000	0.044*	0.000	0.084*	0.000	0.074	0.093	1.167
T test T3	14.245	0.085									
Illinois T1	21.993	0.109									
Illinois T2	21.915	0.109	0.078*	0.000	0.079*	0.000	0.157*	0.000	0.147	0.165	2.182
Illinois T3	21.836	0.108									
5-10-5 Pro-Agility T1	6.857	0.036									
5-10-5 Pro-Agility T2	6.835	0.037	0.021*	0.000	0.028*	0.000	0.049*	0.000	0.045	0.052	1.887
5-10-5 Pro-Agility T3	6.808	0.035									
Edgren T1	15.445	0.113									
Edgren T2	15.839	0.110	-0.394*	0.000	-0.398*	0.000	-0.792*	0.000	-0.849	-0.735	1.775
Edgren T3	16.237	0.107									
10 × 5 m Shuttle T1	22.322	0.102									
10 × 5 m Shuttle T2	22.252	0.101	0.070*	0.000	0.079*	0.000	0.149*	0.000	0.145	0.153	4.756
10 × 5 m Shuttle T3	22.172	0.102									
Compass Drill T1	8.762	0.064									
Compass Drill T2	8.735	0.065	0.027*	0.000	0.029*	0.000	0.056*	0.000	0.052	0.059	2.044
Compass Drill T3	8.707	0.064									
Box Drill T1	14.490	0.099									
Box Drill T2	14.441	0.099	0.048*	0.000	0.054*	0.000	0.102*	0.000	0.098	0.106	3.667
Box Drill T3	14.387	0.098									

Note. * - The mean difference is significant at the 0.05 level; b - Adjustment for multiple comparisons: Bonferroni.

The T test for semester 1 (T1-T2) indicates an insignificant improvement in the result ($p > 0.05$). The Compass Drill for semester 2 (T2-T3) also indicates an insignificant difference ($p > 0.05$). However, the differences between the initial and final tests (T1-T3) are significant even for these two cases ($p < 0.05$). Thus, the progress generated by the training programme throughout the entire academic year is statistically confirmed. For sedentary females, the results confirm the existence of significant progress during both semesters for all agility tests ($p < 0.05$). Therefore, there are no stagnations or insignificant differences as observed in the male group. The effect size values (Cohen's d) calculated for the T1-T3 pair are very large ($d > 0.8$) for both genders. This confirms the practical effect of the agility exercises used. The only exception was identified for the male group in the Pro-Agility test,

where the d score indicates a medium effect size ($d = 0.657$).

Tables 7 and 8 present the dynamics of agility test performance and the comparison of the significance of differences across data sets for physically active students. Most of the compared data sets indicate significant differences. However, for the male group insignificant progress ($p > 0.05$) is reported in three situations: for the Hexagon and Fan test during semester 2 (T2-T3) and for the Illinois test during semester 1 (T1-T2). Cohen's d calculated for the T1-T3 pair indicates high effect size values ($d > 0.8$) for most tests in men. The only exception is the Hexagon test, where a weak value was identified ($d = 0.289$). At the level of the active female group (Table 8), the Friedman test indicates a significant difference between the three agility test moments.

Table 7. Average results and pairwise differences for the three agility assessments (Physically active males, N=105)

Test	Mean	SE	T1-T2	Sig.b	T2-T3	Sig.b	T1-T3	Sig.b	95% CI		d
									Lower	Upper	
Hexagon T1	14.171	0.178									
Hexagon T2	14.118	0.177	0.052*	0.000	0.033	0.744	0.086*	0.011	0.028	0.142	0.289
Hexagon T3	14.085	0.180									
Fan test T1	18.370	0.120									
Fan test T2	18.287	0.124	0.083*	0.016	0.037	0.597	0.120*	0.000	0.113	0.127	3.345
Fan test T3	18.250	0.118									
T test T1	11.315	0.074									
T test T2	11.277	0.074	0.038*	0.000	0.036*	0.000	0.074*	0.000	0.070	0.077	4.373
T test T3	11.241	0.073									
Illinois T1	18.359	0.122									
Illinois T2	18.326	0.122	0.033	0.764	0.093*	0.004	0.126*	0.000	0.120	0.131	4.297
Illinois T3	18.233	0.121									
5-10-5 Pro-Agility T1	5.774	0.033									
5-10-5 Pro-Agility T2	5.756	0.033	0.018*	0.000	0.024*	0.000	0.041*	0.000	0.038	0.044	2.750
5-10-5 Pro-Agility T3	5.733	0.034									
Edgren T1	17.705	0.175									
Edgren T2	17.990	0.163	-0.286*	0.000	-0.438*	0.000	-0.724*	0.000	-0.810	-0.636	1.611
Edgren T3	18.429	0.162									
10 × 5 m Shuttle T1	19.237	0.115									
10 × 5 m Shuttle T2	19.181	0.114	0.057*	0.000	0.061*	0.000	0.117*	0.000	0.111	0.123	3.721
10 × 5 m Shuttle T3	19.120	0.115									
Compass Drill T1	7.070	0.073									
Compass Drill T2	7.047	0.073	0.023*	0.000	0.025*	0.000	0.048*	0.000	0.045	0.050	3.602
Compass Drill T3	7.022	0.072									
Box Drill T1	11.234	0.086									
Box Drill T2	11.194	0.086	0.039*	0.000	0.041*	0.000	0.081*	0.000	0.076	0.085	3.519
Box Drill T3	11.153	0.085									

Note. * - The mean difference is significant at the 0.05 level; b - Adjustment for multiple comparisons: Bonferroni.

Table 8. Average results and pairwise differences for the three agility assessments - Friedman test (Physically active females, N=21)

Test	Mean	SE	χ^2 (df)	Asymp.Sig.	Kendall's W	Adj. Sig. T1-T2	Adj. Sig. T2-T3	Adj. Sig. T1-T3
Hexagon T1	15.140	0.507	42.000					
Hexagon T2	15.093	0.507	(2)	0.000	1.000	0.004	0.004	0.000
Hexagon T3	15.001	0.509						
Fan test T1	20.428	0.283	42.000					
Fan test T2	20.365	0.282	(2)	0.000	1.000	0.004	0.004	0.000
Fan test T3	20.290	0.283						
T test T1	13.305	0.330	42.000					
T test T2	13.262	0.329	(2)	0.000	1.000	0.004	0.004	0.000
T test T3	13.214	0.329						

Table 8. Continued

Test	Mean	SE	χ^2 (df)	Asymp.Sig.	Kendall's W	Adj. Sig. T1-T2	Adj. Sig. T2-T3	Adj. Sig. T1-T3
Illinois T1	19.977	0.258	42.000 (2)	0.000	1.000	0.004	0.004	0.000
Illinois T2	19.907	0.257						
Illinois T3	19.838	0.256						
5-10-5 Pro-Agility T1	6.290	0.089	41.518 (2)	0.000	0.989	0.006	0.003	0.000
5-10-5 Pro-Agility T2	6.268	0.088						
5-10-5 Pro-Agility T3	6.244	0.087						
Edgren T1	17.048	0.362	21.535 (2)	0.000	0.513	0.228	0.368	0.003
Edgren T2	17.429	0.328						
Edgren T3	17.762	0.337						
10 x 5 m Shuttle T1	20.850	0.281	36.286 (2)	0.000	0.864	0.004	0.016	0.000
10 x 5 m Shuttle T2	20.790	0.281						
10 x 5 m Shuttle T3	20.729	0.280						
Compass Drill T1	7.754	0.176	40.095 (2)	0.000	0.955	0.002	0.010	0.000
Compass Drill T2	7.717	0.179						
Compass Drill T3	7.702	0.174						
Box Drill T1	13.200	0.292	42.000 (2)	0.000	1.000	0.004	0.004	0.000
Box Drill T2	13.160	0.293						
Box Drill T3	13.109	0.293						

Note. Adj. Sig. Bonferroni correction (p = 0.0167).

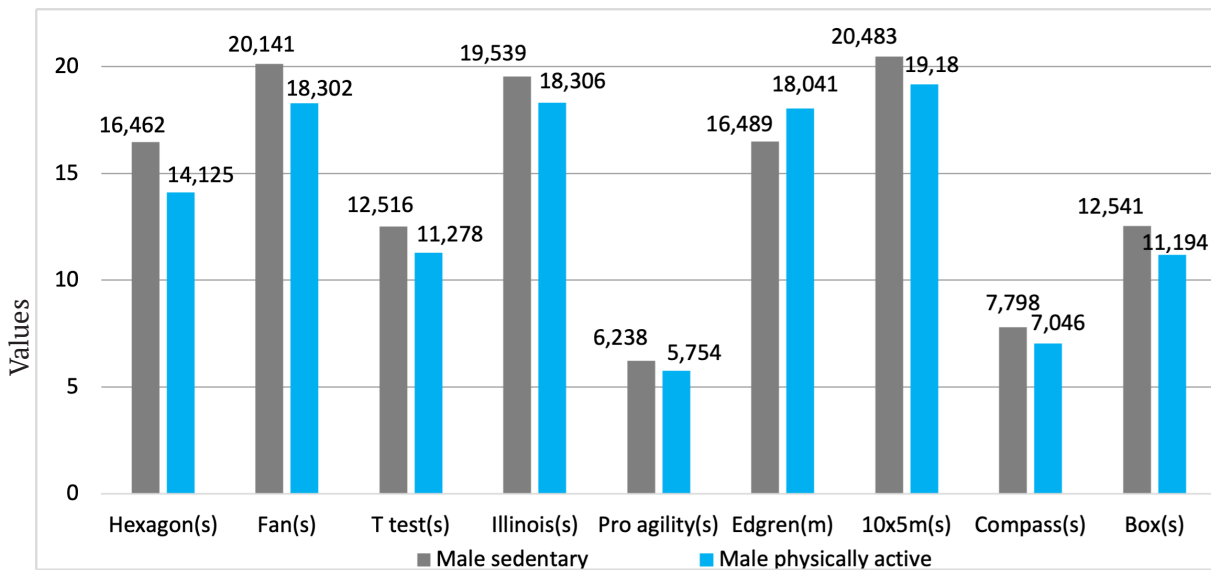


Figure 1. Estimated marginal means for males (sig. <0.05)

The χ^2 values (df = 2) indicate significance levels (p < 0.05) for all nine tests. Effect size expressed by Kendall's coefficient of concordance (Kendall's W) has very high values (> 0.71) for most tests. The exception is the Edgren test, where moderate to large effects are reported (Kendall's W = 0.513). For this test, significant progress was identified only at the level of the entire study year (T1-T3). For the data pairs T1-T2 and T2-T3, insignificant improvements were noted at the semester level (Adj. Sig. > 0.0167). However, both genders register statistically

significant progress (p < 0.05) throughout the entire academic year (T1-T3). This indicates clear improvements for the entire battery of tests.

Figure 1 and 2 compare the estimated mean values for males and females depending on the level of physical activity (sedentary vs. physically active). All differences recorded in the tests are statistically significant (p < 0.05). Sedentary subjects show lower scores than physically active ones (longer times obtained in the timed tests and a shorter distance in the Edgren test).

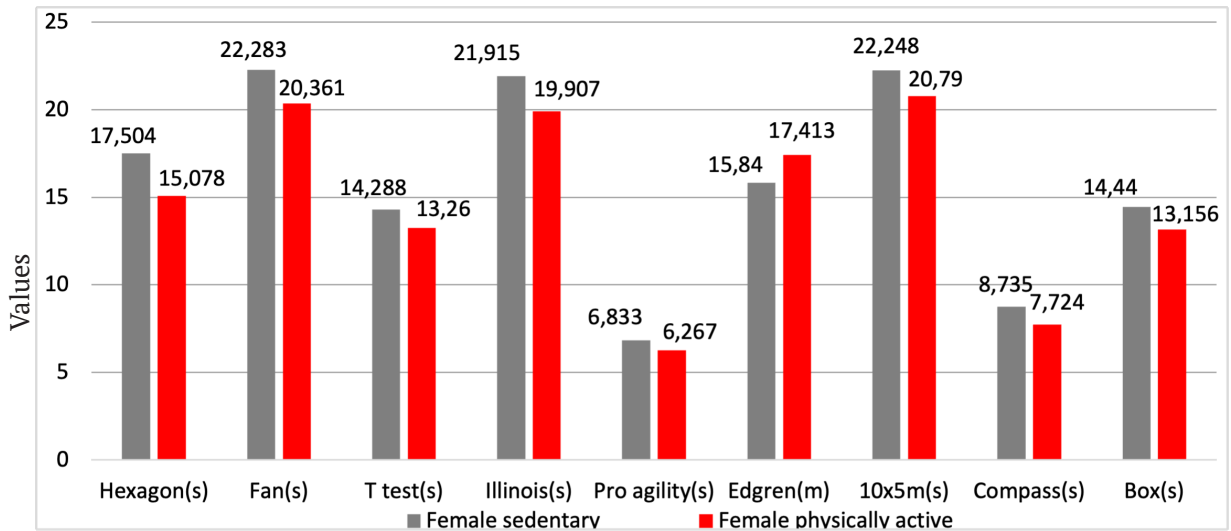


Figure 2. Estimated marginal means for females (sig. <0.05)

Discussion

The purpose of the present study was to develop, implement, and evaluate the effectiveness of an experimental programme aimed at improving non-reactive agility (change of direction speed) in university students with non-sports specialization. The programme was based on two categories of exercises (ladder and cones) integrated into regular physical education classes throughout the academic year. The evaluation was conducted through three testing moments and included nine non-reactive agility tests applied separately according to gender and level of physical activity. The results indicate significant improvements in agility performance for most tests and groups of students. Statistically significant differences were identified between the initial and final testing moments for both genders and for sedentary and physically active students. The effect size values also confirm strong practical effects of the implemented programme in most cases. Some isolated exceptions were identified, mainly in the case of male students, where insignificant improvements were observed during individual semesters. However, the comparison between the initial and final measurements confirms the overall effectiveness of the proposed training structures. These findings indicate that the systematic use of ladder and cone exercises within physical education lessons can contribute to the development of change-of-direction ability in university students.

The increasing orientation of students towards sedentary activities and the role of physical effort in improving academic performance and lifestyle are also analyzed in other studies [36]. Replacing classic soccer training methods with small-sided games is more effective in increasing performance in agility tests. The applied solution (20 weeks × 3 training sessions) for young players (16–18 years old) facilitates obvious progress in the 5-10-5 Pro-

Agility test, from 5.50 s to 5.18 s for the experimental group. The control group shows lower progress, from 5.54 s to 5.41 s [37]. Adaptation to the surface, as well as the neuromuscular and coordination qualities of athletes, are more important in agility tests than the equipment or footwear used. The use of American football cleats versus soccer cleats for young people from the USA (21.1 years old) does not generate differences in the 5-10-5 Pro-Agility test. In both situations, similar values of 5.00 s are obtained [38]. The successive application of the 5-10-5 Pro-Agility test (three tests with a one-week interval; 5 yards = 4.57 m) on New Zealand student athletes (18.1 years) reported significant differences between sessions 2 and 3. The values are relatively close: 5.03 s (S1), 5.04 s (S2), and 5.01 s (S3) [39]. Improving agility indicators requires diversified methods and exercises. The comparison between ladder training (unidimensional movements) and cube training (multidimensional movements), applied for 8 weeks × 2 sessions to college students in Texas, USA, highlights the significant efficiency of both solutions. In the 5-10-5 Pro-Agility test, the ladder group achieves 5.56 s at baseline and 5.34 s at final testing, while the cube group achieves 5.37 s at baseline and 5.23 s at final testing [40]. All the performances analyzed in these studies for athletes in the 5-10-5 Pro-Agility test are better than the values obtained in our students.

A recent study proposes the use of exercises based on immersive virtual reality, which are more effective in optimizing the level of fitness than traditional variants. The application to university students (18–35 years, both sexes) in California, USA, for 4 weeks × 3 sessions × 45–60 minutes also demonstrates usefulness for sprint and non-reactive agility tests. In the 5-10-5 Pro-Agility test, the average results improve from 6.0 s to 5.7 s. In the group that used traditional exercises, no progress was reported [41]. These results are similar to those

obtained by active males in our study (5.74 s). Wearing work gear for police officers influences the results in fitness tests, but no significant differences were found between those who wore a duty belt for agility tests and those who did not. In the 5-10-5 Pro-Agility Shuttle, loaded females scored 8.9 s and unloaded females scored 10.8 s. For males, the situation is reversed: 9.8 s in the loaded version and a better value in the unloaded condition, 8.4 s [42]. The scores recorded by both sexes in our study indicate higher values. However, they should be viewed with caution due to the different testing conditions.

The use of SAQ training (Speed, Agility, Quickness) applied for Chinese university students practicing martial arts (Wushu) (8 weeks × 5 weekly sessions) ensures an improvement in non-reactive agility. The experimental group obtained 20.14 s at the initial testing and 16.83 s at the final testing in the Illinois Agility Test. The control group obtained 21.52 s at the initial testing and 20.45 s at the final testing [43]. Agility training and sprints over different distances are useful in the training of police officers. Positive associations were found between short-distance acceleration capacity and agility values. Students at the Faculty of Security Studies at the University of Banja Luka obtained a mean score of 16.54 s on the Illinois Agility Test (IAT), with extreme values of 15.48 s and 18.27 s [44]. Plyometric exercises applied for six weeks in the training programme of Indonesian badminton players (mostly males, 20–24 years old) ensure the improvement of non-reactive agility indicators. The experimental group obtained 18.31 s at the initial testing and 16.38 s at the final testing in the Illinois Agility Test [45]. All these studies indicate superior final results compared to the male groups tested in our study for the Illinois Agility Test.

Significant correlations between different fitness measurements and the values of the ability to change direction (CODS) are found for female police officers from Abu Dhabi (32.19 years old). For the classic version of the Illinois Agility Test, an average performance of 23.17 s is obtained. For the Illinois Agility Test loaded with 10 kg, an average value of 24.14 s is reported [46]. Implementing specific ladder agility exercises in the extracurricular training of Indonesian students (indoor soccer players) resulted in improved Illinois Agility Test results, with a final mean value of 18.99 s [47]. These studies report lower Illinois Agility Test scores than those obtained by our groups (18.30 s for active males and 19.54 s for active female students). The specific physical demands of university students in Serbia (police officer specialization) correspond to high-intensity efforts in anaerobic mode. For change of direction speed (CODS), evaluated by the Illinois Agility Test, average performances of 20.54 s for females (17.55 s and 22.96 s extreme values) and 18.06 s for males

(15.82 s and 19.91 s extreme values) are reported [48]. Active males in the group studied by us have poorer results, while active females have a better score.

The efficiency of plyometric training is reflected in its effects on muscle power and agility values. The application of these exercises for 6 weeks on young subjects from the USA (24.2 years) ensures significant progress in the Illinois test (17.1 s vs. 16.6 s) and the T test (12.8 s vs. 12.1 s) [49]. Active males in our group have lower mean values for the Illinois test, but better values for the T test.

Non-reactive agility testing of physically active American military men (26.2 years old) on two consecutive days demonstrated good test–retest reliability. For the Edgren Side Step (ESST), values of 23.89 and 24.27 m are obtained. For the T test, the performances are 12.27 and 12.19 s. For the Illinois Agility Test (IAT), values of 18.26 and 18.18 s are obtained [50]. Lower values for the Edgren Side Step were identified for physically active males in the present study (18.04 m), slightly lower values for the Illinois test, but better values for the T test (11.28 s).

Agility tests are included in the Comprehensive High-Level Activity Mobility Predictor (CHAMP) for military males with and without traumatic lower-limb loss (LLL). The application of the tests indicates large differences between subjects with and without LLL: 25.5 s and 12.2 s for the T test, 32.1 s and 18.2 s for the Illinois test, and 15.4 m and 24.3 m for the Edgren Side Step test [51]. For the Illinois test, the active males investigated in our study obtain similar values. However, for the Edgren Side Step test, the results are clearly weaker.

Agility testing in different sports should be performed using tests based on the movement patterns and the specific skills required in the respective sport. In badminton, the X test is proposed, which shows strong and significant correlation coefficients with classic agility tests. The analyzed group (young male university students, 21.56 years old, from Iran) obtained 15.83 s in the Illinois test and 10.23 s in the T test [52]. The results of our students are much weaker in these two tests compared with those reported in this study.

The Speed, Agility, and Quickness training method (SAQ) is more effective in optimizing values in non-reactive agility tests for Chinese university students (19.58 years old) practicing Sanda (a style of martial arts) than traditional variants. The experimental group obtained a value of 7.26 s in the Pro-Agility test (5-10-5), and the control group 7.35 s. In the Illinois test the results were 22.29 s versus 22.46 s, and in the Compass Drill 7.91 s versus 8.16 s [53]. However, our group of active males achieves higher average results in all these tests, for example 7.04 s in the Compass Drill.

The use of agility tests (T test) differentiates the quality of athletes with high and low levels of

training. It is considered useful and recommended for volleyball, basketball, soccer, and American football. Investigations on university students with different levels of fitness (22.3 years for males and 22.4 years for females) from the USA obtained the following results for the T test: low sport (female 13.55 s, male 11.20 s), recreational sport (female 12.52 s, male 10.49 s), and college athletes (female 10.94 s, male 9.94 s). For the Hexagon test, the following scores were obtained: low sport (female 14.31 s, male 14.20 s), recreational sport (female 13.21 s, male 12.33 s), and college athletes (female 12.87 s, male 12.29 s). Strong negative and significant associations between agility tests and vertical jump were found [54]. Only active subjects of both genders tested in our study have values similar to the low sport category for the two tests. Compared with higher categories of involvement in sports activities, the results indicate a weaker level.

The use of specific exercises for the development of non-reactive agility in physical education lessons (frontal, lateral, and backward movements, and changes of direction at variable angles) for Romanian pubertal students (12-week training) indicates significant progress. The experimental group (subjects of both genders) obtained the following results at the initial and final tests: Illinois test (21.73 s and 20.60 s), T test (16.42 s and 15.36 s), Compass Drill (10.06 s and 9.23 s), and Box Drill (14.26 s and 12.19 s) [55]. However, these values cannot be compared with the data obtained in our study due to the mixed groups and classification in a different age stage.

Determining the fitness level of female university students (3rd year of undergraduate studies, over 22 years old) with the specialization of physical education and sports from Niš, Serbia indicates the following values for the 10 × 5 m agility test: an average value of 21.63 s, with extreme scores of 18.43 s and 24.05 s [28]. Our group of active females obtains better results (20.79 s), while sedentary females show weaker results (22.25 s). These findings support the general assumption that a higher level of regular physical activity contributes to better agility performance, since training programmes focused on speed, agility, and quickness have been shown to significantly improve change-of-direction abilities and overall agility performance [56].

Analysis of the fitness level based on the Eurofit tests for male university students from Saudi Arabia (18–22 years old) indicates an average value of 22.8 s for the 10 × 5 m Shuttle Run test. The extreme values recorded are 13.3 s (best performance) and 36.2 s (worst performance) [57]. By comparison, the male students tested in our study obtained better average performances, especially the physically active group (19.18 s).

Endurance and strength training (6 weeks × 3–4 sessions with different orientations: HIIT, full-

body, and turbo) applied to non-athletic Polish female university students (24.09 years) leads to improvement of fitness level indicators. In the agility test 10 × 5 m shuttle run, an average result of 21.22 s is obtained at the initial testing and 20.43 s at the final testing [58]. The level of involvement in physical activities, fitness level values, and body composition differ for Polish university students depending on the university specialization. The best results in the 10 × 5 m shuttle run were obtained by the Physical Education specialization (18.81 s for females and 17.33 s for males). These were followed by Physiotherapy students (21.70 s for females and 18.91 s for males). The lowest results were recorded for students from the SSHE (State School of Higher Education) (21.82 s for females and 19.97 s for males) [59]. A study on the university population in Slovakia (20.73 years) measured the values of motor performance for students with various specializations. Students from Physical Education and Sports obtained the best results, with significant differences for both sexes. In the 10 × 5 m shuttle run test, physical education students achieved 16.97 s for males and 17.86 s for females. Medical students achieved 18.60 s for males and 21.04 s for females. Chemistry and nutrition students achieved 18.82 s for males and 21.83 s for females. Natural sciences students achieved 19.06 s for males and 20.21 s for females [60]. Our groups have similar performances to the non-sports majors listed in the 10 × 5 m shuttle run test, but they are weaker than those of students with sports majors.

Plyometric exercises (applied for 6 weeks × 2 sessions) for recreational soccer players from Malaysia (21.55 years) facilitate significant progress in sprint and agility tests. The initial mean value for the T test is 12.88 s, and the final value is 12.58 s, representing a progress of 2.32% [61]. Ladder training exercises are effective in increasing change-of-direction speed (CODS) performance for Indian university soccer students (21.20 years). The use of ladder drills training (6 weeks × 3 sessions × 30 minutes) improved the result in the T test from 12.24 s to 11.19 s [62]. In the T test, physically active males in the present study obtained values similar to those reported in the presented study.

Success in tennis and solving game situations are conditioned by the execution of fast movements in various directions, in quick response to the trajectory of the ball and the position of the opponents. In this sense, agility is highly demanded. Bulgarian university students practicing tennis obtained the following results in agility tests. For the Compass test, the results are: males (average 10.36 s, extreme values 9.18 s and 12.56 s) and females (average 11.25 s, extreme values 10.02 s and 13.45 s). For the Fan test, the obtained results are: males (average 16.97 s, extreme values 15.05 s and 20.22 s) and females (average 19.04 s, extreme values 16.61 s and 22.77

s) [63]. Speed, agility, and muscle strength training (defining factors for performance in tennis) must be correlated with the level of biological maturation of young Slovenian players. In this context, females can start this training earlier, but males achieve superior results. Very strong associations are found between agility tests and the short 5 m sprint in males. For females, moderate correlations between agility and the 20 m sprint are reported. For the Fan drill test (five directions, 4–4.5 m), U16 males achieve 14.1 s and U18 achieve 13.4 s. For U16 females, a value of 15.4 s and 15.0 s for U18 was recorded [64]. Our better results in the Compass test (7.04 s for active males and 7.72 s for active females) may be explained by a greater distance travelled from the center marker to the extremities in the analyzed study. For the Fan test, our groups record weaker performance values (18.30 s for active males and 20.36 s for active females). This difference can be explained by the fact that the comparison is made with performance athletes.

Repeated performance measurements on a university population (25.35 years, both genders) indicate a high level of reliability for the Hexagon agility test, especially for injury-free groups. Significant differences in performance are measured only between the test times on the same day (T1–T2), with a difference of one hour. This may be an effect of understanding and memorizing the route. No significant differences are reported for tests performed on different days (T2–T3): T1 = 13.83 s, T2 = 12.64 s, and T3 = 12.46 s [65]. Compared with these scores, the average performances of the groups tested in our study are weaker in the Hexagon test (15.97 s for active females and 14.2 s for active males).

Limitations of the study and future directions of investigation

The absence of a control or comparator group is the main limitation of the study. The large number of independent and dependent variables analyzed did not allow the inclusion of all relevant data associated with the study in this manuscript. The results were not correlated with explosive power tests or short-distance sprints, which strongly influence change-of-direction speed. In future publications, the influence of different factors affecting agility

indices in students (e.g., age and anthropometric dimensions) will be presented [66]. BMI level will also be analyzed as a predictor of performance in non-reactive agility tests [67, 68, 69]. Another complementary research direction is reactive agility testing. This approach allows the study of subjects under conditions in which the completion of test routes is conditioned by the ability to respond to visual stimuli that appear unexpectedly. Such situations are frequently encountered in the real demands of sports games [70].

Conclusions

Statistical indicators confirm the usefulness of the experimental programme proposed for university students. The programme aims to improve non-reactive agility indicators for both genders and levels of physical activity. The use of diversified exercise structures based on ladders and cones increases the level of student involvement in the lesson and facilitates significant progress throughout the academic year for most of the applied tests. Even though the agility performances of physically active students are influenced by other external variables that are difficult to quantify (specific demands of sports or active leisure activities practiced), for sedentary student groups the positive influence of the implemented motor structures is supported by the effect size values (Cohen's d). The results obtained are similar to those reported in other investigations on university students, but they are lower compared with performance athletes of the same age range. The number of physically active female students participating in the study (less than 10% of the total) indicates a dominant orientation of young people towards sedentary activities. This aspect negatively influences the skill-related fitness components in which agility is included.

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Conflict of interest

The authors report no potential conflict of interest relevant to this study.

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