

Research Article

Determination of Moving Speed of School Age Children

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School age children (pedestrians) can move at different speeds, which are conditioned by certain parameters. Not all parameters have the same effect on the pedestrian speed. According to the literature, gender and age are the most researched parameters that have an impact on the speed of pedestrians. However, a small number of authors have dealt with the influence of movement regimes (slow, normal, fast, run, and rush) on pedestrian speed, while at the same time taking into account age and gender. For that reason, this article measured the speed of movement of school age children by movement regimes, taking into account age and gender. Within the same movement regime, the influence of age, sex, height, and weight on the speed of movement was investigated. Experimental measurements of the speed of movement of pedestrians aged 7 to 20 years were performed. Based on the results of measurements and statistical analyzes, recommendations on the average speed of movement regimes, age, and gender are given.

1. Introduction

The speed of pedestrians depends on a number of parameters. This article primarily deals with the research of the speed of pedestrian movement according to the movement regimes combined with the knowledge of age and gender. A review of previous research in this area shows that there are certain gaps:

- (i) A small number of authors have dealt with measuring pedestrian speeds depending on the regime of movement, taking into account gender and age
- (ii) Majority of the previous work dealt with only one usual (normal) movement regime, taking into account both age and gender
- (iii) Sample sizes by categories are relatively small, so the question of statistical reliability of the obtained results arises
- (iv) During measurement, age was not always known
- (v) When measuring in advance, the movement regime of pedestrians was not known

- (vi) The accuracy of the measuring equipment affected the obtained results
- (vii) Wide speed limit (min-max) for the same movement regime
- (viii) In the presentation of measured results, the minimum, maximum, and average values are given, without statistical analyzes and conclusions about the reliability of the obtained results, etc.

Having in mind all the above, it is clear that in the previous research on the speed of movement of school age children, there are gaps that need to be explored. Research (measurements) of the speed of movement of school age children were performed in experimental conditions, on the test area. During the preparation of the experiment, the aim was to eliminate the gaps and shortcomings that have been observed in previous research.

Pedestrian speed in practice is used as an input data in many situations (studies). Very often, the speed of pedestrians cannot be determined by known engineering methods, so in these cases, the recommendations given in

the literature are used. The previously stated fact clearly speaks of the importance of the reliable speed measurements.

The main goal of this article is to measure the speed of movement of school age children, with predefined movement regimes with the knowledge of key parameters that affect it within the same mode, in order to obtain more reliable results and give recommendations regarding speed in different regimes.

In addition to the presentation of measured results, the article describes in detail the measurement procedure and the used measuring equipment. The literature review provides an overview of articles that have dealt with similar issues and the results obtained by other authors. Statistical analysis showed that there is a relationship between the pedestrians' speed of movement of certain age and gender within the same movement regime. In the discussion and conclusion, recommendations were given regarding the pedestrian speed, depending on the movement regime, taking into account gender and age.

2. Literature Overview

A large number of authors have researched and measured the parameters of pedestrian flows, and the obtained results can be used for various purposes. The basic parameters of pedestrian flows are flow density and speed [1]. The speed of pedestrian depends on the characteristics of pedestrians (age, gender, and physical abilities), infrastructure (length, width, type of pedestrian object) as well as weather and other external conditions [2]. Similar conclusions were reached by Peters et al. [3] and Xie et al. [4]. Based on the results of research conducted in India, Subramanyam and Prasanna Kumar [5] showed that the speed of movement of male pedestrians is higher by 0.17 m/s compared with the speed of movement of female pedestrians. Bansal et al. [6] concluded that pedestrian speed is affected by age, group size, and crossing patterns. In their work, they linked pedestrian crossing speed and crosswalk characteristics (the classification of road, length, and width of the crosswalk and the width of the pedestrian island). In his research, Tarawneh [7] showed that group size, age, and gender significantly affect pedestrian speed. Some researchers have concluded that age and body height are the factors that have the greatest impact on pedestrian movement [8–10]. It is necessary to know the speed of pedestrians when designing traffic lights, designing pedestrian facilities, for traffic accidents expertise, and the like. Risks related to transportation activities include not only driver-based accidents in a transportation process but also error-based accidents in goods traffic [11]. Pedestrians are the most vulnerable participants in traffic, and pedestrian traffic is affected by a number of factors [12]. The research conducted in Beijing included measuring pedestrian crossing speed [13]. Zhuang and Wu used previously obtained speeds to analyze crossing speed at crosswalks with countdown timers [14]. Stolof et al. also investigated pedestrian crossing speed at crosswalks with countdown timers, but they also investigated pedestrian crossing speed at ordinary signalized crosswalks [15]. In their work, Iryo-

Asano and Alhajyaseen [16] modelled changes in pedestrian speeds when crossing signalized crosswalks. The speed of pedestrians is a direct consequence of the regime, i.e., the way pedestrians move. It is common to use the speed of a normal pedestrian in the analysis of pedestrian movement; however, when examining traffic accidents, it is necessary to know the speed of pedestrian movement for different regimes. It is usually not possible to determine the speed of pedestrians technically, based on the available physical traces. It is common for the speed of pedestrians to be adopted according to the recommendations from the literature, depending on the movement regime [17]. Some researchers have developed models to calculate the pedestrians speed at the time of contact with the vehicle [18]. Otković et al. [19] have developed models that predict children crossing speed, covering children aged 5 to 15 years. Earlier researches in the United Kingdom show that average crossing speed for younger pedestrians is between 1.32 and 1.72 m/s [20–23]. The pedestrian crossing speed for younger pedestrian in the Netherlands is 1.5 m/s [24]. To date, in some research, it has been found that the results of measuring pedestrian speeds have a normal distribution regardless of gender and age [25], that pedestrian speeds are affected by various factors, including street width, weather conditions, number of pedestrians crossing in a group, curbs, road markings, etc. [26], and that the speed of pedestrians is a direct consequence of the pedestrian age and the density of pedestrian flow at pedestrian crossings [1, 27]. Recommendations regarding the speed of pedestrians are different depending on the purpose for which the speeds are used. Thus, the recommendations on changing the speed of pedestrians at signaled pedestrian crossings state that it is necessary to reduce the speed from 1.2 m/s to 0.9 m/s [28].

Table values of pedestrian speeds are usually given within certain limits for the same regime. It is common in the literature to give the upper and lower speed limits for a particular regime. The speed ranges for the same moving regime are often too large to reliably determine the speed of pedestrians. In the same traffic situation, by adopting the lower or upper speed limit in a certain mode, different conclusions can be reached.

Statistical analyses of pedestrian speeds shown in the tables usually do not exist, so the reliability of the obtained data is unknown. In addition to the above, it is not known in which conditions and in what manner the measurements were performed and by which measuring devices. In addition to not knowing the technical parameters that could have influenced the obtained results, the characteristics of the respondents themselves are not known, i.e., their weight, height, etc. are not known. Most of the experiments were conducted during the 70s and 80s of the last century, so it is necessary to analyze the compliance of known data with the measured ones [17]. A special problem is the changes in growing up, on which the key influence chronologically has television, computers, and in the last decade, smartphones. The consequences on psychophysical and psychomotor development have long been known: primarily obesity [29, 30], cardiac, muscular, and skeletal changes [31–33] that, so far, have not been placed in the context of traffic

safety, primarily pedestrian's safety. This influence is especially pronounced in highly developed countries. In the case of Serbia, numerous studies show intensive application and perspectives of IT sector development [34–36]. The context of the COVID-19 pandemic superimposes the use of television, computers, and smartphones, and the negative consequences of the physical development of children and adolescents will certainly be investigated in the context of the impact of the pandemic.

3. Research Method

It is not possible to clearly define certain movement regimes of pedestrians or school age children with technical parameters. For that reason, in order to determine the speed of movement of school age children, measurements of movement speeds were performed in precisely defined conditions and for certain regimes of movement. The defined movement regimes are identical to the tables in the existing literature, as follows:

- (1) Slow walk—Slow
- (2) Normal walk—Normal
- (3) Fast walk—Fast
- (4) Run
- (5) Rush

Bearing in mind that the research covered school children, the measurements were performed on the grounds of primary and secondary schools, for each age group of school children, on a sample of at least 100 respondents. In this way, categories of respondents were formed and are shown in Table 1.

The conducted research was performed on a preformed test area. The test included measurements of children's movement speeds according to predefined regimes. The statistical data obtained by the performed measurement were processed and systematized according to the data given in the literature.

3.1. Measuring Devices Used in the Experiment. The Newtest Powertimer 300-series testing system device was used to determine the speed of school children. The device is designed for the accurate assessment of biomechanical and physiological explosive power, speed, reaction time, and quickness. The Newtest Powertimer 300-series is used to test athletic performance in about 20 different athletic disciplines.

This device enables precise measurements and tests that can be easily translated into numerical values. One of the most important features of this device is that the measurements are performed with an accuracy of 0.001 s.

A PC is used to control the Newtest Powertimer 300-series (Figure 1.), and it is recommended to use a laptop due to the portability of the device itself. Newtest Powertimer Analyzer (version 1.00.137) application allows easy protocol selection and testing control. The measured results obtained in this way are automatically saved and can be downloaded from the Newtest Powertimer database at any time.

TABLE 1: Overview of categories of respondents depending on gender and age.

Age	Number of respondents		Σ
	Male	Female	
From 7 to 8 years	50	53	103
From 8 to 10 years	59	50	109
From 10 to 12 years	55	51	106
From 12 to 15 years	57	51	108
From 15 to 20 years	117	100	217
Total	338	305	643



FIGURE 1: The newest powertimer 300-series testing system.

The Newtest Powertimer 300-series consists of a main console with five inputs for sensors, an audible alarm, a USB output, and a power connector. The Newtest Powertimer 300-series sensors are photocells and a weight-sensitive pad that can also detect some other parameters. Depending on the discipline being measured, a combination of sensors or the use of only one sensor type is possible.

Photocells belong to the IP 67 class, and as such, they enable measurements with an accuracy of ± 0.001 seconds when measuring time and ± 1 mm when measuring jump height. The sensor range can be adjusted in the range of 0.2–3 m. Photocells can be used in the temperature range from -20°C to $+40^{\circ}\text{C}$. Experimental measurement of pedestrian movement parameters can also be performed via video surveillance.

One of the abilities of the Newtest Powertimer 300-series device is to measure the speed of the subjects. To determine the speed of school children, for the purpose of research, the so-called “Speed test” was used.

3.2. Measurement Procedure. Due to the specific categories examined in this research, data collection during the research was performed on the grounds of a primary and secondary schools. In the primary school, the test area (Figure 2.) was formed on a sports field with a concrete base, and during the research, it was flat, dry, and clean. In high school, the research was conducted in a sports gymnasium with parquet flooring. Measurements were performed in May 2019 in daylight conditions. The outside temperature ranged from 15°C to 20°C ; the weather was sunny.

The procedure for measuring the speed of movement of school-aged pedestrians consisted of three phases:

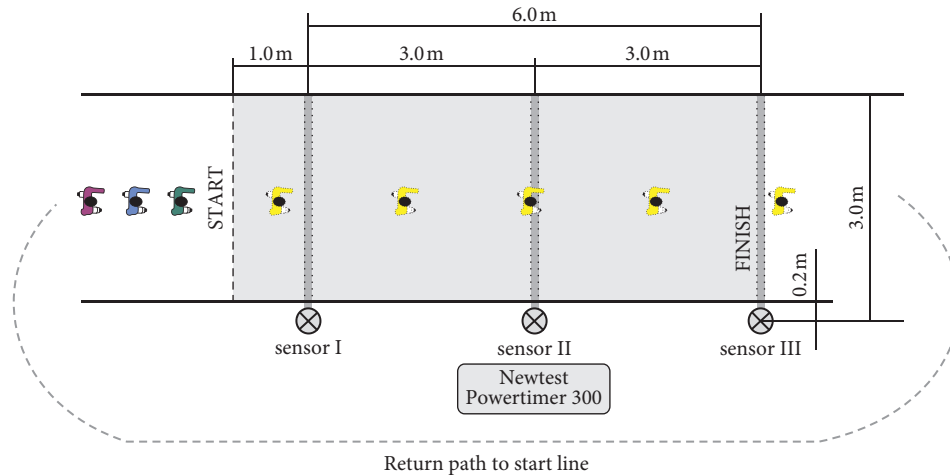


FIGURE 2: Schematic representation of the test area.

- (1) Forming the test area
- (2) Training of respondents
- (3) Measurement of speed depending on the mode

The test area is organized into three spatial units. In the first part of the test area, the respondents formed a line in accordance with the list and the ordinal number of the respondents. For each respondent, the following is known: gender, age, height, and weight. In the second part of the test area, the speed of movement was measured and sensors were placed there; three photocells with the range set at 3 m were used for this research. The test area was formed in such a way as to more accurately reflect the usual width of the road with two traffic lanes. The start of the test is marked by the starting line, which is located 1 m in front of the first sensor. The sensors are placed in a line at a distance of 3 m from each other. The last sensor also represents the finish line. The third part of the test area is parallel to the second part, and it was used to return the respondents to the back of the line.

Before the start of the measurements, a short training was performed, and the respondents were informed about the research that is being performed, as well as the regimes of moving through the test zone. The regimes of movement were demonstratively shown by the researchers, and then after the roll call, a line of respondents was formed.

The passage of the subjects through the test zone was controlled by the researchers, while technical characteristics of the Newtest Powertimer 300-series device limit the number of persons in the test zone to one. Hence, the next respondent needs to wait for the previous respondent to leave the test zone in order for the next measurement to start.

The controlled passage of the subjects next to the sensor provides data in the Newtest Powertimer Analyzer (version 1.00.137) software package. Each passage is defined by the time needed to pass between the first and second sensors and the total time of passage between the sensors. In addition to the time needed to pass the course, the Newtest Powertimer Analyzer provides the ability to calculate the passage speed

for the previously specified times. Data obtained by the measurement were transferred to the Microsoft Office Excel software package, in which a database was formed for additional analysis, such as categorization of participants, expansion of the database on age, height, weight, respondents, etc.

4. Results of the Measurements and Statistical Analysis

The obtained results of the measurement are presented by movement regimes, defined by age groups and gender. A comparative analysis of the results led to the conclusion that the distance covered did not affect the measured speed values. The time for which the subjects crossed the first three and the second three meters on the measuring range was very similar, and the oscillations were insignificant and were represented as positive and negative, for the same regime of movement (Table 2).

Due to the absence of significant differences in times it took the respondents to cross the first and second part of the testing area, all the presented results are expressed for crossing across the entire test area. Based on the conducted research, it can be concluded that the length of the covered distance does not affect the speed of pedestrians within the same regime of the same age and gender.

The mean value, standard deviation, and the minimum and maximum speed values were determined by measuring individual pedestrian speeds. Table 2 shows results of measuring the pedestrian speeds by gender, age, and movement regimes.

Tables 3–7 show the values of parametric characteristics (mathematical expectation and standard deviation), the type of speed distribution for all regimes for both genders, and the verification of the hypothesis of the established distribution. All hypotheses on the nonparametric distribution characteristic were verified by the χ^2 test with a significance threshold greater than $p = 0.05$ (from Tables 3–7). The verification parameters are given in the graphs (in Appendix, Figures 3–8).

TABLE 2: Display of measured results.

7-8	Male				Female			
	Average	Stdev	Max	Min	Average	Stdev	Max	Min
Slow	0.984	0.194	1.400	0.620	0.981	0.241	1.500	0.574
Normal	1.364	0.243	1.800	0.900	1.406	0.203	1.827	1.016
Fast	2.079	0.298	2.518	1.541	2.067	0.216	2.570	1.600
Run	2.415	0.299	2.756	1.920	2.390	0.262	3.057	1.921
Rush	3.649	0.225	4.000	3.100	3.485	0.282	3.976	2.923
8-10	Male				Female			
	Average	Stdev	Max	Min	Average	Stdev	Max	Min
Slow	1.090	0.218	1.590	0.704	1.072	0.179	1.472	0.717
Normal	1.388	0.238	1.900	0.900	1.379	0.222	1.903	0.982
Fast	2.073	0.284	2.715	1.641	1.968	0.236	2.509	1.552
Run	2.678	0.291	3.272	2.221	2.724	0.285	2.756	2.335
Rush	3.929	0.295	4.556	3.409	3.588	0.292	4.084	3.109
10-12	Male				Female			
	Average	Stdev	Max	Min	Average	Stdev	Max	Min
Slow	1.158	0.196	1.653	0.678	1.189	0.170	1.537	0.835
Normal	1.458	0.189	1.844	1.091	1.516	0.177	1.985	1.203
Fast	2.294	0.249	2.864	1.775	2.170	0.211	2.680	1.850
Run	2.798	0.296	3.464	2.311	2.781	0.286	3.297	2.350
Rush	4.061	0.297	4.598	3.466	3.905	0.288	4.468	3.333
12-15	Male				Female			
	Average	Stdev	Max	Min	Average	Stdev	Max	Min
Slow	1.183	0.182	1.542	0.797	1.213	0.174	1.499	0.750
Normal	1.561	0.158	1.909	1.249	1.621	0.173	2.077	1.338
Fast	2.247	0.300	2.841	1.800	2.132	0.175	2.504	1.806
Run	2.984	0.295	3.600	2.500	2.787	0.247	3.300	2.404
Rush	4.223	0.334	4.773	3.484	3.865	0.269	4.448	3.263
15-20	Male				Female			
	Average	Stdev	Max	Min	Average	Stdev	Max	Min
Slow	1.231	0.151	1.664	0.789	1.211	0.169	1.602	0.805
Normal	1.530	0.146	1.912	1.233	1.519	0.116	1.856	1.231
Fast	2.342	0.243	3.085	1.774	2.189	0.220	2.784	1.669
Run	3.018	0.292	3.601	2.443	2.854	0.246	3.472	2.105
Rush	4.516	0.248	4.990	3.947	3.932	0.276	4.570	3.394

TABLE 3: Parametric characteristics, distributions, and significance threshold for the age group of 7-8 years.

Gender	Regime	Mean	Stan. deviation	Distribution	Significance
Male sample = 50	Slow	0.9835	0.1935	Normal	0.2192
	Normal	1.3635	0.2429	Normal	0.7177
	Fast	2.0790	0.2977	Normal	0.4473
	Run	2.4146	0.2992	Normal	0.5919
	Rush	3.6487	0.2250	Normal	0.5713
Female sample = 53	Slow	0.9812	0.2409	Normal	0.2895
	Normal	1.4064	0.2026	Normal	0.8673
	Fast	2.0671	0.2156	Normal	0.8636
	Run	2.3895	0.2616	Normal	0.2678
	Rush	3.4853	0.2817	Normal	0.1806

4.1. Influence of Movement Regime for Same Gender and Ages of Respondents. Using the *t* test for dependent samples in the group of male children aged 7 to 8 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Using the *t* test for dependent samples in the group of female children aged 7 to 8 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Distributions and verifications of

distributions in the comparable vertical of the movement regime (abscissas and ordinates of the histogram are identical) for male (blue) and female (red) children aged 7 to 8 years are given in Appendix in Figure 3.

Using the *t* test for dependent samples in the group of male children aged 8 to 10 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Using the *t* test for dependent

TABLE 4: Parametric characteristics, distributions, and significance threshold for the age group of 8–10 years.

Gender	Regime	Mean	Stan. deviation	Distribution	Significance
Male sample = 59	Slow	1.0897	0.2183	Normal	0.8099
	Normal	1.3877	0.2383	Normal	0.2276
	Fast	2.0725	0.2838	Normal	0.1912
	Run	2.6779	0.2912	Normal	0.8366
	Rush	3.9289	0.2953	Normal	0.0802
Female sample = 50	Slow	1.0717	0.1786	Normal	0.1799
	Normal	1.3790	0.2220	Normal	0.2195
	Fast	1.9676	0.2359	Normal	0.2543
	Run	2.7242	0.2850	Normal	0.1902
	Rush	3.5880	0.2920	Normal	0.2550

TABLE 5: Parametric characteristics, distributions, and significance threshold for the age group of 10–12 years.

Gender	Regime	Mean	Stan. deviation	Distribution	Significance
Male sample = 55	Slow	1.1585	0.1964	Normal	0.8586
	Normal	1.4581	0.1888	Normal	0.8148
	Fast	2.2939	0.2489	Normal	0.6867
	Run	2.7978	0.2959	Normal	0.6028
	Rush	4.0609	0.2969	Normal	0.3843
Female sample = 51	Slow	1.1889	0.1698	Normal	0.3442
	Normal	1.5161	0.1766	Normal	0.4916
	Fast	2.1699	0.2111	Normal	0.6314
	Run	2.7813	0.2855	Normal	0.0555
	Rush	3.9054	0.2879	Normal	0.1865

TABLE 6: Parametric characteristics, distributions, and significance threshold for the age group of 12–15 years.

Gender	Regime	Mean	Stan. deviation	Distribution	Significance
Male sample = 57	Slow	1.1833	0.1823	Normal	0.4283
	Normal	1.5607	0.1577	Normal	0.4541
	Fast	2.2465	0.2998	Normal	0.1542
	Run	2.9840	0.2945	Normal	0.2770
	Rush	4.2232	0.3337	Normal	0.1215
Female sample = 51	Slow	1.2128	0.1739	Normal	0.1419
	Normal	1.6206	0.1729	Normal	0.3115
	Fast	2.1323	0.1754	Normal	0.8915
	Run	2.7873	0.2465	Normal	0.6908
	Rush	3.8651	0.2691	Normal	0.3798

TABLE 7: Parametric characteristics, distributions, and significance threshold for the age group of 15–20 years.

Gender	Regime	Mean	Stan. deviation	Distribution	Significance
Male sample = 117	Slow	1.2311	0.1514	Normal	0.9292
	Normal	1.5300	0.1461	Normal	0.3924
	Fast	2.3417	0.2432	Normal	0.2429
	Run	3.0179	0.2916	Normal	0.3176
	Rush	4.5158	0.2479	Normal	0.7273
Female sample = 100	Slow	1.2106	0.1693	Normal	0.7449
	Normal	1.5189	0.1158	Normal	0.2643
	Fast	2.1887	0.2204	Normal	0.0776
	Run	2.8545	0.2462	Normal	0.8022
	Rush	3.9318	0.2755	Normal	0.8083

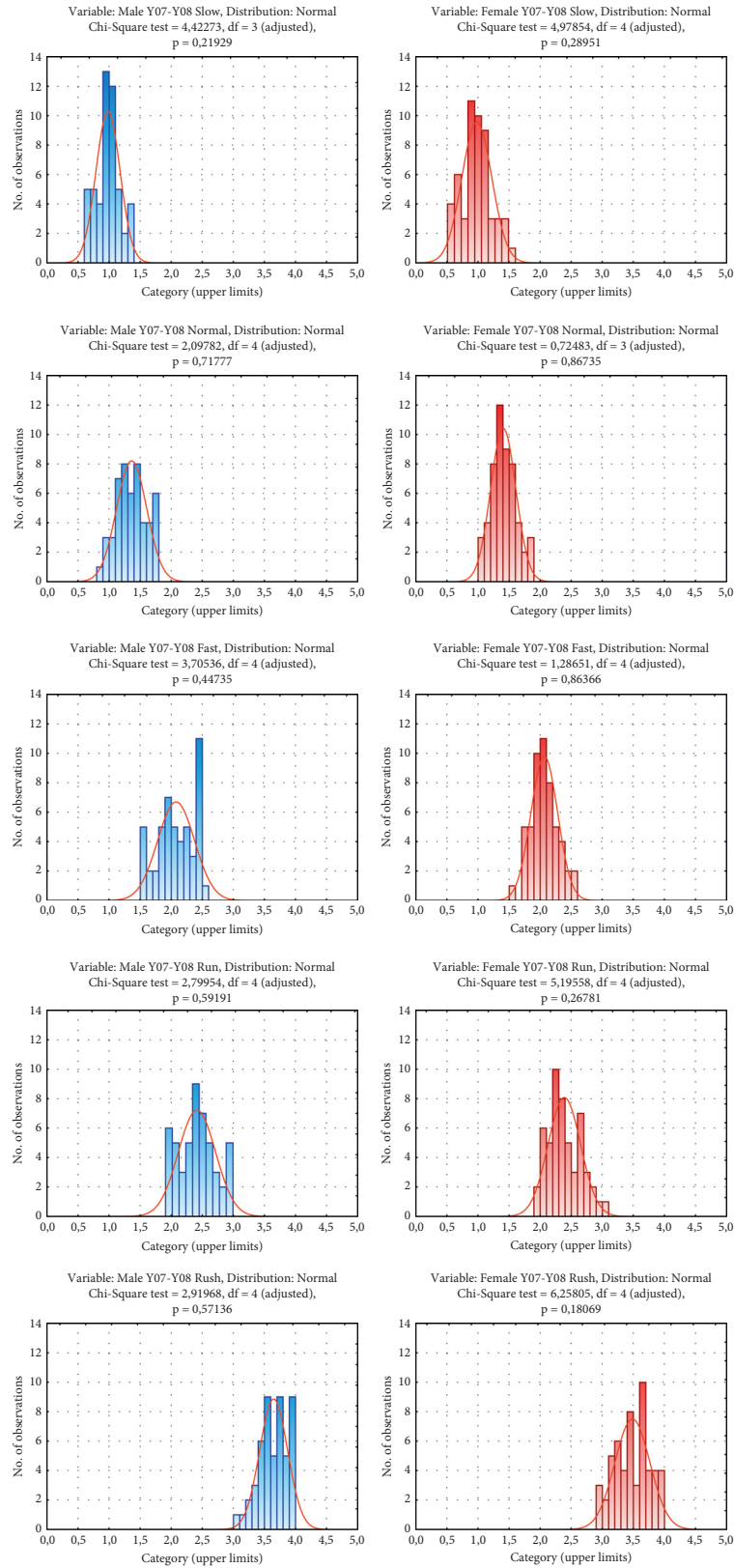


FIGURE 3: Distributions and verifications of distributions of speed in different regimes for male and female children aged 7 to 8 years.

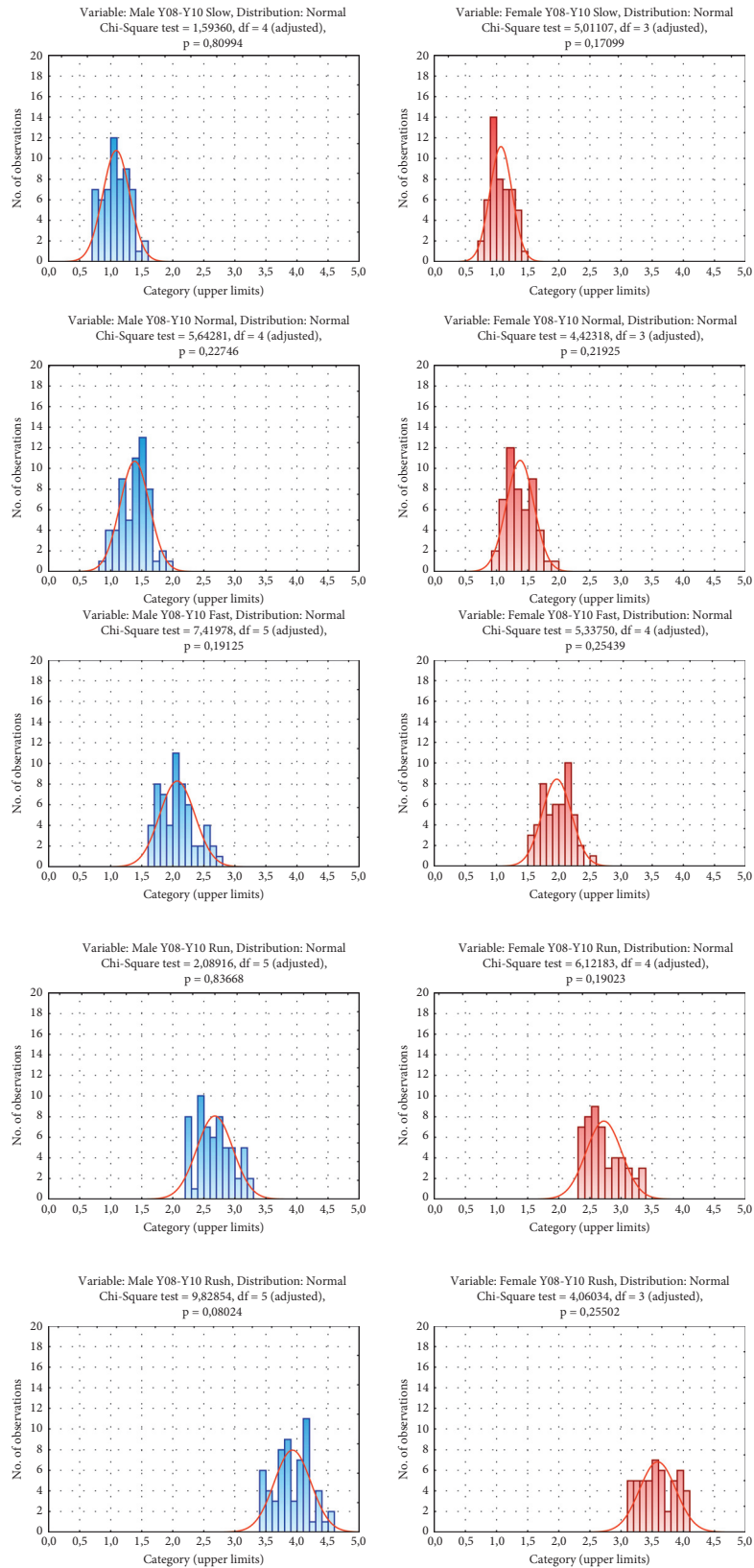


FIGURE 4: Distributions and verifications of distributions of speed in different regimes for male and female children aged 8 to 10 years.

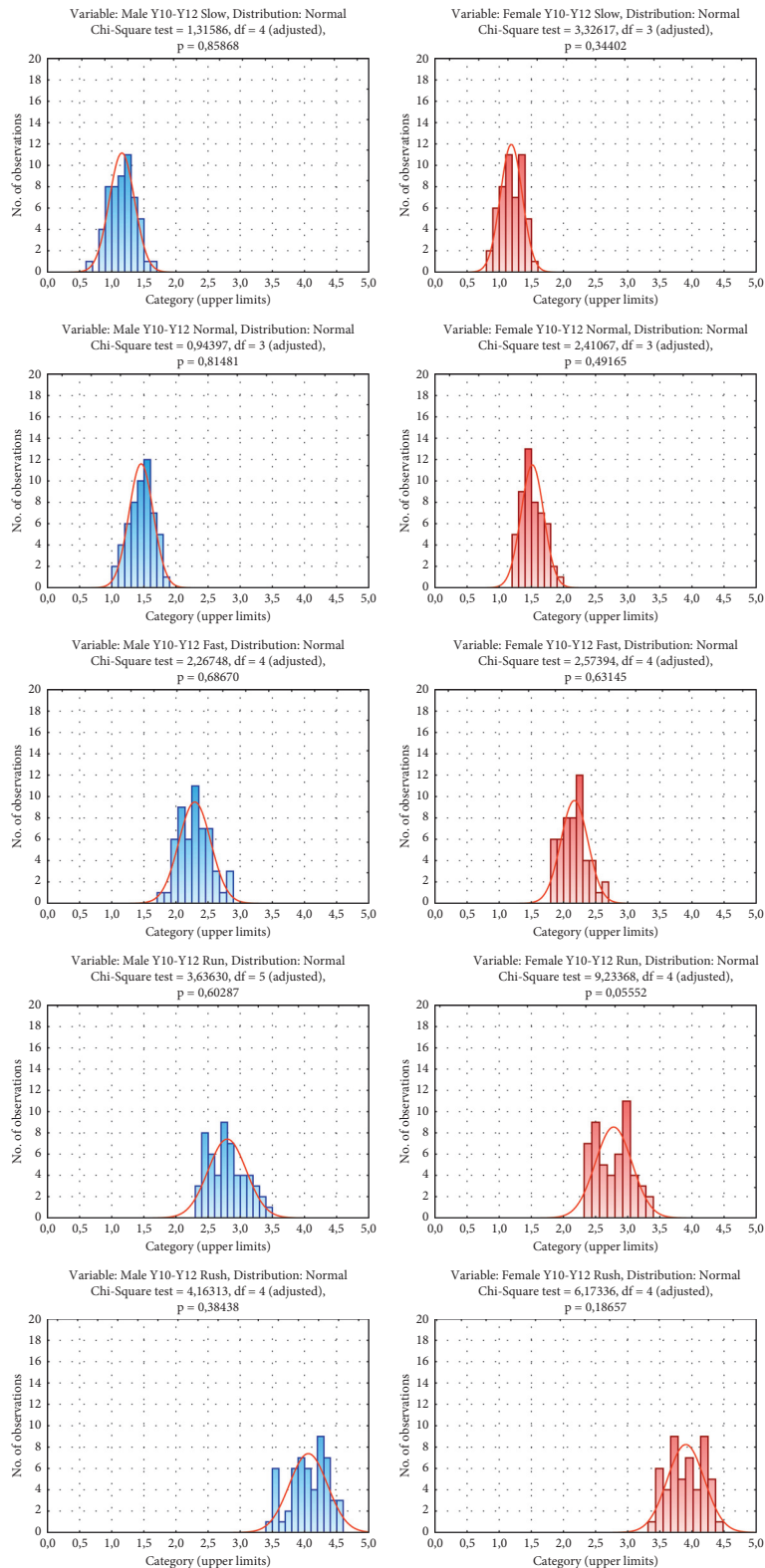


FIGURE 5: Distributions and verifications of distributions of speed in different regimes for male and female children aged 10 to 12 years.

samples in the group of female children aged 8 to 10 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Distributions and verifications of distributions in the comparable

vertical of the movement regime (abscissas and ordinates of the histogram are identical) for male (blue) and female (red) children aged 8 to 10 years are given in Appendix with Figure 4.

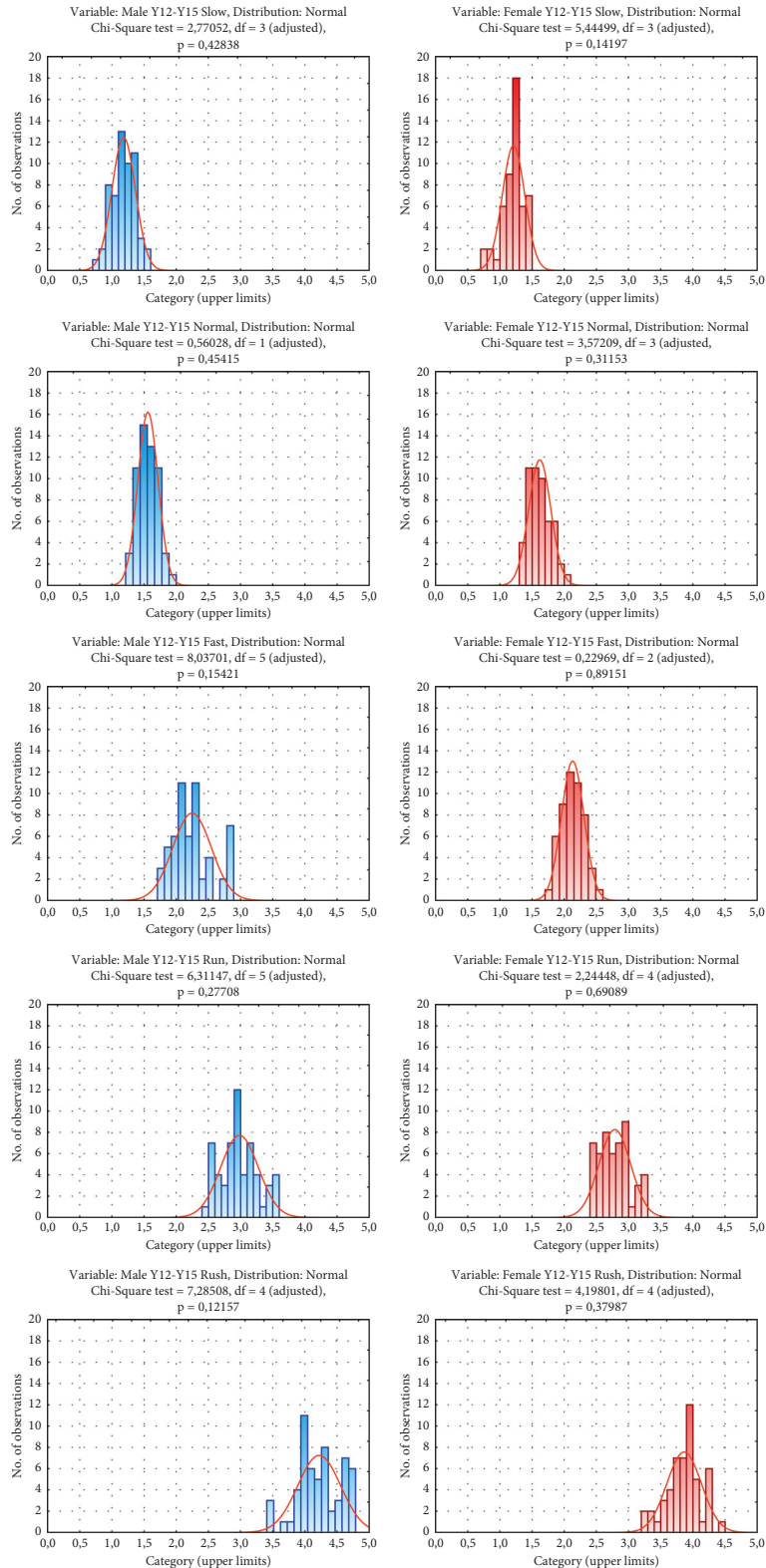


FIGURE 6: Distributions and verifications of distributions of speed in different regimes for male and female children aged 12 to 15 years.

Using the t test for dependent samples in the group of male children aged 10 to 12 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Using the t test for dependent

samples in the group of female children aged 10 to 12 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Distributions and verifications of distributions in the comparable

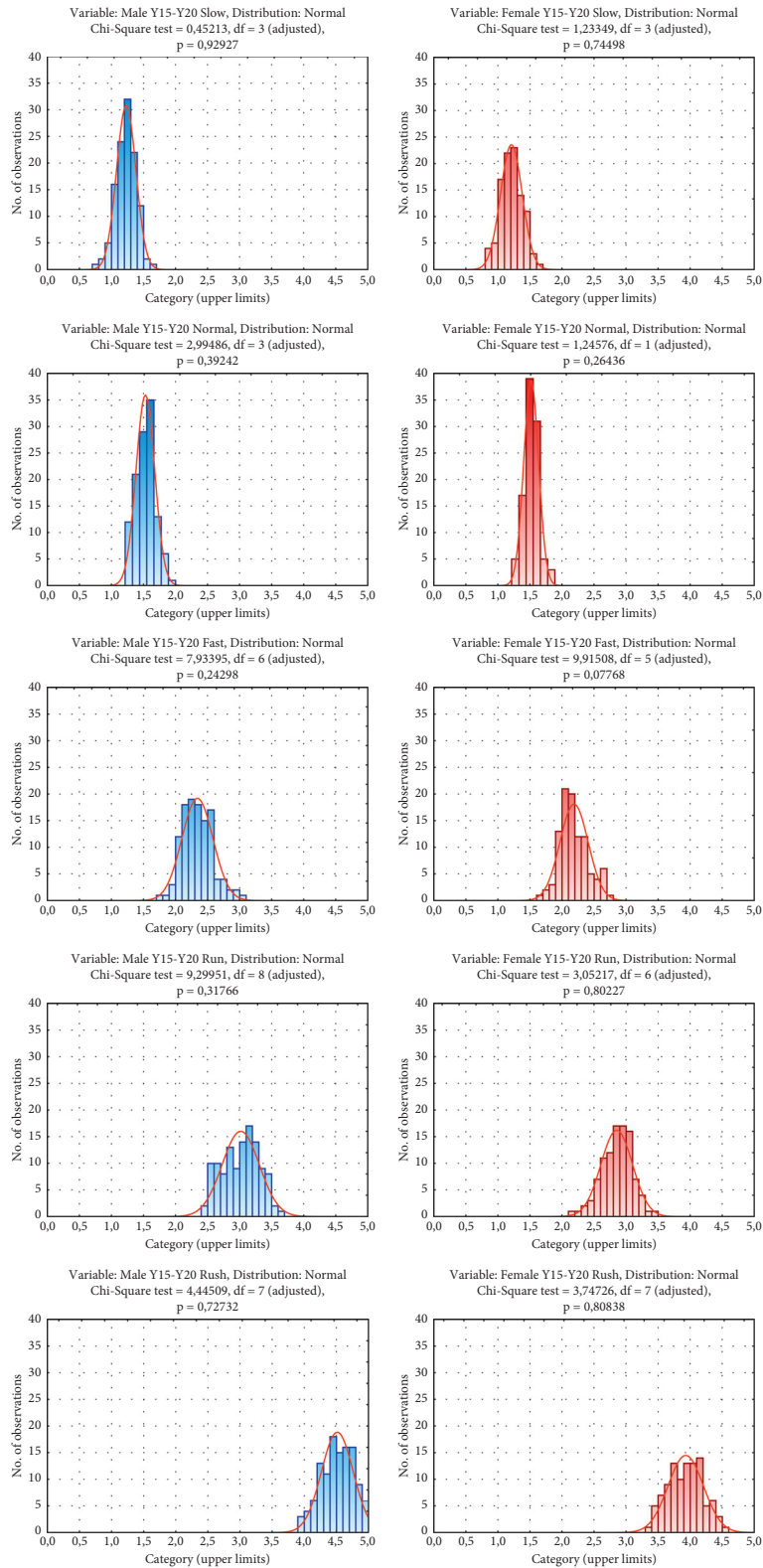


FIGURE 7: Distributions and verifications of distributions of speed in different regimes for male and female children aged 15 to 20 years.

vertical of the movement regime (abscissas and ordinates of the histogram are identical) for male (blue) and female (red) children aged 10 to 12 years are given in Appendix in Figure 5.

Using the t test for dependent samples in the group of male children aged 12 to 15 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Using the t test for dependent

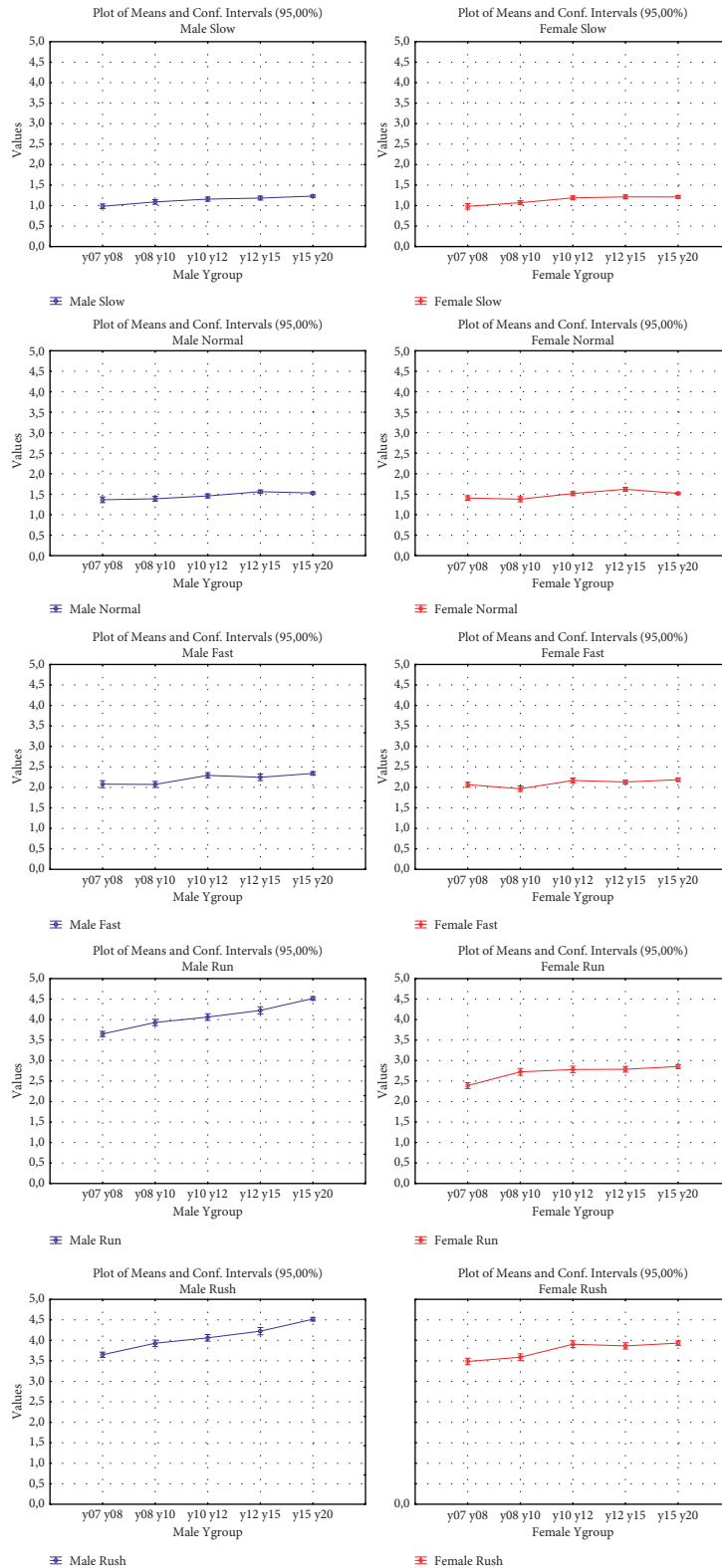


FIGURE 8: Variance analysis of the influence of age groups in different movement regimes for male and female children.

samples in the group of female children aged 12 to 15 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Distributions and verifications of distributions in the comparable

vertical of the movement regime (abscissas and ordinates of the histogram are identical) for male (blue) and female (red) children aged 12 to 15 years are given in Appendix in Figure 6.

TABLE 8: Comparisons of the mean values of speeds of different genders at the same ages by regimes.

Year	Regime				
	Slow	Normal	Fast	Run	Rush
7-8	0.9835 ≈ 0.9812 $p = 0.4788$	1.3635 ≈ 1.4064 $p = 0.1658$	2.0790 ≈ 2.0671 $p = 0.4080$	2.4146 ≈ 2.3895 $p = 0.3254$	3.6487 > 3.4853 $p = 0.0008$
8-10	1.0897 ≈ 1.0717 $p = 0.6131$	1.3877 ≈ 1.3790 $p = 0.8455$	2.0725 ≈ 1.9676 $p = 0.4054$	2.6779 < 2.7242 $p = 0.0404$	3.9289 > 3.5880 $p \leq 0.0001$
10-12	1.1585 ≈ 1.1889 $p = 0.3967$	1.4581 ≈ 1.5161 $p = 0.1062$	2.2939 > 2.1699 $p = 0.0069$	2.7978 ≈ 2.7813 $p = 0.7717$	4.0609 > 3.9054 $p = 0.0073$
12-15	1.1833 ≈ 1.2128 $p = 0.3940$	1.5607 ≈ 1.6206 $p = 0.0624$	2.2465 > 2.1323 $p = 0.0190$	2.9840 > 2.7873 $p = 0.0003$	4.2232 > 3.8651 $p \leq 0.0001$
15-18	1.2311 ≈ 1.2106 $p = 0.3465$	1.5300 ≈ 1.5189 $p = 0.5409$	2.3417 ≈ 2.1887 $p \leq 0.0001$	3.0179 ≈ 2.8545 $p \leq 0.0001$	4.5158 ≈ 3.9318 $p \leq 0.0001$

Using the t test for dependent samples in the group of male children aged 15 to 20 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Using the t test for dependent samples in the group of female children aged 15 to 20 years, there are significant differences between the average values of speeds in all regimes ($p \leq 0.0001$). Distributions and verifications of distributions in the comparable vertical of the movement regime (abscissas and ordinates of the histogram are identical) for male (blue) and female (red) children aged 15 to 20 years are given in Appendix in Figure 7.

For all ages and for both genders, movement regimes are clearly differentiated by absolute statistical differences in movement speeds. With this outcome, a reliable statistical basis for examining the influence of gender and age on the average speed of movement was set.

4.2. Influence of Gender on Movement Speeds for Identical Movement Regimes and Ages. Based on all normal distributions, the mean values from Tables 3–7 by gender, age, and movement regimes were compared using the t test. Results with significance thresholds are given in Table 8.

For the whole interval of age groups, there are no significant differences between male and female children in two movement regimes: “slow” and “normal.” By age, differences in faster regimes were found, as follows:

- (i) For ages 7 to 8, male children are faster only in “rush” regime.
- (ii) For ages 8 to 10, female children are faster in “fast” regime and male children are faster in “rush” regime.
- (iii) For ages 10 to 12, male children are faster in two regimes: “fast” and “rush.”
- (iv) For ages 12 to 15, male children are faster in three regimes: “fast,” “run,” and “rush.”
- (v) For ages 15 to 20, male children are faster in three regimes: “fast,” “run,” and “rush.”

In conclusion, the influence of gender exists to a lesser extent at younger ages and becomes moderately significant at older ages, for all faster regimes of walking or running,

there are significant differences in average speeds in favor of male subjects.

4.3. Influence of Age on Pedestrian Speeds within the Same Regime and Same Genders. The variance analysis of the influence of age groups by regimes and gender was done by the Dunckan test. The presentation of obtained results is shown in Tables 9 and 10.

The influence of age on the average speed of movement within the same regime was statistically moderate in younger subjects and pronounced in older subjects. Differentiation is more pronounced in male respondents, and for them, it becomes absolute with age. As for the age of the female respondents, their differentiation ends at the age of 12 years, after which, the average speeds in the “fast,” “run,” and “rush” modes do not differ significantly.

5. Discussion

The obtained results, primarily the verified nonparametric characteristics of the normal distributions of speed, are consistent with some of the previous studies. Together with these researches, the presented results make the basis for more reliable application of the existing tabularly presented standards where the type of distributions of pedestrian speeds is not emphasized. These results can significantly increase the accuracy of spatiotemporal analyses in traffic accidents involving pedestrians. With the reconstruction of the movement regime, the known age, and gender, the expertise can be conducted with credible speeds of pedestrians. As with the design of security systems in order to reduce risk, the following results must be taken into account.

- (i) At all ages for both genders, movement regimes are clearly differentiated by absolute statistical differences in movement speeds.
- (ii) The influence of gender exists to a lesser extent at a younger age and becomes moderately significant at an older age.
- (iii) Significant differences in average speeds of the pedestrian movement by regimes were found in male subjects. In female subjects, the preadolescent limit (10 to 12 years) was expressed as meritorious.

TABLE 9: Dunckan test of variance analysis on influence of different age groups on speed by movement regimes for male children.

Slow	Y07 Y08	Y08 Y10	Y10 Y12	Y12 Y15	Y15 Y20
	0,9835	1,0897	1,1585	1,1833	1,2311
Y07 Y08		0,0013	0,0000	0,0000	0,0000
Y08 Y10	0,0013		0,0377	0,0064	0,0000
Y10 Y12	0,0000	0,0377		0,4509	0,0365
Y12 Y15	0,0000	0,0064	0,4509		0,1490
Y15 Y20	0,0000	0,0000	0,0365	0,1490	
Normal	Y07 Y08	Y08 Y10	Y10 Y12	Y12 Y15	Y15 Y20
	1,3635	1,3877	1,4581	1,5607	1,5300
Y07 Y08		0,4796	0,0079	0,0000	0,0000
Y08 Y10	0,4796		0,0395	0,0000	0,0001
Y10 Y12	0,0079	0,0395		0,0038	0,0356
Y12 Y15	0,0000	0,0000	0,0038		0,3684
Y15 Y20	0,0000	0,0001	0,0356	0,3684	
Fast	Y07 Y08	Y08 Y10	Y10 Y12	Y12 Y15	Y15 Y20
	2,0790	2,0725	2,2939	2,2465	2,3417
Y07 Y08		0,8944	0,0000	0,0006	0,0000
Y08 Y10	0,8944		0,0000	0,0005	0,0000
Y10 Y12	0,0000	0,0000		0,3308	0,3255
Y12 Y15	0,0006	0,0005	0,3308		0,0637
Y15 Y20	0,0000	0,0000	0,3255	0,0637	
Run	Y07 Y08	Y08 Y10	Y10 Y12	Y12 Y15	Y15 Y20
	2,4146	2,6779	2,7978	2,9840	3,0179
Y07 Y08		0,0000	0,0000	0,0000	0,0000
Y08 Y10	0,0000		0,0237	0,0000	0,0000
Y10 Y12	0,0000	0,0237		0,0004	0,0001
Y12 Y15	0,0000	0,0000	0,0004		0,5231
Y15 Y20	0,0000	0,0000	0,0001	0,5231	
Rush	Y07 Y08	Y08 Y10	Y10 Y12	Y12 Y15	Y15 Y20
	3,6487	3,9289	4,0609	4,2232	4,5158
Y07 Y08		0,0000	0,0000	0,0000	0,0000
Y08 Y10	0,0000		0,0084	0,0000	0,0000
Y10 Y12	0,0000	0,0084		0,0012	0,0000
Y12 Y15	0,0000	0,0000	0,0012		0,0000
Y15 Y20	0,0000	0,0000	0,0000	0,0000	

TABLE 10: Dunckan test of variance analysis on influence of different age groups on speed by movement regimes for female children.

Slow	Y07 Y08	Y08 Y10	Y10 Y12	Y12 Y15	Y15 Y20
	0,9812	1,0717	1,1889	1,2128	1,2106
Y07 Y08		0,0095	0,0000	0,0000	0,0000
Y08 Y10	0,0095		0,0008	0,0001	0,0001
Y10 Y12	0,0000	0,0008		0,5229	0,5353
Y12 Y15	0,0000	0,0001	0,5229		0,9483
Y15 Y20	0,0000	0,0001	0,5353	0,9483	
Normal	Y07 Y08	Y08 Y10	Y10 Y12	Y12 Y15	Y15 Y20
	1,4064	1,3790	1,5161	1,6206	1,5189
Y07 Y08		0,3980	0,0007	0,0000	0,0008
Y08 Y10	0,3980		0,0000	0,0000	0,0000
Y10 Y12	0,0007	0,0000		0,0018	0,9313
Y12 Y15	0,0000	0,0000	0,0018		0,0017
Y15 Y20	0,0008	0,0000	0,9313	0,0017	
Fast	Y07 Y08	Y08 Y10	Y10 Y12	Y12 Y15	Y15 Y20
	2,0671	1,9676	2,1699	2,1323	2,1887
Y07 Y08		0,0132	0,0143	0,1048	0,0044
Y08 Y10	0,0132		0,0000	0,0001	0,0000
Y10 Y12	0,0143	0,0000		0,3497	0,6382
Y12 Y15	0,1048	0,0001	0,3497		0,1864

TABLE 10: Continued.

Y15 Y20	0,0044	0,0000	0,6382	0,1864	
Run	Y07 Y08 2,3895	Y08 Y10 2,7242	Y10 Y12 2,7813	Y12 Y15 2,7873	Y15 Y20 2,8545
Y07 Y08		0,0000	0,0000	0,0000	0,0000
Y08 Y10	0,0000		0,2464	0,2288	0,0138
Y10 Y12	0,0000	0,2464		0,9021	0,1622
Y12 Y15	0,0000	0,2288	0,9021		0,1731
Y15 Y20	0,0000	0,0138	0,1622	0,1731	
Rush	Y07 Y08 3,4853	Y08 Y10 3,5880	Y10 Y12 3,9054	Y12 Y15 3,8651	Y15 Y20 3,9318
Y07 Y08		0,0511	0,0000	0,0000	0,0000
Y08 Y10	0,0511		0,0000	0,0000	0,0000
Y10 Y12	0,0000	0,0000		0,4446	0,6154
Y12 Y15	0,0000	0,0000	0,4446		0,2345
Y15 Y20	0,0000	0,0000	0,6154	0,2345	

- (iv) Speeds of movement do not depend on the length of the distance covered for the conditions of the set test area.
- (v) The weight and height of the respondents did not show statistical significance that can be related to the speed of movement according to defined regimes and age limits.
- (vi) Period of the research is an important basis for a long-term study and the basis for future pedestrian speed standards, primarily due to the expected negative impact of the COVID-19 pandemic on the psychophysical development of children and adolescents.

6. Conclusions

In this article, the speed of movement of school age children in experimental conditions was measured. The measurement was performed both for male and female children by age groups in defined movement regimes. Movement regimes are defined as slow, normal, fast, run, and rush. The age groups are divided into classes of 7-8, 8-10, 10-12, 12-15, and 15-20 years. Based on the measurement of movement speeds of school age children, it was determined that the movement regime has the greatest influence on speed. For the same movement regime, age shows a significant effect on speed especially in younger age groups. The standard deviation of the measured speeds has a lower value in the slow and normal modes compared with fast, run, and rush. A comparative analysis of the measured mean values of the speed of movement of school age children with the values from the literature showed certain similarities, along with the difference between the minimum and maximum values. It is possible that this difference was due to the sample size used in the measurement or the conditions under which the experiment was performed.

Analyzes have shown that measured pedestrian speeds have the normal distribution regardless of the movement regime, age, and gender, which is in accordance with the conclusions of previous article [25]. Comparative analysis of measured speeds in the normal regime for all age categories, regardless of gender coincided with the results given in [20-24].

Measurement of pedestrian speeds in children aged 7 to 20 years show good agreement with the recommendations given for pedestrian speeds on pedestrian traffic lights crossings in previous study [28].

Further research should focus on measuring speeds in real conditions, intersections, pedestrian crossings, etc., which would make it possible to perform a comparative analysis with the results obtained in this article. The obtained mean values of speeds, taking into account the standard deviation, can be used as reliable input data in various analyzes.

Data Availability

The numerical data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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