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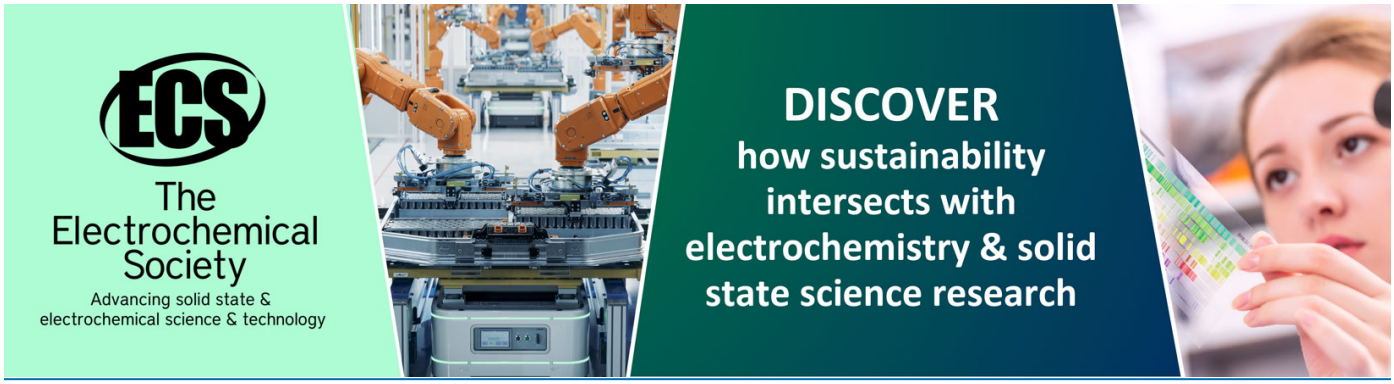

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Analysis of Crossing Speed of the Pedestrians in Marked and Unmarked Crosswalks in the Signalized and Un-Signalized Intersections (Case Study: Rasht city)

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Abstract. Pedestrians affect the traffic in the signalized and un-signalized intersections. Therefore, identifying the behavioural features of the pedestrians is of great importance and may result in better designing facilities for them. In this study, by shooting the four intersections in Rasht for 15 hours and inventory from 4568 pedestrians, crossing speed of the pedestrians in the marked crosswalks and unmarked crosswalks was evaluated and analysed. Results showed that pedestrians' crossing speed in the marked crosswalks is higher than their crossing speed in the unmarked crosswalks in both signalized and un-signalized intersections. Moreover, in the unmarked crosswalks in the signalized intersections, 15th percentile speed of male pedestrians, female pedestrians and group of pedestrians' decrease 6.4%, 5.4% and 12.2%, respectively, compared with the 15th percentile speed in the marked crosswalks. Above-mentioned values in the unmarked crosswalks in the un-signalized intersections for male pedestrians, female pedestrians, and group of pedestrians decrease 1.2%, 3.8%, and 1.4%, respectively.

1. Introduction

One of the main factors concerning the pedestrians crossing based on the traffic and safety considerations is signalized and un-signalized intersections. In these areas, pedestrians are one of the key factors in free passing of the cars, because even with the traffic light, they disrupt the cars' movement in the illegal time. This, in turn, results in the delay increase for both groups-vehicles and pedestrians. Moreover, it increases the risk of car-pedestrian accidents. Therefore, recognizing the pedestrians' behaviour in crossing the signalized and un-signalized intersections is useful in controlling and managing the traffic flow of the transportation network [1].

One of the old measures for pedestrians is marking the crosswalks for the pedestrians. The basis is not clear but practically, after the World War II, crosswalks were marked with white color in Britain and in the late 1920s, it was widely used. Marking the crosswalks is one of the most important safety sighs that is used for the roads and streets, with different types such as longitudinal markings, traverse markings in order to segregate and identify the vehicles' movement boundaries, control the vehicles movement, transfer the message, as well as guide drivers, and other path users. Paying attention to the markings and

obeying the related rules and recommendations helps to secure the safety and traffic order in the travels. Crosswalk marking is one of the different kinds of road markings that are painted on the certain areas in the intersections and streets for the pedestrians' safe crossing.

In this study, by analysis of the crossing speed of 4568 pedestrians in two signalized intersections and two un-signalized intersections in Rasht, differences between crossing speed of the pedestrians in the marked crosswalks and unmarked crosswalks were obtained.

2. Literature Review

Moore (1956) in his article "Psychological Factors of Importance in Traffic Engineering" has recommended that pedestrians' crossing speed while vehicles are approaching to them should be 1.25(m/s) which could vary to 1.22(m/s) as well [2]. Wilson and Grayson (1980) found that average walking speed for men and women are 1.23 and 1.27(m/s) respectively, by examining the relationship between the speed of the pedestrian with respect to age, and sexuality [3]. Griffiths et al. (1984) found that speed of crossing in signalized intersections for teens, adults and elderly is 1.72, 1.66, and 1.47(m/s) respectively [4]. Tanaboriboon and Guyano (1991) in an article named "Analysis of Pedestrian Movement in Bangkok" found that men and women crossing speed is 1.31 and 1.25(m/s) respectively, by viewing the crossing speed of pedestrians in a signalized Intersection in Bangkok [5]. O'Flaherty (1997) has proposed the speed between 1.2 to 1.25 (m/s) for crowded intersections motion of different age groups. In addition, he proposed average speed of 1.6(m/s) for non-crowded areas [6]. Tarawneh (2001), in his article named "Evaluation of Pedestrian Speed in Jordan with Investigation of Some Contributing Factors", checked out the speed of 3500 pedestrians in 27 intersections in a large area in Oman. Based on that, he proposed the average speed and 15th percentile pedestrian speed 1.34 and 1.11(m/s) respectively. In this study, he also expressed that age, gender, size of the group and street width is greatly effective on pedestrians speed, and male pedestrians move faster than female pedestrians in crossing the street significantly [7]. Gates et al. (2006) have pointed out that average speed of pedestrians who are younger than 65 is faster than pedestrians older than 65 years old by 0.3(m/s) by collecting 1947 pedestrians crossing speed from 11 intersections in United States and he stated that there is no difference between men's and women's crossing speed [8]. In 2007, in an article named "Research on Pedestrian Behavior and Traffic Characteristics at Un-signalized Midblock Crosswalk: Case Study in Beijing" Shi and his colleague have found that men crossing speed is faster than women crossing speed by 0.1(m/s) by analyzing crossing speed of 1040 pedestrians in crossing un-signalized intersection [9]. Transportation Engineering Institute of America (1999) has proposed a moving speed between 1.1 to 1.2 (m/s) to pedestrians for crossing the street [10]. The Manual on Uniform Traffic Control Devices in both version (2003 and 2009) have proposed moving speed of 1.21(m/s) for pedestrians to cross Intersections [11], [12]. Due to the book of highway capacity manual (HCM 2000, HCM 2010), Pedestrians crossing speed is based on the proportion of elderly pedestrians in all users [13], [14].

3. Method

For the aim of the present study, two signalized and un-signalized intersections in Rasht were selected. Rasht is the capital city of Guilan Province in the north of Iran with a population of 4340 per square kilometer [15]. The intersections were filmed by video cameras and the information of 4568 pedestrians has also been collected. Using the chronometer and recorded films, crossing time and then crossing speed of each pedestrian was determined based on their gender, age, weight, group movement and crossing the marked and unmarked areas. Among all the harvested pedestrians, 2423 pedestrians crossed the marked areas and 2145 pedestrians crossed the unmarked areas. Finally, data analyzed by the statistical Kolmogorov–Smirnov test, ANOVA and Spearman's correlation.

4. Results

In this study, crossing pedestrians in two signalized intersections, in the morning, at noon and in the evening, were inventoried based on the gender, single-person movements, and group of pedestrians in marked crosswalks and unmarked crosswalks in two un-signalized intersections during the peak hours.

Then, frequency distribution histograms with normal curve for all pedestrians were made in order to identify the speed distribution of the pedestrians in each group (figures 1 to 6). This was conducted for determination of average speed indexes, 15th percentile speed etc. based on table 1 and 2.

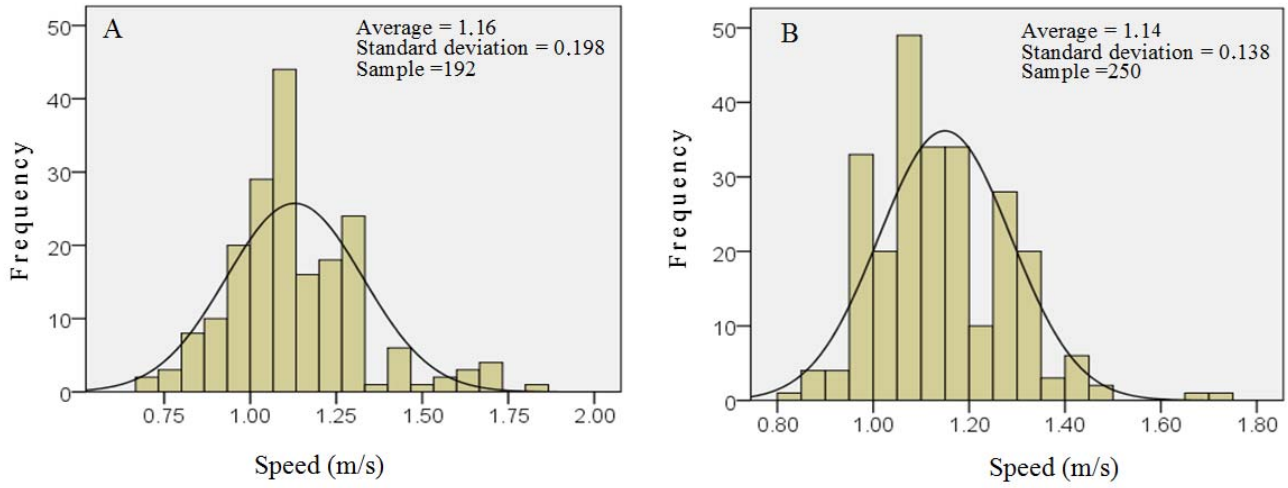

Figure 1. Histogram and normal curve of frequency distribution of male pedestrians in the signalized intersections: A) marked crosswalks; B) unmarked crosswalks

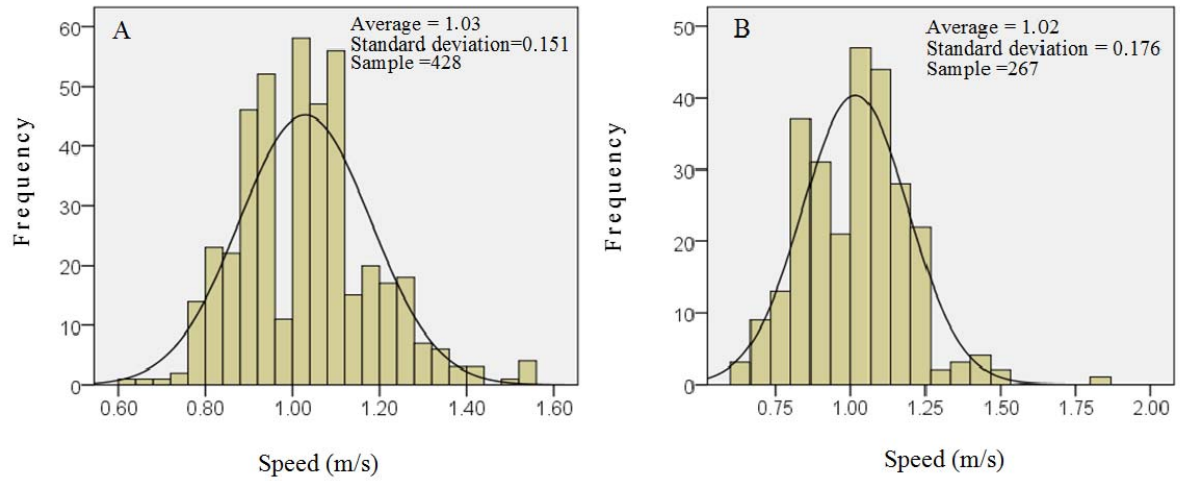

Figure 2. Histogram and normal curve of frequency distribution of female pedestrians in the signalized intersections: A) marked crosswalks; B) unmarked crosswalks

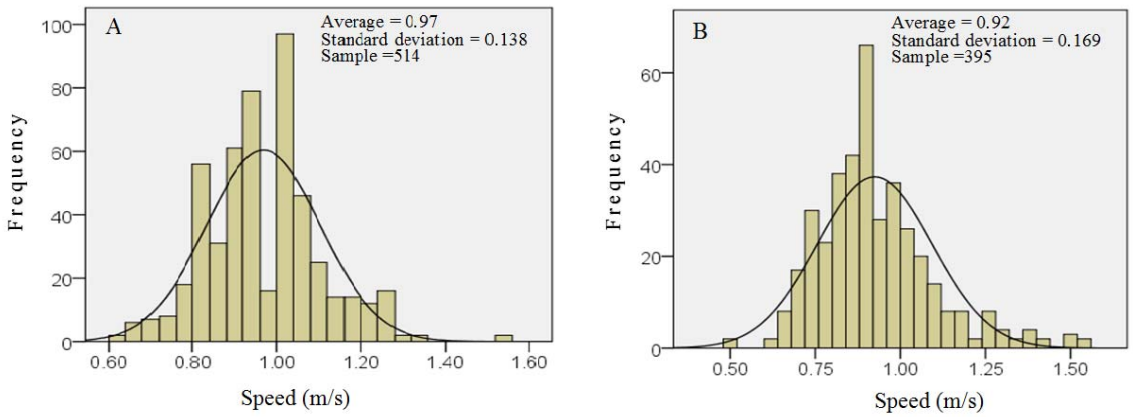

Figure 3. Histogram and normal curve of frequency distribution of group pedestrians in the signalized intersections: A) marked crosswalks; B) unmarked crosswalks

Table 1. The results of the study at signalized intersections

Categories	Cross Condition	Observed Sample	Average Speed (m/s)	Standard Deviation (m/s)	Mode (m/s)	V_{15} (m/s)	The Least Speed (m/s)	The Most Speed (m/s)
Male	Marked	994	1.09	0.180	1.00	0.83	0.41	2.22
	Unmarked	614	1.07	0.184	1.05	0.78	0.62	1.74
Female	Marked	428	1.03	0.151	1.00	0.78	0.64	1.54
	Unmarked	267	1.02	0.176	1.11	0.74	0.65	1.82
Group Movements	Marked	514	0.97	0.136	1.00	0.74	0.62	1.54
	Unmarked	395	0.92	0.169	0.86	0.66	0.52	1.54

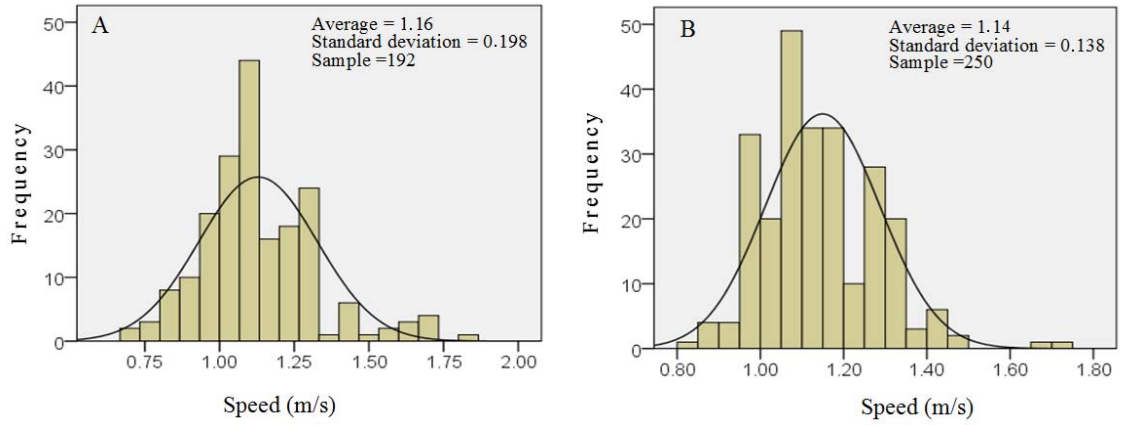

Figure 4. Histogram and normal curve of frequency distribution of male pedestrians in the un-signalized intersections: A) marked crosswalks; B) unmarked crosswalks

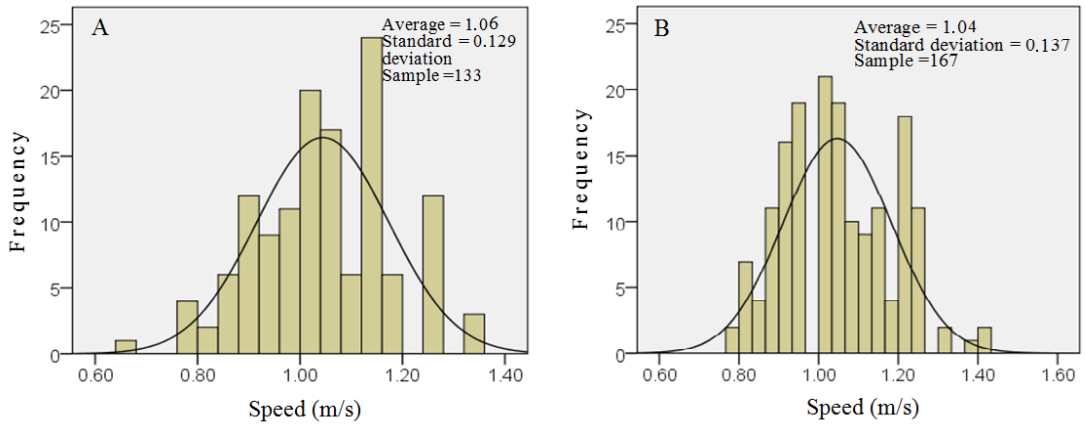

Figure 5. Histogram and normal curve of frequency distribution of female pedestrians in the un-signalized intersections: A) marked crosswalks; B) unmarked crosswalks

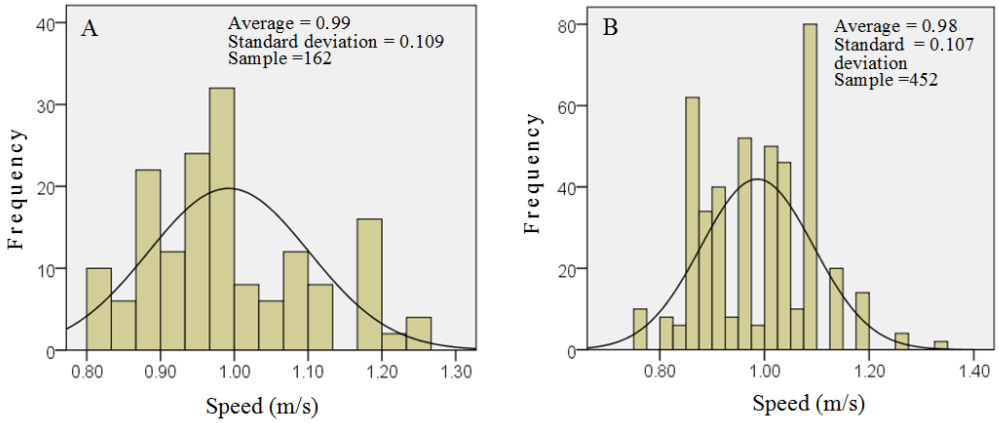

Figure 6. Histogram and normal curve of frequency distribution of group pedestrians in the un-signalized intersections: A) marked crosswalks; B) unmarked crosswalks

Table 2. The results of the study at un-signalized intersections

Categories	Cross Condition	Observed Sample	Average Speed (m/s)	Standard Deviation (m/s)	Mode (m/s)	V_{15} (m/s)	The Least Speed (m/s)	The Most Speed (m/s)
Male	Marked	192	1.16	0.176	1.12	0.89	0.78	1.73
	Unmarked	250	1.14	0.121	1.09	0.88	0.83	1.50
Female	Marked	133	1.06	0.117	1.12	0.83	0.78	1.32
	Unmarked	167	1.04	0.140	1.00	0.80	0.77	1.41
Group Movements	Marked	162	0.99	0.109	0.94	0.76	0.83	1.25
	Unmarked	452	0.98	0.104	1.09	0.75	0.75	1.26

Based on the histogram curves (figures 1 to 6) as well as tables 1 and 2, pedestrians' crossing speed in the marked crosswalks is higher than their crossing speed in the unmarked crosswalks. Furthermore, the highest average speed and 15th percentile speed in both cases (crossing the marked crosswalks and

unmarked crosswalks) is related to the male pedestrians; pedestrians group crossing speed in intersections in both cases was lower and the minimum speed and 15th percentile speed are related to this group.

Average speed and 15th percentile speed in the unmarked crosswalks in the signalized intersections for the male pedestrians was 1.07 and 0.78 m/s, respectively; for the female pedestrians was 1.02 and 0.74 m/s respectively and for the group of pedestrians 0.92 and 0.66 m/s respectively.

Average speed and 15th percentile speed in the unmarked crosswalks in the un-signalized intersections for the male pedestrians was 1.14 and 0.88 m/s, respectively; for the female pedestrians was 1.04 and 0.80 m/s respectively and for the group of pedestrians 0.98 and 0.75 m/s respectively.

5. Analysis and Comparison of the Results

5.1. Analysis of the results obtained from the effect of the age on the pedestrians crossing speed in all intersections

As shown in table 3, the effect of the age on the pedestrians' crossing speed in unmarked crosswalks in all intersections was considered and crossing speed for pedestrians of the same weight was compared in order to remove the weight effect. For this purpose, data normalization was analysed using the statistical Kolmogorov–Smirnov test. After identifying the normal distribution of speed data, ANOVA and Spearman's correlation were used for determination of correlation rate. Then, for determination of difference factors, Gabriel's test was applied (table 4 and 5).

Table 3. The analysis between speed and age of the Pedestrian with the same Weight in unmarked cross condition at all intersections

Gender	Age Group	Weight group	Sample number	Average Speed (m/s)	Standard Deviation (m/s)	Evaluation Results ANOVA upper 95% Certainty	Cohesion Test Result and Spearman Cohesion
Male	teen	Thin	-	-	-	P-Value =0.001 F=9.491 **major difference**	P-Value =0.002 R= -0.544 **correlation is significant**
	young		23	1.43	0.067		
	middle-aged		20	1.38	0.181		
	elderly		18	1.16	0.209		
	teen	Normal	19	1.30	0.161	P-Value =0.033 F=2.958 **major difference**	P-Value =0.008 R=-0.444 **correlation is significant**
	young		140	1.30	0.151		
	middle-aged		79	1.28	0.175		
	elderly		30	1.20	0.204		
	teen	Fat	-	-	-	P-Value =0.022 F=4.287 **major difference**	P-Value =0.064 R=-0.169 **correlation is significant**
	young		27	1.24	0.177		
	middle-aged		20	1.22	0.216		
	elderly		18	1.02	0.127		
Female	teen	Thin	-	-	-	P-Value =0.009 F=6.133 **major difference**	P-Value =0.003 R=-0.598 **correlation is significant**
	young		17	1.27	0.168		
	middle-aged		18	1.15	0.150		
	elderly		17	1.00	0.099		
	teen	Normal	-	-	-	P-Value <0.0001 F=12.074 **major difference**	P-Value <0.0001 R=-.0320 **correlation is significant**
	young		102	1.24	0.176		
	middle-aged		37	1.15	0.158		
	elderly		24	0.98	0.138		
	teen	Fat	-	-	-	P-Value = 0.011 F=4.998 **major difference**	P-Value =0.003 R=-0.433 **correlation is significant**
	young		22	1.14	0.202		
	middle-aged		27	1.00	0.142		
	elderly		20	0.95	0.119		

Table 4. The evaluation result for all group correlation analysis (male)

Gender	Weight Group	Age Group Comparison		P-Value	Cohesion Test Result and Spearman Cohesion
Male	Thin	young	middle-aged elderly	0.622 0.033	Major difference with elderly group (Games-Howell)
		middle-aged	young elderly	0.622 0.120	No Major Difference with any groups (Games-Howell)
		elderly	young middle-aged	0.033 0.120	Major difference with young Group (Games-Howell)
	Normal	teen	young middle-aged elderly	1.00 0.998 0.267	No Major difference with all Groups (Gabriel)
		young	teen middle-aged elderly	1.00 0.921 0.011	Major difference with elderly Group (Gabriel)
		middle-aged	teen young elderly	0.998 0.921 0.155	No Major difference with all Groups (Gabriel)
		elderly	teen young middle-aged	0.267 0.011 0.155	Major difference with young Group (Gabriel)
	Fat	young	middle-aged elderly	0.986 0.020	Major difference with elderly Group (Gabriel)
		middle-aged	young elderly	0.986 0.078	No Major difference with all Groups (Gabriel)
		elderly	young middle-aged	0.020 0.078	Major difference with young Group (Gabriel)

Table 5. The evaluation result for all group correlation analysis (female)

Gender	Weight Group	Age Group Comparison		P-Value	Cohesion Test Result and Spearman Cohesion
Female	Thin	young	middle-aged elderly	0.307 0.007	Major difference with elderly group (Gabriel)
		middle-aged	young elderly	0.0307 0.170	No Major Difference with any groups (Gabriel)
		elderly	young middle-aged	0.007 0.170	Major difference with young Group (Gabriel)
	Normal	young	middle-aged elderly	0.017 0.013	Major difference with all Groups (Gabriel)
		middle-aged	young elderly	0.0001 0.013	Major difference with all Groups (Gabriel)
		elderly	young middle-aged	0.052 0.018	Major difference with all Groups (Gabriel)
	Fat	young	middle-aged elderly	0.052 0.805	Major difference with elderly group (Gabriel)
		middle-aged	young elderly	0.018 0.805	No Major Difference with any groups (Gabriel)
		elderly	young middle-aged	0.307 0.007	Major difference with young Group (Gabriel)

As shown in tables 3 to 5, crossing speed for all pedestrians in all intersections was compared using the statistical tests. Concerning the effect of the age on crossing speed of the pedestrians, results showed that the effect of the age on female pedestrians and male pedestrians is different and weight is an effective factor in decreasing the pedestrians crossing speed. Based on the results in table 3, average crossing speed of the male pedestrians in the unmarked crosswalks in all weight groups has meaningful difference with 95% confidence.

For determination of the difference factors, Gabriel's test was used. As shown in table 4 for the male pedestrians, in the thin group, the difference is observed between young group and old group (P=0.033) and no meaningful statistical difference is observed between the middle-aged group and young group (P=0.622). Results showed that there is a meaningful difference between young group and old group in normal weight group (P=0.011). Likewise, by comparison of young and teenage groups, a meaningful level of P=1.00 is observed that shows the identical crossing speed for both of these groups. Crossing speed decrease of the middle-aged pedestrians in this weight group compared with that of the teenage group (P=0.998) and young group (P=0.921) showed that the statistical difference is not high. However, coefficients for the old people show the high difference with other groups. Crossing speed difference of the fat male pedestrians was statistically meaningful. Gabriel's test showed that there is a statistical meaningful difference between the young group and the old group with P=0.020 and there is a statistical meaningful difference of 95% confidence between the middle-aged group and the old group. However, P=0.986 in Gabriel's test showed that there is less difference in crossing speed of the fat young male pedestrians with the middle-aged pedestrians of the same weight.

Based on the results of table 3, crossing speed of the female pedestrians in all weight groups with 95% confidence has a meaningful difference. As shown in table 5, for the female pedestrians in thin group, results of the Gabriel test shows that there is a meaningful difference between the old group and the young group (P=0.007). There is difference in crossing speed between the middle-aged group and young group, however, this difference was not meaningful with 95% confidence. In normal weight groups, all age groups show a statistical meaningful difference. In addition, results of the Gabriel test for the fat female pedestrian group shows a statistical meaningful difference with 95% confidence (P=0.018) between the young female pedestrians and the old female pedestrians. There is a meaningful difference in crossing speed between the fat young female group and fat middle-aged female group with 95% confidence (P=0.018). There is no statistical meaningful difference between middle-aged group and the old group (P=0.805).

5.2. Comparison of the results

As shown in figure 7, the highest 15th percentile speed in both marked crosswalks and unmarked crosswalks is related to the male pedestrians; while the group of pedestrians had a lower crossing speed in both cases in the intersections and had the minimum average speed and 15th percentile speed. Additionally, crossing speed in marked crosswalks is higher than the crossing speed in unmarked crosswalks in both signalized intersections and un- signalized intersections.

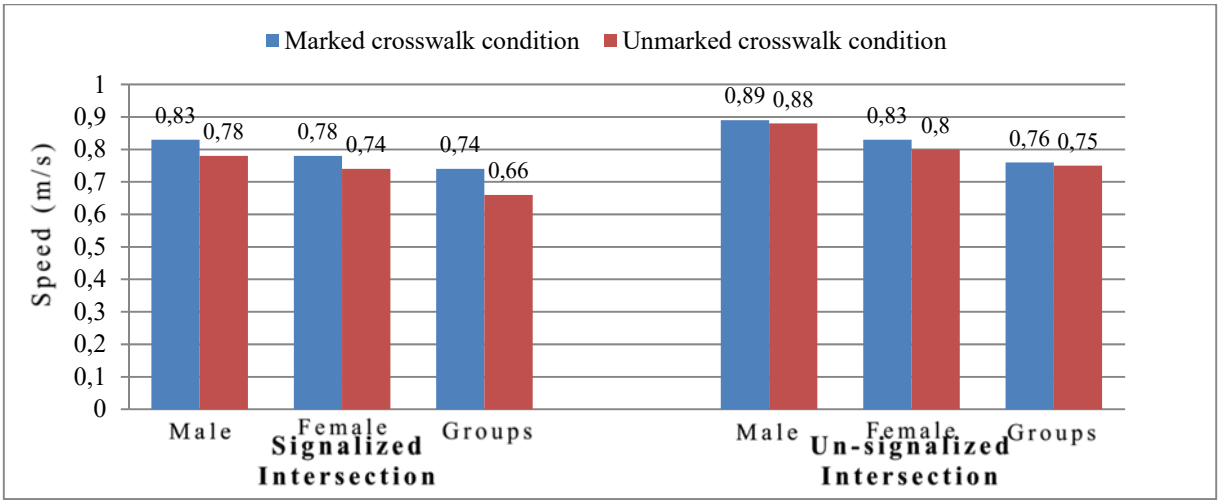

Figure 7. Compare the 15th percentile crossing speed of pedestrians taken in marked crosswalks condition and unmarked crosswalks condition

Results of table 6 shows that 15th percentile speed of the male pedestrians, female pedestrians, and group of pedestrians decreases 6.4, 5.4 and 12. 2%, respectively, in the unmarked crosswalks in the signalized intersections compared with their 15th percentile speed in the marked crosswalks. Moreover, 15th percentile speed of the male pedestrians, female pedestrians, and group of pedestrians decreases 1.2, 3.8 and 1.4%, respectively in the unmarked crosswalks in the un-signalized intersections compared with their 15th percentile speed in the marked crosswalks.

Table 6. The Comparison of crosswalk speed in unmarked and marked condition

Type of intersection	Categories	Reduction of marked condition
Signalized	Male	6.4%
	Female	5.4%
	Group movement	12.2%
Un-signalized	Male	1.2%
	Female	3.8%
	Group movement	1.4%

6. Conclusion

In this study, by analysis of the crossing speed of the pedestrians in marked crosswalks and unmarked crosswalks in the signalized and un-signalized intersections, following results were obtained:

- Crossing speed of the pedestrians in marked crosswalks is higher than the unmarked crosswalks in both signalized and un-signalized intersections;
- In crossing the marked crosswalks in signalized intersections, average speed and 15th percentile speed for the male pedestrians was 1.07 and 0.78 m/s, respectively; for the female pedestrians was 1.02 and 0.74 m/s, respectively; and for the group of the pedestrians was 0.92 and 0.66 m/s, respectively.
- In crossing the unmarked crosswalks in the un- signalized intersections, average speed and 15th percentile speed for the male pedestrians was 1.14 and 0.88 m/s, respectively; for the female pedestrians was 04.1 and 80.0 m/s, respectively; and for the group of the pedestrians was 0.98 and 0.75 m/s, respectively.

- 15th percentile speed of the male pedestrians, female pedestrians, and group of pedestrians decreases 6.4, 5.4 and 12.2%, respectively, in the unmarked crosswalks in the signalized intersections compared with their 15th percentile speed in the marked crosswalks.
- 15th percentile speed of the male pedestrians, female pedestrians, and group of pedestrians decreases 1.2, 3.8 and 1.4%, respectively, in the unmarked crosswalks in the un-signalized intersections compared with their 15th percentile speed in the marked crosswalks.
- Crossing speed of the male pedestrians in the unmarked crosswalks in all weight groups has a statistical meaningful difference with 95% confidence.
- Crossing speed of the female pedestrians in the unmarked crosswalks in all weight groups has a statistical meaningful difference with 95% confidence.

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