

Evaluation of Factors Affecting Pedestrian Walking Speed in Pedestrianized Areas

(Case Study: Tehran City)

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Abstract

The behavior and reaction of pedestrians play a special role in the development and management of pedestrian facilities, especially in the central business district of cities. Pedestrianized areas increase the welfare and safety of pedestrians and help improve economic viability and environmental criteria. Through a comprehensive review of relevant studies, it is shown that no study has been conducted so far to evaluate the effect of different parameters such as age, gender, weight, rainfall, and umbrella carrying on the walking speed on crowded and walkable streets in Tehran, Iran. Additionally, to the best of our knowledge, no study has been conducted to determine the average speed of pedestrians under normal and rainy conditions. Therefore, the present study applies the walking speed of 5805 pedestrians through the crowded pedestrianized areas of Tehran in the year 2019 to compare the walking speed of the pedestrians between normal and rainy conditions. Further, factors such as gender, weight, and rainfall on the walking speed of pedestrians are analyzed using the t-test. According to the obtained results, it can be found that based on a 95% confidence level, the difference in speed between men and women is statistically significant for all age and weight groups except teenagers and elderly pedestrians, and males walk faster than females in all conditions. Rainfall has shown to have an effect on the walking speed of male pedestrians, and females tend to walk slower than males. The values of 0.79 and 0.99 m/s for the 15th percentile speed and the mean speed of 1.09 and 1.12 through the walkable facilities are recommended for normal and rainy weather, respectively. Based on increasing the 15th percentile and the mean speed of pedestrians under rainy conditions, it is suggested that implementing safety measures such as weather-appropriate signage to control walking speed in order to reduce potential hazards and accidents in pedestrianized areas. The results of the present study can also lead to safer and more user-centric urban spaces that prioritize pedestrian comfort, convenience, and inclusivity under various weather conditions.

Keywords: Walkable street, pedestrian, walking speed, rain condition, age

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1. Introduction

Motor vehicle traffic endangers non-motorized users, particularly the elderly, disabled, and children, limiting their mobility. Car-centric urban planning reduces green spaces, lifestyles, and harms public health [Hillnhütter, 2016]. Walking is regarded as one of the most significant forms of non-motorized transportation and it's the most ancient mode of transportation [Amato, 2004; Jabbari et al., 2021]. Walking is one of the basic requirements of transportation systems, especially when intermodal and integrating trips are in mind. Walking by pedestrians could lead to achieving development sustainable cities since there is no emission regarding this kind of transportation mode and it helps the health of people. Pedestrianized areas have become the main gathering places for urban dwellers and tourists, and practice shows it has increased the welfare and safety of citizens [Samet, 2016; Koloushani et al., 2020]. Pedestrian infrastructures, such as signalized crossings, midblock crosswalks, sidewalks, and pedestrian-only streets, have considerable effects on traffic flow and safety which need to be managed by traffic engineers and urban planners [Rahman, 2022]. Walking behaviors differ among individuals due to age, gender, location, and health. Understanding these factors helps urban planners design safer, more accessible pedestrian-friendly spaces [Gates et al., 2006; Rastogi & Chandra, 2013; Ghani et al., 2016]. Regarding the important role of walking in development of sustainable cities, the present study can inform policy makers, traffic engineers and urban planners to promote walking as a sustainable mode of transportation, improve public health, and reduce reliance on cars, thereby reducing traffic congestion in urban areas. Another contribution of the present study is to optimize the design of pedestrianized areas to improve pedestrian flow and efficiency in cities, based on the most

important factors influencing pedestrian walking behavior.

To achieve the contributions and research necessity based on the current subject, the present study seeks to estimate and compare the walking speed of pedestrians between normal and rainy conditions. The study focuses on 5805 pedestrians on two sidewalks, namely Tajrish square to Shariati street and Panzdah-e-Khordad street in Tehran, Iran. Additionally, the study examines the effect of different parameters, including age, gender, weight, rainfall, and umbrella carrying, on the walking speed.

2. Literature Review

The speed of pedestrians is also affected by individual characteristics such as gender, age [Bargegol et al., 2015], length of crosswalk sections [Banerjee et al., 2018], crossing on marked or un-marked section [Bargegol et al., 2015], pedestrian flow rate [Galiza & Ferreira, 2013], and distance from the central business district [Bargegol et al., 2015]. The studies based on evaluating the analysis of pedestrian behaviors, characteristics, and finding out how the other transportation modes affect pedestrian speed are explained as follows:

Coffin and Morrall (1995) determined the walking speeds of elderly pedestrians at crosswalks in Calgary, Canada. They showed that the design walking speed in the city is 1.0 m/s. However, the design speeds for these pedestrians at mid-block crosswalks and signalized intersections are 1.0 and 1.2 m/s, respectively.

In a study, Bargegol et al. (2014) evaluated the effect of vehicle conflict on pedestrian crossing speed in signalized and unsignalized intersections in Rasht city, Iran. They found that the average speed of male and female pedestrians crossing signalized intersections with conflicting vehicles was 1.09 and 1.03, respectively. However, the average speed of male and female pedestrians crossing

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unsignalized intersections with conflicting vehicles was 1.13 and 1.04, respectively. Thus, their results showed that the average speed for men in all urban areas of Rasht city was higher than for women.

In another study, Behbahani et al. (2017) also worked on the analysis of the crossing speed of pedestrians in marked and unmarked crosswalks in signalized and unsignalized intersections in Rasht city, Iran. They found that the average speed of male and female pedestrians in crossing marked crosswalks in signalized intersections is 1.07 and 1.02 m/s, respectively. However, in crossing marked crosswalks in unsignalized intersections, the average speed of male and female pedestrians is 1.14 and 1.04 m/s, respectively. Thus, their results show that the average speed for male pedestrians in all urban areas of Rasht city was higher than that of female pedestrians.

Saeedi and Rassafi (2019) also studied pedestrian movements at crosswalks using chaos theory. They found that as the number of pedestrians at the crosswalk increases and decreases, the frequency of chaos increases, leading to a longer distance for the pedestrian crossing path. Rasoulzadeh Sheikh et al. (2023) examined pedestrian access in transit-oriented development in district 6 of Tehran. They found satisfactory performance of the model. Additionally, high sensitivity was observed for parking, while low sensitivity was observed for public space.

Additionally, some studies have worked on identifying factors that contribute to influencing the walking speed of pedestrians. Sarsam and Abdulameer (2014) conducted research to evaluate the walking speeds of pedestrians in Baghdad city, Iraq. They indicated that male pedestrians walk faster than female pedestrians in Baghdad city. In another study, Pinna and Murrau (2018) investigated the effect of pedestrians' age on their speed on sidewalks using a statistical model in the downtown area of Oristano in Sardinia, Italy. Their findings revealed that as age increases, walking speed

decreases. Specifically, young pedestrians walk faster than other age groups.

Liang et al. (2020) investigated the effect of weather on walking speed in cold areas. They found that ice sports are the main factor attracting pedestrians to walk in cold areas. Further results showed that as the temperature decreases and the ground becomes covered with snow, walking speed decreases and reaches 0.102 m/s. Franěk and Režný (2021) examined the effect of visual environmental features on walking speed. They found that walking speed and noise are low in areas with high natural characteristics and a high environmental preference. Shiran et al. (2022) studied the factors influencing the location of urban pedestrian streets in Qom city, Iran. They found that car ownership and students are the most and least influential factors contributing to the choice of pedestrian streets.

Bargegol et al. (2022) evaluated the effect of rain and personality characteristics on the walking speed of pedestrians. They indicated that rainy conditions reduced the average speed of pedestrians compared with normal conditions. Moreover, wearing a hijab caused female pedestrians to walk slower than females without a hijab in the adolescent age group. However, for elderly females, weight and age caused them to reduce their speeds as weight and age increased. Miao et al. (2023) investigated the effect of pedestrian characteristics, type of roads, and weather conditions on walking speeds. They found that on flat roads, walking speed increases, while on uneven roads and in cold weather conditions, walking speed decreases. Moreover, male pedestrians walk faster than female pedestrians in all areas. As the weight and age of pedestrians increase, there is a reduction in walking speed.

Taghipour et al. (2023) also investigated the effect of factors contributing to the quality of pedestrian zones in regards to the perspective of citizens in Rasht city. They indicated that suitable design for the disabled and the elderly,

lighting at night, proper placement of trash cans, and drinking fountains are the most factors affecting the quality of pedestrian zones.

Erturan and Aksel (2023) conducted a study on the multidimensional analysis of walkability in the city centers of Beşiktaş in Istanbul, Turkey, and Delft in the Netherlands. They utilized mobile methodologies to consider factors such as traffic safety, accessibility, comfort, pleasure, and mixed-use. The researchers demonstrated that the "Go-Along" method, which incorporates both perceptual and spatial elements, is effective in analyzing walking patterns. In a separate study, Jiao and Fei (2023) employed an in-flight drone to monitor walking speeds. They discovered that this method can be applied to streets of all scales, providing valuable insights into how urban settings and layouts influence people's walking behavior.

Li et al. (2023) evaluated the accessibility of public transportation station areas based on walking perception. The results indicate that the presence of crosswalks with signal lights, the combination of sidewalks and non-motorized lanes, the quantity of obstacles, and the number of vehicle entrances on sidewalks can significantly increase perceived difficulty. Additionally, they identified 15 minutes and 20 minutes as the thresholds for perceived walking times for bus and rail transit station areas, respectively. In another study, Banerjee et al. (2024) assessed the behavioral characteristics that influence the walking speed of pedestrians on skywalks and foot-over bridges (FOBs) in a case study conducted in India. They found that socio-demographic factors, group behavioral characteristics, and land use type are the most influential factors affecting walking speed on skywalks and FOBs. Furthermore, their findings demonstrate that the average walking speed is higher on skywalks compared to FOBs, and the squeezing effect significantly reduces walking speeds.

Fonseca et al. (2024) focused on evaluating the impact of individual and urban factors on pedestrian perceptions and attitudes towards

walking in the cities of Bologna and Porto in Italy and Portugal, respectively. They showed that people often enjoy walking for physical activity, saving money, and optimizing time. However, they dislike walking under poor sidewalk conditions and adverse weather. Giannoulaki and Christoforou (2024) presented a review study on pedestrian walking speed, examining physiological, psychological, and environmental factors. They found that these factors have a dramatic effect on pedestrian speed. Han et al. (2024) studied the correlation of unobserved factors of old town street walkability using the Structural Equation Modeling (SEM) approach. They revealed that the obtained model has good predictive power with real data. In their model, they showed that centrality and feasibility are the most important factors of walkability, while convenience is the least important.

Thus, based on a comprehensive review of previous studies on the influence of factors affecting pedestrian walking speed in pedestrianized areas, no research has been conducted so far to evaluate the effect of different parameters such as age, gender, weight, rainfall, and umbrella carrying on the walking speed on crowded and walkable streets in Tehran, Iran. Additionally, to the best of our knowledge, no study has been conducted to determine the average speed of pedestrians on walkable streets in Tehran under normal and rainy conditions.

3. Methodology

In order to estimate the walking speed of pedestrians under normal and rainy conditions and evaluate the effect of different parameters such as age, gender, weight, rainfall, and umbrella carrying on the walking speed on two sidewalks, the research method based on the flowchart in Figure 1 is considered. According to Figure 1, the data for analysis is collected on Tajrish square to Shariati street and Panzdah-e-Khordad street in Tehran, Iran, and descriptive statistics for personal characteristics and

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weather conditions are applied. Then, the average speed for pedestrians under normal and rainy weather based on the average and 15th percentile is determined. To investigate the effect of different parameters such as age, gender, weight, rainfall, and umbrella carrying, the normality of speed data is checked using the Kolmogorov-Smirnov test for parametric tests

(such as t-test) and non-parametric tests (such as Mann-Whitney U test) via SPSS software.

After determining the type of test, the results and findings regarding the effect of age, gender, weight, rainfall, and umbrella carrying on walking speed are explained. Finally, the obtained results are compared with previous studies to verify the results in the present study.

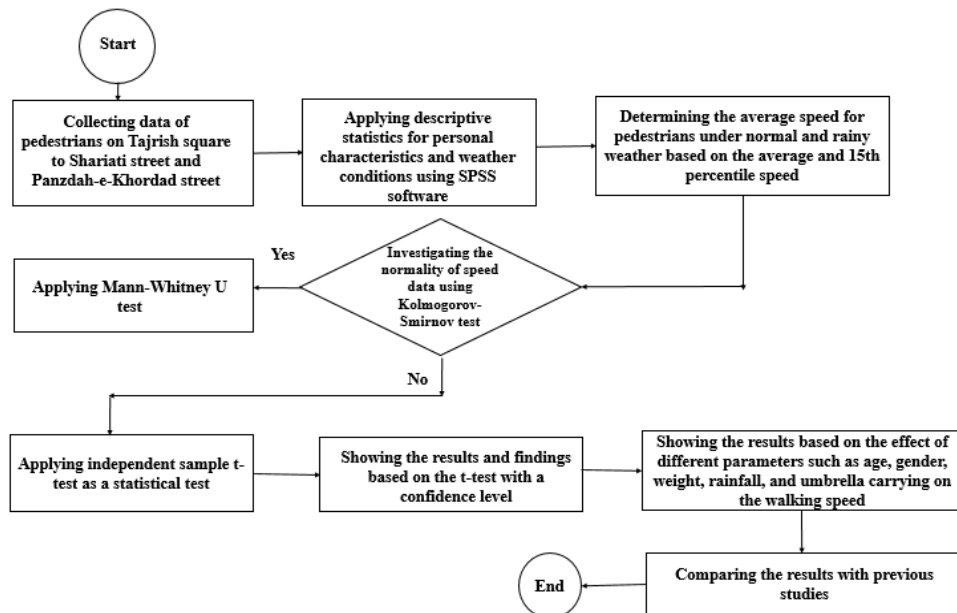


Figure 1. Flowchart of the present study

3.1. Study Area and Data Collection

The present study was conducted in Tehran, the capital of Iran. According to the official census in 2019, the population of Tehran is 8,693,000, with a population density of 12,000 people per square kilometer [Iran Statistical Center, 2019]. To study the behavior of pedestrians, crowded pedestrian facilities in Tehran were selected, specifically around shopping centers, entertainment areas, and pedestrian attraction areas. Therefore, the present study was conducted on the proposed streets shown in Figure 2, as these streets have a high number of pedestrians due to their proximity to shopping centers, entertainment areas, and pedestrian attraction areas. In particular, Tajrish square to Shariati street in Figure 2(a) is one of the most popular walking routes in Tehran. It is a lively and vibrant place, and pedestrians can enjoy the beautiful market with its traditional and old

texture. Moreover, Panzdah-e-Khordad street in Figure 2(b), with the benefit of the name and history of an ancient city, is perceived by the public as an urban space that carries economic (commercial) significance and serves as a communication hub within the city. It is fully aligned with the existing passages. Additionally, this street is a vibrant and lively path that enhances social life, contributes to identity formation, and serves as a memory maker. It is also a gathering place for the community. Therefore, data on these locations were collected due to the popularity and attractions of Tajrish square, Shariati street, and Panzdah-e-Khordad street.

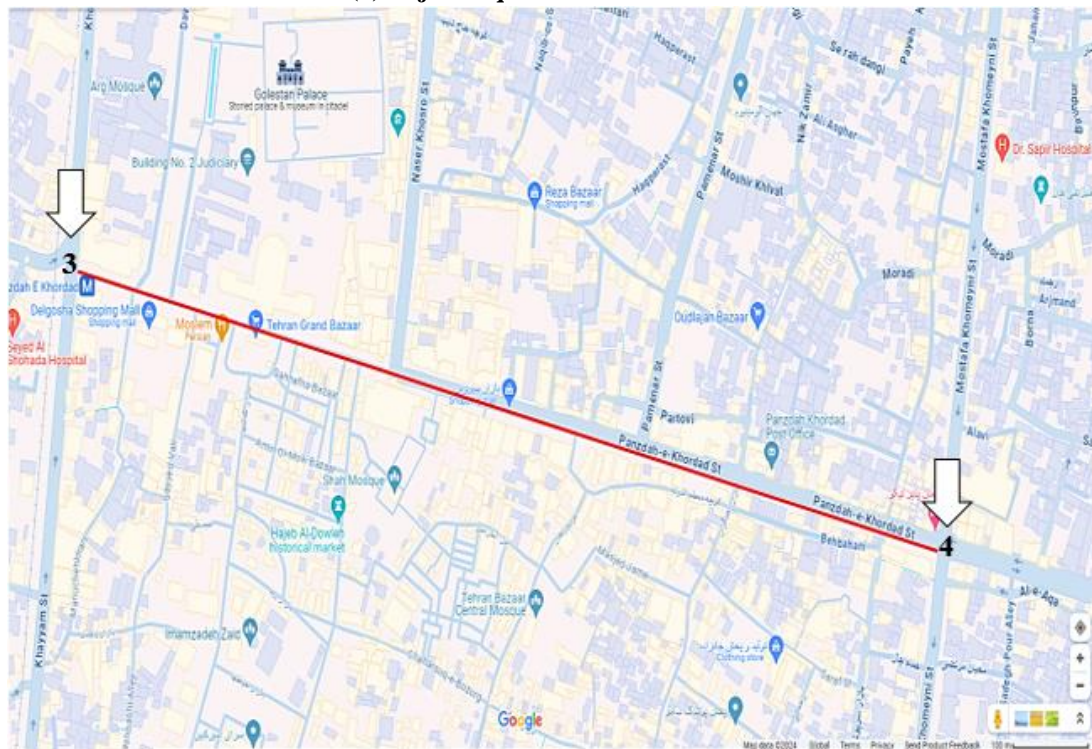
Then, intersections of numbers 1 to 4 were filmed using a video camera recording during peak activity times in both normal and rainy conditions. Finally, 5805 pieces of pedestrian speed information were collected and evaluated

over a three-month period in 2019. The information was categorized by gender, weight, age, and weather conditions, and is presented in Table 1. A total of 4935 pedestrian samples were collected in normal conditions, while 870 samples were collected in rainy conditions. Information on pedestrian characteristics was

collected based on the appearance features of the walkers, following the standards set by the World Health Organization (WHO). Table 2 shows the number of samples collected for pedestrian facilities, categorized by gender and weather condition.



(a) Tajrish square to Shariati street



(b) Panzdeh-e-Khordad street

Figure 2. Study area of two locations in Tehran, Iran

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Table 1. Information on pedestrian facilities

Name of path	Facilities number	Number of samples		Land use near to facilities
		Normal weather	Rainy weather	
Tajrish square to Shariati street	1	2583	158	Commercial and recreational purposes
Panzdah-e-Khordad street	2	2352	712	Commercial and administrative purposes

Table 2. Number of sample on pedestrian facilities

Weather condition	Classification	Number of samples
Normal	Male	2004
	Female	1248
	Group movement	1683
	All pedestrians	4935
Rainfall	Male	499
	Female	371
	All pedestrians	870

3.2. Analyzing Method

The analyzing method in the present study is selected based on whether the data are normal or not, using the Kolmogorov-Smirnov test to investigate both parametric tests (such as t-test) and non-parametric tests (such as Mann-Whitney U test). It should be noted that researchers decide on the selection of parametric tests and non-parametric tests based on the Kolmogorov-Smirnov test and the suitability of data for each test. The t-test is a statistical test that has been used by various researchers in the road and transportation field to validate their results and evaluate the impact of one factor on other factors [Shirmohammadi and Hadadi, 2019; Shirmohammadi and Hadadi, 2020]. In the t-test, the distribution of "t" is a function of the degrees of freedom, and it approaches the normal distribution as degrees of freedom increase. Additionally, the dispersion increases with the reduction in the degrees of freedom. Moreover, the degrees of freedom themselves are a function of the sample size. The more samples available, the more accurate the results. This test compares the mean and standard deviation of two samples to determine if there is a significant difference between them. To do this, the value of T should

be estimated using Eq. (1). Then, the calculated T should be compared with the T distribution table [Kim, 2015; Behbahani et al., 2017]. For this purpose, the degree of freedom is required, which can be obtained according to Eq. (2).

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{(S_1)^2}{n_1} + \frac{(S_2)^2}{n_2}}} \quad (1)$$

$$df = (n_1 + n_2) - 2 \quad (2)$$

Where, \bar{x}_1 and \bar{x}_2 denote the average, and S_1 and S_2 are the standard deviations of samples 1 and 2, respectively. In addition, n_1 and n_2 show the sample sizes, and df is the degree of freedom.

Based on the T number, with respect to the occurrence probability of the first type error ($\alpha = 0.05$) and the calculated degree of freedom, the result is interpreted. If the p-value is less than 0.05, then the null hypotheses are rejected. In other words, it means that there is a significant difference between the means of the samples [Bargegol et al., 2014]. The assumptions corresponding to the above test are given as below in Equation (3):

$$\begin{cases} H_0: m_1 = m_2 \\ H_1: m_1 \neq m_2 \end{cases} \quad (3)$$

The Mann-Whitney U test, also known as the Wilcoxon Rank Sum Test, is a non-parametric statistical test used to compare two samples or groups. This test is based on the selection of using the Kolmogorov-Smirnov test and non-parametric test [McKnight & Najab, 2010]. The Mann-Whitney U test has also been widely used in different fields of transportation [Kamis et al., 2022; Wolnowska & Kasyk, 2022]. Thus, in the present study, the data are analyzed using SPSS software to investigate inferential and descriptive results.

4. Results and Discussions

Following the collection and analysis of data on pedestrian walking speed, the effect of gender in the same age and weight categories, rainfall and carrying umbrellas were then examined. According to descriptive statistics for walking speed, personal characteristics, and weather conditions based on SPSS software, the results of the analysis are described below.

Figure 3 shows the average, standard deviation and 15th percentile walking speed of pedestrians in all crowded pedestrian facilities in the city of Tehran under normal and rainy conditions. As shown in Figures 3(a) and 3(b), male pedestrians have the highest values of average and 15th percentile walking speed, while female pedestrians walk slower than male pedestrians under normal conditions. Similarly, in rainy conditions, male pedestrians have the highest values of average and 15th percentile walking speed, while female pedestrians walk slower than males. As pedestrians in the city of Tehran mostly experience sunny days throughout the year under normal weather conditions. Therefore, it would be better to use the values 1.09 and 0.79 for the average and 15th percentile walking speed for all pedestrians when designing walkable street facilities in Tehran under normal weather conditions.

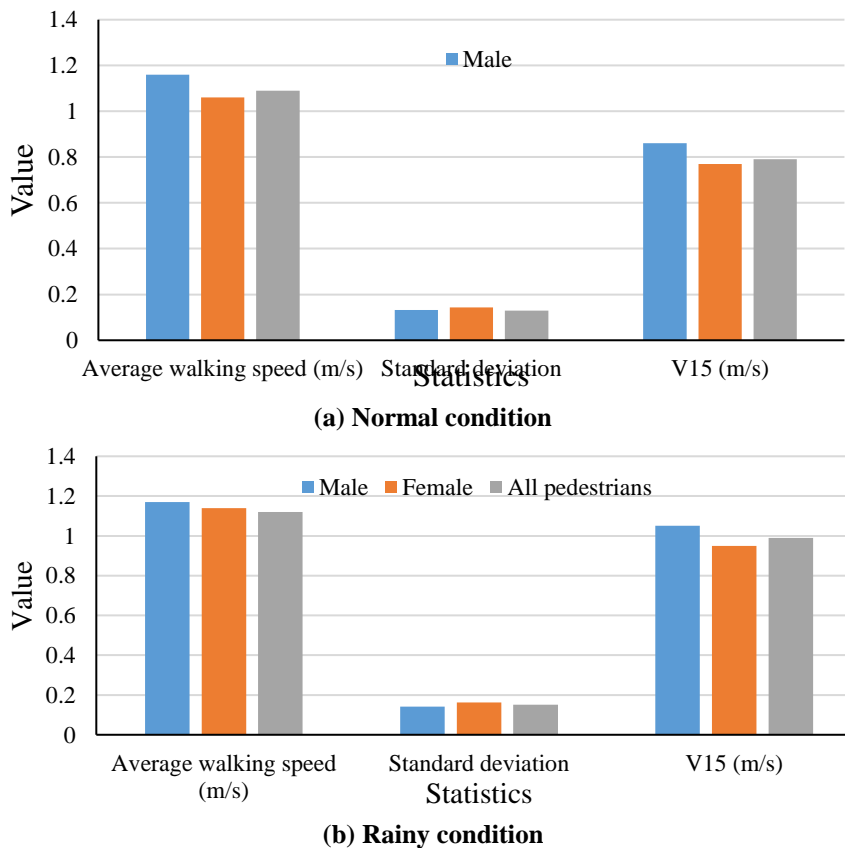


Figure 3. Pedestrians walking speed result

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4.1. Effect of Personal Characteristic on the Walking Speed

The normality of speed data for males and females was investigated by the Kolmogorov-Smirnov test, and it was shown that the speed data has a normal distribution for all pedestrians. Thus, the data for walking speeds of pedestrians was analyzed using an independent sample t-test. Table 3 shows the results of the speed difference between males and females on different pedestrianized areas under normal and rainy weather conditions using a t-test. To eliminate the effects of unequal distribution of age and weight, comparisons were made in the same age and weight categories. According to the results of the independent sample t-test shown in Table 3, in addition to the teenager age group, no significant speed difference was observed in the elder age group in all three weight groups. In

other words, in these age groups (the teenager and the elderly), males and females tend to walk at almost equal speeds on the walkable street, and gender does not have a significant effect on the walking speed of pedestrians on the walkable street.

In rainy weather, the walking speeds of pedestrians were investigated by gender category. This is because recognizing the weight and age of pedestrians was difficult in rainy conditions. The results of statistical tests showed that gender in rainy conditions also affects the walking speed of pedestrians. Therefore, these comparisons show that males walk faster than females in all conditions. However, the results of statistical tests for the data in this study show that in teenagers (under 20 years old), gender does not have a significant effect on pedestrian speed.

Table 3. Comparison of speed on walkable street in the same age and weight

Weather conditions	Weight	Age	Gender	P-value & T	Results of t-test with confidence level of 95%		
Normal	Thin	Teenager	Male	P = 0.423	The difference is not significant.		
			Female	T = 0.126			
		Young	Male	P = 0.024		The difference is significant.	
			Female	T = 8.487			
		Middle-aged	Male	P = 0.061		The difference is significant.	
			Female	T = 1.762			
		Elderly	Male	P = 0.000		The difference is not significant.	
			Female	T = 2.138			
	Normal	Normal	Teenager	Male	P = 0.354	The difference is not significant.	
				Female	T = 0.322		
			Young	Male	P = 0.000		The difference is significant.
				Female	T = 1.324		
Middle-aged	Male	P = 0.000	The difference is significant.				
	Female	T = 1.138					
Elderly	Male	P = 0.483	The difference is not significant.				
	Female	T = 3.847					
Normal	Thin	Teenager	Male	N/A	N/A		
			Female	N/A			
	Young	Male	P = 0.000	The difference is significant.			
		Female	T = 1.569				
	Middle-aged	Male	P = 0.000	The difference is significant.			
		Female	T = 1.473				
	Elderly	Male	P = 0.438	The difference is not significant.			
		Female	T = 2.323				

Weather conditions	Weight	Age	Gender	P-value & T	Results of t-test with confidence level of 95%
Rainfall	N/A	N/A	Male Female	P = 0.000 T = 3.824	The difference is significant.

N/A: Not Available

4.2. Effect of Rainfall on the Walking Speed

Table 4 shows the effect of weather conditions on the walking speed of pedestrians. An independent sample t-test was used to compare pedestrian speed in normal and rainy weather conditions. The comparisons were made between pedestrians of the same gender. All pedestrians were compared and statistically tested based solely on the type of weather conditions. The results of the independent sample t-test in both gender groups showed a statistically significant difference. This

comparison revealed that rainy weather has an effect on pedestrian walking speed, as shown in Table 4. Males and females have different speed values in normal weather conditions compared to rainy conditions, and this difference is statistically significant with 95% confidence. However, it is important to note that there were no significant differences in the results of females' speed. In other words, rain does not affect the walking speed of females, and they enjoy walking in rainy conditions through the pedestrianized areas facilities.

Table 4. Comparison of pedestrians speed under normal and rainy weather conditions

Facility type	Gender	Weather condition	P-value & T	Results of t-test with confidence level of 95%
Walkable street	Male	Normal	P = 0.000 T = 1.312	The difference is significant.
		Rainfall		
	Female	Normal	P = 0.231 T = 0.421	
		Rainfall		

4.3. Effect of Umbrella on the Walking Speed

To compare the walking speed of pedestrians in rainy conditions, they were divided into two groups - those with umbrellas and those without umbrellas. This was done because umbrellas were believed to be a factor that could affect the speed of pedestrians. Table 5 presents the results of the pedestrian walking speed with and

without umbrellas in rainy conditions, which were analyzed using an independent sample t-test. As shown in Table 5, it was found that there is no significant difference in the speed of pedestrians with and without umbrellas in both gender groups. This suggests that carrying an umbrella does not have an impact on the speed of pedestrians in rainy conditions.

Table 5. Comparison of pedestrians walking speed with and without umbrella in rainy weather for different gender groups

Gender	Umbrella's availability	P-Value & T	Results of t-test with confidence level of 95%
Male	With umbrella	P = 0.351 T = 0.104	The difference is not significant.
	Without umbrella		
Female	With umbrella	P = 0.135 T = 0.531	
	Without umbrella		

4.4. Comparison of the Results with Previous Studies

Table 6 compares the 15th percentile values of pedestrian walking speed ($v_{15} = 0.79$ m/s) of

the present study for all pedestrians with that of other studies across the globe under normal conditions. Results indicate that in the city of Tehran, pedestrians generally walk slower than

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pedestrians in other parts of the world. The result is also different from the studies undertaken in the city of Rasht in the north of Iran [Bargegol et al., 2014; Behbahani et al., 2017]. The cause of such difference could be attributed to the distinctive characteristics of the northern regions of Iran when compared to the conditions in other parts of Iran. The city of Rasht is popular and known worldwide for its food creativity, and its citizens tend to enjoy walking through pedestrianized areas while

trying different foods in a clean and relaxed environment. In Tehran, people also used to walk slower than in other cities because of various factors such as traffic jams, crowded activity areas, overpopulation, and dispersed urban form. The high values of the 15th percentile speed difference of pedestrians in other parts of the world indicate that pedestrians may be exposed to a risk of crashes, which can result in a reduction in pedestrian safety [Coffin & Morrall 1995; HCM, 2016].

Table 6. Comparison present study with other research

References	Speed value (m/s)	Difference with other research (%)
[Coffin & Morrall 1995]	1.0	-21%
[Bargegol et al., 2014]	0.89	-11%
[HCM, 2016]	1.34	-41%
[Behbahani et al., 2017]	0.83	-5%

4.5. Limitations and Suggestions for Further Studies

The limitations of the present study are described as follows: the present study only evaluates the pedestrian speeds in urban areas based on field data, and no predictive models regarding the intensity of rainfall and its effect on walking speed have been investigated. Thus, it is suggested that future studies focus on proposing a mathematical model that relates the walking index to the variables proposed in the present study, which are relevant for estimating walking speed in pedestrianized areas.

Further, future studies could focus on modeling pedestrian behavior, including speed, acceleration, and deceleration. This could help propose safety indicators for pedestrian behavior in urban areas. These indicators could be based on statistical models like regression models and artificial intelligence models such as machine learning and artificial neural networks (ANNs). These models could be used to determine the precise speed and acceleration/deceleration of pedestrians.

5. Conclusions

Walking plays an important role in achieving sustainable development in cities. To encourage pedestrians to walk in urban areas, urban

authorities and transportation engineers should focus on various aspects of safety and traffic issues that contribute to the overall safety and traffic conditions in urban areas. In order to facilitate and improve this mode of transportation in cities, this study examines the behavior of 5805 pedestrians in two pedestrianized areas of Tehran, namely Tajrish square to Shariati street and Panzdah-e-Khordad street. The study evaluates the effects of gender, age, weight, rainfall, and carrying an umbrella on pedestrian walking speed. Based on the findings, the following conclusions can be drawn:

1. Pedestrians experience the lowest speed values in pedestrianized areas, which may be due to the special design of these areas with pedestrian priority, as well as the location of walkable streets in tourist corridors, recreational areas, or shopping areas. To optimize pathways and reduce congestion, improve flow, and enhance overall accessibility, city planners and designers should provide personalized amenities such as seating areas, rest spots, and accessible pathways based on pedestrian characteristics. These amenities should be suitable for normal and rainy weather conditions on crowded

pedestrianized streets, taking into consideration the needs of males and females of different ages.

2. With a 95% confidence level in all age and weight groups except the teenager age group (under 20 years) and in the elder age group, the speed difference between males and females is statistically significant and females walk less than males.

3. The highest values of the 15th percentile in both normal and rainy weather conditions are related to males, while females walk at a slower speed and the lowest values of the 15th percentile belong to them. The values of 0.79 and 0.99 m/s are recommended as the 15th percentile speed of pedestrians through the walkable facilities for all pedestrians under normal and rainy weather, respectively. These values can be used for traffic design purposes in Tehran. Therefore, based on the increasing the 15th percentile speed of pedestrians under rainy conditions, it is suggested that implementing safety measures such as weather-appropriate signage to control walking speed in order to reduce potential hazards and accidents in pedestrianized areas under rainy weather is necessary.

4. Based on the obtained result, rain does not have an effect on the females' walking speed in pedestrianized areas, and they walk at a speed close to normal in rainy conditions. However, there is a significant difference in walking speed between rainy and normal conditions for males. Thus, it is recommended that urban planners design pedestrian-friendly spaces with appropriate shelter and weather protection to enhance comfort and promote year-round usability, especially in areas where the majority of the population is male.

5. In both gender groups, the difference between the pedestrian speed with and without umbrellas is not significant. This indicates that the umbrella does not have an effect on pedestrian speed in rainy conditions. Thus, it can be concluded that carrying an umbrella is not a safety challenge or an

impediment to walking for pedestrians on the studied walkable streets.

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