Original article

A gender based comparison and correlation of spatiotemporal gait parameters and postural stability

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Abstract. *Background and aim:* Postural stability during gait is a crucial factor that reduces the risk of falls. Researchers determine the most effective way to assist patients whose postural stability deficit predominantly related to gait parameters. The aim of this study was to investigate the comparison and relationship between spatiotemporal gait parameters and postural stability in young male and female. *Methods:* 96 participants (male, and female) with age range from 18-40 years were selected to conduct this cross-sectional correlation study. Any participants with cardiovascular, neuromuscular diseases, musculoskeletal injury, vision, and hearing problem were excluded from the study. To measure spatiotemporal data, the Physilog application by Gaitup was used. Stabilometer was used to assess unipedal dynamic postural stability. Statistical analysis of data was performed by using SPSS software. Mann Whitney U test, Kruskall Wallis H test, and Spearman rank correlation coefficient tests were used to statistical analysis. *Results:* The results of this study revealed that anteroposterior stability for left leg was significant (p=.002) between male and female. The gait parameters as stride length (Left Leg, p=.050), (Right leg, p=.001); gait speed (Left Leg, p=.006), (Right leg, p=.009); and maximal heel clearance (Left Leg, p=.001), (Right leg, p=.001) were significant between genders. No significant relationship was found among the dynamic postural stability and spatiotemporal parameters of gait. *Conclusions*: In summary, this research illustrates the putative mechanisms of gait parameters and postural dynamic stability parameters differences in male and female participants and also relationship among them. (www.actabiomedica.it)

Key words: Gait, Stability, Cadence, Gait Speed, Hill Strike, Gait Cycle, Stride Length

Introduction

Spatiotemporal parameters are frequently used to determine whether certain populations divert from the norm. Spatiotemporal parameters are easy markers for investigating the influence of aging on walking patterns (1). Some studies reported increased stride width and decreased gait speed for different ages (2, 3). However, there are other factors influencing gait that have not been covered thoroughly. These include gender, weight, height, and body mass index (BMI). It is important to study such factors to develop appropriate therapeutic programs for gait problems. Gender differences in a healthy population reveal contradictory discoveries regarding spatiotemporal parameters of gait. There is a common perception that males walk differently from females (4). Cho et al. (5) demonstrated that the gait speed in women was lower than men, while the stride length and step width in men was higher than in women. Al-Obaidi et al. (6) demonstrated that the gait speed, step length and stride length were greater in men than women. The men were taller than the women, and spatiotemporal variables were affected by height. Samson et al. (7) investigated the various effects of height and body weight on spatiotemporal parameters (walking speed, stride length and cadence). There were many significant factors in this study for both genders. Spatiotemporal parameters were affected in both males and females due to height differences. Stride length was influenced by body weight in women. There was no significant effect of body weight and stride length in men, and cadence was not correlated with height and body weight.

Postural stability is known as the ability of an individual to maintain an upright position under various effects from internal and external factors. There are two situations of postural stability—static and dynamic (8). Postural stability represents a coordination of functions for the trunk muscles and joints, especially hips, knees, and ankles (9). Muscle dysfunction and weak core strength can lead to poor balance performance, which can result in incorrect walking patterns (10). Gait patterns are characterized by phases of instability that allow for efficient postural stability of the body with each step (11). Ku et al. (12) studied postural stability and assessed the differences between males and females regarding postural stability. This study showed that women displayed less postural stability than men in some of the groups. Olchowik et al. (13) investigated the effect of height on dynamic parameters and demonstrated that a response of postural amplitude for lower limbs significantly depended on height.

Greve et al. (14) studied the relationship between height, weight, body mass index, gender and postural stability in young adults. Their results showed that the men presented lower stability in antero-posterior and medio-lateral stability than the women. All groups demonstrated a stronger relation for antero-posterior and medio-lateral stability indices with height, weight and body mass index (BMI). Increased body mass required greater movement to maintain postural balance. Height and BMI presented moderate correlations with balance.

Several studies have established a relationship between variables in spatiotemporal parameters and postural stability (8, 15,16). Their results demonstrated a change in step length, step width, walking speed and step frequency. Based on these differences, subjects were able to either maintain or increase their postural stability in both the medio-lateral and antero-posterior directions. Cromwell and Newton (17) studied the relationship between postural stability and gait stability in healthy older adults. Their study established a strong reverse relationship between gait stability and dynamic balance in healthy older adults. Lencioni et al. (8) investigated dynamic balance while walking and the relationship with spatiotemporal gait parameters, age, sex and anthropometry in healthy subjects. These studies demonstrated that the dynamic balance was affected by sex, age, body mass and height mainly in the antero-posterior. A strong role in stability influenced by body mass during the level of walking. Increasing gait speed, cadence and stride length led to a decrease in dynamic stability in the antero-posterior direction. A significant correlation was found with stride length, speed and step width, but not with cadence in medio-lateral stability. Dynamic balance while walking is predicted by stride length and step width. Herssens et al. (1) examined the relationship between spatiotemporal parameters and dynamic stability. They demonstrated that gender had no effect on the antero-posterior and medio-lateral postural stability. The BMI affects medio-lateral postural stability.

There are several factors that affect gait, such as age, gender, and body size. These factors play important roles in certain phases of the gait. Based on that, this study was conducted to investigate the differences and relationships between spatiotemporal gait parameters and postural stability in healthy young adults of different gender and height. This might help to improve the quality of rehabilitation programs for gait.

Materials and methods

Design and setting

A cross-sectional study design was adopted to conduct this study. This research was conducted in the main lab of Department of Physical Therapy, College of Applied Medical Sciences at Imam Abdulrahman bin Faisal University, Dammam. Participants were recruited through advertisements. Each participant came to the physiotherapy labs on one occasion for about two hours.

Ethical considerations

The approval to undertake this study was obtained from the institutional review board of the Imam Abdulrahman bin Faisal University (IRB-PGS-2019-03-255). All collected data was stored in a secure place only accessible by the researchers. Written signed consent was taken from every participant.

Sample size

The sample size was calculated using https://www.ai-therapy.com/psychology-statistics/sample-size-calculator. The total sample size was 96. This was obtained from Lencioni et al. (7). The Correlation coefficient between dynamic balance and body height was 0.33. The level of significance was (α) = 0.05, and the power was 0.8.

Participants

There were totally 96 participants (Male=65; Female=31) participated in this study. The mean age for male were of 22.63±4.74 years and female were of 22.48±4.67 years, male's height was of 170.07±6.19 cm and female's were of 158.74±6.16 cm., male weight were 71.47±12.80 kg and female were of 61.79±14.38 kg. Any participant with any types of pulmonary or cardiovascular diseases, neuromuscular diseases, any injuries to the musculoskeletal system including pain, loss of range of motion, and loss of coordination within the past year, and any condition affecting balance such as vision or hearing problems was excluded from the study.

Outcome measures

Dynamic postural stability

A stabilometer from Techno-body was used to assess postural stability in a dynamic unipedal position. The unstable platform of the device allowed participants to move in the anteroposterior (AP) and mediolateral (ML) axes. The device contains numerous sets for evaluating postural stability, and it is valid and reliable (17). For the application used to assess the dynamic postural stability, circular zones with different sizes arranged inside each other appear on the screen in front of participants. A plus sign appears inside the circles. This plus sign simulates the movement of the platform. The researcher asked the participants to maintain the plus sign in the center of the circles as much as possible for 30 seconds in each test. A unipedal dynamic postural stability assessment was performed using one level of stability (level 20, relatively middle stability). Each test was conducted on the right leg and left leg for 30 seconds. The researcher stood behind each participant to avoid falling in the event of an inability to remain stable. There were two tests for every participant.

Spatiotemporal parameters

Physilog applications from Gait Up with sensors were used to analyze and measure spatiotemporal gait parameters. These sensors were connected with the computer wirelessly. This platform is safe, reliable, low cost, and being used in different fields of study (18). Spatiotemporal data was measured using the Physilog application by Gait Up. The Physilog was used to determine the heel strike in seconds, gait cycle in seconds, total double support (%), stride length in meters, gait speed in meters per second, maximal angle in degrees per second, foot speed in meters per second, cadence in steps per minute, maximal heel clearance in meters and swing width in meters. The Gait Up sensors were fixed to both shoes and connected to the software on the researcher's personal tablet. Participants were asked to walk in an open space on a hard straightway for 30 seconds.

Procedures

The researcher performed identical testing procedures for each participant. The procedure began with an interview with each participant. They then had to read and sign the consent form, and they were free to ask any questions regarding the test. The height and weight of each participant was measured using the Detecto digital weight scale. Regarding spatiotemporal data, the Physilog application by Gait Up was used to determine the heel strike, gait cycle, total double support, stride length, gait speed, maximal angular, foot speed, cadence, maximal heel clearance and swing width. The Gait Up sensors were connected with the software on the researcher's personal tablet and tied to both shoes. Participants were asked to walk in an open space on a hard straightway for 30 seconds. Postural stability was measured using stabilometers for each participant on the right leg and left leg. Participants stood on each single leg (left and right), and platform instability was set to level 20 (relatively middle stability) dynamic stability measurements. Participants were asked to perform three dynamic tests for 30 seconds with 30 seconds of rest between each test.

Statistical analysis

The data was analyzed using IBM SPSS Statistics 26. Descriptive statistics were obtained for demographic variables. The normality test was performed using the Shapiro Wilks test and found data were not normally distributed. Non-parametric tests were used to analysis data statistically. The two-group comparison was performed using the Mann Whitney U test and the three-group comparison using the Kruskall Wallis H test. The correlation analysis was performed using a Spearman rank correlation coefficient. Statistically significant was consider at $p \le 0.05$ value.

Results

Participants characteristics

A total of 96 participants participated in this research, and among those, 65 (67.7%) were male, and 31 (32.3%) were female. The mean (SD) of age for the male group was 22.63 (4.74) years, and for the female group, 22.48 (4.67) years. The mean (SD) height for the male group was 170.07(6.19) cm, and for the female group, 158.74 (6.16) cm. The mean (SD) weight for the male group was 71.47 (12.8) kg, and for the female group, 61.79 (14.38) kg. Participants were grouped into three categories based on height (Table 1).

The results from this study revealed that the dynamic stability measures were not normal. Therefore, the non-parametric approach was used to test the hypothesis for the dynamic stability measures. There was a statistically significant difference (p=.002) between male and female groups, with antero-posterior (left) as the median (IQR) for male =.53(.34) and for female =.96(.76) (Table 2)

The results from table 3 showed that anteroposterior stability for left leg was statistically significant among the group with height (p =.001).

Table 4 reveals that a non-parametric test was applied. It was found that most of the spatiotemporal variables are significant. On the comparison between male and female, for the spatiotemporal measures, a significant difference was obtained for stride length, gait speed and maximal heel clearance.

Table 1. Frequency statistics for gender and height categories.

	Male		Female	
Height group	**N**	**%**	**N**	**%**
<=160 cm	5	7.7	20	64.5
161-170 cm	29	44.6	11	33.5
>=171 cm	31	47.7	0	0

Table 2. Statistics of dynamic postural stability in relation to gender.

		Male (N=65)		Female (N=31)		
Dynamic Stability		**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Sig.**
Anteroposterior	**Left**	0.64 (0.34)	0.53 (0.34)	1.00 (0.62)	0.96 (0.76)	.002*
	Right	0.52 (0.28)	0.45 (0.46)	0.70 (0.62)	0.51 (0.46)	.520
Mediolateral	**Left**	0.73 (0.37)	0.65 0.40	1.05 (0.70)	0.73 (1.13)	.109
	Right	0.64 (0.37)	0.58 (0.31)	0.84 (0.65)	0.70 (0.41)	.243

SD: Standard deviation; IQR: Interquartile Range; *Statistically significant at 5% level of significance.

Table 3. Statistics of dynamic postural stability in relation to height.

Dynamic Stability		<=160 cm N (25)		161-170 cm N (40)		>=171 cm N (31)		Sig.
		Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
Anteroposterior	**Left**	1.07(0.60)	1.04(0.77)	0.64(0.45)	1.04(0.39)	0.66(0.39)	0.60(0.35)	.001*
	Right	0.75(0.66)	0.54(0.56)	0.55(0.32)	0.44(0.27)	0.49(0.25)	0.42(0.29)	.289
Mediolateral	**Left**	1.08(0.69)	0.89(0.9)	0.79(.501)	0.61(0.44)	0.70(0.27)	0.65(0.34)	.125
	Right	0.85(0.53)	0.55(0.39)	0.68(0.53)	0.55(0.33)	0.64(0.28)	0.63(0.33)	.139

SD: Standard deviation; IQR: Interquartile Range; * Statistically significant at 5% level of significance.

Table 4. Statistics of spatiotemporal measures between gender.

Spatio Temporal	Foot Type	Male (N=65)		Female (N=31)		Sig.
		Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
Heel Strike	Left	1.82(2.49)	1.85(1.25)	1.87(1.32)	1.85(1.84)	0.09
	Right	1.83(1.21)	1.81(1.47)	1.87(1.52)	1.86(1.99)	0.18
Gai Cycle	Left	1.13(0.09)	1.10(0.10)	1.13(0.11)	1.10(0.15)	0.83
	Right	1.14(0.09)	1.11(0.14)	1.15(0.12	1.12(0.18)	0.93
Total Double Support	Left	20.6(3.60)	21.4(5.3)	22.10(3.63)	22.0(5.8)	0.10
	Right	20.6(3.60)	21.4(5.3)	22.11(3.63)	22.0(5.8)	0.10
Stride Length	Left	1.32(0.10)	1.29(0.15)	1.27(0.08)	1.27(1.27)	0.05*
	Right	1.31(0.09)	1.28(0.12)	1.24(0.08)	1.24(0.09)	.001*
Gait Speed	Left	1.21(0.11)	1.22(0.11)	1.14(0.12)	1.12(0.16)	.006*
	Right	1.19(0.12)	1.19(0.14)	1.12(0.12)	1.11(0.14)	.009*
Maximal Angular	Left	4.34(1.16)	4.01(7.37)	4.08(7.07)	3.94(5.55)	.552
	Right	4.15(9.05)	4.01(8.05)	3.62(0.33)	3.60(0.39)	.661
Foot Speed	Left	3.71(0.57)	3.74(0.38)	3.62(0.33)	3.62(.039)	.063
	Right	3.70(0.38)	3.70(0.07)	3.60(0.33)	3.56(0.47)	.179
Maximal Heel Clearance	Left	0.32(0.05)	0.31(0.07)	0.28(0.05)	0.27(0.06)	.001*
	Right	0.31(0.04)	0.30(0.05)	0.28(0.04)	0.27(0.05)	.001*
Cadence	Left	1.09(6.11)	1.09(7.13)	1.08(7.97)	1.08(1.27)	.742
	Right	1.09(6.03)	1.09(8.03)	1.08(7.82)	1.09(1.25)	.925
Swing Width	Left	0.04(7.82)	1.08(1.25)	0.04(0.01)	0.03(0.02)	.169
	Right	4.37(0.01)	4.45(0.02)	3.79(0.21)	3.77(0.02)	.153

SD: Standard deviation; IQR: Interquartile Range; * Statistically significant at 5% level of significance.

Table 5 showed that Significant differences were obtained for stride length, gait speed, foot speed and maximal heel clearance.

Swing width is significantly correlated with antero-posterior (r=.205, p=.045) (Table 6). It was found that there was a weak positive relationship between the heel strike and antero- posterior for the left side, foot speed and antero-posterior for right side and maximum angular with medio-lateral right side in both genders. We also found that the heel strike has a weak negative relationship with the right side for antero-posterior and medio-lateral. Similarly,

Table 5. Statistics of spatiotemporal measures in relation to height.

Spatiotemporal		**<=160 cm N (25)**		**161-170 cm N (40)**		**>=171 cm N (31)**		
Parameters	**Foot Types**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Sig.**
Heel Strike	**Left**	18.18 (3.91)	18.98 (1.96)	18.34 (1.03)	18.46 (1.38)	18.51 (1.24)	18.47 (1.17)	.207
	Right	18.84 (1.55)	18.73 (2.47)	18.31 (1.07)	18.21 (1.36)	18.23 (1.39)	18.03 (1.60)	.178
Gait Cycle	**Left**	1.13 (0.11)	1.09 (0.17)	1.12 (0 .09)	1.11 (0 .11)	1.14 (0.09)	1.11 (0.09)	.791
	Right	1.14 (0.11	1.10 (0.19)	1.14 (0.10)	1.12 (0.13)	1.15 (0.11)	1.10 (0.16)	.846
Total Double Support	**Left**	21.93 (3.35)	21.56 (5.1)	20.77 (3.87)	20.52 (6.0)	20.86 (3.66)	21.76 (5.5)	.414
	Right	21.93 (3.35)	21.56 (5.1)	20.77 (3.87)	20.52 (6.0)	20.86 (3.66)	21.76 (5.5)	.404
Stride Length	**Left**	1.24 (0.07)	1.22 (0.11)	1.31 (0.10)	1.27 (0.12)	1.33 (0.98)	1.31 (0.14)	.002*
	Right	1.23 (0.02)	1.23 (0.08)	1.29 (0.09)	1.28 (0.09)	1.32 (.09)	1.31 (0.12)	.001*
Gait Speed	**Left**	1.13 (0.09)	1.30 (0.14)	1.21 (0.13)	1.20 (0.13)	1.21 (0.11)	1.23 (0.16)	.008*
	Right	1.12 (0.11)	1.11 (0.14)	1.18 (0.13)	1.17 (0.13)	1.19 (0.12)	1.20 (0.17)	.03*
Maximal Angular	**Left**	415.98 (77.68)	403.75 (44.91)	434.83 (100.57)	409.12 (79.37)	422.58 (126.8)	385.69 (64.59)	.635
	Right	400.55 (42.44)	403.42 (62.9)	413.4 (86.53	396.57 (56.0)	417.73 (89.52)	402.67 (89.45)	.994
Foot Speed	**Left**	3.58 (.27)	3.57 (0.38)	3.70 (0.37)	3.71 (0.41)	3.73 (0.65)	3.81 (0.30)	.017*
	Right	3.59 (0.28)	3.56 (0.46)	3.63 (0.45)	3.68 (0.45)	3.78 (0.29)	3.73 (0.30)	.061*
Maximal Heel Clearance	**Left**	.29 (.044)	.283 (.05)	.306 (.05)	.29 (.07)	.339 (.045)	.32 (.06)	.001*
	Right	0.29 (0.42)	0.28 (0.05)	0.29 (.041)	0.29 (.04)	.318 (0.04)	0.31 (0.06)	.007*
Cadence	**Left**	109.3 (7.35)	109.68 (11.24)	109.23 (6.88)	108.48 (7.86)	107.82 (6.09)	108.75 (7.57)	.758
	Right	109.38 (7.32)	108.97 (12.01)	109.19 (6.88)	109.23 (8.4)	107.81 (5.74)	108.78 (8.94)	.657
Swing Width	**Left**	0.032 (0.01)	0.037 (0.02)	0.039 (0.018)	0.038 (0.02)	0.038 (0.014)	0.037 (0.03)	.394
	Right	-0.035 (.019)	-0.036 (0.02)	-0.042 (0.015)	-0.042 (0.02)	-.046 (0.01)	-.045 (0.02)	.053

SD: Standard deviation; IQR: Interquartile Range; * Statistically significant at 5% level of significance.

Table 6. Correlation between spatiotemporal parameters and dynamic postural stability.

	Anteroposterior Left		Mediolateral Left		Anteroposterior Right		Mediolateral Right	
	Correlation coefficient	Sig.	Correlation coefficient	Sig.	Correlation coefficient	Sig.	Correlation coefficient	Sig.
Heel strike left	.155	.132	.003	.975				
Heel strike right					-.144	.162	-.146	.156
Gait cycle left	.068	.509	-.180	.080				
Gait cycle right					-.054	.602	-.102	.324
Total double support left	.132	.200	.004	.965				
Total double support right					-.091	.379	.112	.277
Stride length left	-.141	.171	-.064	.535				
Stride length right					.081	.435	-.178	.082
Gait speed left	-.150	.144	-.027	.796				
Gait speed right					.087	.398	-.049	.635
Maximal Angular left	.060	.562	.120	.245				
Maximal Angular right					-.036	.725	.187	.067
Foot speed left	-.167	.103	.012	.905				
Foot speed right					.160	.120	.013	.898
Maximal heel clearance left	-.125	.225	.035	.732				
Maximal heel clearance right					.052	.616	-.108	.294
Cadence left	-.065	.530	.161	.118				
Cadence right					.049	.634	.065	.529
Swing width left	-.184	.073	-.018	.863				
Swing width right					.205	.045	.068	.512

antero-posterior stability has a weak negative relationship for stride length, gait speed, foot speed, cadence and swing width on the left side. Additionally, medio-lateral stability has a negative relationship with gait cycle on the left side and stride length on the right side.

Discussion

The aim of this study was to investigate the comparison and relationship of spatiotemporal gait parameters and postural stability in healthy young adults.

Dynamic postural stability in relation to gender and height: In relation to postural stability, this study found that the male group had higher significant antero-posterior stability than the female group. These findings of this study was disagree with a previous study (8) that found that medio-lateral stability was higher significant among males than females. The differences between the present study and Lencioni et al. (8) could be attributed to differences in the age and smaller number of the participants. The age of their participants ranged between 21 and 71 years, whereas our participants were young adults ranging between 18 and 40. In contrast, Greve et al. (14) showed that males presented lower stability indices (antero-posterior and medio-lateral) than the female. That study was different from the present study in assessing postural stability, as it evaluated static stability. However, the current study tested dynamic stability. Herssens et al. (1) suggested that there are no differences in the antero-posterior and medio-lateral between male and female. The previous study was different from the present study; the participants had a wider range of age, between 20 and 89 years.

In the current study, there was a significant difference for antero-posterior stability in the group of people with lower height when compared to the group of people with greater height. Our findings regarding antero-posterior are in good agreement with Olchowik et al. (13), who assessed the effect of height on postural stability. In that study, a greater decline in postural stability was observed in the shorter group than in the taller group. However, the results from this study disagree with the studies conducted by Ku et al. (12). This was attributed to a worse level of postural stability related to greater height. As seen in table 2, this study reveals that dynamic stability measures are not normal. Hence, a non-parametric approach was used for the hypothesis testing of the dynamic stability measures. On the comparison between the male and female group, antero-posterior (left) stability is statistically significant (p=.002). The median (IQR) was .53(.34) for males and .96(.76) for females. Antero-posterior stability is significantly high among the group with lower height (p =.001). Therefore, the present study is in agreement with previous studies in regard to dynamic stability levels in people with lower height.

There are other studies such as Ku et al. (12) and Olchowik et al. (13) that showed significant differnces in postural stability between males and females. Postural stability was tested for each participant while standing on one leg and on two legs. Females displayed less postural stability than males. However, the effect of height on dynamic stability in females was significantly high. These results agree with the current study, as people with lower height reported higher postural stability levels. Moreover, in the present study, females showed lower stability levels than males. Sarkar et al. (20) investigated the level of postural stability in male and female participants. There were differences in the level of postural stability in males and females which agreed with the current study. In contrast, King et al. (21) investigated some factors that could affect postural stability. Participants in this study were pre-pubertal males and females. The stability of the posture was assessed in both unipedal and bipedal leg stances. Their results demonstrated that there were no differences between the level of postural stability in both males and females. The present study disagreed with the previous results. This may be due to the use of both the unipedal and bipedal stability test, and the investigation of BMI in relationship to postural stability. Nevertheless, the current study used only a unipedal test.

One study was in a disagreement with the present study that demonstrated the relationship between height, gender, and postural stability in young adults (14). There were 40 participants (15 female and 25 male) with ages ranging from 20 to 30 years old. The Biodex balance system was used to examine postural stability. Results from the prior study showed that males presented with lower stability indices (antero-posterior and medio-lateral) than females. These results may be affected by the small sample size. Therefore, larger sample sizes may show different results such as results from the present study. Moreover, it is important to understand the factors that affect stability. This helps in accurate diagnoses, quality of treatment and rehabilitation (finding specific exercises), which is essential to preventing falls and disability. Height and weight variables impact the stability limits of the individual and can be affected by motor strategies relating to balance control (14).

Spatiotemporal measures in relation gender and height: Several studies (5,6,7,22) agreed with the present study. A study conducted by Cho et al., (5) demonstrated a lower gait speed in females compared to males. Males had a higher stride length and step than females Al-Obaidi et al. (6) studied the basic gait parameters in healthy males and females. Males reported greater gait speed, step length and stride length than females. This might be due to the greater height of male participants compared to female. Therefore, the spatiotemporal variables were affected by height. Samson et al. (7) investigated the effects of height on walking speed, stride length and cadence. 239 participants were examined with 118 women and 121 men in an age range of 19 to 90. This study found that height affected the differences in gait speed and stride length between young and old participants. Height had a significant effect on gait variables for both genders. Furthermore, this comes along the results of the present study, as gait was affected by height. In addition, Öberg et al. (22) reported that males had a greater gait speed, and step length than females. However, females had a higher step frequency than male. The present study also agreed with previous studies on most of the spatiotemporal variables that were significant. On the comparison between male and female for spatiotemporal measures, a significant difference was obtained for stride length, gait speed and maximal heel clearance.

Spatiotemporal parameters in relation to dynamic postural stability: In this study, it was found that swing width is significantly correlated (r=.205, p=.045) with antero-posterior stability; as the swing width increases, dynamic stability decreases. However, there is no study that found the same relationship. Several studies (17, 23, 8, 24) reported that there is a relationship between postural stability and spatiotemporal variables. However, Cromwell, Newton, (17) and Guffey et al. (23) evaluated postural stability by using the Berg balance scale, and their participants were children and older age people respectively. Likewise, the participants in Lencioni et al.'s study (8) had a wider age range of 21 to 79 with a small sample size. Also, McAndrew Young and Dingwell (24) assessed the statiotemporal parameters during walking on the treadmill. The participants in our study were young adult males and females. Based on table 6, the swing width was significantly correlated (r=.205, p=.045) with antero-posterior stability. A weak positive relationship was found between the heel strike and antero-posterior for the left side and the foot speed and antero-posterior for the right side and maximum angular with medio-lateral right side in both genders. We also found that heel strike has a weak negative relationship on the right side for antero-posterior and medio-lateral. Similarly, antero-posterior stability has a weak negative relationship for stride length, gait speed, foot speed, cadence and swing width on the left side. Additionally, medio-lateral stability has a negative relationship with gait cycle on the left side and stride length on the right side.

Based on the previous findings (17, 23, 8, 24), we understand that there is a contradiction in the results of some studies about the relationships between variables in spatiotemporal parameters and postural stability. However, the present study revealed only one relationship in swing width with antero-posterior postural stability. This result was not found in other studies. Therefore, this result could be investigated in future research. In contrast, the results of other studies as stated above showed changes in step length, step width, walking speed and step frequency. These differences may help individuals to maintain or increase postural stability in both the medio-lateral and antero-posterior directions. Moreover, several outcome measures were used in various studies. For instant, the Berg balance test was used to examine stability in individuals. This test also helps to analyze gait. Another device - the Mac Reflex motion analysis system was used to collect sagittal-plane data with a single camera. Moreover, the GAITRite system was used to record the spatiotemporal parameter in addition to the use of the Berg balance test. However, in the present study, the Gait Up device and the Stabilometer from Techno-body were used to measure spatiotemporal and postural stability. This might be one reason for the contradictory results between studies from the literature and the present study.

There were some limitations in the present study as well in previous studies. For example, some studies used wider age range,such as Lencioni et al. (8), but a small sample size, but in present study the age ranged was 19-25 years. The results from that study could not be generalized. On the other hand, most of the participants for this study was overweight, study did not include heights above 185 cm. In addition, we did not measure bipedal postural stability. Hence, further studies should include wider age ranges, heights, and more comprehensive measurements. Another limitation, the used stability level, was in the middle range for a unipedal test. However, there are several stability levels that could challenge participants' postural stability. Thus, more outcome measures and different stability levels should be used to find more accurate results that may help to improve the quality of rehabilitation programs.

Conclusion

In this study, we set out to assess the differences and relationships between spatiotemporal parameters and dynamic postural stability for different genders and height groups. The findings of this research showed several significant results in different spatiotemporal gait parameters, but these results are totally belong to present research's sample not to the any specific population. Based on these results, gait rehabilitation programs can be modified to improve gait parameters in all conditions. However, further studies should investigate larger sample sizes, different categorical variables, different populations, and other gait parameters using different outcome measures and devices.

Ethical Approval: The approval to undertake this study was obtained from the institutional review board of the Imam Abdulrahman Bin Faisal University (IRB-PGS-2019-03-255).

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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Received: 21 August 2022
Accepted: 29 January 2023
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