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Analysis of Basic Spatial Gait Parameters in Laboratory

Shehla Inam[1] and Muhammad Waqar[2]

Abstract:

Human gait is performed by the locomotion of the lower limbs. The basic spatial parameters of gait cycle were measured in laboratory for the young healthy subjects including 13 females and one male in two conditions i.e. barefoot (assuming healthy gait) and wearing only one shoe (assuming unhealthy or compensated gait). The comparison between the two conditions was studied for the average values of step length, stride length, base of support and step width. Also, the standard deviation and coefficient of variance were calculated individually for each parameter of healthy subjects. The average values of the initial three parameters were greater for the healthy subjects while the fourth parameter calculated was greater for the unhealthy subjects.

Keywords: *Basic gait parameters; gait analysis; spatial gait parameters; gait laboratory* ***studies***

1. Introduction

A gait cycle is the time period during which one of the legs is initially in contact with ground and after going through seven events of locomotion starting with initial contact, comes back to its initial position [3]. The gait analysis of a patient could help in revealing certain biomechanical problems which could be cured either through medical equipment, physical therapy or surgery. Also, this includes the neural and muscles pain [12] Rehabilitation plays and important role in coping up the injuries that are encountered in sports. Rehabilitation process involves certain steps designed in [2]. Tommy Oberg et.al studied the basic gait parameters of 233 subjects in a 5.5 m long gait laboratory including both men and women. The parameters were measured for the slow, medium and fast gait. They found the significant age-variability in walking speed and step length for normal and fast gait and the effect of age and sex for normal and fast gait [1]. M.M. Samson et.al investigated the effects of age, weight and height on the normal walking speed of the healthy subjects including both men and women. They used certain devices such as Kistler force plates for cadence measurement, an infrared reflecting system for measuring the walking speed and the stride length via the formula. They concluded that cadence did not depend upon the age, weight and height while the stride length and walking speed reduced with the age [4]. Emily A. Ready et.al investigated the effects of auditory cues on the gait of healthy

[1] Department of Biomedical Engineering, Riphah International University, Islamabad, Pakistan
[2] Department of Biomedical Engineering and Sciences, National University of Sciences and Technology Islamabad, Pakistan
*Corresponding Author: shehlainam10@gmail.com

subjects depending on their ability of beat perception while following certain conditions. Thus, the spatiotemporal gait parameters were influenced when walking to music- and metronome-based rhythmic auditory stimuli [5]. In [6], the relationship between two gait parameters i.e. in-laboratory gait speed measured through pressure sensor of a sheet-type and daily gait speed via accelometer was investigated among the older subjects. The relationship between both parameters was found out to be low, However, the average daily gait speed was significantly lower than average in-laboratory gait speed. Claudiane A.Fukuchi and MarcosDuarte proposed a simple method to predict the gait pattern of the subjects based on their speed by creating a reference database consisting a range of gait speeds and predicted database for gait pattern. Thus, the predicted data was the same compared with the experimental measures for the joint angles and joint moments [7]. Pierre Martz et.al assessed the influence of body mass index on the gait parameters of the patients including both obese and non-obese patients suffering from total hip anthroplasty before and after the six months of surgery. The patients had shown a significant functional improvement regardless of BMI [8]. Roth et.al studied the relationship between the spatial parameter i.e. speed of walk and the 18 temporal parameters among the patients of one-month hemiplegia. The experiment was performed with the help of footswitches connected to portable device. The speed was found to be corelated with most but not all the temporal parameters [9]. In [10], the authors studied the difference in the biomechanic parameters among the healthy and the moderate and chronic osteoarthritis patients. They concluded that the knee osteoarthritis patients showed results such as lower knee and ankle joint moments, ground reaction forces, knee reaction force and knee excursion on desired speed. There was decreased knee joint excursion for all conditions during analytic differences in walking speed. M.Ambrus et.al analyzed the difference in the stride length-cadence relationship among fifteen patients of Parkinson's disease and fifteen age-matched subjects both on treadmill and overground through linear regression. It was observed that the treadmill had positive impact on the gait of patients of Parkinson's disease [13]. The differences in kinetic and kinematic were studied during the landing mechanics of a single leg drop jump between an athlete suffering from no ACL injury history in their past and an athlete who suffered from the ACL reconstruction surgery. The latter had low range of their hip, ankle and knee motion in two planes i.e. sagittal and frontal during a single drop jump and had relatively higher ground reaction forces [14].

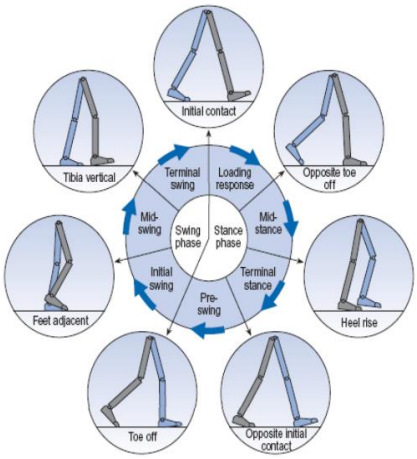

Fig. 1 Seven Events of Gait Cycle

2. Methodology

2.1. Subjects Recruitment

The seven parameters of gait of 14 subjects including 13 females and one male of age (21.38±1.64), weight (56.57 ±10.03) and height (64.92″±3.53) were measured and studied. The experiment was performed with the consent of subjects in the laboratory of Department of Biomedical Engineering, Riphah International University, Islamabad.

2.2. Measurement of Parameters

The parameters that were measured included step length, step width, stride length, base of support, stride length/ length of lower extremity and cadence. The study was undertaken in such a way that the subjects were asked first to perform the gait barefoot.

This was assumed as a healthy gait. Next, they were asked to perform an unhealthy or compensated gait. This was done by wearing one shoe in one foot and the other left barefoot. This gave an expression of a compensated gait because of the difference in the height of both feet and also the change in their gait was observed. All the desired parameters were measured with the help of a long scale of 100 centimeters and a stop watch was used to calculate the cadence. In cases, where the measurements exceeded 100 centimeters, a point was marked, and the measurements were added by putting the scale on the marked point and re-measuring from the initial value of the scale i.e. 1 centimeter. The comparison between the assumed healthy and unhealthy subjects was studied only for four parameters i.e. step length, stride length, base of support or walking base and step width. After measuring each parameter of all the subjects, the average, standard deviation (St.Dev.), and coefficient of variance (CV) for each parameter were calculated as shown in table II.

Table I: Gender information of each subject

Sr.No.	Gender	Age	Height	Weight	Dominant Leg	History of Injury	If flat foot	Family History
1	female	22	5'3"	53	right	no	no	diabetic
2	female	22	6.0'	70	right	no	yes	diabetic
3	female	22	5'8"	49	left	no	no	no
4	female	22	5'3"	58	right	no	yes	diabetic
5	female	22	5'3"	56	right	no	no	diabetic
6	female	21	5'2"	46	right	no	no	no
7	female	21	5'3"	72	left	no	no	diabetic
8	female	22	5'7"	50	right	no	no	no
9	female	21	5'3"	80	right	no	no	no
10	female	23	5'5"	50	right	no	no	no
11	female	24	5.2'	60	right	no	no	no
12	female	23	5'0"	50	right	no	no	no
13	female	18	5'6"	48	right	no	no	no
14	male	18	6.0'	50	right	no	no	diabetic

2.3. Gender Information

Before carrying out experiment, the basic information including the gender, height, weight, dominant leg, history of injury, flat footness and family history of each subject was recorded as shown in table I.

3. Results and Discussion

The parameters for the healthy gait of the subjects that were measured are shown in table II.

Table II: Measured parameters of healthy subjects

Sr.No.	Step L (cm)	Stride L (cm)	BOS (cm)	Step W (cm)	Cadence (steps/min)	SL/LEL	Speed (cm/s)
1	58.2	85	22.5	8	82	0.6	79.5
2	62.1	96.2	24.75	14.5	35	0.96	36.2
3	59.9	92.5	22.5	5.6	76	0.94	75.8
4	40.6	86.3	23.8	4.8	105	0.9	71.1
5	39.5	82.3	24.9	3.3	101	0.83	66.5
6	36.1	80.8	22.4	2.54	114	2.3	68.6
7	48.4	121.9	23.4	5.08	273	3.12	220.2
8	59.7	120.6	23.1	2.54	240	3.12	238.8
9	51.3	107.4	24.1	3.81	20	0.6	17.1
10	12	45	22.1	8.5	38	0.48	7.6
11	16	78	26.1	5.5	108	0.85	28.8
12	41	81	24.5	10	78	0.96	53.3
13	52	89	23	15	70	0.76	60.7
14	74.5	137.5	22.8	25	110	1.50	136.6
Average	**46.5**	**93.1**	**23.6**	**8.2**	**103.6**	**1.2**	**46.5**
St.Dev	**17.4**	**23.0**	**1.2**	**6.3**	**71.5**	**0.9**	**17.4**
CV	**37.3**	**24.7**	**5.0**	**77.1**	**69.1**	**73.6**	**37.3**

Likewise, the parameters for the unhealthy gait that were measured are shown in table III.

3.1. Step Length

The step length is the distance covered by one right and left leg as shown in Fig. 2. The subjects were asked to only take a step and stand on the same position. Initially, the value was measured by standing barefoot. Next, each subject was asked to wear a shoe only in one foot and the other foot bare which depicted as the compensated or unhealthy gait. Hence, in both cases, the values were measured with the help of a long scale in centimeters from the heel of trailing foot to

the heel of leading foot. The average of the values obtained is shown in Fig.3

Table III: Measured parameters of unhealthy subjects

Sr.No.	Step L (cm)	Stride L (cm)	BOS (cm)	Step W (cm)
1	34.6	76.4	23	13.9
2	60	118.5	25.5	15
3	64.5	82.5	23	9.5
4	41	87	24.2	5.1
5	41.3	83	25.5	4
6	44.4	93.9	2.6	5.6
7	56.1	117.1	25.6	4.8
8	56.9	119.3	23.1	2.5
9	48.3	104.1	24.1	3.2
10	9.8	19.5	12	19
11	35	69.5	22.5	9.2
12	36	97	26.6	12
13	47	67	23.2	12
14	56	130	23	24
Average	45.1	90.3	21.7	10.0
St.Dev	14.0	28.4	6.5	6.4
CV	31.2	31.4	29.9	64.2

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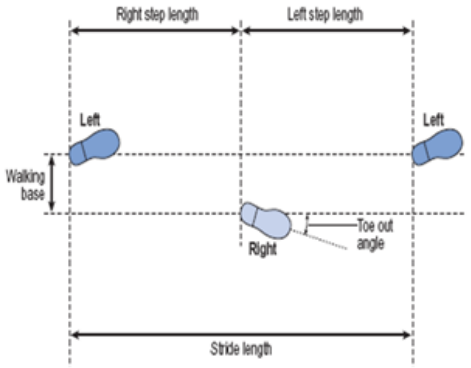

Fig. 2: Walking base (BOS), Step Length and Stride Length [3]

The Fig. 3 shows that the step length of the healthy subjects i.e. having worn no shoes had a greater step length as compared to those wearing only one shoe. This could be because the muscles of the healthy subjects were more active and felt no hindrance in performing the step because of greater stability. However, the unhealthy subjects did require taking relatively smaller steps to not losing their balance.

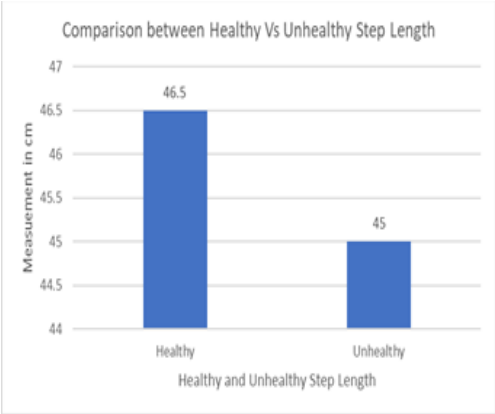

Fig 3: Healthy Vs Unhealthy Step Length

3.2. Stride Length

The stride length is the distance covered by two consecutive steps as shown in Figure 3. Each subject was asked to firstly, take steps barefoot and next time, take steps while wearing only one shoe. Thus, the values were measured with the help of a long scale in centimeters by measuring the distance from the heel of the already heading foot when one step was taken previously, and to the heel of the foot which was brought ahead of it to take another step. The average of the values is shown in Fig. 4.

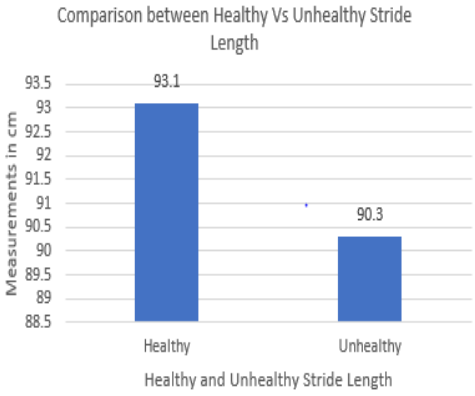

Fig 4: Healthy Vs Unhealthy Stride Length

From Figure 4, it can be observed that the stride length of the healthy subjects was

greater as compared to that of unhealthy subjects due to covering a large distance and taking longer steps. Their muscles had more control in maintaining stability and performing stable steps.

3.3. Base of Support or Walking Base

The base of support as shown in Figure 2 is actually the area covered by the whole length of the foot. Hence, it was measured by measuring the length of the foot with the help of a scale in centimeters by placing both the feet still. The average of the values of the base of support obtained for both cases i.e. healthy (barefoot) and unhealthy (one foot with shoe) is shown in Fig. 5.

Fig. 5 shows that the base of the support for the unhealthy subjects is smaller than those of healthy subjects. It may be because the subjects with abnormal gait require greater stability to stand on their feet as compared to those with a normal gait.

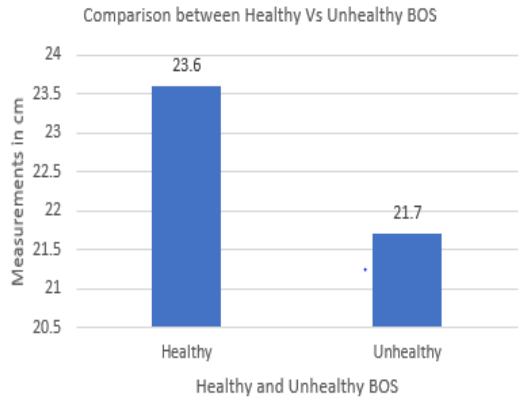

Fig 5: Healthy Vs Unhealthy Walking Base

3.4. Step Width

The step width as shown in Figure 6 is the horizontal distance between the two feet while taking a step. Thus, it was measured by measuring the distance horizontally from the heel of the leading foot to heel of the trailing foot in both cases i.e. healthy and unhealthy gait. The Figure 7 shows the average values of the step width for both cases.

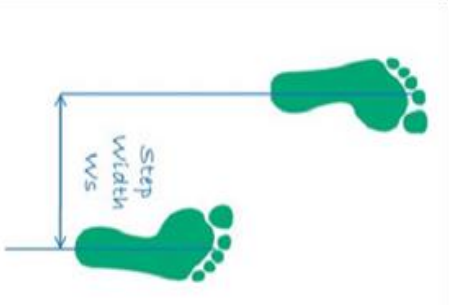

Fig 6: Step Width [11]

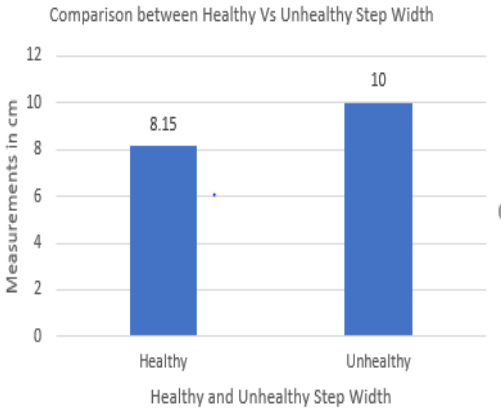

Fig 7: Healthy Vs Unhealthy Step Width

It can be observed from the Figure 7 that the average value of step width of unhealthy subjects is relatively greater than those of healthy subjects. This may be because they require greater step width to increase their balance and stability.

However, the other parameters i.e. cadence, and the ratio stride length/ lower extremity were not measured for the unhealthy condition of the subjects.

3.5. Cadence

Cadence is the number of steps taken in one minute. Thus, the healthy subjects were asked to perform the gait barefoot in their normal speed in one minute. The values were recorded with the help of a stop watch which are shown in table II. However, cadence of the unhealthy subjects was not calculated.

3.6. Stride Length/ Lower Extremity Length (SL/LEL)

The lower extremity's length was measured by tape measurement from greater trochanter to lateral maleollus. Thus, the ratio of SL/LEL was calculated for the healthy gaited subjects as shown in table II. The average value calculated is 1.2±0.9.

3.7. Speed

The walking speed of the healthy or barefoot gait of the subjects was measured by formula,

Speed= Step Length Cadence*

The values calculated for the speed could be observed in table II. The average value for the speed of healthy gaited subjects calculated is 46.5±17.4.

4. Conclusion

The basic gait parameters play a vital role in the overall gait performance of a person. Thus, an experiment was carried out to study the basic spatial parameters of the healthy subjects in two conditions i.e. once barefooted and next wearing only one shoe assuming it as compensated gait. The parameters such as step length, stride length and base of support of the healthy gaited subjects were greater as compared to that of unhealthy gaited subjects. However, the step width of the unhealthy gaited subjects was greater. Moreover, the other parameters i.e. cadence, SL/LEL and speed were measured only for the healthy subjects. The studies on these parameters for the compensated gait could play a vital role in the future research.

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