Kinematic analysis of human gait cycle

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Abstract:
Kinematic system is used in gait analysis to record the position and orientation of the body segments, the angles of the joints and the corresponding linear and angular velocities and acceleration. Gait analysis is used for two very different purposes to aid directly in the treatment of individual patients and to improve our understanding of gait through research. The purpose of the study is to show an ideal kinematics appearance of human gait cycle for walking in order to get measurement values that can be depended on in the hospitals of rehabilitation, the centers of physical therapy and the clinical of medical sports as a reference data for kinematic joint parameter. In this study, 20 subjects and one abnormal subject (undergoes foot flat) were selected from the society; the 20 subjects were not to have any pathology that would affect gait and had to be unfamiliar with treadmill walking, then a video recording was made for them by using a single digital video camera recorder fitted on a stand of three legs in a sagittal plane while subjects walked on a motorized treadmill one by one, the treadmill is often used in rehabilitation programs because it allows standard and controlled conditions and it needs small space. Then by special motion analysis software (Dartfish) was used to study the knee and hip joint kinematics and the spatial –temporal gait parameters (step length, stride length, stride duration, cadence) from the video recording. Results obtained from the Dartfish program are important in understanding that the knee and hip angles differ in each gait cycle, similarly to spatial- temporal parameters, the spatial- temporal parameters differ in each gait cycle analyzed for subjects.

Keywords: kinematic analysis, treadmill, gait cycle, Dartfish, gait analysis

Introduction

Gait analysis can be described as a field of biomechanical engineering dealing with the subject of human locomotion. By means of different measuring techniques available (for example video recording), human gait data are captured (i.e. the gait pattern is recorded as a function of time) and further analysis and calculations are done in order to obtain all the data required for evaluating the quality of the subject's gait, including basic gait parameters (stride length, cadence, velocity, etc.) joint angle during each gait cycle [1].

Walking is one of the most common and most important forms of human movement. Gait analysis entails measurement, analysis and assessment of the biomechanical features that are associated with the walking task [2].

Since the measuring and recording techniques for capturing gait patterns have developed very much in the last decades, gait analysis is now frequently used in every-day practice of those involved in the rehabilitation of human

movement. Therefore gait analysis has its applications now in almost all considerable fields of human locomotion, both healthy and pathological: rehabilitation medicine, orthopedics, kinesiology, sports science, and other related fields [1].
In general, gait analysis is considered an acceptable tool for kinesiology analysis of movement disorders, including for evaluating gait and posture disturbances. The use of gait analysis to evaluate and treat musculoskeletal disorders (e.g., polio, muscular dystrophy, amputation, osteoarthritis, trauma) and neurological disorders (e.g., cerebral palsy, stroke, brain trauma) is arguably the area where the best examples to date of the positive uses of improved gait analysis techniques and technology can be seen. There are now gait analysis laboratories in a number of hospitals in most developed countries. Most of these facilities have now examined the pathological gait of thousands of patients and used this information to direct their surgical, orthotic and therapeutic intervention. Gait analysis has not only altered overall treatment philosophies but has prompted modifications to surgical techniques [2].

Aim of the Study

The purpose of the study, is to show an ideal kinematics appearance of human gait cycle for walking in order to get measurement values that can be depended on in the hospitals of rehabilitation, the centers of physical therapy and the clinical of medical sports, instead of depending on the measurement values that are dependent on the development countries for the same movement. If gait analysis is used for evaluation of disabled people, a comparison must be made with the data from healthy people. This study provides such normative data for joint angle parameters. Special motion analysis software (Dartfish) is used to get the kinematics and temporal – spatial parameters values from the video recording of subjects while walking on the treadmill device. The analysis used done to prove that joint angles, step, and stride length, stride, time, cadence; angular velocities differ in each gait cycle analyzed for one subjects.

Subjects

The study was made on 20 able-bodied volunteers (male) and one subject abnormal (undergoes foot flat); the average age was 21.7 ±2.515years; the mean weight 70.975 ±7.87kg; and the mean height 178.45 ±7.24cm. Subjects wore shorts, shirt, and training shoes. The subjects were in good health, with no conditions that affected their gait pattern or tolerance to the evaluation 45 protocol. Subjects were not to have any pathology that would affect gait and had to be unfamiliar with treadmill walking. While the subjects were few, previous work used small groups for within-subject analysis and found appropriate significance. A limiting factor for the used pool of able-bodied volunteers was resource-related.

Instruments and Equipments

Digital Video Camera

Two-dimensional motion was obtained by using a single digital video camera recorder, this camera gives 25 frames per second, it contains video compression format [MPEG2/JPEG] (still images), recording time [approximately 650 minute]. Have a hard disk [30 giga byte], Handy cam station and USB cable to transport the recording videos from the hard disk by connecting it to the computer. The camera is fitted on a stand of three legs then located perpendicular to the line of progression as subjects walked, the camera is fitted at high (1.5) m and the distance of the camera from the center of the trajectory line of the subject on the treadmill is (3.90) m.

Treadmill Device

Treadmill is often used in the research projects to simulate over ground locomotion, assuming that locomotion is similar on a treadmill and over ground [3]. Subjects walked on a motorized treadmill. Subjects were instructed to walk on the treadmill without using handrails and they were asked to walk as they normally would while keeping each foot on a separate belt. All subjects were tested in one session. The speed of treadmill is 5 km/h (1.38889 m/s) where data was collected from all subjectsm no other instructions or external pacers were used to avoid artificially setting the participant's cadence or stride length. Data were collected when each subject had reached a steady state of being able to replicate the walking speed, consistently data were obtained from the right side of each subject. The treadmill was used to be allowing for recording multiple gait cycles, and the statistical analysis of the disturbances. Walking can be performed any time, under any weather, and with more general safety than over ground walking, especially in urban environments. Moreover, the treadmill is often used in rehabilitation programs because it allows standard and controlled conditions and it needs small space.

Data Analysis

After the video recording of the subjects movements has been made, the video files transferred from the camera to the computer through the USB connection, then Dartfish programs is used to get the diagrams of stick figures that represent the angular changes at the hip, knee joints then a graphical representation for its knee, hip angles is done by using Matlab program, then the Spatial - temporal variables (step, stride length and the stride time) measured during all phases of gait cycle (each phase contain number of frames), By selecting the analyzer from the main toolbar to open it, and then the clip found in the tray is dragged and dropped in the window of the analyzer to work on it by using the drawing toolbar.

Results and discussion

The following steps are done by using Darfish program:

Measurement of the Hip Angle (Normal)

The hip angles from six complete gait cycles for one subject (normal) were measured as shown in (Fig.1- 4) and one example was shown in (Table 1). The graphical representation of the hip angles is given in the (Fig .9).

From the graphical representation of one normal subject at the hip (six complete gait cycles) there is a single peak of flexion and extension in each cycle. The hip extends during the stance phase, and then starts to flex at about heel strike for the other leg, continuing flexion through the swing phase. The range of hip flexion/extension increases with stride length; the increase is mainly in flexion, since the hip will not extend more than about 30 degrees.

At the hip, there are only two movements in the step cycle, and both are active. That is, the hip flexors (ilipsoas) produce flexion, and the extensors produce extension [4]. From (Fig.9) at initial contact, mean hip flexion is approximately 20 degree, while mean hip flexion in swing (midswing) is 26 degree. In late stance, maximal hip extension is 4.5 degree [5].

Measurement of the Knee Angle of the Right and Left Legs (Normal)

The knee angles of the right and left legs from six complete gait cycles for one subject (normal) were measured as shown in (Fig.1-4) and one example is shown in (Table1). The graphical representation of the knee angles of the right and left legs is given in the (Fig.10-11) respectively.

From the graphical representation of the one normal subject at the knee (six complete gait cycles) two peaks of flexion- a small one in the stance phase, where the knee yields to flatten the path of the C.G., and a second, larger peak which allows the foot to clear the ground (since the hip is tilted down about 5 degrees on the swing side). The flexion in stance phase increases with walking speed. The flexion in the swing phase is followed by an extension which ends just before heel contact [4]. From (Fig.10) knee flexion of the right leg in early stance shows a typical 2 degree flexion/extension pattern during loading, mean knee flexion in midstance approximately 20 degree, mean knee flexion in swing reached a peak of 70 degree [1]. From (Fig. 11) Knee of the left leg shows large peak of flexion in early stance at a typical 5 degree mean knee flexion in midstance reaching a peak of 72 degree, in the second small peak of flexion (swing) mean knee flexion reached a peak of 25 degree in midswing.

The knee angle is not zero at extended legs, at heel-up phase of gait, because the knee angle models also the anatomical angle between the femur and the tibia in frontal plane. Knee angles of the gait cycle play a major role with regard to the energy expended during walking and are commonly affected by pathological disorders [1]. Maximum knee flexion angle is with greater values in the treadmill walking. When all subjects are compared, significant increases are seen during treadmill walking in hip range of motion, maximum hip flexion joint angle and cadence, while a significant decrease is observed in stance time [7]. To conclude the subject is normal (standard) since his results and graphics agree favorably with that found in the previous research [1, 3, 5, 6].

Measurement of the Hip Angle (Abnormal)

The hip angles from six complete gait cycles for one subject (abnormal) (undergoes foot flat) were measured as shown in (Fig.5-6) and one example is shown in (Table 2). The graphical representation of the hip angles is in (Fig12).

From (Fig.12) the first heal contact hip flexion is approximately 16 degree. During loading mean hip flexion is 30.5 degree, while in late stance maximal hip extension is 6 degree in midswing mean hip flexion reaching 19 degree, the stance phase represents 45% of the gait cycle, and swing phase represents 55%, in this subject the graphical representation showed another peak of extension (very small) in the swing phase reaching maximal peak at 12 degree. From the stick figures of the abnormal subject, the phase of initial contact is much smaller at some cycles and disappears in the other cycles and as mentioned in the condition of initial stance in chapter three, the foot here doesn't touch the floor at the heel, and the other leg not at the end of terminal stance .The loading response phase is too long, at the stick figure of the mid stance phase (Fig.5) the other leg is not in mid swing phase but still in contact with ground at all the phase until reaching the terminal stance phase (Fig.6) where the heel of other leg doesn't hit the ground but the foot is found completely on the ground (foot flat), and also at the terminal swing phase. So from that it is concluded that one leg is under the condition of the phase. But the other leg is not.

Measurement of the Knee Angle of the Right and Left Legs (Abnormal)

The knee angles from six complete gait cycles for one subject (abnormal) were measured as shown in (Fig.5-6) and one example is shown in (Table 2). The graphical representation of the knee angles of the right and left legs is given in (Fig.13 and 14) respectively.

From (Fig.13) knee of the right leg shows two peaks of flexion small peak (stance phase) and large peak (in swing), at initial heal contact knee shows atypical flexion at 5 degree, in mid stance the mean peak of knee flexion 30 degree, during mid swing mean peak of flexion is approximately 60 degrees, Stance phase represents 50% of the gait cycle. From (Fig.14) knee angle of the left leg shows at initial contact 12 degrees flexion/extension pattern and decreases to 8 degrees during loading response. In mid stance maximal peak of flexion is approximately 69 degrees. In swing phase the peak of flexion (very small) has maximal peak at 19 degrees, it is very rapid. At the end of swing phase the knee of subject shows very small peak of extension reaching maximal peak at 3 degrees that means there is a problem, stance phase represents 50% of the gait cycle.

Measurements of the Hip and Knee Angles of the Right and Left Legs for 20 Subjects

The knees, and hip angles for each subject from three complete gait cycles were measured and one example at initial contact is shown in (Tables 3). For each subject, knee angles was calculated at four positions including initial contact, mid stance, and peak values of extension and flexion. Mid stance is defined as the point when the knee joint has attained maximum flexion after initial contact; hip angle is calculated at the same four positions. The hip and knee angles differ in each gait cycle, similarly to spatial-temporal parameters and differ also in one subject [1].

Measurement of the Hip and Knee Angular Velocity

The knees, and hip angular velocity for one subject from six complete gait cycles were measured as shown in (Fig.7-8) and one example is shown in (Table4). The graphical representation of the hip and knee angular velocity is in (Fig.15 and 16) respectively. From (Fig.15) initial contact mean hip flexion is approximately 4800 deg/sec, while mean hip extension in mid stance is 1500 degree/sec, in late stance hip flexion approximately 2600 degree/sec, mean hip extension in swing 1400 degree/sec. From (Fig.16) knee flexion in early stance shows a typically 5100 degree /sec flexion /extension pattern, during loading mean knee extension in mid stance 1800 degree/sec, maximal knee flexion in swing phase reaches a peak 5400 degree/sec.

Measurement of the Spatial – Temporal Parameters

The step, and stride length from three complete gait cycles for each subject were measured and one example is shown in (Table 5), and the bar charts of the stride length and the stride time are shown in (Fig 17, and 18). (Fig.19) shows, an example, the stance, swing and double support phases for one subject steps.

The stride analysis variables most commonly used to describe a gait pattern:

• Step length is the distance between the point of initial contact of one foot and the point of initial contact of the opposite foot. In normal gait, right and left step lengths are similar.

• Stride length is the distance between successive points of initial contact of the same foot. Right and left stride lengths are normally equal.

• Cadence or walking rate is calculated in steps per minute [1, 3].

The spatial - temporal variables (step, stride length and the stride time) differ in each gait cycle analyzed for one subject and for each gait cycle for the other subject. Step length of the right step (CV =37.37001 %) is greater than those of the left (CV =37.1194%) [3]. (Fig. 5.19) shows that the stance , swing, and double support phases differ in each gait cycle analyzed for one subject, the stance phase represents (62%-68%), the swing phase represents (32%-38%), and the double support phase which is the shortest one represents (12.26%-17.86%) of the gait cycle. Speed of walking does not influence step kinematic variability since is constant. According to Owings TM, Grabiner MD. The primary independent variables is the variability of step length, step width, and step time. Walking velocity does not influence step kinematic variability. Handrail usage influence the variability of step length, but not of step time. The accuracy of step variability is estimated proportional to the number of steps that are collected. The use of an instrumented treadmill allows simultaneous collection of spatial and temporal step kinematics for a large number of continuous steps [8].

Statistical Analysis (AV, SD)

Table (6) shows the average and the standard deviations of parameters (knee, hip angles, angular velocity, stride time, step and stride length, cadenace) for each subject from three complete gait cycles. These parameters agree with these of past research [1, 3, 5, 6].

Conclusion

1-This new motion analysis software can be used in the investigation of professional athletes; on the basis of these measurements the doctors and the athletes can get useful information about training design.

2-There is small differences were found between the left and right sides of one subject, and between these values of subjects.

3-These results establish that the step length of the right step is greater than those of the left step.

4-The spatial- temporal parameters differ in each gait cycle analyzed for one subject and also these parameters differ between subjects.

5-Knee and hip angles differ in each gait cycle, similarly to spatial- parameters.

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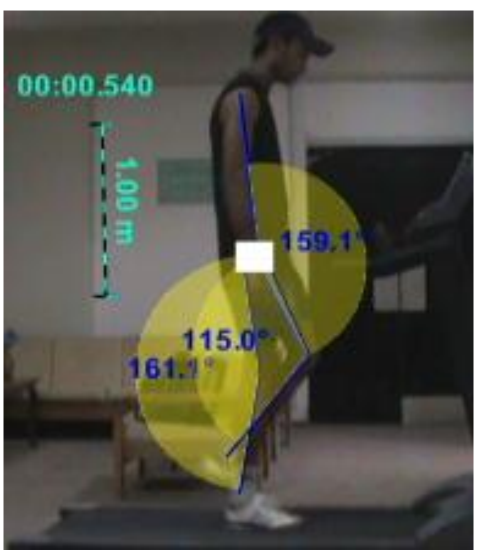

Fig.1 Loading response phase (gait cycle 3)

Fig.2 Midstanc phase (gait cycle 3)

Fig.3 Initial swing phase (gait cycle 3)

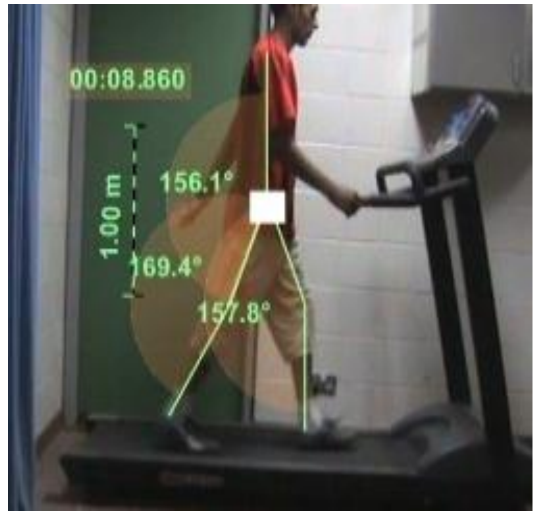

Fig.5 Midstancephase (abnormal) (gait cycle 6)

Fig.4 Terminal swing phase (gait cycle 3)

Fig.6 Terminal stance phase (abnormal) (gait cycle 6)

Gait cycle3	hip angle (degree)	back knee angle (degree)	front knee angle (degree)
Initial contact	161.8	179	179.8
Initial contact	158.7	178.9	178.1
Initial contact	160.1	179.6	178.1
Loading response	159.9	160	166.3
Loading response	158.1	156.8	159.7
Loading response	158.1	142.1	153.6
Loading response	158	132.6	150.5
Loading response	163.3	134.4	151.1
Mid stance	168	123.5	157.3
Mid stance	162.1	110.9	153.1
Mid stance	166	120.7	147.3
Mid stance	154.8	101.6	166.2
Mid stance	167.7	110.8	147.9
Mid stance	170.4	109.5	156.7
Mid stance	170.6	121.2	157.6
Mid stance	176.5	126.7	170.7
Mid stance	178.3	138.1	136.7
Terminal stance	176.4	145.3	170.7
Terminal stance	169.9	162.1	179.5
Terminal stance	173.1	177.7	166.8
Terminal stance	173.1	159	159.8
Toe off	174.1	158.9	157.9
Toe off	176.7	144.5	144.5
Toe off	176.1	145.3	132
Initial swing	153.4	149.1	111.6
Initial swing	160.7	154	109.9
Initial swing	160.5	150.5	101.8
Mid swing	163	144.8	105.2
Mid swing	162.2	171.9	118.3
Mid swing	158.4	178.4	129.5
Mid swing	147.9	169.6	133.3
Mid swing	154.5	177.3	166.8
Terminal swing	164.7	177.9	179.9
Terminal swing	160.1	176.9	179.8

Fig.7 Midstance phase (gait cycle 1)

Fig.8 Initial swing phase (gait cycle 1)

Table (1) Normal Subject, Gait Cycle 3, Relative Angular Displacement

Table (2) Abnormal subject, gait cycle 4, relative angular displacement

Gait 4	Hip angle (degree)	back knee angle (degree)	front knee angle (degree)
Loading response	160.4	172.7	160.4
Loading response	150.2	178.1	150.9
Loading response	154.4	169	161.5
Loading response	150.2	152.4	152.7
Mid stance	159.2	150.7	151.3
Mid stance	159	119.3	148.9
Mid stance	173.3	115.1	149.5
Mid stance	175.6	133.2	162.6
Mid stance	178.5	117	156.9
Mid stance	153.1	123.8	156.4
Mid stance	169.6	133.6	167.8
Terminal stance	155.5	136.5	175.4
Terminal stance	161.3	144.7	174.3
Terminal stance	161.3	153	175.7
Terminal stance	160.7	160.4	171.7
Toe off	159.2	161.6	178.7
Toe off	157.5	157.5	180
Toe off	158.2	152.8	163
Toe off	168.4	156.3	163.4
Toe off	170.6	165.4	138.4
Initial swing	169.5	160.8	108.4
Initial swing	168.3	166.8	110.4
Mid swing	170	163.8	114.7
Mid swing	158.4	166.2	106.1
Mid swing	161.8	170.8	116.9
Mid swing	162.7	158.1	129.3
Mid swing	154	179	129.3
Mid swing	159.7	179.6	140.4
Terminal swing	152.1	172.1	142.2
Terminal swing	161.5	164.5	157.2
Terminal swing	158.9	177.6	158.7
Terminal swing	152.5	169.7	155.2

Table (3) 20 subjects, gait cycle ,at initial contact, relative angular displacement

Initial contact	hip angle (degree)	back knee angle (degree)	front knee angle (degree)
1	169.4	152.8	173.4
2	154.7	179.3	158.1
	161.2	179.4	164.4
3	149.7	158.5	156
	153.6	155.2	154.4
	159.4	110.7	151.4
	155.1	109.4	153
	146.3	124	153.6
4	147.5	160	148.8
5	150.4	177.2	154.8
	153.2	180	155.7
	151.1	179.7	162.6
6	155.4	170.2	157.7
	155.2	178.8	158
	160.8	178	167.2
7	165.4	176.6	178.4
	156.8	172.8	176.9
	162.6	177.7	176.9
	152.8	179.5	171.5
8	149.3	177.9	160.8
	147.7	179.8	157.5
9	162.9	159.4	166.2
	163	158.2	166.8
	151.1	151.4	150.5
10	153.1	180	161.6
	155.5	179.4	155.9
	146	176.3	159.8
11	157.5	155.6	155.9
	153.6	157.7	153.4
12	145.7	169.4	161.7
	149.8	164.8	166.9
13	158.2	161	162.3
14	153.2	153.8	159.8
	149	145.9	163
15	144.6	165.4	155.4
	141.4	160.6	152.1
16	158.4	172.9	174.9
	148.7	175.5	166.3
17	147.8	148.7	178
	148.3	174.6	149.5
18	150.5	179	157.2
	158.9	173.7	173.7
19	145	166.1	166
	148.3	159.7	164.4
20	158.5	174.1	163.7
	165.4	167.9	171.5

Table (4) Normal subject, hip & knee angular velocity at gait cycle 6.

Gait 2	Step length of the left leg meter	Step length of the right leg meter	Stride length meter
1	0.6	0.8	1.4
2	0.57	0.6	1.17
3	0.5	0.49	1
4	0.6	0.49	1.1
5	0.69	0.67	1.36
6	0.89	0.66	1.55
7	0.45	0.71	1.16
8	0.5	0.58	1.1
9	0.65	0.5	1.2
10	0.58	0.75	1.33
11	0.4	0.42	0.8
12	0.5	0.55	1.1
13	0.57	0.45	1
14	0.4	0.44	0.8
15	0.61	0.62	1.23
16	0.43	0.49	0.9
17	0.43	0.42	0.9
18	0.52	0.51	1.03
19	0.44	0.56	1
20	0.55	0.64	1.19

Table (5)steps length of the left &right legs,stride length at gait cycle 2 for 20 subjects

Parameters	Average	Average (180-α)	Standard of deviation	Average in the previous literature
Front knee angle at initial contact (degree)	163.9471	16.1	9.03678	2-34
Front knee angle at mid stance (degree)	161.3844424	18.6	24.96659229	10-60
Front knee angle at terminal stance (degree)	168.222069	11.8	11.83580062	0-13
Front knee angle at mid swing (degree)	127.9774194	52	15.702767	25-90
Back knee angle at initial contact (degree)	169.7471545	10.3	12.97970247	2-34
Back knee angle at mid stance (degree)	125.9102673	54.1	23.839729	10-60
Back knee angle at terminal stance (degree)	162.0887759	17.9	9.522392224	0-13
Back knee angle at mid swing (degree)	169.1543011	10.8	11.1530923	25-90
Hip angle at initial contact (degree)	153.7479675	26.3	6.129428471	
Hip angle at mid stance	170.7	9.3	6.5	
Hip angle at terminal stance (degree)	171.22	8.8	6.539	
Hip angle at mid swing (degree)	155.2806452	24.7	6.346955143	
Step length of the left leg (meter)	0.6105		0.226614172	0.4-0.8
Step length of the right leg (meter)	0.5635		0.210582928	0.4-0.8
Stride length (meter)	1.174		0.382197925	0.6-1.7
Stride time (second)	1.06		0.04	0.8-1.8
cadence (steps/minute)	66.4		5.816	
Knee angular velocity (degree/second)	3123.745		1677.87	
Hip angular velocity (degree/second)	2233.286		1052.41	

swing	675	1362
Mid swing	2905	5470
Mid swing	1475	2607.5
Terminal swing	762.5	1130
Terminal swing	1605	1917.5
Terminal swing	3030	3935

Table(6)Average & standard deviation of kinematics & temporal spatial parameters for 20 subjects from three gait cycle(a represent the measurement angle)

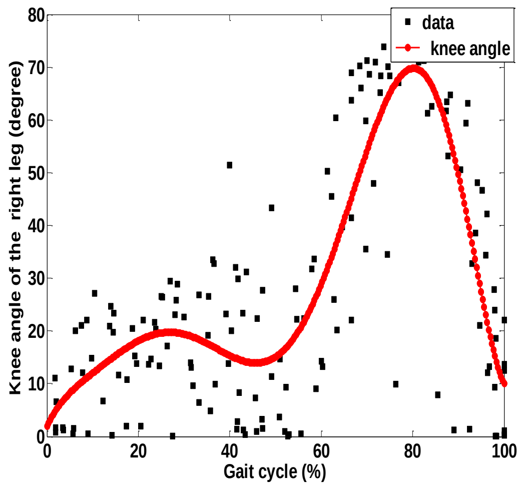

Figure (9) One subject (normal) hip angles function in time divided into percentage of gait cycle.

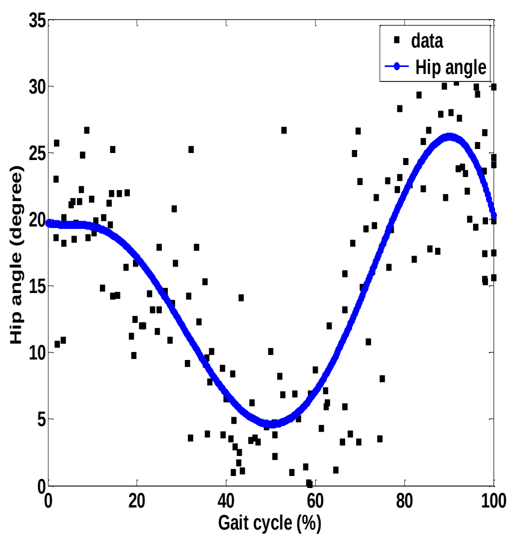

Figure (10) One subject (normal) right knee angles function in time divided into percentage of gait cycle.

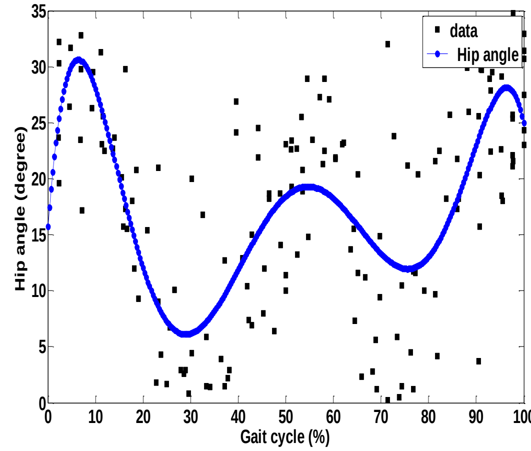

Figure (11) One subject (normal) left knee angles function in time divided into percentage of gait cycle.

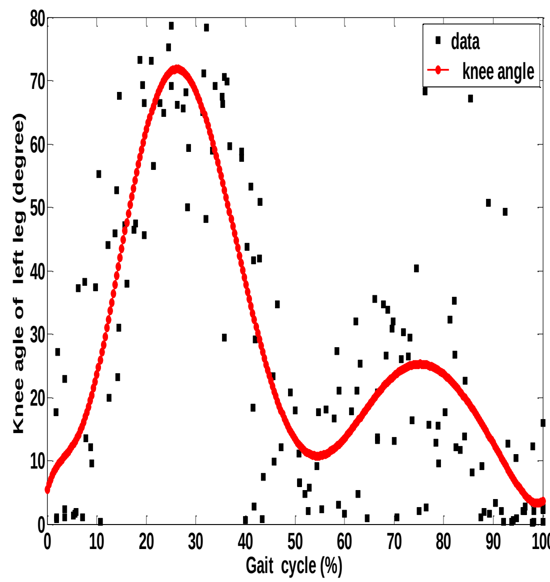

Figure (12) One subject (abnormal) hip angles function in time divided into percentage of gait cycle

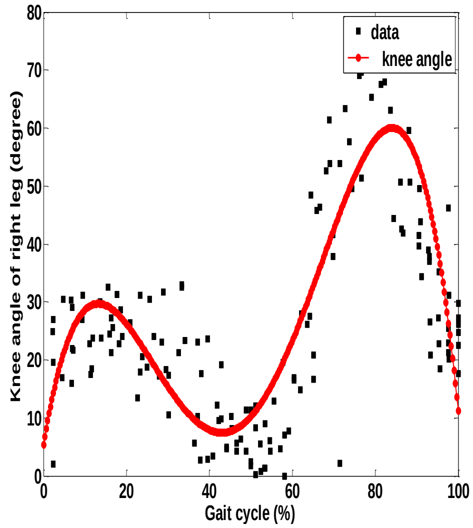

Figure (13) One subject (abnormal) right knee angles function in time divided into percentage of gait cycle

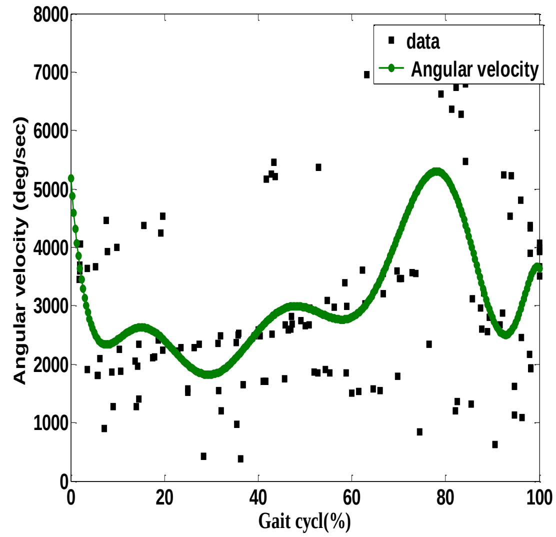

Figure (15) One subject hip angular velocity function in time divided into percentage of gait cycle.

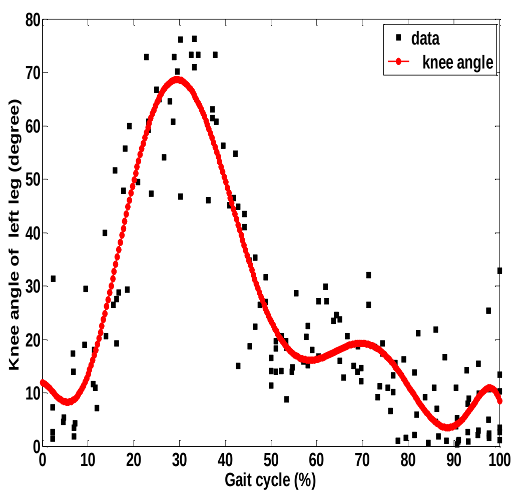

Figure (14) One subject (abnormal) left knee angles function in time divided into percentage of gait cycle.

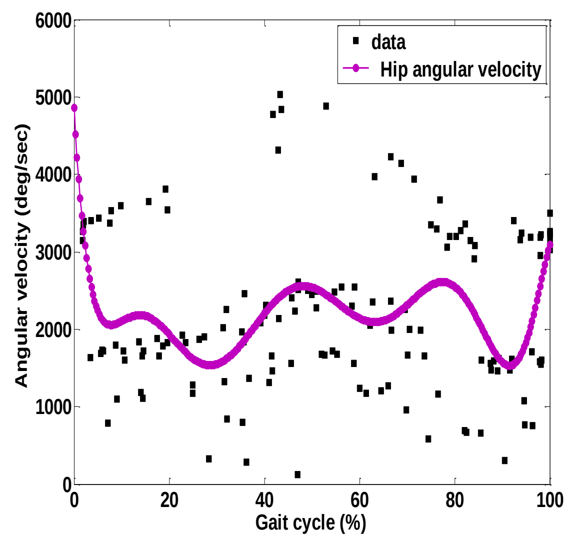

Figure (16) one subject knee angular velocity function in time divided into percentage of gait cycle.

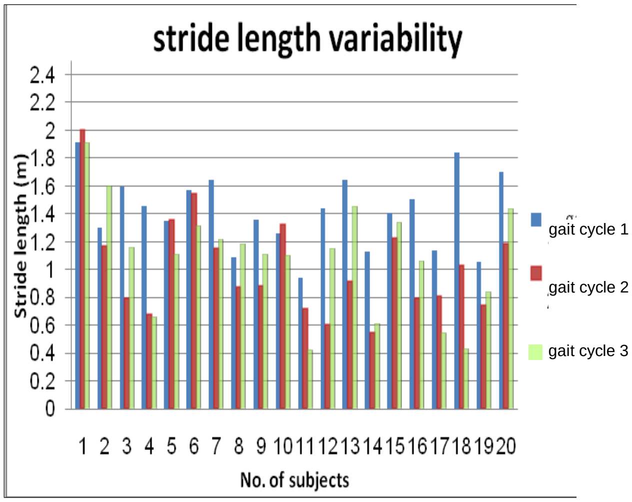

Figure (17) Stride length variability

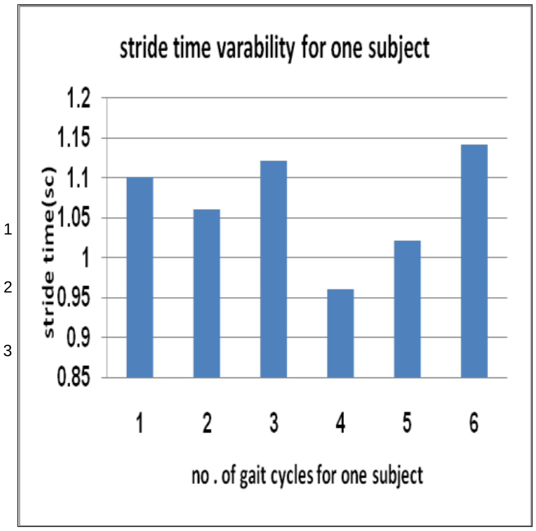

Figure (18) Stride time variability

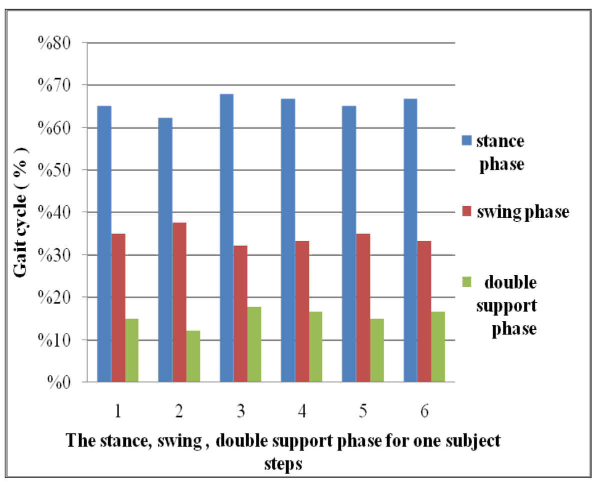

Figure (19) The stance, swing, double support phase for one subject steps.

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الخلاصة:

يستخدم نظام الكينماتيك في تحليل الحركة لتسجيل موقع ودوران أجزاء الجسم، زوايا المفاصل, والسرعة الخطية والزاوية والتعجيل الخطي والزاوي، تحليل الحركة يستخدم لغرضين مختلفين جداً لكي يساعد بصورة مباشرة في معالجة المرضى ولتعميق مفهوم الحركة لدينا من خلال البحث. الغرض من هذه الدراسة هو اجراء وتصميم نموذج للمظاهر الكينماتيكية المثالية الخاصة بحركة المشي من اجل الحصول على قيم قياسية يمكن الاعتماد عليها في مستشفيات التأهيل ومراكز الطب الفيزيائي و العيادات ذات التخصص الرياضي كقاعدة بيانات للرجوع اليها. في هذه الدراسة تم اختيارعشرين شخص من المتبرعين وشخص واحد يعاني من مرض ذا تأثير على الحركة ، هؤلاء الأشخاص العشرون لا يملكون أي مرض ذا تأثير على الحركة, وليس لديهم سابق معرفة في كيفية السير على جهاز السير المتحرك ,حيث تم أجراء تصوير لهؤلاء الأشخاص باستخدام كاميرة تصوير فيدوية رقمية (Sonyنوع) مثبتة على حامل من ثلاث أرجل في مستوى جانبي بينما الأشخاص يسيرون على جهاز السيرالألي المتحرك بصورة متسلسلة, أن جهاز السير المتحرك غالبا ما يستخدم في برامج التأهيل لأنه يسمح بحالات ثابتة ومسيطرة في مساحة صغيرة. وباستخدام برنامج التحليل الحركي (Dartfish) تم دراسة كينماتيكية مفاصل الورك والركبة وحساب المتغيرات الزمنية – المكانية (طول الخطوة، طول الخطوة الكاملة, زمن الخطوة الكاملة ، التردد) من التصوير الفديوي.أن النتائج التي تم الحصول عليها من برنامج (Dartfish) كانت مهمة في فهم أن زوايا الورك الركبة تختلف في كل دورة مشي كاملة ، بصورة مشابهة للمتغيرات الزمنية – المكانية ، وان المتغيرات الزمنية – المكانية تختلف في كل دورة مشي كاملة للأشخاص.