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Research of Lower Limb Rehabilitation Training Gait

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Abstract

Gait analysis is an important part of the lower limb disorder walking rehabilitation training, based on the research of the walking gait, helpful for recovery equipment control system design has important significance. This article mainly through 3 d motion capture system, the movement of human lower limb joints character such as displacement, velocity, and the body center of gravity test analysis, and in view of the human lower limb joints, four degrees of freedom model is set up, and establish the corresponding mathematical model, and using the simulation software, to verify the rationality of structure, for the future of medical rehabilitation, and provide important data for the intelligent control of the organization.

Keywords: *Gait analysis, Rehabilitation training, Joint*

1. Introduction

In the 21st century, the progress of science and technology led to the development of the society, people's living standards improve at the same time, also led to the world's population aging problem. There are a large number of cerebrovascular disease in elderly a crowd or most such patients with hemiplegia patients with nervous system disease symptoms. In recent years, due to the risk of disease of heart head blood-vessel to rise in the number of middle-aged and old patients with hemiplegia, and showed a trend of getting younger over on age. At the same time, the speeding up of the life section gather together, means of transport, the rapid growth of the nerve injury caused by traffic accidents or the number of physical injury is more and more. Medical theory and clinical medical certificate, such patients in addition to the early surgical treatment and necessary drug treatment, correct and scientific rehabilitation training for the recovery of limb motor function and play a very important role. These patients have a certain movement disorders, rehabilitation training need someone to help to carry out, but the lack of professional nursing staff and medical expenses and other practical problems, most patients choose their own training at home, because not enough scientific training method and the lack of volume many patients missed the best time to recover, many people can not get effective rehabilitation training and gradually lose the ability body activity, not only brought a lot of pain to the patient, and caused great burden to family and society.[1-2]

Based on lower limb disorder body recovery key technology study, construct the balance function analysis model of mutilation disabled people collect enough different posture balance parameters of the disabled, draw lessons from normal population balance analysis method, study to establish the mutilation of disabled people body balance function analysis model, and analysis of sample data, draw lessons from normal people

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balance method and physicians in different professional knowledge, to form the mutilation disabled people balance ability evaluation index system and quantitative standard, for the design and development of passive lower limb rehabilitation training device simulation model and corresponding algorithm, lower limb rehabilitation equipment foundation is established.

2. Lower Limb Walking Gait Analysis

Human lower limb movement is. a whole movement which has the characteristics of repeated periodic, binding and symmetry. It can realize some human behaviors, such as moving forward, stepping back, rotating, leaping over, running, jumping, *etc.*, [11]. Not only can do the periodic motion, such as walking, but also can do the non-periodic motion, such as leaping over, jumping. Wearable lower limb exoskeleton of rehabilitation training robot is mainly used for effective rehabilitation training for lower limb movement disabilities. Analyzing of normal walking gait of human lower limbers and laying the foundation for the exoskeleton structure design and control.

Human lower limb movement made by the central nervous system to command and control, power provided by the muscles and the movement of the lower limbs are completed by the commands of nervous system which is executed by human bones as leverage. In the process of walking, it showed cyclical that the human feet and the ground are alternately contact and separation. A walk cycle describes the motions from initial placement of the side of the heel on the ground to when the same heel contacts the ground for a second time during walking, the average adult gait cycle is about 1 ~ 1.32 s[12]. According to the location of the lower limbs on foot, a gait cycle can be divided into stance phase and swing phase. The gait cycle diagram as shown in Figure 1.

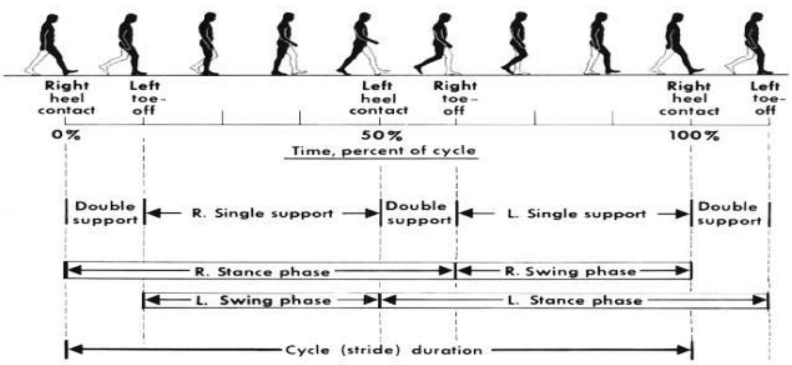


Figure 1. The Human Body Normal Gait Cycle Diagram of Lower Limbs

Stance phase: The heel strikes the ground and begins to assume the body’s full weight, it occupies approximately 40% of the walking cycle.[14]

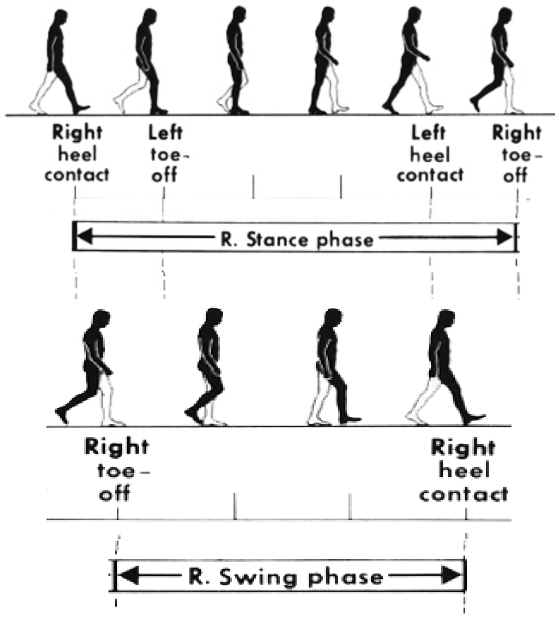
Swing phase: The toes leave the ground and ends when the heel strikes the ground, it occupies approximately 60% of the walking cycle.

A stance phase contains a single foot stance and double stances, a stance period for single foot stance most of the time. Double foot stance phase refers to the stance foot touches the ground bearing reaction period for the first time, or weight loss reaction of the other foot and off the ground. Each gait cycle includes two double stance phase, the first double stance phase occupies 10% of before the gait cycle, the second double stance phase occupies between 50% and 60%.

Swing phase is divided into early, middle and late stages. The early swing phase refers to from stance leg off the ground to the leg and knee joint maximum buckling, the main action is foot clearance and flex toe driving the knees and accelerating the body forward swing, in the gait cycle stages of 60% ~ 70%.

The middle of the swing phase refers to the middle of the step of activities, knee joint swing from the biggest buckling to the leg vertical to the ground, in the gait cycle stages of 70% ~ 85%.

The end of the swing phase is the activity which the before landing. Lower limbs forward movement preparing for foot strike by slowing down, in the gait cycle stages of 85% ~ 100%. After that leg swings to slow down and adjusts the position of the foot to ready to enter the next cycle [7-8]。Lower limbs stance phase and swing phase as shown in Figure 2.



a) Stance phase b) Swing phase

Figure 2. The Stance Phase and Swing Phase Diagram of Lower Limbs

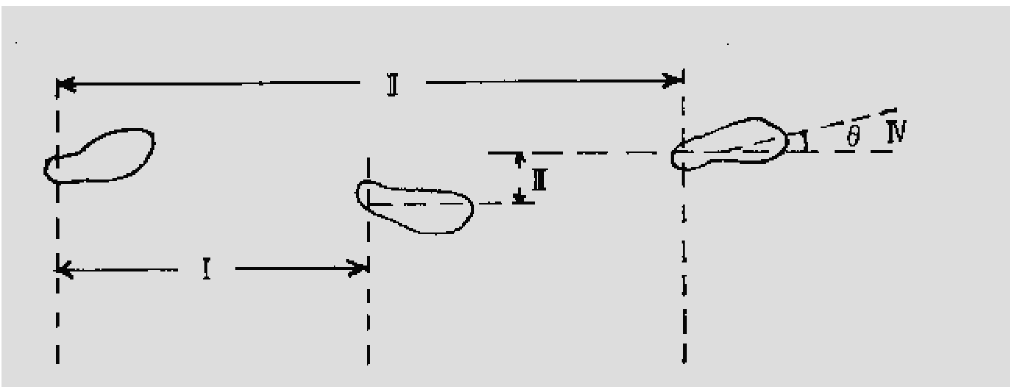
Step length is the longitudinal linear distance between two points of toe or two heel.

Stride length is related to the longitudinal linear distance between two consecutive contacts of the same side feet (heel).

Stride width: the distance between the left foot and right foot during walking.

Toe out angle: the angle between one side of the center line of the foot with the side of walking straight.

Normal step length is about 50-80 cm, stride length is about 100 ~ 100 cm, stride width is about 8-3.5 cm, toe out angle of about 6.75°. As shown in Figure 3.



Ⅰ:Step length Ⅱ:Stride length Ⅲ: Stride width Ⅳ:Toe out angle

Figure 3. Feet Parameters

Improving the lower limb movement, a gait cycle parameters are shown in Table 1.

Table 1. Motion Parameters of Lower Limb Joints within a Gait Cycle

Gait cycle / Location	Stance phase				Swing phase		
	Heel strike	Forefoot strike	The mid-term Of stance	Heel off the ground	Acceleration period	Swing mid-term	Deceleration phase
Pelvic rotation	Forward 4°～5°	Forward 4°～5°	Interposition	Backward 4°～5°	Backward 4°～5°	Interposition	Forward 4°～5°
Hip joint	Bend 30°	Bend 30°	Bend 30°～0°	Extension 10°	Bend 20°	Bend 20°～30°	Bend 30°
Knee joint	Extension 0°	Bend 15°	Bend 15°～0°	Extension 0°	Bend 35°～60°	Bend 60°～30°	Bend 30°～ 0°
Ankle joint	The mid-term Of stance	Plantar bend 15°	Dorsiflexion 10°	The mid-term Of stance	Plantar bend 20°～10°	The mid-term Of stance	The mid-term Of stance

3. Lower Limbs Motion Parameters of Acquisition

3.1. Human Motion Data Acquisition of Lower Limbs

Through the dynamic data acquisition system to collect human lower limb movement, using the CORTEX system to produce the human body skeleton image, analysis using MATLAB software, the coordinates of the data collected by each joint Angle, speed, provide data basis for exoskeleton structure design.

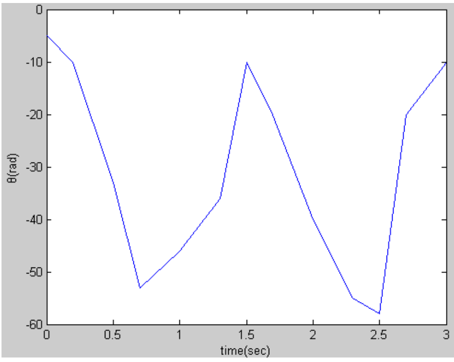
The gait data acquisition and image collection using the fiend 3d dynamic capture system, the system contains capture camera, the connecting cable, power supply system and used for the transmission of data hub, system calibration device and ball maker. The system is equipped with special dynamic capture software, they can capture process control, system setting, capture data editing processing, output, *etc.*, The system shown in Figure 4.

Figure 4.The CORTEX System Overall Layout

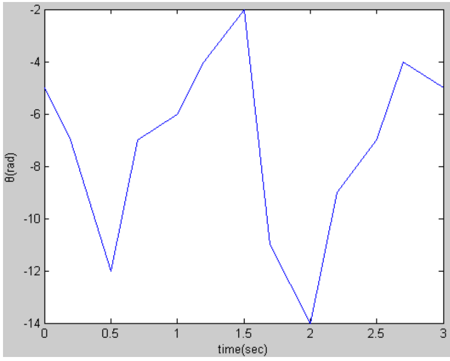
3.2. Human Motion Data Acquisition of Lower Limbs

Experiment personnel's waist, hip, knee, ankle, thigh, calf and paste maker in areas such as the toe or heel points, the researchers in a normal walking gait, dynamically capture system to capture the tracks of the camera will capture the maker at the same time generate maker point coordinate value.

After completion of the experiment, We use the fitting function about MATLAB software to fit the angle of lower limbs joints, each joint Angle curve as shown in Figure 5.



a.The right leg knee joint rotation curve



b. The left leg knee joint rotation curve

Figure 5 .The Knee Joint Angle of the Curve

The MATLAB image shows that the left and right leg knee curve was positively to the characteristics of performance in a gait cycle for the entire sine cycles.

3.3. Zero Moment Point (ZMP) Gait Planning

At present, the human lower limb gait planning is the most commonly used method is based on the ZMP (Zero Moment Point) stability judgment method. ZMP refers to the feet when in contact with the ground reaction force (N) also can produce torque (M), if there is a little (P) its reaction force and inertial force with a Zero net torque and Point called Zero Moment Point. as shown in Figure 6.

Analysis of lower limb movement and determine the ZMP trajectory. This method is first based on expectations of gait planning out the feet and torso motion, then according to the trajectory calculate the ZMP trajectory, within the scope of the variable parameter of effective, calculate meet the largest stability margin of the lower limbs motion trajectory of each joint trajectory as a bipedal robot. According to the constraint parameters, the method to set foot on the obstacles of gait design. This method is intuitive, and can be the only each joint movement trajectory of lower limbs. Can meet under the condition of stable walking bipedal robot, get various joints smooth trajectory. But to make the stability of the biped robot to walk is higher, must be repeated calculation, comparison, due to the large amount of calculation, this method works tedious, so implementation is more difficult.[3]

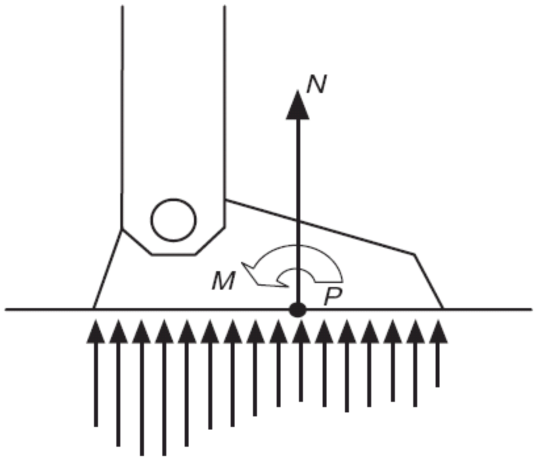


Figure 6. ZMP Interpretation Chart

3.4. Four Degrees of Freedom Modeling Method

Because of human lower limb mainly includes the state of freedom, like the waist and legs, thighs and legs, legs and feet in a free state, the position cannot be mutual constraints, in the process of the movement of institutions, forming a four bar linkage, and hip, knee and ankle is the hinge arm of four bar linkage, because this several parts only do reciprocating motion, hip under small force in the movement, the basic will not cause damage in patients with hip; Knee and ankle in the vertical plane turning, absorb a certain amount of stretch and squeeze, a great influence on the rotation of the body, so the analysis of the motion parameters of both is to control the main parameters of mechanism motion. [13] Hinge four-bar design simulator is shown in Figure 7.

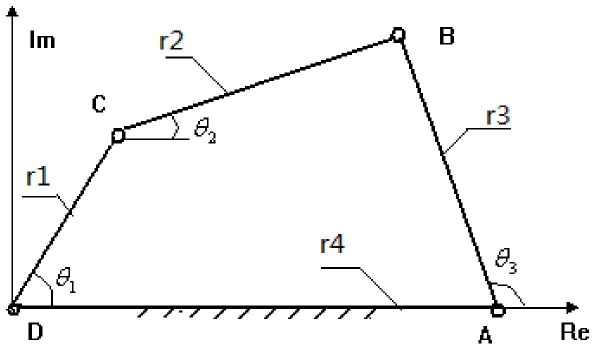


Figure 7. Four-Combined-Pole-Installation

Set Figure 7, as an example ,the parameters are set as following, $r_1 = 400mm, r_2 = 1000mm, r_3 = 700mm, r_4 = 1200mm$, Given angular displacement of link r1 is $\theta_1 = 60^\circ$, the angular displacement θ_2 of the link r2 and θ_3 of the link r3 can be determined. Shown in the Figure 7, the complex vector of 4-combined-pole-installation. According to Newton-Simpson's rule, the displacement equation can be derived as following:

$$r_1 e^{j\theta_1} + r_2 e^{j\theta_2} = r_3 e^{j\theta_3} + r_4 e^{j\theta_4} \tag{1}$$

Expansion and compilation the above formula, then we got,

$$\begin{cases} f_1(\theta_2,\theta_3) = r_1\cos\theta_1 + r_2\cos\theta_2 - r_4 - r_3\cos\theta_3 = 0 \\ f_2(\theta_2,\theta_3) = r_1\sin\theta_1 + r_2\sin\theta_2 - r_3\sin\theta_3 = 0 \end{cases} \quad (2)$$

Jacobian matrix is set up in the following:

$$J = \begin{bmatrix} -r_2\sin\theta_2 & -r_3\sin\theta_3 \\ r_2\cos\theta_2 & -r_3\cos\theta_3 \end{bmatrix} \quad (3)$$

That can be compiled through M function, estimate component 2 and 3 components of angular displacement, and through the MATLAB calculation, can get component 2 and 3 angular displacement of the same basic components., we got the results as: In the same way, we can adjust Angle parameters in the M function, institutional changes in the Angle of more reasonable, make it more suitable for actual structural design, the resulting images are basically the same with the actual measured in the image.

4. Conclusion

Through using grading methods for normal population balance and physicians professional knowledge, form the mutilation disabled people balance ability evaluation index system and quantitative standard, here use modern equipment for data acquisition, especially analysis of four degrees of freedom of the lower limb motion mechanism is established ontology is designed, using MATLAB/Simulink simulation software for knee point B of displacement, velocity and acceleration analysis, and carries out a comparative analysis on gait with the normal population. Involves the robot mechanical structure, control system and feedback system design and implementation, targeted on the relevant experiments, for the clinical application of rehabilitation training platform and related key problems in the field of rehabilitation engineering research platform and equipment foundation.

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