UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FACULTY OF ELECTRICAL ENGINEERING

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PROJECT REPORT

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Design and Development of Turning Motion Trajectory for Limb Assisting Device

Low Wai Tuck

Bachelor of Mechatronics Engineering

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I hereby declare that I have read through this report entitle "Design and Development of Turning Motion Trajectory for Lower Limb Assistive Device" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering.

Signature : ______________________

Supervisor name : ______________________

Date : ______________________

DESIGN AND DEVELOPMENT OF TURNING MOTION TRAJECTORY FOR LIMB ASSISTIVE DEVICE

LOW WAI TUCK

A report is submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronic Engineering

Faculty of Electrical Engineering

UNIVERSITY TEKNIKAL MALAYSIA MELAKA

2013/2014

I declare that this report entitle *"Design and Development of Turning Motion Trajectory for Limb Assistive Device"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature: …………………………………………………

Name: ……………………………………………………..

Date: ……………………………………………………….

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ABSTRACT

Nowadays, the number of disorders such as stroke, spinal cord injury and traumatic brain injury is increasing drastically in the society. For every year, there are about 40 million people around the world suffer for mobility disorder and cannot perform their daily life activity. By improved architecture of lower limb assistive device (LAD) in hip for turning motion, patients can have more perfect motion in walking. However, the angle and torque for turning trajectory still have not been discover fully and need to be test. The accuracy and stability for the lower limb devices is importance in order to avoid the excessive turning that might hurt the user. The design of exoskeleton robot is follows the turning trajectory of a normal person. The performance of the hip turning motion is analyzed in term of stability, accuracy and repeatability. Position analysis is done and the suitable angle for turning motion is tested in few positions. Method of accuracy tracking and stability test has been conducted in order to improve the performance of the device. The expected result and the actual result for turning motion is different and need to be improve. The testing will be conducted by using a higher torque motor in order to get an accurate result for turning motion. In FYP2, it is important to improve the performance of the prototype and thesis. For the different type of turning trajectory, it having different of accuracy. The accuracy of the prototype is tested by using 2 method of turning trajectory. There are totally different phases of turning motion that analyzed in the each motion of turning. The results are plotted and show the error of turning, standard deviation and mean error. The result shows that the method one has a higher accuracy of turning which is 98.5% and standard deviation for 0.436 in 45 degrees of turning. For method two, the accuracy and standard deviation are 98.39% and 0.500 respectively. It is prove that method 1 is easier to control and have a higher accuracy as compared to method 2.For the future work, the error of output turning angle should be reduce. The turning angle should be accurate as to improve the safety for the user. For the hardware part, the higher torque motor is needed for the next step. By this, the hardware can attach to a real human body and get a better analysis based on the performances.

ABSTRAK

Pada masa kini, bilangan gangguan seperti strok, kecederaan saraf tunjang dan kecederaan otak trauma semakin meningkat secara drastik dalam masyarakat. Bagi setiap tahun, terdapat kira-kira 40 juta orang di seluruh dunia mengalami sakit pergerakan dan tidak boleh melakukan aktiviti kehidupan harian mereka.(LAD) di pinggul untuk menukarkan gerakan dapatbmelakukan pergerakan yang lebih sempurna dalam berjalan. Walau bagaimanapun, sudut dan tork untuk bertukar trajektori masih belum menerokai sepenuhnya dan perlu dikaji. Ketepatan dan kestabilan bagi peranti anggota badan yang lebih rendah adalah kepentingan untuk mengelakkan perubahan yang berlebihan yang mungkin akan membawa pengguna. Reka bentuk robot Exoskeleton adalah berikut trajektori perubahan daripada orang biasa. Prestasi gerakan perubahan pinggul dianalisis dari segi kestabilan, ketepatan dan kebolehulangan. Analisis kedudukan dilakukan dan sudut yang sesuai untuk menjadikan gerakan diuji dalam beberapa jawatan. Kaedah mengesan ketepatan dan ujian kestabilan telah dijalankan untuk meningkatkan prestasi peranti. Hasil yang dijangka dan hasil sebenar untuk menukarkan gerakan adalah berbeza dan perlu memperbaiki. Ujian ini akan dijalankan dengan menggunakan motor tork yang lebih tinggi untuk mendapatkan hasil yang tepat untuk menukarkan gerakan. Untuk jenis yang berbeza menjadikan trajektori, ia mempunyai kejituan. Ketepatan prototaip diuji dengan menggunakan 2 kaedah bertukar trajektori. Terdapat fasa-fasa berbeza menjadikan gerakan yang dianalisis dalam setiap gerakan perubahan. Keputusan diplotkan dan menunjukkan kesilapan membelok, sisihan piawai dan min ralat. Hasilnya menunjukkan bahawa satu kaedah yang mempunyai ketepatan yang lebih tinggi perubahan yang 98.5% dan sisihan piawai bagi 0,436 di 45 darjah perubahan. Untuk kaedah dua, ketepatan dan sisihan piawai adalah 98.39% dan 0.500 masing-masing. Ia membuktikan bahawa kaedah 1 adalah lebih mudah untuk mengawal dan mempunyai ketepatan yang lebih tinggi berbanding dengan kaedah 2. Bagi kerja masa depan, kesilapan output sudut bertukar harus mengurangkan. Sudut bertukar ini tepat untuk meningkatkan keselamatan untuk pengguna. Perkakasan boleh melampirkan kepada badan manusia yang sebenar dan mendapatkan analisis yang lebih baik berdasarkan prestasi.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Nowadays, the number of neurological disorders such as stroke, spinal cord injury and traumatic brain injury is increasing drastically in the society. Every year, there are estimated about 40 million people all around the world suffer from the problem. From the research, most of the patients are in the age group of 20 to 25[1]. Most of the patient affected by permanent movement disorder, such as hemiplegia, paraplegia or tremor.[2, 3]

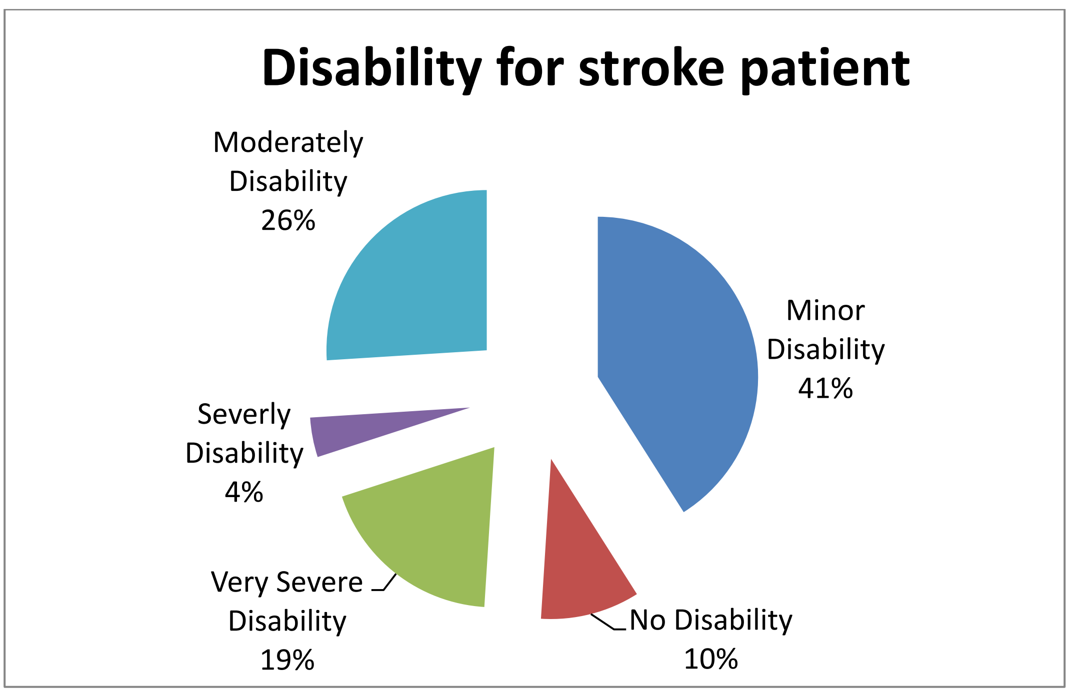

Figure 1: Chart for disable person

The victim of the disease will cause mobility disorder and limit their movement. Most of them could not able to walk normally. Although the facilities and technology in rehabilitation and neuron rehabilitation is getting improved, the presence of mechatronic systems design is still in small amount. For the early 60's, most of the researches are done by created powered hip exoskeleton devices to increase human strength[4, 5].

In summary, the thesis presents an improved architecture in hip exoskeleton unit. The theses mainly focus in the motion of turning trajectory on the hip. The turning trajectory is the motion of medial and lateral rotational on the hip. This enable the patient have more perfect movement in turning motion while walking.

Besides, the performance of the exoskeleton will improve as it concerns more on the other aspect like turning other than walking trajectory. It is helpful for the disable person and help them in daily life activity.

1.2 Problem Statement

Development of a wearable lower limb exoskeleton robot must obey the physical human robot interaction fields (PHRI). The fields that focus are power, size, torque and safety. Suitable actuators that obey the movement of lower limb are electric motor. For safety, the size of the motor has to be compact and small which fulfill with the design of the wearable lower limb assistive devices. However, it has to be producing enough torque for the turning motion trajectory.

Stroke patient have limited degree of rotational for the lower limb part. The lower limb assistive device in the hip helps the patient in the turning motion. A suitable motor is needed to give enough torque for turning motion. The accuracy of the turning angle is important as well in turning motion trajectory. However, the suitable trajectory torque and angle for the turning motion are still not known. Especially, the particularly design for one leg assistive device for half body impaired person is still does not assist.

Besides, the design needs a high accuracy mechanism in term of rotational as the patient need to use the devices repeatedly. It is also avoid the excessive turning that might hurt the patient. Therefore, the maximum turning angle for the lateral and medial rotational has to be finding out. A suitable actuator is needed as it is design for the patients that are under rehabilitations.

Moreover, the controller of motor has to be precise and give fast response which does not need a steady-state error of 0. It must achieve the suitable angle for turning trajectory. The pattern for the turning trajectory must be suitable and obey the cubic polynomial which get the best performance and does not hurt the user.

1.3 Project Objectives

I. To design an exoskeleton robot that follows the turning trajectory of a normal person.
II. To analyze the phase of turning trajectory according to the cubic polynomial.
III. To analyze the performance of the hip turning motion in term of accuracy and repeatability and the phase of turning.

1.4 Scope of the Project

I. The design is limit for two degree of freedom for the purpose of turning motion.
II. The motion of turning trajectory is only focus on medial and lateral rotation
III. The motion of the motor is control by Arduino Controller.
IV. The use of the dc motor only can attach to the prototype but not human.
V. For hardware part, the turning motion trajectory is tested by using a DC motor and feedback by encoder.
VI. The design of the turning trajectory for turning motion only for one side of leg.
VII. The prototype is not attach to a real person as the design is smaller due to the torque supply and safety for the user.

1.5 Outline of the Dissertation

The thesis includes several chapters and the road map of this thesis process as follows:

- Chapter 1: Introduction

Include project motivation and the problem that happen in design the turning motion trajectory for lower limb assistive device. The project objective and the scope are listed in the chapter.

- Chapter2: Literature review

It includes the theory regarding the turning trajectory. The system block diagram is present in the chapter as the overview of the project. The chapter also introduces the background of human gait and cubic polynomial. Performances indices and comparison among the solution trade of is also being explained in the chapter.

- Chapter3: Research Methodology

In the chapter, the design of procedure is discussed. The analysis is also done to test the performance of the device in term of accuracy, repeatability and stability.

- Chapter4: Result

The accuracy for motor and prototype has been finding out and analyze. The error is calculated and being analyze. The phase of turning for 2 methods is plotted in term of the turning trajectory.

- Chapter5: Discussion

The chapter is discussing the result for the experiment. The deviation of the turning angle is discussed. All the error and phase of turning is discuss.

- Chapter 6: Conclusion and Recommendation

Conclude the current progress and plan for FYP2 and give recommendation for future plan.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory of Turning Trajectory

2.1.1 System block diagram

For the study of turning motion trajectory of lower limb assisting device, a simple block diagram is draw based on the requirement needed. First, a desire input (error) is act as a source and send to the controller which is signal conditioning. Then, the output will send to the actuator. The position will definitely deviate from the desired position. In order to make correction to the deviate, an encoder feedback is used to send a feedback signal to the signal conditioning. Then, the desire input can be fulfilling after the correction.

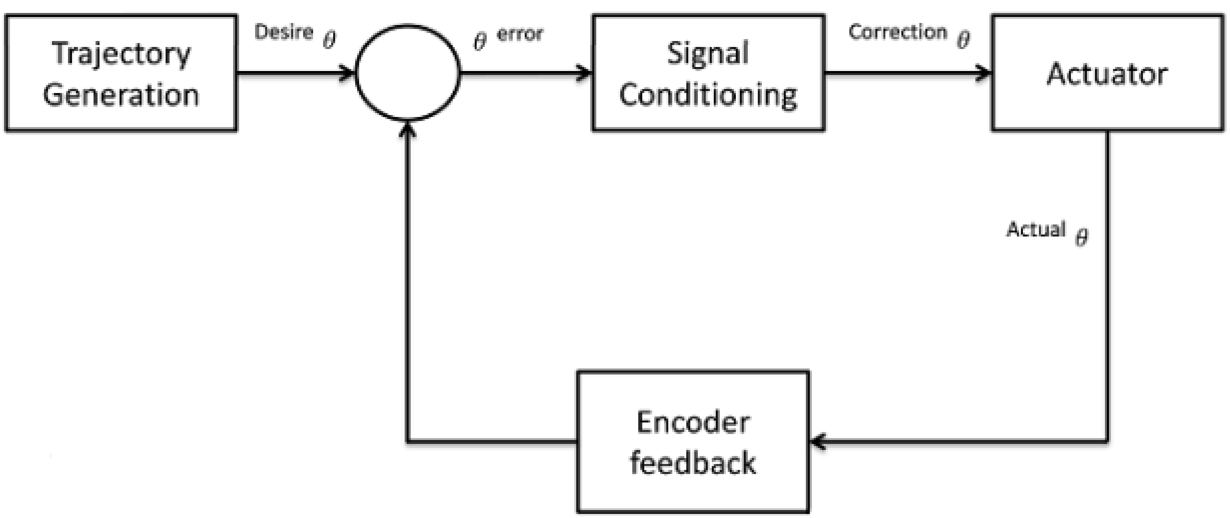

Figure 2: Simple block diagram for the system

θ_{Desire} : Desire angle of the trajectory

θ_{error} : Difference of trajectory angle between desired angle and actual output angle

$\theta_{Corrected}$: Corrected signal which make correction at actual output angle to meet desired angle

θ_{Actual} : Actual output angle

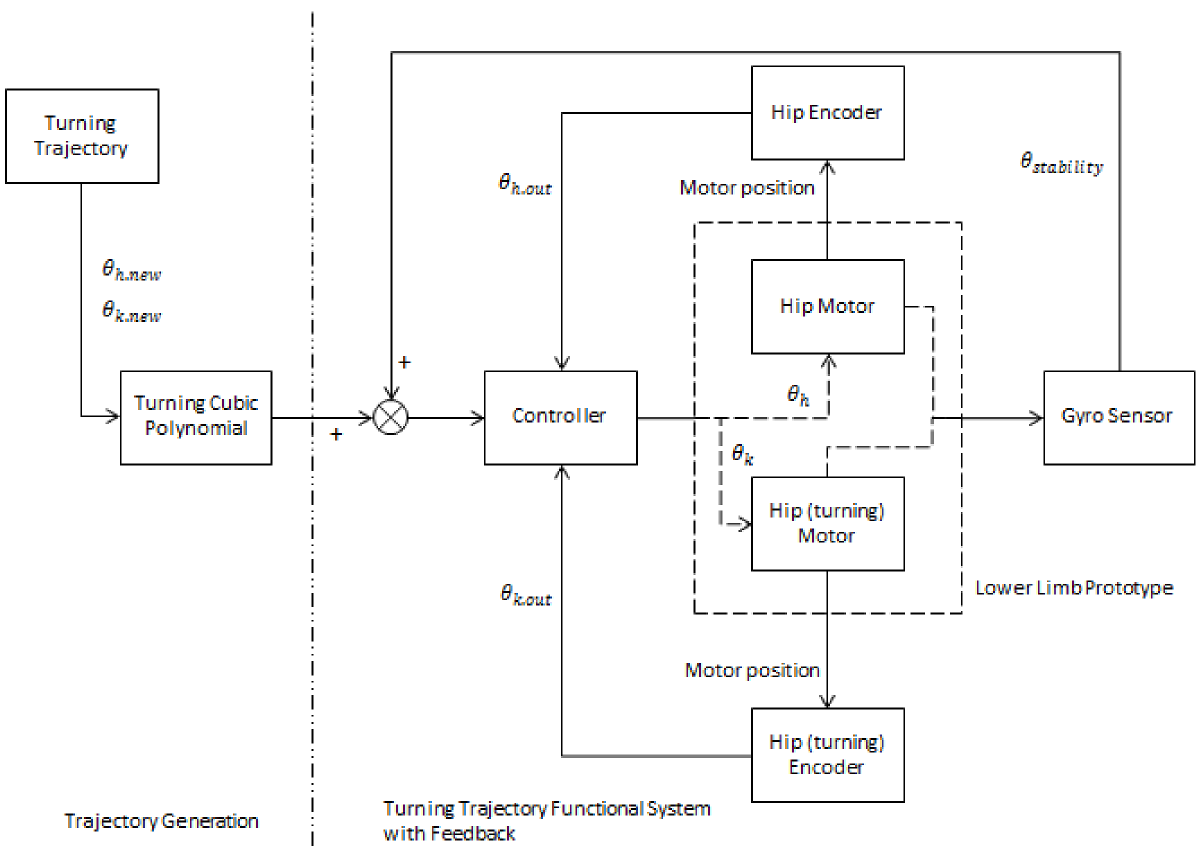

Figure 3: detail flow chart for the system

2.1.2 **Human Gait**

Human walking is in series with repeated motion in 3 dimensions. The hip exoskeleton unit should be able to accommodate the hip's basic motions which are flexion and extension, abduction and adduction, and medial and lateral rotation (3-DOFmotion)[6]. For the understanding of human body's joints, a Cartesian coordinate system can be used to display the relation of a human body.

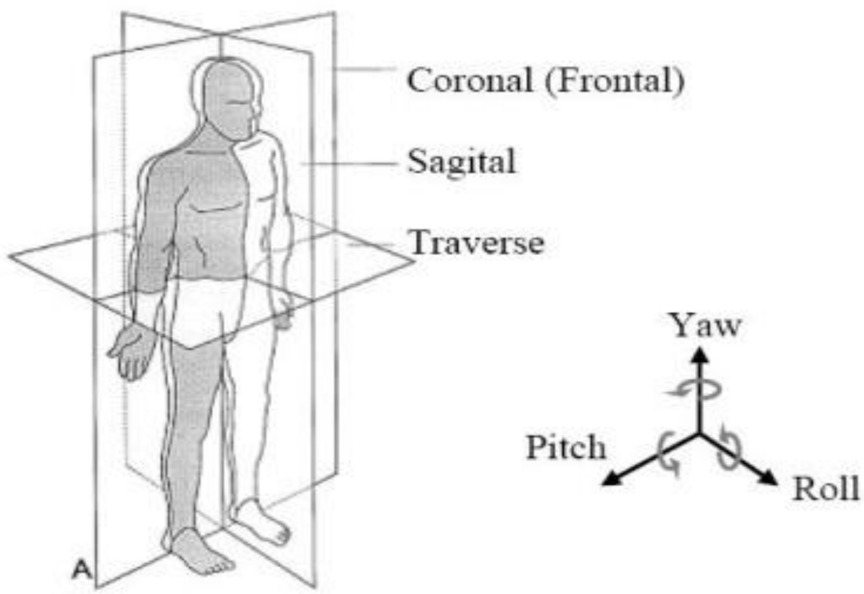

Figure 4: Cartesian coordinate system

- Sagittal Plane- Bisects the body from front to back, dividing it into right and left symmetrical halves. Movements which generally occur in this plane are flexion, extension, and hyperextension.

- Coronal Plane- It is referred to the frontal plane. Bisects the body from side to side and divides the body into equal front and back halves. Abduction and adduction are movements commonly performed in this plane.

- Transverse Plane- It is referred to as the horizontal plane divides the body horizontally into superior (upper) and inferior (lower) halves. Rotational movements such as spinal rotation and supination and pronation of the forearm occur in the transverse plane.[7]

For the thesis, the main focus is on the medial and lateral rotational of the lower limb. The rotational to the inner and outer is different in term of the limit of the maximum angle.

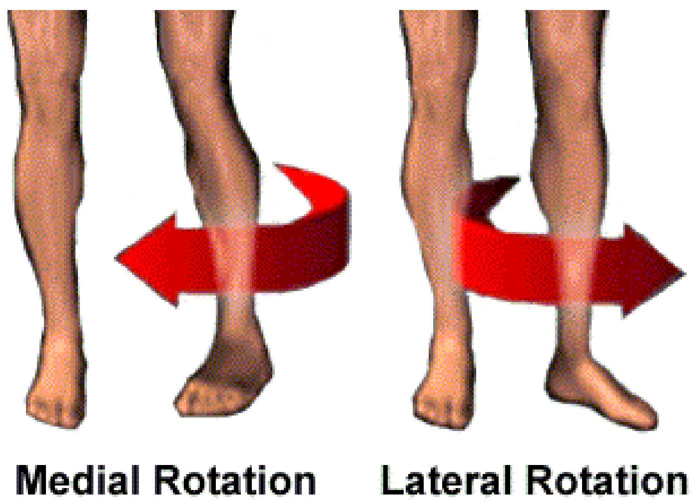

Figure 5: Medial and lateral rotational

2.1.3 **Anatomy of turning trajectory**

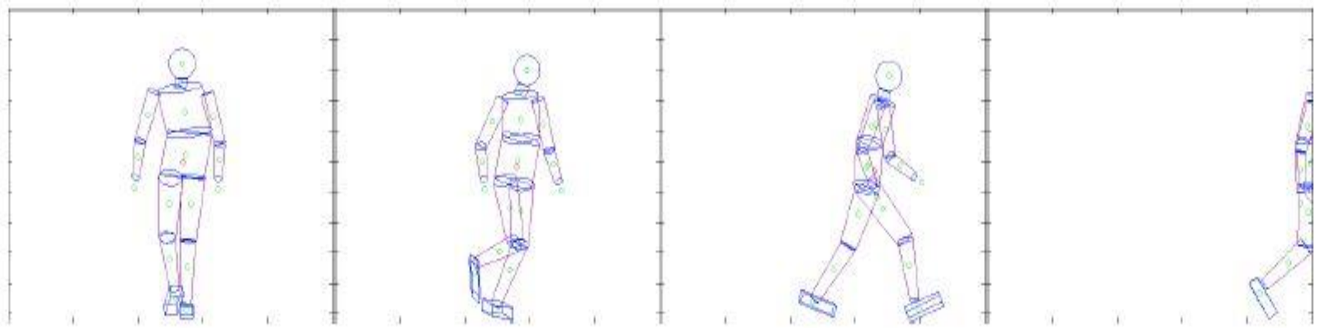

Figure 6: Human Turning pattern

There are four phase in turning motion during walking[8]

i.) Normal walking

ii.) Start to turn

iii.) Landing the swing foot

iv.) Back to normal walking

There are two types of turning pattern generally during walking. Two types of turning pattern have different of turning angle.

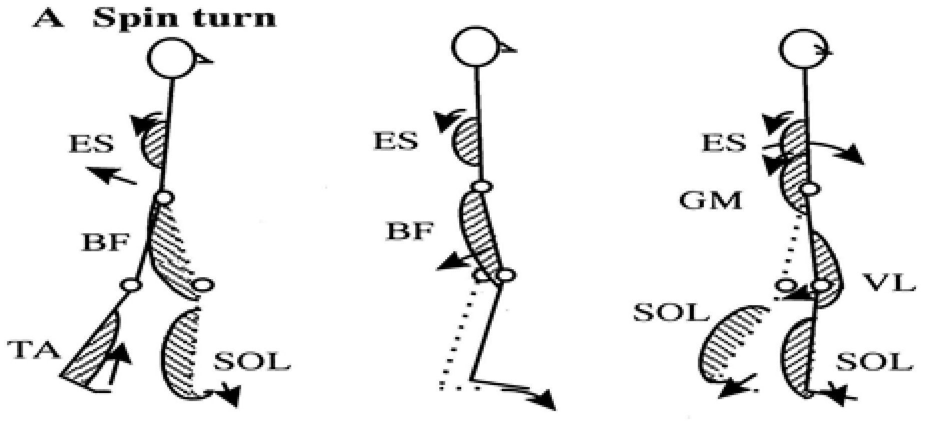

Figure 7: Spin turn pattern

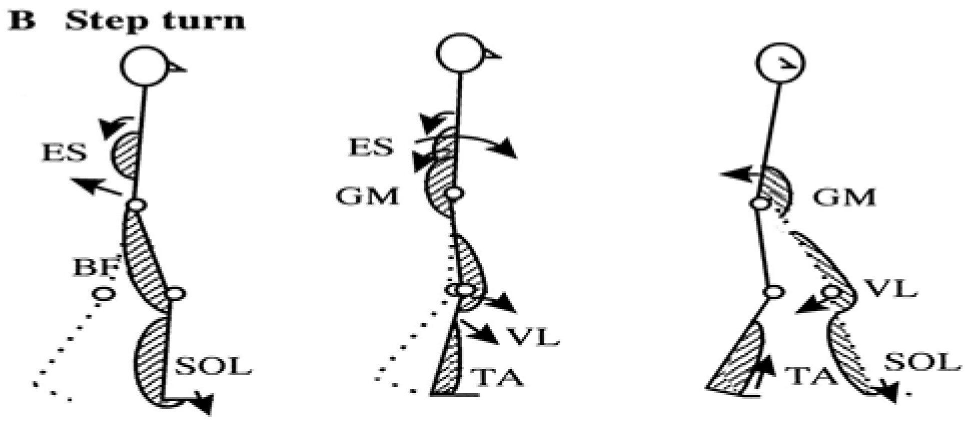

Figure 8: Step turn pattern

2.1.3.1 Spin turn

This strategy allows the body to spin on the forward leg while producing a braking force (axial leg). The torso is kept behind the axial leg presumably to balance the centrifugal force caused by rotating the body and to step toward the new direction. As a result the subjects could not use this strategy after the COM passed the stance foot. The existence of push-off power is also advantageous to put spin on the body so the spin turn is restricted to less of the cycle than the step turn. [9]

2.1.3.2 Step turn

This strategy is easier and more stable for the patient that having disability. This is because the base of support while changing in direction is much wider than for the spin turn. We can see a constant step rhythm during changing direction in the subjects who always used the step turn.