POSTURAL STABILITY AND RISK OF FALL OF PERSON WITH TRILATERAL PROSTHESIS

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ABSTRACT

Postural stability is defined as the ability to maintain an upright position. It comes in two forms, static and dynamic. Static postural stability is when you are standing and not moving while dynamic stability is when you are moving or doing specific movements. Amputees impair the ability to balance especially when trilateral amputation involved. By losing 3 limbs of the body, postural stability may affect and required specific kind of training for the amputee to do daily activity. Risk of fall also may high than normal persons as the balance are off than usual. The parameter used to measure the postural stability and indicate the risk of fall is postural stability index. Postural stability index includes the total of anterior/posterior stability index (APSI) and medial-lateral stability index (MLSI). These parameters can be measured using Biodex Balance System SD (BSS). In procedure of this study, subjects were undergone two tests of postural stability and Fall Risk tests. Ten normal subjects and one trilateral amputee subject participate in this study. Normal subjects do the procedure with two conditions. First condition is normal (N) which subjects in standing-up position and both hands at the sides. Second condition, normal subjects can't use both (N/N) hand and dominant leg to impersonate trilateral amputee. Trilateral amputee also undergoes the procedure with 2 conditions which are with prosthetics (P) and without prosthetics (N/P). The postural stability index then compared between two conditions for normal subjects and trilateral amputee subject respectively. Also, subjects undergo the procedure on two levels of platform; less stable platform level 3 for normal subjects' perusal and level 5 for amputee subjects' perusal, more stable platform level 12 used on normal and amputee subjects. The study found that there's difference in stability index on normal subject between normal condition and condition where can't use both hands and dominant leg. The differences are identified for each platform. For platform 3 procedure on normal subject, the stability index with condition N/N is increase by 75% from stability index with condition N. Platform 12

procedure on normal subjects, stability index with condition N/N increase by 41% from condition N and on amputee subject, stability index for condition N/P increase by 33% than condition P. Procedure for platform 5 on amputee subject, condition N/P stability index increase by 50% than P condition. Fall Risk test also determined by stability index value which then compare between N condition and N/N condition for normal subject, P condition and N/P condition for amputee subject. Stability index in Fall risk test for normal subjects with N/N condition higher than N condition by increasing 71% while for amputee subject, N/P condition higher than P condition increase by 29%. The test claimed that a lower score is more desirable than a higher score means lower stability index more stable the person is and vice versa which concluded that normal person with normal condition have higher postural stability than trilateral amputee.

ABSTRAK

Kestabilan postur dimaksudkan sebagai keupayaan untuk mengekalkan posisi atau pergerakan. Ia datang dalam dua jenis iaitu statik dan dinamik. Kestabilan postur statik adalah apabila cuma posisi berdiri yang stabil dan tidak bergerak manakala kestabilan dinamik adalah apabila kestabilan badan dalam posisi yang lain selain berdiri atau melakukan pergerakan tertentu.Untuk Orang kurang upaya seperti kudung menjejaskan keupayaan untuk mengimbangi badan ketika berdiri dan bergerak terutamanya jika ia melibatkan kehilangan 3 anggota badan dalam satu masa. Keadaan itu akan memberi kesan kepada kestabilan postur. Kebiasaannya, beberapa jenis latihan akan disediakan kepada orang kudung untuk melakukan aktiviti harian terutamanya yang baru mempunyai keadaan tersebut. Risiko jatuh untuk orang kdudung yang hilang 3 anggota badan juga tinggi daripada orang biasa keranakeseimabnag badan mereka sudah tidak sama seperti biasa. Parameter yang digunakan untuk mengukur kestabilan postur dan risiko jatuh adalah indeks kestabilan postur. Indeks kestabilan postur termasuk jumlah indeks kestabilan *anterior / posterior (APSI)* dan indeks kestabilan *medial / lateral (MLSI).* Semua parameter ini boleh menjadi langkah menggunakan *Biodex Balance System SD (BBS*). Dalam prosedur kajian ini, 2 ujian telah dijalankan iaitu ujian kestabilan postur dan ujian trerhadap risiko jatuh. Sepuluh subjek normal dan satu subjek trilateral mengambil bahagian dalam kajian ini. Subjek normal melakukan prosedur dengan dua keadaan. Keadaan pertama adalah normal (N) dimana subjek dalam kedudukan berdiri dan kedua-dua tangan di sisi. Keadaan kedua, subjek normal tidak boleh menggunakan kedua-dua tangan (N / N) dan kaki dominan untuk menyamar sebagai trilateral. Subjek trilateral juga menjalani prosedur dengan 2 keadaan dimana keadan pertama, lengkap dengan prostetik (P) dan keadaan kedua tanpa menggunakan prostetik (N / P). Indeks kestabilan postur kemudiannya dibandingkan antara dua keadaan

tersebut untuk subjek normal dan subjek trilateral secara berasingan. Juga, semua subjek perlu menjalani prosedur pada dua tahap platform. Subjek normal menggunakan platform 3 dan platform 12 manakala untuk subjek trilateral akan menggunakan platform 3 dan juga sama seperti subjek normal, platform 12. Kajian mendapati bahawa terdapat perbezaan dalam indeks kestabilan dalam keadaan N dan keadaan N/N. Perbezaan dikenal pasti untuk setiap platform. Untuk platform 3 prosedur untuk subjek normal, indeks kestabilan dengan keadaan N / N meningkat sebanyak 75% daripada indeks kestabilan keadaan N. Dengan menggunakan platform 12 prosedur yang dilakukan normal subjek, indeks kestabilan dengan keadaan N / N mempunyai peningkatan sebanyak 41% dari keadaan N manakala untuk subjek trilateral, indeks kestabilan bagi keadaan N / P meningkat sebanyak 33% daripada keadaan P. Prosedur untuk platform 5 pada trilateral subjek, keadaan N / P indeks kestabilan meningkat sebanyak 50% daripada keadaan P. Ujian risiko jatuh juga ditentukan oleh nilai indeks kestabilan dimana dibandingkan antara keadaan N dan keadaan N / N untuk subjek normal, keadaan P dan keadaan N / P untuk subjek trilateral. Indeks kestabilan dalam ujian risiko jatuh untuk subjek normal dalam keadaan N / N lebih tinggi daripada keadaan N dengan peningkatan sebanyak 71% manakala bagi trilateral, keadaan N/P lebih tinggi daripada keadaan P dengan peningkatan sebanyak 29%. Syarikat pembuataan *Biodex Balance System* mengatakan bahawa untuk memastikan seseorang itu mempunyai kestabilan yang baik, nilain indek kestabilan mestilah kurang.

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LIST OF ABBREVIATIONS AND SYMBOLS

BSS	Biodex Stability System
APSI	Anterior / Posterior Stability Index
MLSI	Medial–Lateral Stability Index
OSI	Overall Stability Index
SOT	Sensory Organization Test
PSI	Postural Stability Index
COP	Center of Pressure
COM	Center of Mass
W/C	Wheelchair
ADLs	Activity Daily Life
BMI	Body Mass Index
NS	Normal Subject
TS	Trilateral Amputee Subject
N	Normal
O	Obese
OW	Overweight

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CHAPTER 1: INTRODUCTION

1.1 Overview

There are many types of amputation and many factors that cause it. There are several different types of extremity amputations that can occur including fingers or partial hand (transphalangeal or transcarpal), wrist disarticulation (through the wrist joint), below-elbow (transradial), elbow disarticulation (through the elbow joint), above-elbow (transhumeral), bilateral (both sides of the body are affected), shoulder disarticulation (through the shoulder joint), interscapular thoracic (removal of entire shoulder girdle), and trilateral amputation (involving amputation of three limbs) (Steven A. Ovadia et al. 2015).

Most of the common causes of amputation are birth defect, terrible wounds and illness are regular reasons somebody may lose limbs. Predicaments that come from diabetes and vascular ailment represent most of amputation and some disease patients might be liable to amputation as well. Wounds that happen amid military battle, and vehicle, cruiser and sailing accidents additionally are regular causes. Leg removal, both above and underneath the knee, is commonly more typical than arm and hand removal.

A wide range of amputees may figure out how to adjust their live by doing every day exercises, for example, eating, put on garments and strolling in various manner. They likewise should experience physiotherapy and their standard post-treatment is phantom pain. phantom pain is a term that portrays continuous, physical sensation in the limbs that has been lose. Most patients experience some level of phantom pain following a removal. They can feel shooting agony, consuming or notwithstanding tingling in the limbs that is no longer there. Sometimes, phantom pain can be stayed away from if the nerve closes are stifled inside 12 hours of the damage, which counteracts the development of pain memory pathways. There likewise are prescriptions and treatments that can help.

Amputees have a lengthy, difficult experience to recuperation. Most patients should get settled with a prosthetic and will experience non-intrusive treatment for quite a long time or years following the removal. This procedure is close to home and can change enormously from patient to patient. Recuperation additionally can be influenced by the reason for removal, the particular limb lost and whether the removal happened above or beneath the joint. Removals that happen over the joint will in general be progressively hard to recuperate from and can influence the patient's capacity to utilize a prosthesis (Ovadia et al. 2015).

After somebody has experienced a removal, the fundamental quest for everyday living will turn out to be substantially more troublesome, or maybe even inconceivable. Beforehand clear errands, for example, sustenance readiness or housework may turn into a huge test, and the amputee might be restricted in the exercises they can perform unaided. A significant number of these are assignments that we regularly underestimate, for example, getting dressed, washing, or conveying shopping. Upper-appendage amputees who have lost their predominant hand or arm are all around prone to experience issues finishing assignments that require manual handiness, and to adjust for this should figure out how to utilize their beforehand non-overwhelming appendage. For example, one particularly taxing transfer of skill would figure out how to compose with their more fragile hand. Envision losing three limbs immediately, it must be difficult to try and remain without prosthetic. Achieving perfect postural steadiness may be unusual.

Postural stability is the ability to maintain balance using the muscles in your ankles, knees, and hips in response to movement. Postural stability also defined as the ability to maintain an upright position. It comes in two forms, static and dynamic. Static postural solidness is standing and not moving while dynamic strength is while moving or doing explicit developments. Effective postural control requires the commitment from a complex tactile framework including visual, somatosensory, and

vestibular modalities just as engine control frameworks. For amputees to come back to their day by day life exercises, the capacity to keep up postural equalization is basic while adjusting the development or simply standing position. The support and control of stability, regardless of whether under static or dynamic conditions, is considered as a basic prerequisite for physical and every day activities. Accordingly postural control factors have frequently been utilized to assess patients with different musculoskeletal or neuromuscular clutters (Rogers et al. 2013).

Balance is a complex function involving numerous neuromuscular processes. Balance is constrained by tactile information, focal handling, and neuromuscular reactions. The tactile parts incorporate the vestibular, visual and proprioceptive frameworks. A suitable motor reaction requires a flawless neuromuscular framework and adequate muscle solidarity to restore the focal point of mass inside the base of help when balance is aggravated. Proprioceptive weakness has additionally been associated as one with the potential reasons for equalization impedances in amputee. Amputee has been related with diminished muscle quality and proprioception. This may influence the nature of tactile data and upset the connection between postural reactions and tangible data (Luana Colloca et al. 2017).

The Biodex Balance System (BSS) by Biodex Mecial System Inc. has been used to evaluate postural balance in recent years. The BBS is a multiaxial device that objectively measures and records an individual's ability to stabilize the involved joint under dynamic stress. It uses a circular platform that is free to move in the anterior–posterior and medial–lateral axes simultaneously. The BBS allows up to 20° of foot platform tilt, which permits the ankle joint mechanoreceptors to be stimulated maximally. The BBS measures, in degrees, the tilt about each axis during dynamic conditions and calculates a medial–lateral stability index (MLSI), anterior–posterior stability index (APSI), and an overall stability index (OSI). These indexes represent fluctuations around

a zero-point established prior to testing when the platform is stable. For example, an OSI of 5° would be interpreted to mean that on average, the displacement from center is 5°. Previous studies have shown that BBS is reliable for evaluating dynamic postural balance in healthy subjects.

As mentioned in World Health Organization, a fall is characterized as an inadvertent loss of balance bringing about the individual fall on the ground. Individuals with limb loss has an expanded danger of falling when contrasted with the overall public and falls are related with diminished certainty with equalization, parity, and social interest. Falls in patients with limb loss could be decimating, considerably more so in the old and fragile populace. It is significant for an amputee to have the option to fall securely and to have the option to drop themselves down to the floor, to diminish dread and so as to do exercises on the ground. When all is said in done, amputee have high danger of falling. Falling is a wellbeing hazard that has gotten significant consideration in the writing. Falls may result in death or genuine damage or significant utilitarian impediment and inability. Most examinations that have researched falling danger been directed with old populaces however thinking by relationship recommends that amputee face comparable dangers that make them as inclined to falling as the old; indeed, most amputee are beyond 55 years old years. Danger of falling among the amputee may be marginally unique as every appendage choose the adjusting of the body.

Amputation may make the individual with limb loss feel off guard. There are investigation of falls in individuals with limb loss are related to less stability capacity. Also the expectation that individuals with limb loss will be double to 3.6 million by 2050, which also means will increase risk of falling contrasted with physically fit people. While an investigation found that roughly 26% of inviduals with limb loss extending in age from 20–92 years had fallen, the yearly frequency of falls in amputee community (Wong et al. 2016).

1.2 Problem Statement

As for normal subjects, balance and postural adjustments during standing are generally achieved using “ankle strategy” that the ankle joint will be first line defense against falls as it is designed to move in all directions, while amputee use different strategies to maintain balance. Furthermore, some attributed changes in postural control in amputee disability. This interference is likely to contribute to different adaptive changes in postural control and balance in amputee. The purpose of this study was to evaluate the reliability of dynamic standing balance in individuals between trilateral amputee and normal person using Biodex balance system and to compare the balance indices between the two groups.

As many types of amputation, trilateral amputation may become highlight in this research. Losing one limb may not as hard losing three at once. Trilateral amputee needs to go through physiotheraphy to reduce the risk of fall and learn how to balance their body while standing or walking.

1.3 Objectives

The purpose of this study

1. To evaluate the reliability of dynamic standing balance or called dynamic postural stability and risk of fall in individuals whether trilateral amputee and normal person using Biodex balance system and to compare the balance indices between two groups.

1.4 Report Structure

This project contains five chapters that consists of an introduction, literature review, methodology, results and discussion and conclusion. The introduction part gives an overview about amputation, Postural stability, fall of risk and Biodex Balance System. Problem statement and objectives of the research are related to trilateral amputation postural stability and fall risk were elaborated in this chapter.

Second chapter is literature review, related information and input are compiled to support the objective based on the previous research work. All this compilation with make this study more understandable. Methodology come as third chapter covers the detailed explanation of experimental procedure, the instrumentation used, the subject's information, the requirement that subjects need to pass to make sure the accuracy of the results. Results are tabulated and analysed briefly. Lastly, conclusion suggests the improvement from the current work and future work.

1.5 Scope of study

This study focusses on the trilateral amputation type. The postural stability test and fall risk assessment on amputee that lost three limbs at once and compare it to normal person. However, there's kind of limit to invite trilateral amputee to go through the procedure as only one trilateral amputee was found to live in Petaling Jaya area. Therefore, to proceed with the procedures, normal person will test the postural stability and assess their fall risk by making their three limbs non-function at same time. The tests done at Human Performance and Motion Analysis laboratory under Biomedical Engineering Department, University of Malaya. The study provides the background of amputation, postural stability and fall of risk amongst amputee at introduction to make this study more understandable. Also, the input to answer the objective on analysed result provided to prove this study is reasonable. Study procedure been summarized in flowchart

in Figure 1.1. Somehow, acknowledged that the study has limitation on procedure and result analysis which can be improved in future work.

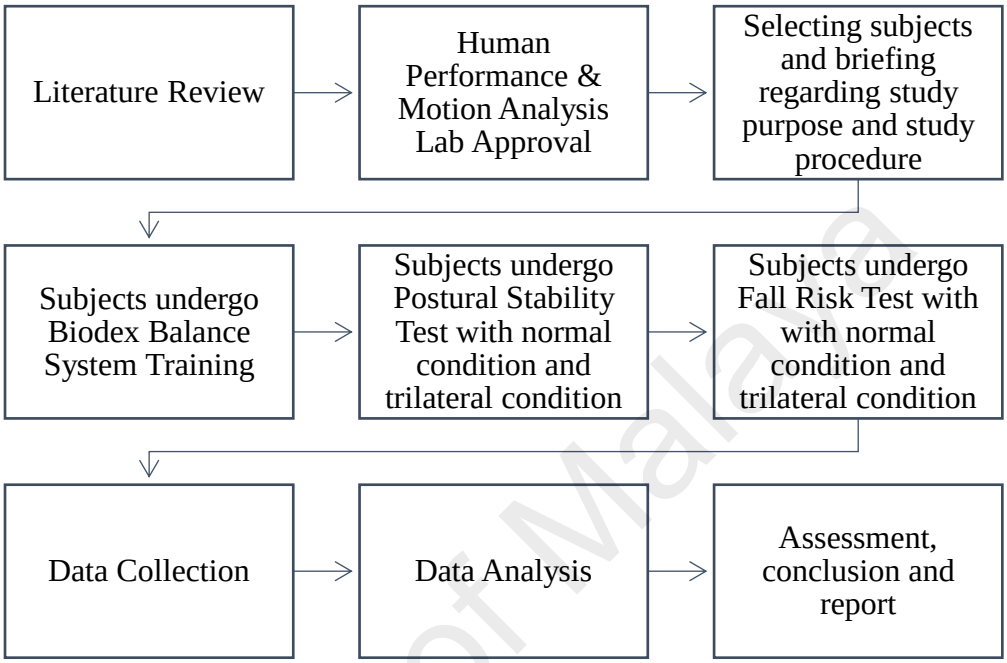


Figure 1.1: The progression or sequential steps in a study

CHAPTER 2: LITERATURE REVIEW

This chapter represent both a summary and explanation of the complete and current state of knowledge study in Postural Stability and Risk of Fall amongst community including normal persons and amputees.

2.1 Stability Tests

Postural control is the ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support. Unsupported, standing humans are in unstable equilibrium, or balance, because the force of gravity must be counteracted continually by muscular energy. Measurement of postural control is difficult because the location of the center of body mass (center of gravity) is not determined easily (Thierry Paillard et al. 2015). As improvement made by time, there are some completed researched by different methodology and all their objective is one – Postural stability measurement.

2.1.1 Sensory Organization Test (SOT)

Currently, doctors, specialists, and scientists regularly utilize the Equilibrium Score (ES) from the Sensory Organization Test (SOT) to survey the postural strength of a patient or subject. SOT gives data about the joining of the visual, proprioceptive, and vestibular segments of parity, which prompts a result which is ES. Since the SOT based ES does not think of some as key biomechanical parts of postural solidness, another proportion of postural soundness proposed, which called the "Postural Stability Index" (PSI). Another list of postural security that represents extra biomechanical properties of standing that ought to be reflected in a clinically important score. No development of the subject outcomes in an ideal score of 100 additionally portrayed. In the event that the subject falls or the estimation of the ES is negative, the subject gets a score of 0. In this manner, the ES goes somewhere in the range of 0 and 100. The presumptions about the

general greatness of the breaking points of solidness just as the extent of foremost and back influence can bring blunders into the ES figuring for people whose cut off points of strength fluctuate fundamentally from the age-and stature coordinated standards. The assumptions about the overall magnitude of the limits of stability as well as the magnitude of anterior and posterior sway can introduce errors into the ES calculation for individuals whose limits of stability vary significantly from the age- and height-matched norms. Some studies believe that in a clinical setting, a single number or a small set of numbers representing postural stability is desirable so that clinicians can quickly determine whether a patient requires a balance intervention or whether an intervention has been effective in improving postural stability. There are study that proposed a solitary measure characterizing postural stability that depends on the material science of standing and that makes less presumptions than Equilibrium Score (Hans Chaudhry et al. 2004).

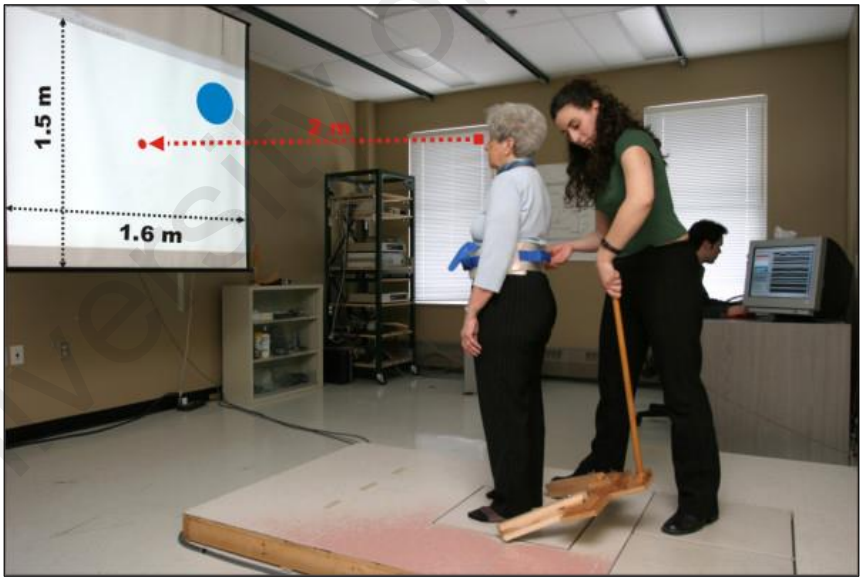


Figure 2.1: Illustration of experimental paradigm and measurement set-up (Hans Chaudhry et al. 2004).

2.1.2 Force Plate

As the name implies, force plate is a device that measures ground reaction forces as the person stands quietly in conditions “eyes open, surround and platform stable” and “eyes closed, surround and platform stable” only, as described above and is used to determine the COP (center of pressure) displacement. It is then used to obtain sway of the COM (center of mass) which can be used to determine the ES (equilibrium score) (Hans Chaudhry et al. 2011). A Brief Review Force Plate uses a strain gauge and features excellent linearity and temperature characteristics, allowing calibration with a static load. Minimal zero-drifting enables stable measurement. Key features of force plate are the design and combinations of the internal sensors and top plates.

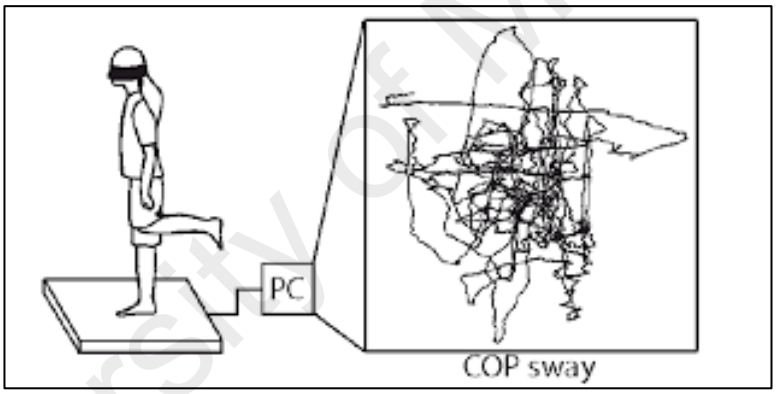


Figure 2.2: Example of static balance test on a force plate (single leg stance, eyes closed, arms free). An example of the COP sway of this test is on the right side (Andrej Panjan & Nejc Sarabon. 2015).

Obtaining and signal processing of the COP sway is a requirement of a test. More often than not, makes of a force plate framework offers software for procurement of the COP, however the examining recurrence of the obtaining should be focus on. In the event that it is excessively low, at that point probably won't most likely procure little and high recurrence changes of the COP. The suggested examining recurrence is somewhere in the range of 100 and 1000 Hz. Higher frequency of sampling are redundant, and they will just expand the measure of information obtained. Handling of obtained information

comprise of pre-preparing and real preparing where last outcomes are figured (Andrej Panjan & Nejc Sarabon. 2015).

2.1.3 Balance Master

This device consists of a movable support surface (force plate) and a visual surround with a harness to prevent fall during testing. It can determine the COP displacement as well as the sway of COM in conditions eyes open, surround and platform stable; eyes closed, surround and platform stable; eyes open, sway-referenced platform; eyes closed, sway-referenced platform. It can be used to determine the ES and PSI. This device also consists of a movable support surface (force plate) and a visual surround, which can move in a sway-referenced manner, along with a harness to prevent fall during testing. It can determine the COP displacement as well as the sway of COM (Hans Chaudhry et al. 2011).

Figure 2.3: The EquiTest system is ideal for the comprehensive balance program (Adpted from Balance & Mobility Academy)

The EquiTest system utilizes a dynamic force plate with rotation and translation capabilities to quantify the vertical forces exerted through the patient's feet to measure center of gravity position and postural control; and a dynamic visual surround to measure the patient's use of visual information to maintain balance. It provides assessment and

retraining capabilities with visual biofeedback on either a stable or unstable support surface and in a stable or dynamic visual environment.

2.2 Stability Amongst Amputee

Amputees had more lesser static and dynamic stability than physically fit controls. Amputees had a more prominent issue controlling unique parity in the anteroposterior direction than the mediolateral direction (Ahmed ha et al. 2010).

Most research studies, which focus on stability in subjects with lower limb amputation, are concentrated on stability control in quiet standing positions. Lower-limb amputation is mainly a result of trauma, vascular disease, diabetes, or congenital disorders. Researcher state an increase in postural sways in subjects with lower limb amputation (short- and long-term prosthesis users) compared to healthy subjects. The standing stability in patients with amputations is altered in the way of postural sway increases and the stability control strategy changes as results (Viton et al., 2000). In most of the studies, a one force plate is used to measure postural stability parameters. There are studies that separate analyse procedure between the prosthetic and non-amputated leg, show a lowering of the load and decrease of the COP (centre of pressure) sway on the prosthetic limb (Quai, Brauer, & Nitz, 2005). Research confirms that good intact limb stability for the functional integration of an amputated subject into life is conditional (Schoppen et al., 2003).

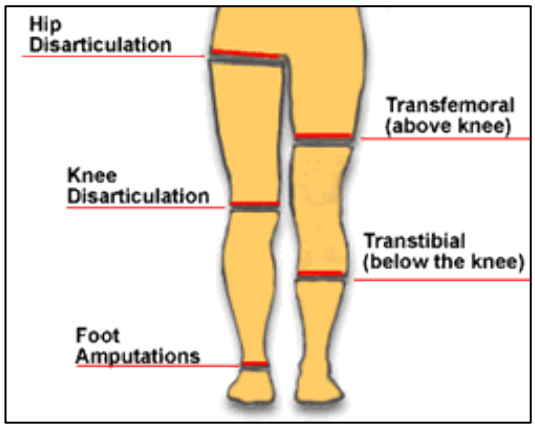


Figure 2.4: The major categories of lower limb amputations (Adapted from Amputee Rehabilitation, Musculoskeletal Program)

The upper limbs are the most significant piece of the body that have practical capacity to perform day by day exercises, self-care obligations, side interests and sports. Static stability very little impact on upper limbs loss as they clearly can stand appropriately, yet powerful parity may influence as the center of mass changed by losing any limbs or utilizing prosthetic.

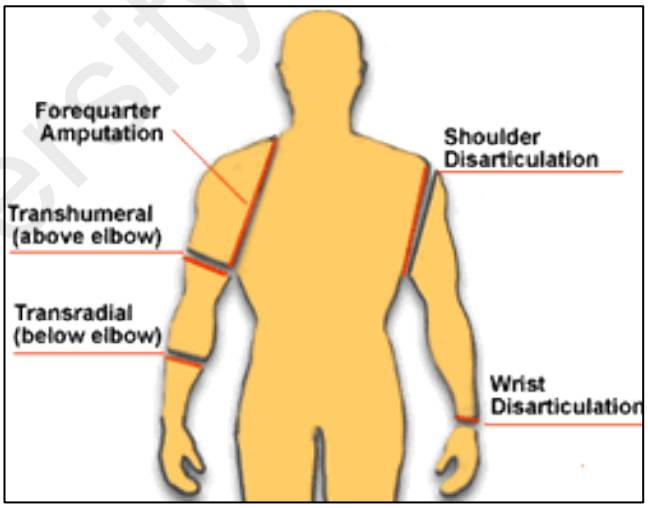


Figure 2.5: The major categories of upper-limb amputations (Adapted from Amputee Rehabilitation, Musculoskeletal Program).

2.3 Relationship Between Stability and Amputee

People with amputation lose their capacity to stand and walk in view of the amputation level. Commitment of amputation level, type of amputation, or reason for amputation to adjust balancing impairment may the factor to influence the stability of amputee. Besides, it is disputable how much the referenced parameters impact standing stability (Kamali M et al. 2013). Body execution require legitimate and dynamic connection between stability (postural control) and portability. Truth be told, movement execution, emphatically related with motor cortex yield depends, for soundness purposes which fundamental objective is postural modification expected to help the body development additionally static position (Claudia Isabel, 2013)

The other parameter that may meddle with balance and stability is dominant limb that can be characterized based on strength of muscle, practical use and individual preference. Dominance of limb ought to be resolved by which leg the individual picks and depends on to do an assortment of utilitarian exercises, including maintain stability and balance. (Angelica Castilho, 2011)

Disturbs motor and proprioceptive function likewise have impact in stability of amputee. Biomechanical parts of the stride of amputee is important to improving their step work and their personal satisfaction. Notwithstanding biomechanical debilitations, people with amputation likewise experience disturbed somatosensory that is the arrangement of the piece of the tactile framework worried about the cognizant impression of vibration, touch, pain, weight, postion, temperature and movement, which emerge from the fascia, joints, skin and muscles. (Rainer Beurskens, 2014) Either the measure of postural sway or the measure of time a stable position can be kept up is estimated under six sensory conditions. The sensory conditions efficiently join two distinct surfaces (typical and orientationally erroneous) and three diverse visual conditions (ordinary,

missing vision, and orientationally off base vision). An orientationally incorrect surface is given by having subjects remain on thick, consistent froth to such an extent that somatosensory contributions from the feet never again are furnishing precise data about postural influence with reference to the vertical plane. (Fay B. Horak, 1987)

Stability amid standing, which is defined as the ability to keep up the body focus of gravity inside its base of support, is accomplished by a complex synchronized performance of different system (musculoskeletal and neurologic frameworks). imbalance may be the after effect of diminished proprioception in-arrangement brought about by loss of feedback from foot position. It is notable that stability amid calm standing and keeping in mind that endeavor different errands (strolling and hand undertakings) is constrained by the hip and lower leg. In stable standing position, no external perturbation is applied on the body. In lower-limbs amputees, the lower leg joint system is lost with the goal that steadiness is predominantly constrained by hip joint components. Lower leg joint stability is defined as repositioning of the focal point of gravity by movement of the lower leg joint with little movement of the hip and knee joints, which is finished by getting the muscles encompassing the lower leg joint. Interestingly, hip technique is finished by dynamic trunk turn around the hip joint to settle the focal point of gravity inside the base of support. (Kamali M et al. 2013)

2.4 Biodex Stability Test amongst Amputee

Postural stability test was directed utilizing a Biodex stability system for its known unwavering quality in target evaluation of postural stability. There is a conceivable job for postural training with Biodex Balance System in improving the balance and steadiness in human lives particularly the person who required it the most. The helpfulness of offset preparing with BBS in improving postural balance and stability are all around shown in past examinations in older individuals, particularly those with neuropathy, diabetes and

amputation. (Akbari. 2012; Salsabili. 2011). This device consists of a circular platform with series of strain gauges which can be used to assess subject's control of balance on either static or unstable surface condition. For that, there's study of prosthetic foot that prescribed to help amputees regulate the body's center of mass within the base of support to achieve postural equilibrium during quiet standing, as opposed to the plantar flexors-dorsiflexors mechanism in able-bodied person. From the center of Mass excursion about the anterior- posterior and medial- lateral axes from the center point, the BSS measures the overall stability index (OSI), anterior-posterior stability index (APSI) and medial-lateral stability index (MLSI). oreover, OSI was recommended as the best parity pointer. The stage was incorporated with PC programming (Version 3.1 Biodex Medical Systems) that empowers the gadget to compute the stability indexes. (N Ariffin et al. 2014)

2.5 Risk of Fall Related to Amputee

Every year, a huge number of more established individuals—those 65 and older—fall. Truth be told, more than one out of four older individuals falls every year, except not exactly half tell their doctor. Falling once double your odds of falling once more. Danger of fall-related damage requiring therapeutic consideration in individuals with lower limbs amputation gives off an impression of being higher than in more established grown-up inpatients. Mediation projects to anticipate fall-related damage in individuals with lower limbs amputation should target ladies and racial minorities. Individuals with lower limbs amputation that live in the network fall at a rate that surpasses that of other defenceless populaces, for example, hospitalized older individuals. Past research in a little single state think about has recognized components related with fall-related damage. Past investigations with fewer than 50 subjects suggest a heightened risk of falls and fall-related injuries among people with lower limb amputation (Wong et al. 2015; Wong et al. 2016). Falls have been associated with a fear of falling and lower levels of balance confidence among people with limb loss (Miller et al. 2011) with decreased balance

confidence associated with lower levels of prosthetic function (Wong et al. 2014). Falls, decreased confidence, and lower prosthetic function (Barnett et al. 2013). The personal, indirect, and non-medical costs incurred after fall-related injury may extend far beyond the $25,000 average estimated direct medical costs in the 6 months following a fall for 16 people with transfemoral amputations seen between 1987 and 2014 (Mundell et al. 2017).

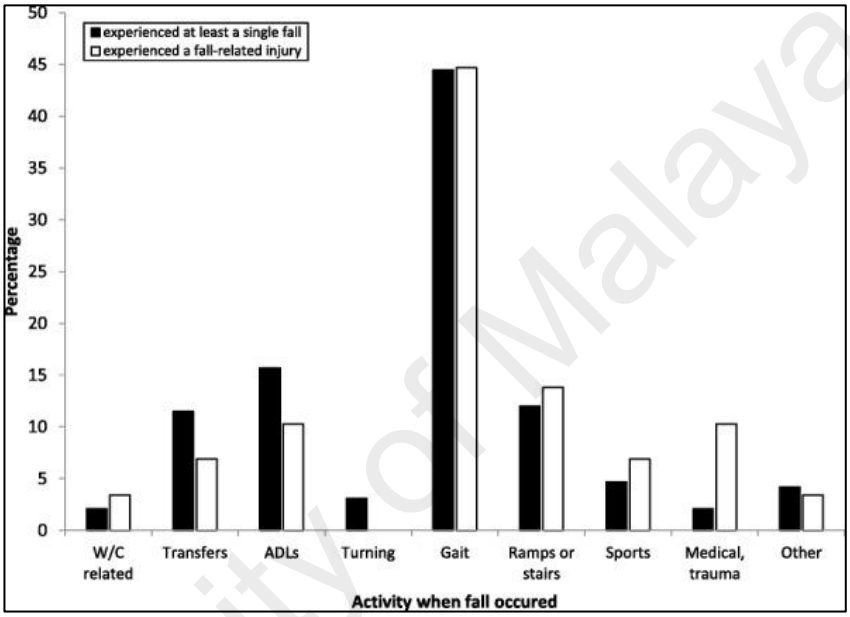


Figure 2.6: Activities when fall occurred among people with limb loss who experienced falls and those who experienced fall-related injuries. Black; Experienced at least a single fall. White; Experienced a fall-related injury. W/C: wheelchair; ADLs: activities of daily life (Stanford Chihuri,2018)

There are a lot of consequence after falls on amputee such as fractures to the femur, trauma to the stump, increasing in fear of falling, lengthy hospital stays, and patient is discharged to a long-term facility or Mobility and social activity restriction. By knowing the consequence and researcher come up with solution to reduce the effect by knowing how to minimize injury during a fall and knowing what to do immediately after falling. These kinds of education are important to amputee as their risk of fall are higher than normal people.

2.5 Summary

There are 31 previous studies that related to this research and the data can be useful to support the conclusion by this research. Table 2.1 listed the previous studies that been evaluated prior the research.

Table 2.1: Related studies to the research

No	Authors	Title	Experiment setup	Pros	Cons	Remarks
1	Jagoda Walowska; Bartosz Bolach; Eugeniusz Bolach	The influence of Pilates exercises on body balance in the standing position of hearing-impaired people	Eighty students (aged 13-24) were enrolled and randomly allocated into two groups: test group (n = 41) which attended an original program based on modified Pilates exercises and control group (n = 39) which attended standard physical education classes. Stabilographic tests were conducted at baseline and after 6-week training program.	The Pilate movement use in this study modified to be as useful and suitable for study's objective.	The study didn't use any hearing impairment people as subject while the objective of study to relate the Pilates exercise with impaired hearing people body balance in stand position.	Despite the pros and cons, authors still mentioned at the end of the study papers that further research is required.
2	Yilmaz, R; Inanir, A; Kazanci, NO ; Cakan, N; Gul, A	Evaluation of Dynamic Postural Balance in Pediatric Familial Mediterranean Fever Patients	The study examined 50 paediatric patients with FMF and 130 healthy age-and sex-matched children as control subjects. Dynamic postural stability was measured using the Biodex Stability System (BSS).	- The subjects and controls group use are in big quantity allowing the study to be more accurate. - The study results were calculated as the mean of three	- In this study, balance is measured during attack-free periods, and thus could not compare balance between attack and attack-free periods and assess the effects of pain. - Lack of an evaluation of the effects of sensory inputs on balance - The study referred to	As the study used out dated disease severity index, authors suggested that in future study (same prospect) can used Autoinflam

				measurements made at 20-second intervals, also provide more accurate results.	out dated disease severity index	matory Disease Activity index.
3	Jacek Wilczyński	Postural Stability in Goalkeepers of the Polish National Junior Handball Team	Eleven players of the Polish junior national handball team (age 16.82 ± 1.6 years, body height 191.27 ± 3.1 cm, body mass 88.41 ± 12.26 kg, BMI 24.18 ± 3.22 kg/m2, training experience 6.54 ± 1.86 year) took part in the study. The Biodex Balance System and AccuGait AMTI platforms were used to assess postural stability. The Postural Stability Test was conducted on the Biodex Balance System platform, with double support in a stable position with open eyes. The Postural Stability Test consisted of three 20-s trials, separated by a 10-s rest interval. The subject's eyes were focused on a screen where a dot appeared.	Subjects used need to undergo same training and pressure which will provide accurate results to study.	As 2 systems are used in this study but both of them test different parameters. This take long time for study to finish. Also, Data distribution used Shapiro-Wilk test, t-test, Pearson's linear correlation coefficients which required a lot of time.	Despites the cons that study is taking a lot of times, actually the study is very good as the method is very fair and accurate.
4	Jacek Wilczyński; Paweł Półrola	Body posture and postural stability of people practicing qigong	The study involved 32 people. The mean age of those tested was 54 years. Posture study used optoelectronic method Diers formetric III 4D. Postural	The study used most advance non-invasive system for evaluating	- The study comparing results between sexes but men subjects quantity is very low compare to women	-

			stability was tested on the platform Biodex Balance System. The studies were performed at the Posture Laboratory of the Institute of Physiotherapy at Jan Kochanowski University in Kielce.	posture which also quick, free of harmful radiation, and large optical measurement of posture and spine	quantity. This will provide unfair comparison and inaccurate results.	
5	Jacek Wilczy Nski; Agnieszka Pedrycz; Dariusz Mucha; Tadeusz Ambrohy; Dawid Mucha	Body Posture, Postural Stability, and Metabolic Age in Patients with Parkinson's Disease	32 people were evaluated. The study was conducted in the Laboratory of Posturology at Jan Kochanowski University in Kielce (Poland). Body posture was examined using the optoelectronic body posture Formetric Diers Method III 4D. Postural stability was evaluated using the Biodex Balance System platform. Body composition was assessed with the method of bioelectrical impedance analysis using the Tanita MC 780 MA analyser.	- The study was non-invasive and free of charge. Other than that, the system used also quick and touchless photometric 4D measurement. -All the parameters registered by the posturological platform were collected completely noninvasively, and the device was deemed safe for the patients recruited to the study	Subjects size and grouping male and female are not convincing. There's no control group.	-

6	Bina Eftekhar-Sadat, Roghayyeh Azizi; Akbar Aliasgharzadeh; Vahideh Toopchizadeh and Morteza Ghojazade	Effect of balance training with Biodex Stability System on balance in diabetic neuropathy	In this randomized clinical trial, 34 elderly DN patients were divided into intervention (n = 17) and control (n = 17) groups. The experimental group underwent a balance training program using the Biodex Balance System (BBS) for 10 sessions. All subjects in both groups were assessed using timed 'up and go' (TUG) test, the Berg balance scale, and the fall risk and postural stability tests, at baseline and at the end of the study.	- This study included only those patients with moderate-to severe Toronto score and confirmed neuropathy with electrodiagnostic studies, which allowed a better evaluation of the effects on DN patients with lower bias on the results.	The results should be interpreted cautiously as the patients had severe scores and the sample size was small for a randomized clinical trial.	
7	Elbadawi ibrahim mohammad Elhinidi; marwa mostafa ibrahim ismaEEl; tamEr mohamEd El-saEEd;	Effect of dual-task training on postural stability in children with infantile hemiparesis	Thirty patients participated in this study; patients were classified randomly into two equal groups: study and control groups. Both groups received conventional physical therapy treatment including mobility exercises, balance exercises, gait training exercises, and exercises to improve physical conditioning. In addition, the study group received a selected dual-task training program including balance and cognitive activities. The treatment program was	To ensure the safety of every patient, the session started with the balance platform in the "locked" or static position.	Motion of the study quite difficult for subjects to do it.	

			conducted thrice per week for six successive weeks. The patients were assessed with the Biodex Balance System. These measures were recorded two times: before the application of the treatment program (pre) and after the end of the treatment program (post).			
8	Fatih Celebi, Feyza Hologlu; Sibel Akbulut; Ali Altug Bicakci	Effects of Rapid Maxillary Expansion on Head Posture, Postural Stability, and Fall Risk	A sample of 51 adolescent patients was randomly divided into two groups. In the first group, which consisted of 28 patients (15 females and 13 males), RME was performed as a part of routine orthodontic treatment. The remaining 23 individuals (12 females and 11 males) served as the control group. Lateral cephalometric radiographs taken in natural head position, postural stability, and fall risk scores were obtained during the first visit. They were repeated on average 3.8 months and 3.5 months later for the study and control groups, respectively. The changes were analyzed using the Wilcoxon signed-rank test, paired samples t-test, Mann–Whitney	- This study interpret many parameters in one time. - This study journal written very clear and can be understand easily to the reader despite complicated words or term that been used, the study then explained clearly.	- The literacture and objective of the study may require a longer time to detect significant difference. - total sample size in this study was only 51 individuals (28 in study group and 23 in control group). Larger sample size can present the more definitive conclusions to the literature. Therefore, results in the present study must be interpreted with caution.	

			U-test, and independent samples t-test.			
9	Karimi, N ; Ebrahimi, I ; Kahrizi, S ; Torkaman, G	Evaluation of postural balance using the biodex balance system in subjects with and without low back pain	Twenty-three mate patients with LBP (mean age: 30.4 +/- 6.5 years) and twenty age-matched healthy mate subjects (mean age: 29.8 +/- 6.4 years) participated in this study. Medial-lateral stability index (MLSI), Anteriorposterior stability index (APSI) and an Overall stability index (OSI) were measured in two measurement sessions using the BBS. Balance was measured in four conditions; bilateral and unilateral stance with eyes open and eyes closed; over a period of 20s.	- Parameter of study are complete and a lot. Enough to prove the objectives.	- The subject size needs to be bigger in order to get significant data or difference.	

10	Melissa Paniccia; Katherine E. Wilson; Anne Hunt	Postural Stability in Healthy Child and Youth Athletes: The Effect of Age, Sex, and Concussion-Related Factors on Performance	This study comprised 889 healthy/uninjured child and youth athletes (54% female, 46% male) between the ages of 9 and 18 years old. Participants completed preseason baseline testing, which included demographic information (age, sex, concussion history), self-report version of the PCSI were used (PCSI-C, 9 to 12-year-old; PCSI-Y, 13 to 18 year olds). Postural stability was assessed via sway index under 4 sway conditions of increasing difficulty by removing visual and proprioceptive cues.	- The subjects size are convincing. - All subjects are completed preseason baseline testing, so the result will be fair.	No control group to make comparison. If there's any, the results will be more reliable	No full journal provided, only review
11	Nerrolyn Ramstrand; Kjell-Åke Nilsson	A Comparison of Foot Placement Strategies of Transtibial Amputees and Able-Bodied Subjects During Stair Ambulation	Three-dimensional motion analysis was used to determine foot positioning and to calculate temporospectral parameters during stair ascent and descent of 10 transtibial amputees (mean age = 56) and a control group consisting of 10 healthy able-bodied individuals (mean age = 26.7).	- Control group is used to compare the results. This is correct procedure.	- Subjects size is small. - Control group and amputees age are too much differences as it may affect the results.	No full journal provided, only review

12	Schafer, ZA; Perry, JL; Vanicek, N	A personalised exercise programme for individuals with lower limb amputation reduces falls and improves gait biomechanics: A block randomised controlled trial	Fieen LLAs, recruited from their local prosthetic services centre, were block randomised, by age and level of amputation, into two groups: exercise group (transfemoral, n = 5; transtibial, n = 2) and control group (transfemoral, n = 5; transtibial, n = 3). The exercise group completed a 12-week programme, focusing on strength, balance, flexibility and walking endurance, delivered in group sessions at the University, and combined with a personalised home exercise programme. Temporal-spatial, 3D kinematic and kinetic gait parameters were collected at baseline and postintervention. Falls incidence was also followed up at 12 months	- Parameter of study are complete and a lot. Enough to prove the objectives.	- Small subjects' size	Subjects size may be small as transfemoral/ transtibial type of amputation are hard to find.
13	Halsne EG1; McDonald CL1; Morgan SJ1; Cheever SM1; Hafner BJ1	Assessment of low- and high-level task performance in people with transtibial amputation using crossover and energy-storing prosthetic feet: A pilot study.	Participants with transtibial amputation completed a battery of performance-based outcome measures, including the Five Times Sit-to-Stand, Timed-Up-and-Go, Four Square Step Test, and the Comprehensive High-level Activity Mobility Predictor. Participants wore duplicate prostheses fit with	- Paired t tests were used to evaluate differences between feet and order of testing, giving more reliable results.	- No significant result and future research needs. - Small subjects' size	

			crossover feet and energy-storing feet to perform the tests; the order of foot conditions was randomized. Paired t tests were used to evaluate differences between feet and order of testing.			
14	Nafiseh Khalaj1; Noor Azuan Abu Osman1; Abdul Halim Mokhtar2; Mahboobeh Mehdikhani1; Wan Abu Bakar Wan Abas1	Balance and Risk of Fall in Individuals with Bilateral Mild and Moderate Knee Osteoarthritis	Sixty subjects aged between 50 and 70 years volunteered in this study. They were categorized into three groups which were healthy (n = 20), mild (n = 20) and moderate (n = 20) bilateral knee osteoarthritis groups. Dynamic and static balance and risk of fall were assessed using Biodex Stability System. In addition, Timed Up and Go test was used as a clinical test for balance.	- This study was approved by Medical Ethic Committee in University Malaya Medical Centre (UMMC) -All participants read and signed a written consent form - showing participants are aware with the procedure and any effect.	- Subjects size is small	

15	Helen J. Connor; Heather C. Curtis; Wayne Dite	Clinical Identification of Multiple Fall Risk Early After Unilateral Transtibial Amputation	All people with a unilateral transtibial amputation who were wearing a prosthesis at discharge, over 18 years of age, willing to participate, and gave informed consent were recruited into the study. All participants were tested at discharge and at 6 months post discharge. Personnel used to score and administer the balance tests at 6 months were blinded to pre-test scores and participant background, as well as mobility and 6-month fall history. At the 6-month test, participants repeated balance and mobility tests and the LCI advanced score and were also interviewed to determine fall history since discharge.	- Physical measurement was done and each person tested differently which make the result fair.	- The sample size is small and it is a sample of convenience (although from 2 independent centres) - fall recall was done retrospectively by participants (which is likely to underestimate fall rates) - daily activity and LCI rating were all based on participant self-report and were all done at 1 point in time only (on the 6-month retest day)	
16	Segal, AD; Orendurff, MS; Czerniecki, JM ; Schoen, J; Klute, GK	Comparison of transtibial amputee and non-amputee biomechanics during a common turning task	Comparison of the biomechanics of unilateral transtibial amputees and non-amputees completing a common turning task. Full body gait analysis was completed for subjects walking at comparable self-selected speeds around a 1 m radius circular path. Peak internal and external rotation moments of the hip, knee and ankle,	- Many parameters are covered in the study make the result more reliable	- No subjects size mentioned	No full journal provided, only review

			mediolateral ground reaction impulse (ML GRI), peak effective limb length, and stride length were compared across conditions (non-amputee, amputee prosthetic limb, amputee sound limb).			
17	Rainer Beurskens; jason M. Wilken; and Jonathan B. Dingwell	Dynamic Stability of Individuals with Transtibial Amputation Walking in Destabilizing Environments	9 persons with unilateral transtibial amputation and 13 able-bodied controls walked on a large treadmill in a Computer Assisted Rehabilitation Environment (CAREN). While walking, subjects were either not perturbed, or were perturbed either by continuous mediolateral platform movements or by continuous mediolateral movements of the visual scene. Participants walked in a Computer Assisted Rehabilitation Environment (CAREN) (Motek, Amsterdam, Netherlands). Subjects walked on a 2 × 3m instrumented treadmill embedded in a 4m-diameter six degree-of-freedom motion platform inside a 7m-diameter dome that created an immersive virtual environment.	All subjects signed informed consent statements approved by both Brooke Army Medical Center and The University of Texas. - preferring subjects aware the procedure.	As visual perturbations involve, the motion may be hard for the amputee to do it	

18	Sturk, JA; Lemaire, ED; Sinitski, E; Dudek, NL; Besemann, M; Hebert, JS; Baddour, N	Gait differences between K3 and K4 persons with transfemoral amputation across level and non-level walking conditions	Four K3 and six K4 transfemoral amputation and 10 matched able-bodied individuals walked in a virtual environment with simulated level and non-level surfaces on a self-paced treadmill. Stability measures included medial-lateral margin of stability, step parameters, and gait variability (standard deviations for speed, temporal spatial parameters, root-mean-square of medial-lateral trunk acceleration)	Parameter of study are enough to prove the objectives	High performing and community ambulatory transfemoral amputees cannot match the ambulatory abilities of able-bodied individuals. This may affect the reliability of results.	
19	Roeles, S; Rowe, PJ; Bruijn, SM; Childs, CR ; Tarfali, GD; Steenbrink, F; Pijnappels, M	Gait stability in response to platform, belt, and sensory perturbations in young and older adults	Nine young (25.13.4years) and nine older (70.17.6years) adults walked on the CAREN Extended (Motek BV, The Netherlands). The perturbation effect was quantified by deviation in MoS over six post-perturbation steps compared to baseline walking. Contra-lateral sway and deceleration perturbations resulted in the largest ML (1.9-4 times larger than other types) and AP (1.6-5.6 times larger than other types) perturbation effects, respectively. Aer both perturbation types, participants increased MoS by taking wider, shorter, and faster steps	Parameter studied in this experiment may giving reliable results even though there's many of them	Subject size is small	

20	Hakim, RM; Frey, CM; Spadoni, KE; Meyer, K	Identifying Fallers Using Clinical Balance Measures in Community-Dwelling Adults with Lower Extremity Amputation: A Cross-Sectional Study	A cross-sectional study was conducted on a convenience sample of 40 independently ambulatory participants with unilateral LE amputations and a prosthetic device (20 falters and 20 no fallers) who were tested during a single session using: The Amputee Mobility Predictor with Prosthesis (AMP PRO). Functional Reach (FR), Single Limb Stance (SLS) and the Timed-Up-and GO (TUG).	The study content is specific which may save time to get the results.	heterogeneous sample and self-report of fall history are not recorded. This parameter may affect the results.	No full journal provided, only review
21	Dr Natalie Vanicek; Siobhan Catherine Strike; Lars McNaughton	Lower Limb Kinematic and Kinetic Differences between Transtibial Amputee Fallers and Non-Fallers	Eleven transtibial amputees were recruited from the local Artificial Limb Unit over a four-month period. Inclusion criteria stipulated participants must have worn their prosthesis on a daily basis without experiencing pain. They must have been able to ascend stairs independently without walking aids, although the use of handrails was permitted. Participants were classified into either the (n = 5) non-faller and (n = 6) faller groups based on their fall's history in the nine month period leading up to testing. There were no significant differences between	Both kinetic and kinematic parameters are taken, make the result more reliable.	'Light' handrail use affects kinetic data to some level by redistributing the joint moments across the ankle and knee joints. Therefore, some caution should be used when interpreting the kinetic results as handrail use varied across subjects	

			the two groups on these characteristics. A three-step wooden staircase was built for this study. The steps were 80 cm wide, with a rise of 20 cm, a tread of 25 cm, and a final tread of 80 cm. One Kistler force plate (model 9286AA Kistler GmbH, Winterthur, Switzerland) with built-in charge amplifiers not to the bottom step which housed the force plate. Three-dimensional kinematic and kinetic values were obtained using Qualisys Track Manager software (Qualisys, Gothenburg, Sweden) while the participants walked along a level walkway and proceeded to climb the staircase. Ten ProReflex MCU1000 cameras (Qualisys, Gothenburg, Sweden) captured 3D marker coordinate data at 100 Hz and were synchronized with the force plate that sampled at 500 Hz. The motion capture system was calibrated using a 300 mm calibration wand and L-frame reference object identifying the lab origin.			

22	Eduardo J. Beltran; Jonathan B. Dingwell2; and Jason M. Wilken	Margins of stability in young adults with traumatic transtibial amputation walking in destabilizing environment	Participants included nine young, healthy individuals with traumatic unilateral transtibial amputation and thirteen young, healthy able-bodied adults (Table 1). All TTA were screened to ensure they were free of orthopedic and neurological disorders to the intact side. All participants provided written informed consent prior to participation. All subjects walked in a Computer Assisted Rehabilitation Environment (CAREN; Motek, Amsterdam, Netherlands) which consisted of a 7-diameter dome allowing projection of a 300° field-of-view virtual environment and a 6 degrees-of-freedom platform with embedded treadmill. The virtual reality scene depicted a dirt path through a forest with mountains in the background. White poles, 2.4 m in height and spaced every 3 m, lined the path to enhance the visual parallax (Bardy et al., 1996; McAndrew et al., 2010). Subjects were tethered to a safety harness mounted on the platform behind the treadmill	Subjects were tethered to a safety harness mounted on the platform behind the treadmill and out of the subject's field of view. This will ensure the safety of subjects.	- Relative functional importance of any specific sub-component measure to MOS is difficult to determine. It should be noted that no subjects fell, therefore all subjects recovered from any steps with small or negative MOS. - The results may not extrapolate to other sub-groups of individuals with lower-limb amputation such as older individuals with amputation of vascular etiology.	

			and out of the subject's field of view. Following a 6-minute warm-up period, each participant completed five 3-minute walking trials in the CAREN with each of the following conditions: no perturbation (NOP), platform perturbations (PLAT), and visual perturbations (VIS). Net visual progression through the virtual scene was matched to the treadmill speed for all conditions. During NOP, the platform was stationary and visual progression remained matched to the treadmill speed. During PLAT, the platform translated continuously while visual progression was unperturbed. During VIS, the platform was stationary, and the virtual scene translated continuously. Platform and visual perturbations were designed to represent irregular environments such as uneven terrain and crowded spaces, respectively, that cause disturbances in walking stability.			

23	Cleveland T. Barnett; Natalie Vanicek; David F. Rusaw	Predictive Relationships Exist Between Postural Control and Falls Efficacy in Unilateral Transtibial Prosthesis Users	Participants (N=24) included a group of active unilateral transtibial prosthesis users of primarily traumatic etiology (n=12) with at least 1 year of prosthetic experience and age- and sex-matched control participants (n=12). Twelve-month within- and between-participants repeated measures design. Participants performed the limits of stability (LOS) test protocol at study baseline and at 6-month follow-up. Participants also completed the Falls Efficacy Scale-International (FES-I) questionnaire, reflecting the fear of falling, and reported the number of falls monthly between study baseline and 6-month follow-up, and additionally at 9- and 12-month follow-up.	Postural control variables derived from centre of pressure data obtained during the LOS test, which was performed on and reported by the Neurocom Pro Balance Master, namely reaction time, movement velocity (MVL), endpoint excursion (EPE), maximum excursion (MXE), and directional control (DCL). Number of falls and total FES-I scores. By all this parameter, the study may receive reliable results.	Subjects size are small. Parameters studied may take longer time.	No full journal provided, only review

24	Scott R. Brown ; Matt Brughelli; Seth Lenetsky	Profiling Single-Leg Balance by Leg Preference and Position in Rugby Union Athletes	Thirty healthy male academy (development-level) rugby union athletes (M ± SD: age 22.2 ± 3.5 years, body height 185.3 ± 7.0 cm, body mass 96.8 ± 11.3 kg, body mass index 28.2 ± 3.2 kg/m2, and rugby experience 8.6 ± 4.2 years), grouped into forwards (n = 15) and backs (n = 15), volunteered as participants for this research. All athletes were free from injury within the previous 6 months, either chronic or acute, that may have inhibited them from performing the required balance tasks. This cross-sectional analysis comprised single-leg balance assessments at two stability difficulties. The assessment took place during the athletes' respective off-seasons after a rest day (~24 hr) and before training that day. All athletes performed a general self-selected lower-extremity dynamic warm-up similar to the team's weight training, practice, and match warm-up procedures. The leg that the athlete preferred to kick the ball with or which they	- Subjects used need to undergo same training and pressure which will provide accurate results to study. - Subjects used have not much differences, this point will give reliable results.	- Unreported and/or misdiagnosed injuries (musculoskeletal [ankle sprain] and/or neurological [mild traumatic brain injury; concussion]) have the potential to confound the results and interpretations of our findings - Lack of normative data unique to sex, sport, position, and leg at which to make meaningful comparisons at this time.	

			could kick the ball the furthest distance was noted as the preferred leg. Dynamic balance was assessed on the Biodex Balance SD System (Biodex Medical Systems, Inc., Shirley, NY). This system measures the degree of tilt about each axis via eight springs located at the perimeter of the balance platform. When uncompressed, the length, thickness, and outside diameter of each spring are 13.97, 0.24, and 3.11 cm, respectively. When compressed to 7.52 cm in length, each spring produces a spring rate of 13.81 N/cm and 88.9 N of force (Arnold & Schmitz, 1998). The Biodex Balance SD System collects data at 20 Hz and calculates three index scores (APSI, MLSI, and OSI), which represent fluctuations around a zero point of the plate.			
25	Asghar Akbari; Alireza sarmadi; Parisa zafardanesh	The Effect of Ankle Taping and Balance Exercises on Postural Stability Indices in Healthy Women	Thirty healthy female students were randomly assigned into two equal groups: ankle taping and balance exercise. The balance exercise group performed balance exercises for 6 weeks, with 3 sessions per	Before the study, subjects are allowed to get used to system which can lead to fair results.	This study does not have control study to be compared with.	

			week and each session lasting 40 minutes. Ankle joint taping was performed for 6 weeks and was renewed three times a week. Before and after the interventions, overall, anteroposterior, and mediolateral stability indices were measured with a Biodex Balance System in bilateral and unilateral stance positions with the eyes open and closed.			
26	Nooranida Arifin; Noor Azuan Abu Osman; Sadeeq Ali; Wan Abu Bakar Wan Abas	The effects of prosthetic foot type and visual alteration on postural steadiness in below-knee amputees	Ten male below-knee amputees were instructed to stand quietly on the Biodex® balance platform while wearing solid ankle cushion heel (SACH), single axis (SA) and energy storage and release (ESAR) prosthetic foot under different visual input conditions (eyes-opened and eyes-closed). The overall stability index (OSI), anterior- posterior stability index (APSI), and medial-lateral stability index (MLSI) were computed. Perceived balance assessment of each foot was evaluated using Activities-specific Balance Confidence (ABC) score.	- The study got apporved by the Institutional Review Board in accordance with the Helsinki Declaration which mean all the procedure may not harmed any subjects. - Subjects are all first recruited via the Universiy of Malaya Medical Centre that undergone the same rehabilitation	The study did not quantify the contribution form the intcat limb or muscular of the residual limb which may influence the control of postural steadiness	

				programs which then lead to reliable result		
27	Angélica Castilho AlonsoI; Guilherme Carlos BrechI; Andréia Moraes BourquinII; Julia Maria D'Andréa GreveIII	The influence of lower-limb dominance on postural balance	Forty healthy sedentary males aged 20 to 40 years, without any injuries, were evaluated. A singlefoot balance test was carried out using the Biodex Balance System equipment, comparing the dominant leg with the nondominant leg of the same individual. The instability protocols used were level 8 (more stable) and level 2 (less stable), and three instability indices were calculated: anteroposterior, mediolateral and general.	There are calculation for sample size to make sure the size is enough.	In this study, they claimed thats no knowledge about the effect of dominance on athletes who used their legs in repetitive asymmetrical activities that would have the potential to generate distinct balance patterns in single-foot evaluations and therefore to interfere with the training and rehabilitation of these athletes. This may effect the reliability of results.	

28	Rafael Sierra-Guzma; Fernando Jim´ enez-Diaz; Carlos Ram´ ırez; Paula Esteban; Javier Abia ´n-Vic´ en	Whole-Body–Vibration Training and Balance in Recreational Athletes With Chronic Ankle Instability	ifty recreational athletes with self-reported CAI volunteered for the study. They were assigned by concealed random allocation using random numbers generated by online software (http://www.randomization.com) to 1 of 3 groups: vibration (VIB; 11 men, 6 women; age ¼ 22.4 6 2.6 years, height¼172.0 6 8.3 cm, mass¼70.2 6 8.2 kg), nonvibration (NVIB; 10 men, 6 women; age¼21.8 6 2.1 years, height¼171.3 6 9.0 cm, mass¼66.2 6 10.1 kg), or control (CON; 12 men, 5 women; age¼23.6 6 3.4 years, height¼172.7 6 10.8 cm, mass¼70.6 6 11.7 kg; Table 1). Sample size was calculated based on the work of Sefton et al,18 who measured posteromedial reach in participants with CAI. The minimal number of participants required to attain a power of 0.8 and a bilateral a level of .05 was calculated to be 16 per group. A clinical trial was performed using a randomized, between-groups design. Participants were assessed at 3 times:	- Participants followed a 6-week balance-training protocol for an unstable ankle based on previous research which lead to reliable result as participants used to the system already - All participants data are recorded including body composition and then compared.	- All participants had homogeneous characteristics, the intervention might not have challenged their sensorimotor systems equally - The vibration load was the same for all participants rather than being determined individually to create fair results	

			pretraining (Pre), posttraining 1 (Post1; 48 hours after the last training session), and posttraining 2 (Post2; 6 weeks after the last training session). Measurements were performed in the following order: body-composition analysis, Biodex Balance System test (BBS; Biodex Medical Systems, Shirley, NY), and Star Excursion Balance Test (SEBT). Assessors (R.S.G., F.J.D., C.R., P.E.) and the researcher (J.A.V.) who performed the statistical analysis were blinded to group allocation.			

29	Magdalena Cyma; Katarzyna Marciniak; Maciej Tomczak; Rafal Stemplewski	Postural Stability and Physical Activity of Workers Working at Height	For evaluation of postural stability, the one-leg standing test with eyes open (OLST-EO) and closed (OLST-EC) was used. The test assesses balance in a static position and it is conducted to evaluate balance with and without vision control. The subject stands straight, arms lowered alongside the hips, first on one leg with eyes open, and then performs the same test with eyes closed. The countdown should be stopped when the lifted leg touches the floor or when the subject moves his arms away from his body to stabilize his position. T-test for independent data was used to evaluate differences between groups with regard to quantitative variables (standing on one leg with open and closed eyes tests, physical activity indexes, BMI, age). To determine the correlation between the variables, Pearson's r coefficients were calculated, whereas in order to compare the groups with regard to the test concerning standing on one leg with closed eyes,	Despite differences in particular aspects, the overall level of physical activity was similar. This may indicate that postural stability is rather affected by exposure to distress conditions, such as work at heights.	- Precise assessment of the level of physical activity in daily life of HW using accelerometers, for example, Actigraph (especially in the context of timeline of performed activity during day), could help enhance the analysis of obtained results. - The experimental group is relatively small. The study conducted on a larger sample could have generated a stronger overall evidence base. - there was no analysis of physical activity level in leisure time in the context of socioeconomic status	

			under control of physical activity, Analysis of Covariance (ANCOVA) was used			
30	Fuzhong Li; Peter Harmer; M.P.H., Kathleen Fitzgerald; Elizabeth Eckstrom	Tai Chi and Postural Stability in Patients with Parkinson's Disease	This study conducted a randomized, controlled trial to determine whether a tailored tai chi program could improve postural control in patients with idiopathic Parkinson's disease. We randomly assigned 195 patients with stage 1 to 4 disease on the Hoehn and Yahr staging scale (which ranges from 1 to 5, with higher stages indicating more severe disease) to one of three groups: tai chi, resistance training, or stretching. The patients participated in 60-minute exercise sessions twice weekly for 24 weeks. The primary outcomes were changes from	- Subjects used are enough to get reliable reults - Good awareness of study the study get as referrals from neurologists or physical therapists, and information distributed to local support groups for persons with Parkinson's disease.	- The behavior-based treatments given, participants were aware of their intervention assignments. This awareness may have introduced biases in the results, since persons interested in participating may have had positive expectations about the benefits of exercise - The study did not include a nonexercise control group, so the net gain of tai chi training cannot be gauged.	

			baseline in the limits-of-stability test (maximum excursion and directional control; range, 0 to 100%). Secondary outcomes included measures of gait and strength,			
31	P. Lenka; D.N.Tiberwala	Effect of Stump Length on Postural Steadiness During Quiet Stance in Unilateral Trans-Tibial Amputee	Twenty unilateral Trans Tibial Amputees (TTAs) amputee patient of active groups of both sexes (34.25±9.57 years) were selected, having a minimum one year experience of using BK prosthesis (PTB socket and SACH foot) and , among them 10 patient having stump length getter than 15 cm (19.33±2.04 cm) and 10 patient having stump length less than 15 cm (9.2±0.91 cm).The subjects were selected through proper clinical assessment (to exclude other clinical conditions affecting stability before testing the stability. A two load cell (strain gauge, Gauge factor-2, length-10mm, and resistanc-350 ohm) based unidirectional (vertical component of COP) force plate (top plate, 52X 52 X 17 cm,	The subjects used in this study were selected through proper clinical assessment to exclude other clinical conditions affecting stability before testing the stability	Small subjects size that may effect results.	

			measured unloaded vertical natural frequency fnat ≤ 260 HZ) was used for stabilometric analysis [21]. The testing of the subjects was carried out in a fixed visual and acoustic environment and the base of support was symmetric to central line or at 0, 0 coordinate. The toe out angle was fixed to 30 degree to central line. The distance between bases of feet was 6cm.			

CHAPTER 3 – METHODOLOGY

This chapter brief the procedure applied, ethics, participants involve, theorical analysis explained included formula used by the system and instrument equipped in order to get the expected data which then been analysis to verify the objective of study.

3.1 Participants

There are 11 subjects take part in this study including one amputee. They have undergone same procedure and their result are compared to get the difference in order to achieve the goals of study.

3.1.1 Normal subjects

A group of 10 subjects have been selected in this study, 5 male and 5 females. The age of the subject is among 22 – 33 years old. Their height and weight are taken for record to calculate their Body Mass Index. In term of experience in using Biodex Balance System, all of them never heard, see or try this system before. Consider getting accurate data, they are advised to start the test with training in normal standing up position to get used with the system.

3.1.2 Amputee subject

One 33 years-old trilateral amputee also took part in the study as the reference subject. 8 years being the amputee from the electric shock accident. His trilateral amputation involves both of his upper limb and his left leg. Both of upper limbs amputation type are transradial which includes below elbow to the rest of arm and hand. For upper limb amputation, Ottobock Myoeletric hand protheses are equipped to both of his arms. Type of lower limb amputation he has is transtibial amputation which affect below knee to the rest of foot. For his lower limb amputation, he got assist from pin lock

prosthesis type as shown in Figure 3.1. By assistance from these 3 protheses, he can walk, stand, drive and work independently.

Figure 3.1: Pin lock prosthesis on trilateral amputee's left leg

He has experience in using Biodex Balance System as he used to be subjects for previous study which related to other parameters. He is also normal in Body Mass Index by weighting 70kg with height 173cm.

3.2 Instruments

In this study, the only instrument use is Biodex Balance System SD by Biodex Medical System Inc. as figure 3.2. The size of device is 76x112x20cm. It is featuring four test protocols, six training modes and intuitive “touch-screen” operation, the Balance System SD allows testing and training in both static and dynamic formats. Other than amputee, it is also suitable for older adults plus closed-chain, weight-bearing assessment and training for lower extremity patients. Using this device, neuro muscular control can be assesed by quantifying the ability to maintain dynamic bilateral and unilateral postural stability on a static or unstable surface. There are four test protocols including fall risk, athletic single leg stability, limits of stability and postural stability are used in this study. The Balance System SD also serves as a valuable training device to enhance kinesthetics abilities that may provide some degree of compensation for impaired proprioceptive

reflex mechanisms following injury. An easy to follow touch-screen format makes the system simple to learn and operate, leading the user step-by-step through testing protocols and training modes. All test results and training sessions are documented on easy to read reports which can be placed into the patient's file. Comparisons to normative data can be made for population-specific tests using the Fall Screening and Athlete Single Leg Stability protocols.

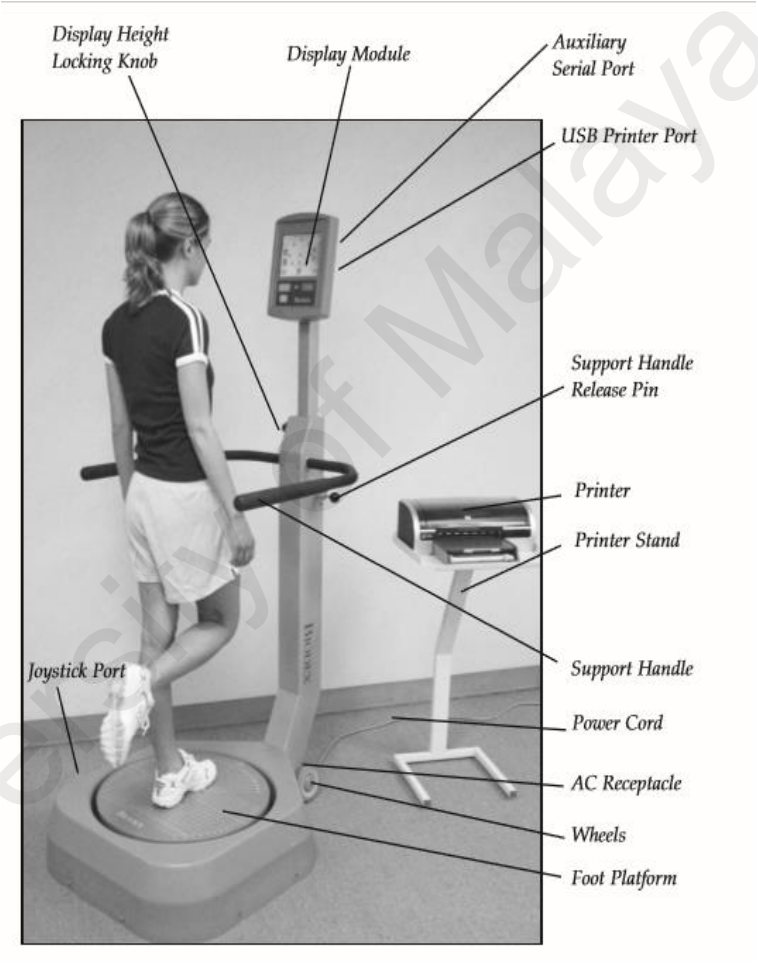


Figure 3.2: The Biodex Balance System SD.

Biodex Balance System test formats include Postural Stability, Limits of Stability, Athlete Single Leg, and Fall Risk as shown in Figure 3.3. Both the Athlete Single Leg and Fall Risk results can be compared to normative data. Postural Stability and Limits of Stability testing are available at variable levels of difficulty. Bilateral reports (comparison

of postural stability performance of standing on one leg versus standing on the other) are available in More Options of Postural stability testing.

Figure 3.3: Biodex Testing option display in menu screen

3.3 Experimental setup

10 normal subjects are first informed with the procedure and purpose of the study so that they are fully aware of the consequences during the procedure. As all normal subjects did not have experience with Biodex Balance System SD, they undergo test with training mode for one time prior to the experiment. All subjects will undergo 3 parameters of tests; postural stability test, athlete single leg test and fall risk test.

During the tests, normal subjects were asked to be in stand-up position with both hand at the sides and their foot position recorded by coordinate on foot platform. The details including the risk of falling during the test was informed prior to the experiment to ensure fully understand the exepriment.

After normal subjects completed 3 tests with normal stand-up position, and the results were saved and recorded, they will proceed with trilateral amputation act where they can't use their both hand and their dominant leg at the same time while undergo the tests as shown in Figure 3.4 and Figure 3.5. The results then also saved and recorded.

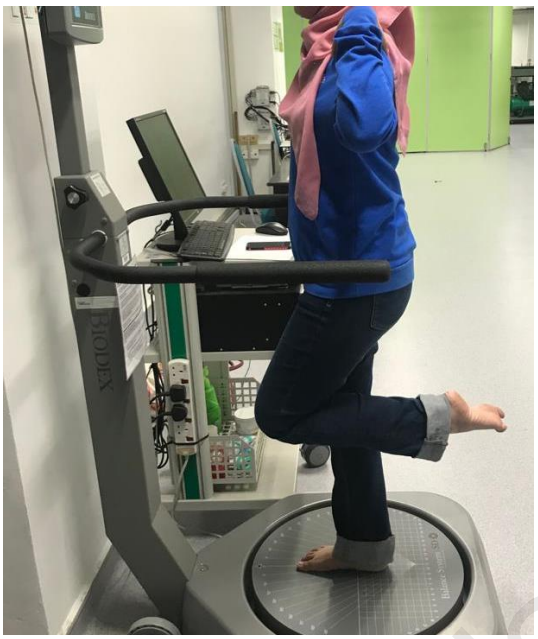


Figure 3.4: Normal subject act like trilateral amputee to get results compare with normal results. (side view)

Figure 3.5: Back view to see clear that both hands and dominant leg not been used throughout the test.

Amputee subject has undergo different procedure, where the subject does all 3 tests will all protheses equipped to their body. The results then saved and extracted. After that, subjects undergo the second tests without prostheses except for the leg protheses.

The leg prosthesis remained because the subject has difficulty in balancing. The subject is only required to lift up his prosthesis as much as he is abled to as shown in Figure 3.6.

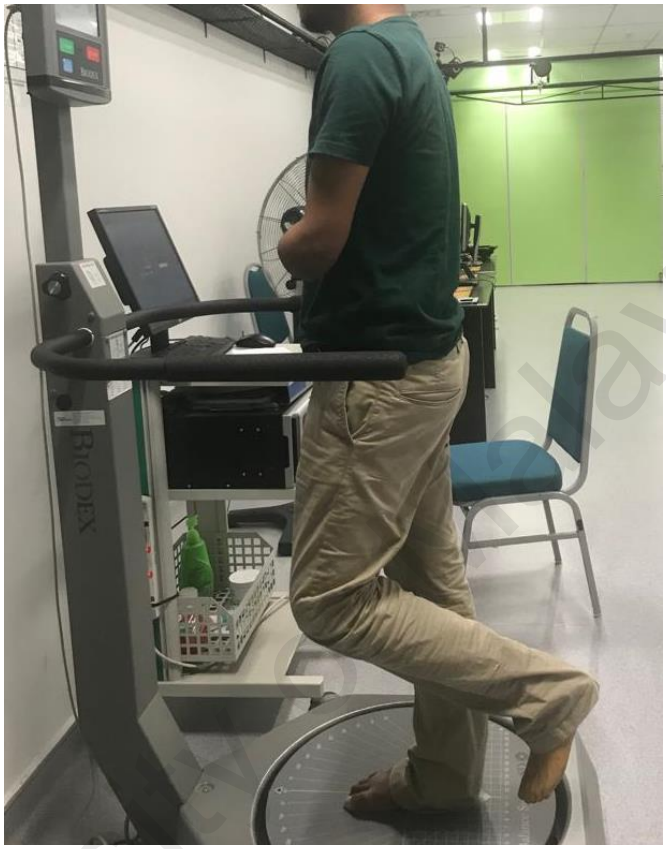


Figure 3.6: Amputee subject lift up the leg prostheses instead take it off. This consideration as precaution procedure.

3.4 Parameter and Test Protocol

In this study, two main parameters are highlighted. There are the postural stability test and fall risk. Both parameter has different protocol. For postural stability, subjects undergo test that need to stand up on only one foot. Therefore, Athlete Single Leg testing option on Balance System SD (BSS) also been selected and used.

3.4.1 Postural Stability Test Protocol

The Postural Stability Test emphasizes a subject's ability to maintain center of balance. The subject's score on this test assesses deviations from center, thus a lower

score is more desirable than a higher score. Platform stability varied during this test such as trial time, number of trials, starting and ending platform stability, rest countdowns or bilateral test also can be set.

The test started by subjects need to balance themselves first on foot platform and make sure the cursor that display on the screen is at centre on target display as shown in Figure 3.7. Instead of moving the angle of body, the subjects required to move the position of foot to make it relevant data capture for later option. The display module set to be in the same level as the subject's eye level throughout the experiment to ensure the their postural condition is normal.

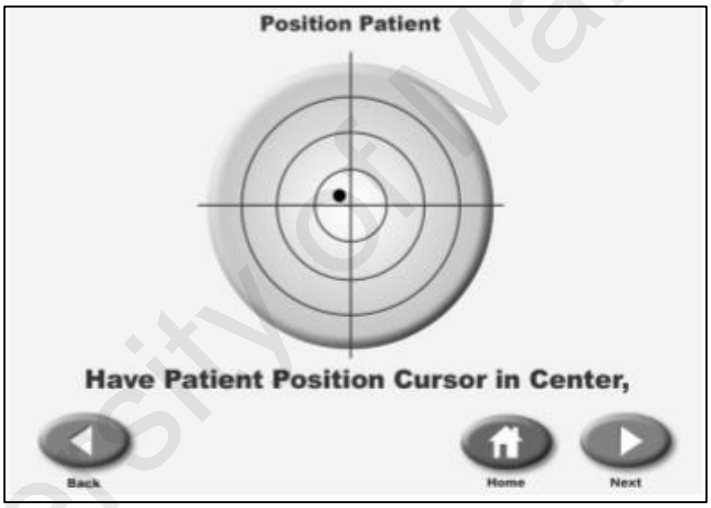


Figure 3.7: Screen display to show the cursor position.

After the cursor is at center of target, the data like heel position and foot angle coordinate are then captured and recorded in patient's menu shown in Figure 3.9. The coordinate can be found on surface of foot platform as Figure 3.8.

Figure 3.8: The surface of foot platform coordinate

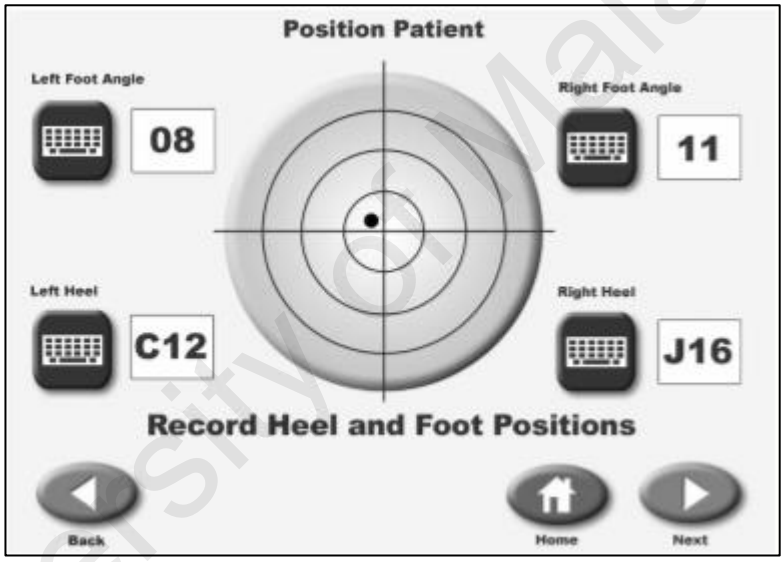


Figure 3.9: The position patient display to record the coordinate of heel position and foot angle.

After the coordinate was determined, the protocol of test are then key in into the option display as Figure 3.10. The protocol data include test trial time, foot platform setting, number of trial and rest countdown. This protocol is important to be as same for every tests of subjects as this will decide the difference and accurate data of results recorded.

The protocol for postural stability testing is 20 seconds of test trial time, two initial platform setting chosen which are level 12 (most stable) and level 5, three times test trials

with 10 seconds rest countdown in the middle of trials. The protocol allowed six tests in total; three tests for level 12 platform setting and three tests for level 5 platform setting.

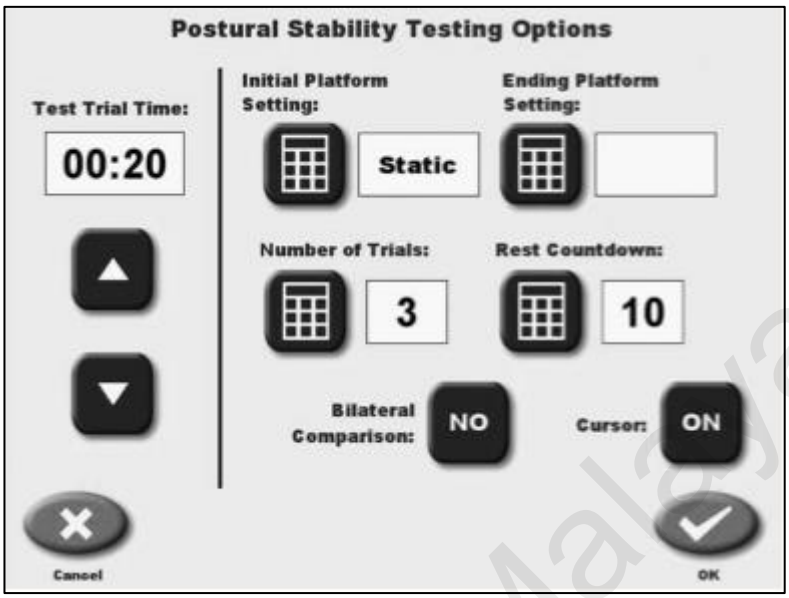


Figure 3.10: Postural stability testing option display to key in the data of foot position, and platform setting and test trial duration

The tests was followed by the protocol that set up in the system and the subjects were asked to relax the body and try to balance themselves throughout the tests. In rest countdown, the subjects can hold the support handle to get their balance back. The tests will be ended after 3 trials and the results were displayed on screen as shown in Figure 3.11 which transferred to computer for analyse purpose. The results include anterior/posterior index, medial lateral index, percentage time in zone, percentage time in quadrant for both legs, right and left separately.

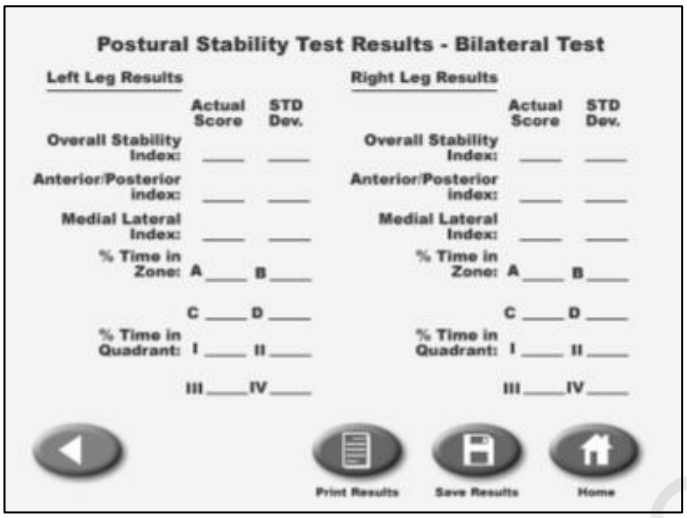


Figure 3.11: The sheet of result display on screen

3.4.2 Athlete Single Leg Stability Test Protocol

As in study required the single leg position, this test was chosen to set the exact data and protocol that suitable to get the expected results. Subjects stand on dominant leg for this test. They are required to balance themselves in 20 seconds to get used with single leg stand position first. The protocol of this test is same as postural stability test shown in Figure 3.12; 20 seconds of test trial time, two initial platform setting chosen which are level 12 (most stable) and level 5, three times test trials with 10 seconds rest countdown in the middle of trials. During the rest countdown, subjects rested their leg, but the dominant leg can't be move from position to make sure the data keyed in the data as accurate as possible.

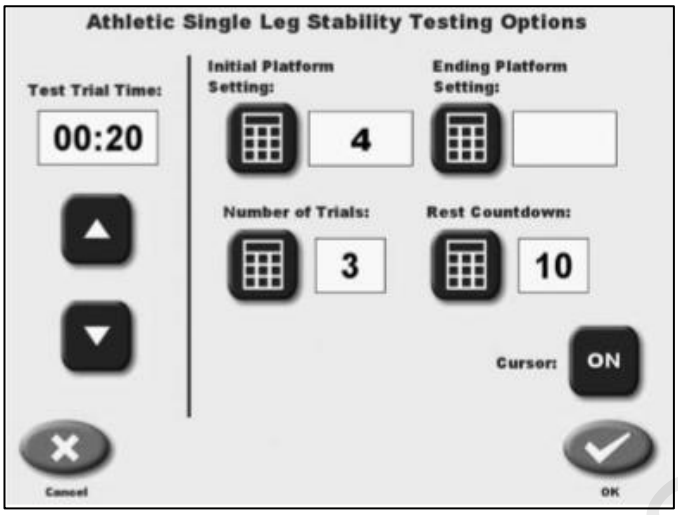


Figure 3.12: The protocol set up on testing option display.

The results of this tests are different from postural stability tests, but anterior/posterior index and medial lateral index still included which the most important data to analyse the results as shown in Figure 3.13. The added data for this test is comparison with normal score, also, important data for results.

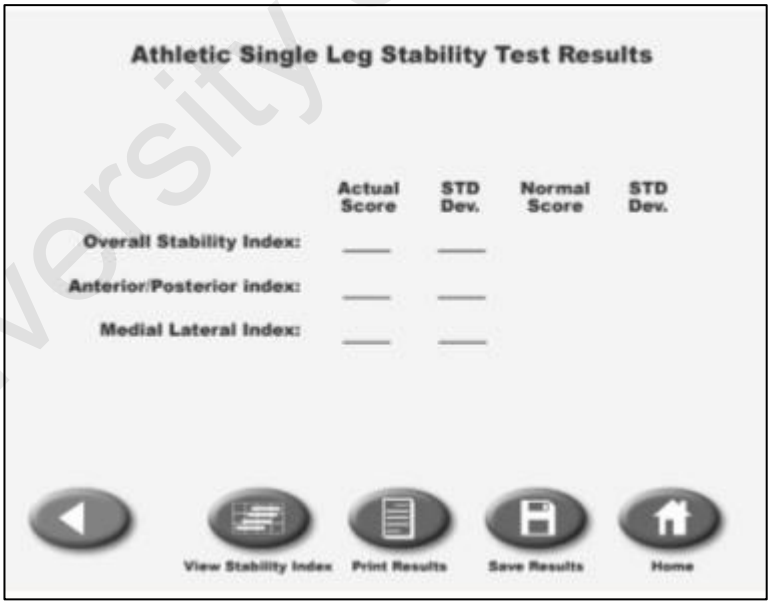


Figure 3.13: The results sheet display for athlete single leg stability tests

3.4.3 Fall Risk Test Protocol

The Fall Risk test allows identification of potential fall subjects. The test also overall stability index and comparative results with normative value as shown in Figure 3.15. Scores higher than normative values suggest further assessment for lower extremity strength, proprioception, and vestibular or visual deficiencies but in this study the higher score is expected. But in this study, only overall stability index used to be evaluated and compared as the difference can be observed clearly.

The tests have two versions; first version as normal subject stand on platform with both legs on foot platform, second version required normal subject to act as trilateral amputee and stand on platform with one leg only (dominant). For amputee; first version should be with all prosthetics attached and the second one, prosthetics left aside.

The test protocol incorporated in this system was included to give normative data to assess the subject's risk for falling. During testing, the subjects undergo three trials of 20 seconds each beginning with an initial platform setting of 12 and ending at a platform setting of 5, with ten-second rest periods in between each trial. The protocol as shown in Figure 3.14 applied to both version of tests; first version and second one. At the completion of the test a Fall Risk Assessment Report can be printed with a score compared to normative data.

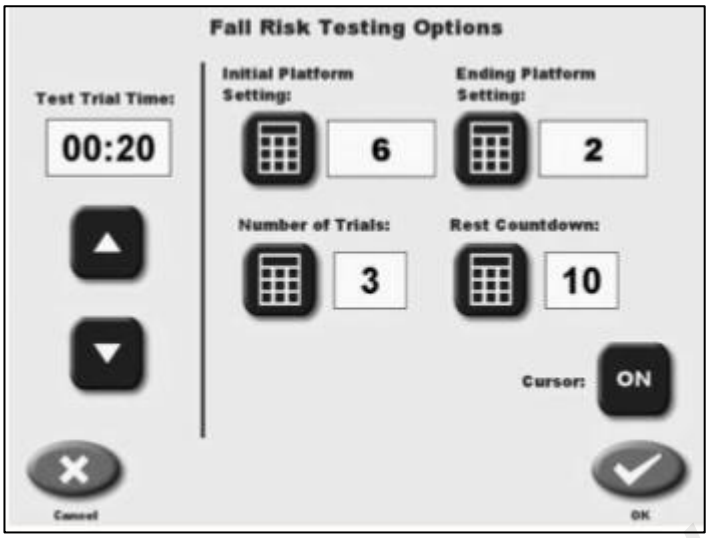


Figure 3.14: The protocol set up in the fall risk testing option display

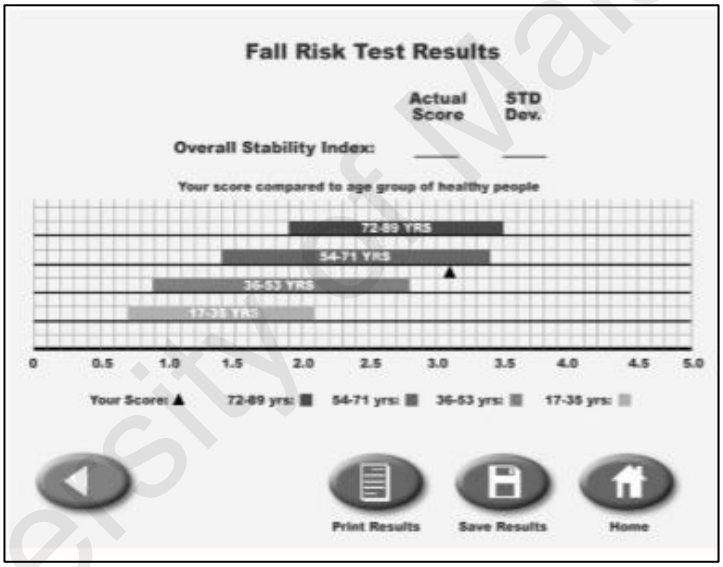


Figure 3.15: Test result of fall risk test sheet

BSS measures the overall stability index (OSI), anterior/posterior stability index (APSI), and medial/lateral stability index (MLSI), which represented the standard deviation of platform fluctuation from a horizontal position (zero point). Furthermore, OSI is considered as an efficient balance indicator of the ability to control balance. The platform was integrated with computer software that enables the device to calculate the stability indexes. An increased stability index during the assessment was interpreted as decreased postural stability. OSI, MLSI, and APSI scores were expressed as follows:

$$OSI = \sqrt{\sum(0-Y)^2 + \sum(0-X)^2}/number\ of\ samples,$$

$$APSI = \sqrt{\sum(0-Y)^2}/number\ of\ samples,$$

$$MLSI = \sqrt{\sum(0-X)^2}/number\ of\ samples,$$

Where Y is the total anterior-posterior deviation in the sagittal plane and X is the total medial-lateral deviation in the frontal plane. (Nooranida Arifin et al. 2014)

CHAPTER 4 – RESULTS AND DISCUSSION

This chapter evaluate and summarises the findings of this study based upon the information gathered as a result from the methodology also presented any contributions made. The findings then analysed to conclude the objectives of the study. This chapter also compare the finding with prior study's finding to prove the reliability of data.

4.1 Participants Data

Body Mass Index of participants are calculated as their height and weight are recorded as shown in Table 4.1. 11 subjects included 10 normal subjects and 1 trilateral amputee subjects. 2 out of 11 subjects are obese, 1 of them is overweight and the rest are normal. All 10 normal subjects do not have postural stability problem, also their occupation and daily life activity did not risk them any postural problem**.**

Table 4.1: Demographics data of participants

Subjects		Gender	Age (years)	Height (cm)	Weight (kg)	BMI	Condition
Normal Subject	S1	M	27	175	75	24.49	N
	S2	M	25	172	60	20.28	N
	S3	M	26	167	89	31.91	O
	S4	F	22	167	64	22.95	N
	S5	M	31	169	75	26.26	OW
	S6	F	30	161	81	31.25	O
	S7	F	26	161	59	22.76	N
	S8	F	26	161	50	19.29	N
	S9	M	25	168	53	18.78	N
	S10	F	26	159	52	20.57	N
Trilateral Amputee subject	S11	M	32	173	70	23.39	N

S: Subject; F: Female; M: Male; BMI: Body Mass Index; N: Normal; O: Obese; OW: Overweight

4.2 Postural Stability Data

During postural stability test, the data that collected and recorded are overall stability index (OSI), anterior/posterior stability index (APSI), and medial/lateral stability index (MLSI). OSI is considered as an efficient balance indicator of the ability to control balance by subjects. The Postural Stability Test emphasizes a patient's ability to maintain center of balance. The subjects' score on this test assesses deviations from center, thus a lower score is more desirable than a higher score. The subject's performance is noted as a stability index. The stability index represents the variance of platform displacement in degrees from level. A high number is indicative of a lot of motion, which is indicative of the subject having trouble balancing (Nooranida Arifin et al. 2014). This means expected result are normal condition postural stability should be lower than condition where both hands and dominant leg can't be used.

The data from postural stability test for normal subjects recorded in Table 4.1 which then summarize in Graph 4.1 and Graph 4.2 to see the significant difference. The data included APSI, MLSI and OSI for both conditions; normal condition and trilateral amputation condition but only OSI highlighted and become the main parameter in this study. The platform setting are set to level 3 and level 12. Platform change by level, the lesser the level, the platform will be more flexible and smooth which hard to stand on it. Level 12 is the most stable platform and easy to balance ourslef on this level. The data for each level also recorded as well as difference condition as plan to achieve the study goals. The conditions are normal where subject just stand with both feet on platform and trilateral condition where subjects can't use 3 limbs during the procedure. To make it fair and accurate, all subjects can't use both hands and their dominant leg to obtain more accurate data without biased.

Data for postural stability for trilateral amputee subjects are recorded in Table 4.2. This data will be reference to all results as amputee results are the most accurate one since they experienced of postural balancing in their daily life. By using data taken from procedure, average values are calculated to find the differences between two conditions procedure either on normal subjects and trilateral amputee subject.

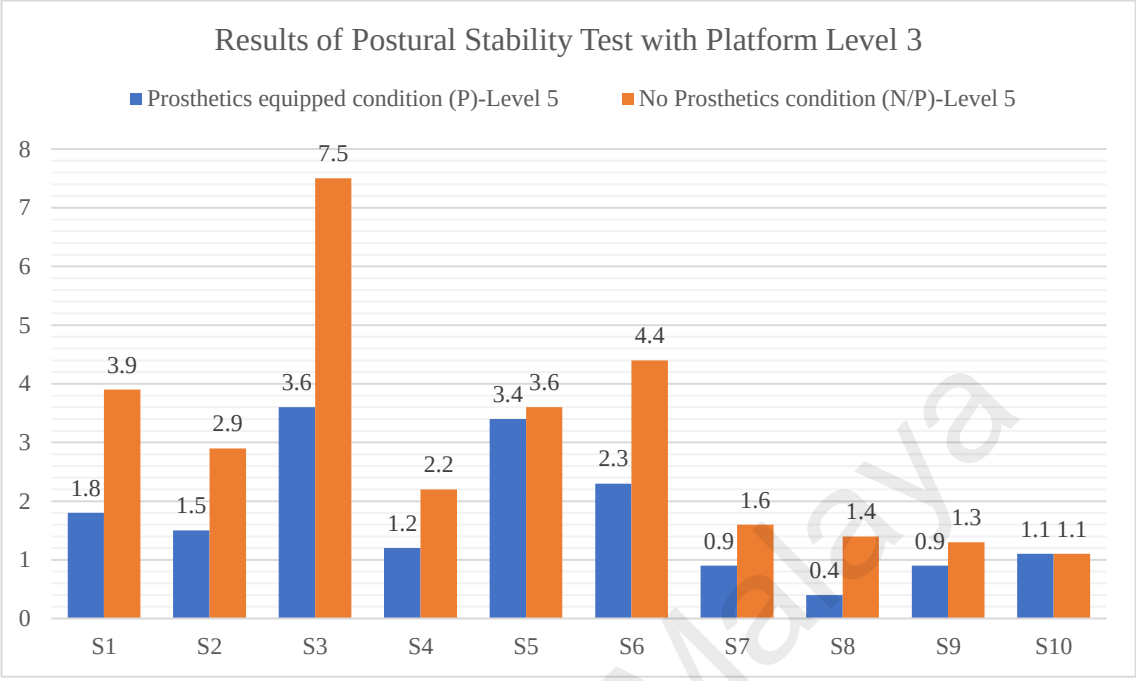
Table 4.2: Data of postural stability test with standard deviation during procedure by normal subjects (Refer to appendix A – Appendix F)

Platform	Subject	N			N/N		
		OSI	APSI	MLSI	OSI	APSI	MLSI
3	S1	1.8 (0.96)	1.1 (0.98)	1.1 (0.77)	3.9 (4.13)	2.6 (3.64)	2.2 (2.66)
	S2	1.5 (1)	1 (0.95)	0.8 (0.7)	2.9 (2.62)	2.1 (2.39)	1.6 (1.6)
	S3	3.6 (2.44)	2.8 (2.26)	1.8 (1.71)	7.5 (5.22)	5.5 (4.96)	3.9 (3.68)
	S4	1.2(0.63)	0.9 (0.69)	0.6 (0.39)	2.2 (1.68)	1.6 (1.68)	1.2 (0.92)
	S5	3.4(2.97)	2.3 (2.36)	2 (2.38)	3.6 (3.79)	2.7 (3.25)	1.8 (2.51)
	S6	2.3 (2.38)	1.8 (2.25)	1.1 (1.21)	4.4 (4.05)	3.8 (4.14)	1.6 (1.45)
	S7	0.9 (0.4)	0.5 (0.41)	0.7 (0.38)	1.6 (0.88)	0.8 (0.74)	1.2 (0.79)
	S8	0.4 (0.12)	0.4 (0.13)	0.2 (0.14)	1.4 (1.09)	1.2 (1.11)	0.6 (0.53)
	S9	0.9 (0.39)	0.6 (0.42)	0.5 (0.39)	1.3 (0.7)	0.9 (0.68)	0.8 (0.63)
	S10	1.1 (0.53)	0.9 (0.56)	0.4 (0.32)	1.1 (0.63)	0.8 (0.67)	0.5 (0.37)
12	S1	0.3 (0.36)	0.2 (0.28)	0.2 (0.27)	1 (0.26)	0.6 (0.35)	0.7 (0.37)
	S2	1.6 (0.31)	1.4 (0.42)	0.5 (0.25)	1.7 (0.46)	1 (0.68)	1.2 (0.35)
	S3	1.1 (0.33)	0.9 (0.4)	0.3 (0.35)	1.2 (0.47)	0.8 (0.44)	0.7 (0.51)
	S4	1.1 (0.33)	0.9 (0.33)	0.5 (0.3)	1.8 (0.32)	1.7 (0.41)	0.5 (0.26)
	S5	0.6 (0.4)	0.5 (0.42)	0.2 (0.2)	1.2 (0.36)	0.8 (0.44)	0.7 (0.58)
	S6	1.6 (0.25)	0.5 (0.35)	1.4 (0.39)	1.9 (0.88)	1.3 (1.12)	1 (0.59)
	S7	0.8 (0.36)	0.7 (0.35)	0.3 (0.22)	0.9 (0.31)	0.4 (0.26)	0.8 (0.38)
	S8	0.7 (0.41)	0.6 (0.41)	0.1 (0.13)	1.6 (0.6)	1.5 (0.59)	0.6 (0.38)
	S9	0.7 (0.28)	0.4 (0.29)	0.4 (0.27)	0.9 (0.4)	0.6 (0.35)	0.6 (0.37)
	S10	0.8 (0.26)	0.7 (0.3)	0.3 (0.25)	0.9 (0.49)	0.8 (0.55)	0.6 (0.27)

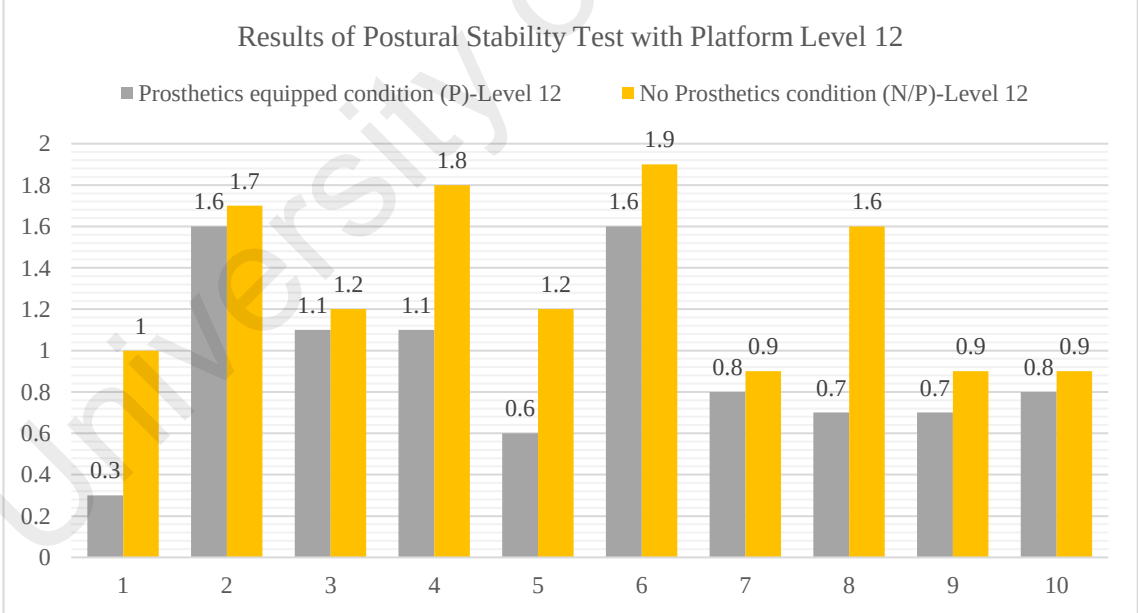
N=Normal condition; N/N=Both hand and dominant leg can't be used condition; OSI=Overall Stability Index; APSI= anterior/posterior stability index; MLSI=medial/lateral stability index; ( )=standard deviation.

Postural Stability Test for Platform level 3 and level 12 for normal subjects data from Table 4.1 then summarized into Graph 4.1 and Graph 4.2 to see the difference of postural stability between two condition with only OSI parameter .

Graph 4.1: Postural Stability difference between normal and trilateral amputation condition for platform level 3-normal subjects



Graph 4.2: Postural Stability difference between normal and trilateral amputation condition for platform level 12-normal subjects



Graph 4.1 and Graph 4.2 show that condition trilateral amputation have higher value of postural stability than normal condition which mean trilateral amputation have lesser stability then normal condition. The difference then calculated as shown in Table 4.4 and discussed after the calculation.

Table 4.3: Data of postural stability test with standard deviation during procedure by trilateral amputee. (Refer to Appendix G to Appendix L)

Platform	P			N/P		
	OSI	APSI	MLSI	OSI	APSI	MLSI
5	1 (0.41)	0.7 (0.44)	0.5 (0.4)	1.5 (0.64)	1 (0.68)	0.9 (0.57)
12	0.6 (0.3)	0.4 (0.32)	0.4 (0.34)	0.8 (0.26)	0.5 (0.27)	0.5 (0.34)

P=With prosthetics equipped; N/P=No prosthetics used.

Data from Table 4.2 summarize to the the Graph 4.3 to see the significant difference of postural stability that amputee subject made thorughout the experiment with platform level 5 and level 12. it is obvious that no prosthetics condition obtained higher value means the condition contribute less stability than other condition.

Graph 4.3: Postural Stability difference between prosthetics equipped and No prosthetics equipped condition for platform level 5 and level 12-trilateral amputee subjects

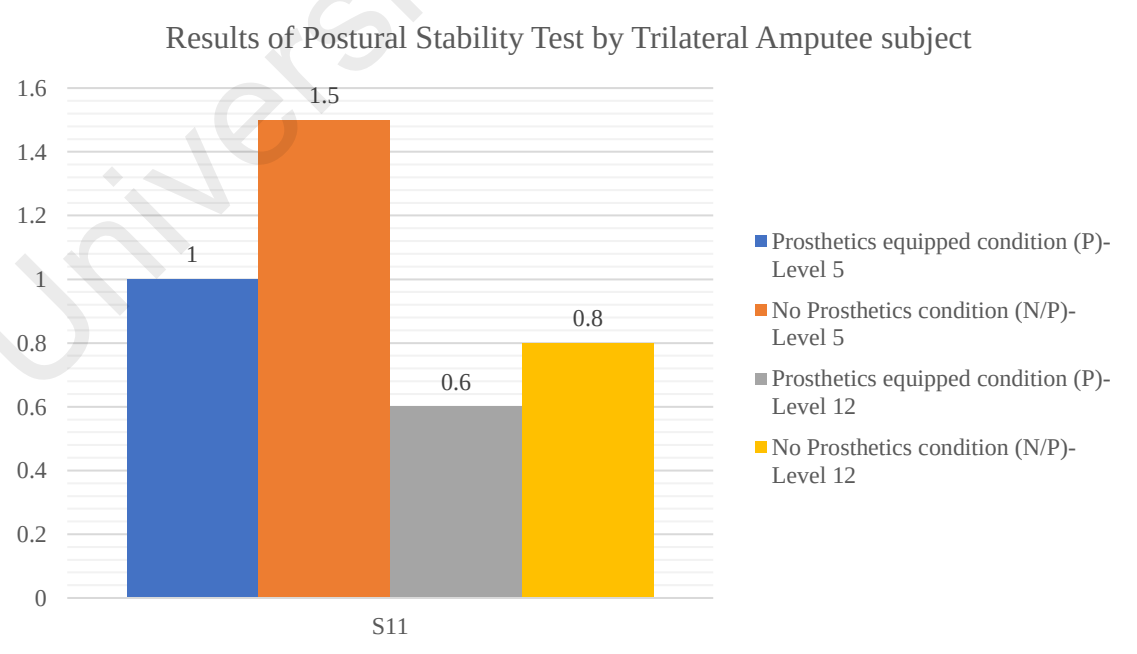


Table 4.4: Average data value with standard deviation for postural stability test on normal subjects.

Platform	N			N/N		
	OSI	APSI	MLSI	OSI	APSI	MLSI
3	1.71 (1.18)	1.23 (1.1)	0.92 (0.84)	2.99 (2.48)	2.20 (2.33)	1.54 (1.51)
12	0.93 (0.33)	0.68 (0.36)	0.42 (0.26)	1.31 (0.46)	0.95 (0.52)	0.72 (0.41)

Refer to Table 4.3, result comparing between N and N/N. First comparison is platform setting 3. OSI for N is 1.71 which lower than OSI for N/N that is 2.99. Same goes APSI and MLSI for N which are 1.23 and 0.92 respectively, obviously lower than APSI and MLSI for N/N 2.20 and 1.54 respectively.

For platform setting level 12, OSI, APSI and MLSI for N are 0.93, 0.68 and 0.42 respectively, lower than value for N/N which are 1.31, 0.95 and 0.72 respectively. This numbers prove the postural stability in normal condition is lower than condition where 3 limbs not functioning during the procedure. This study results demonstrated as claimed by Biodex manufacturer, the lower the value of stability index, the better the balancing. This result ties well with previous studies wherein Balance Control in lower extremity amputees during quiet standing: systematic review state that transfemoral group exhibits greater postural sway, follow by transtibial and a healthy group (Pei Xuan Ku, 2013). In order to get difference of Actual Score of OSI, APSI and MLSI are follow the equation;

$$Difference\ of\ total\ score = Actual\ Score\ NN\ or\ NP - Actual\ Score\ N\ or\ P$$

The way to obtain difference of standard deviation, other calculation follows;

$$Total\ differences\ of\ standard\ deviation$$

$$= \sqrt{(standard\ deviation\ NN\ or\ NP)^2 + (standard\ deviation\ N\ or\ P)^2}$$

Table 4.5: The difference of data value of postural stability of normal subjects between two procedure condition; N and N/N.

Platform	OSI	APSI	MLSI
3	1.28 (2.75)	0.97 (2.57)	0.62 (1.73)
12	0.38 (0.57)	0.27 (0.64)	0.30 (0.49)

In table 4.4, all differences value is positive which means the stability during normal condition better than condition where both hands and dominant leg can't be used or the condition where trilateral amputee without prosthetics. To provide postural support in maintaining standing posture, lower limb plays important role. The upper limb not involved much in supporting body weight. In a general sense, the upper and lower limbs are anatomically symmetrical across the sagittal plane of the body, but one of the bilateral limbs is preferentially used. In humans, this characteristic is called lateral dominance. Approximately 90% of adults exhibit right-side dominance in manipulative functions of the upper limb and in mobilizing functions of the lower limb. However, when the lower limb is used as a postural support during single-leg stance, there is no clear lateral dominance in postural stability, even though the dominant side in maintaining stability is often shown at the individual level. These findings regarding the postural support function have been assessed primarily by the measure of fluctuation of center of pressure (CoP) during stance on a stable surface (Takeo Kiyota et al. 2014).

The control strategy for maintaining single-leg standing posture on vibrating (swaying) surfaces is sometimes needed in particular cases. The lateral dominance of postural stability in dynamic conditions has been investigated using a movable platform, but no significant lateral difference was found. For maintaining a stable standing posture against gravity force, the body alignment should be controlled appropriately, and CoP position should be kept within the base of support. On this movable platform, especially,

CoP position must remain on the supporting point. However, this point does not move by external force; rather, it moves by the person's involuntary and irregular body sway on the movable platform. Therefore, it would be difficult to anticipate its movement and set CoP on the supporting point. This would lead to large intraindividual variability in postural stability during single-leg stance on movable platform, resulting in no significant lateral dominance. (Takeo Kiyota et al. 2014).

Table 4.6: The difference of data value of postural stability of trilateral amputee subjects between two procedure condition; P and N/P

Platform	OSI	APSI	MLSI
5	0.5 (0.76)	0.3 (0.81)	0.4 (0.7)
12	0.2 (0.40)	0.1 (0.42)	0.1 (0.48)

The results from normal subjects then been compared to results from trilateral amputee. The results of amputee shown in table 4.5. Normal subject average difference in OSI for platform setting level 3 for normal subjects is 1.28 and trilateral amputee with platform setting level 5 is 0.5. This may cause by the difference of stability platform setting. During the procedure for amputee, the amputee claims that the lowest level he can do is level 5 as level 3 is hard for him to proceed with procedure. The study only required comparison results between 2 conditions on normal subjects and 2 condition on trilateral amputee. As long as the amputee done all the procedure with same level platform setting on both conditions, it will obtain fair and unbiased results. For Platform setting level 12, the average difference for normal subjects is 0.38 while for trilateral amputee is 0.2. Trilateral amputee has less difference as the amputee have more experienced in using Biodex Balance System SD and gain consistency in all procedure whether with prosthetics and without prosthetics. This point also affected the Risk of Fall tests result.

4.2 Risk of Fall Data

Risk of fall procedure include in this study to prove that trilateral amputee has higher risk to fall than normal person. The relationship between risk of fall and stability index is when the stability index is low, risk of fall also low and vice versa. Biodex balance system have Risk Fall Test where it will show actual score of overall stability index with standard deviation and age group to be compared with subject's score. All data during the procedure are recorded in Table 4.6.

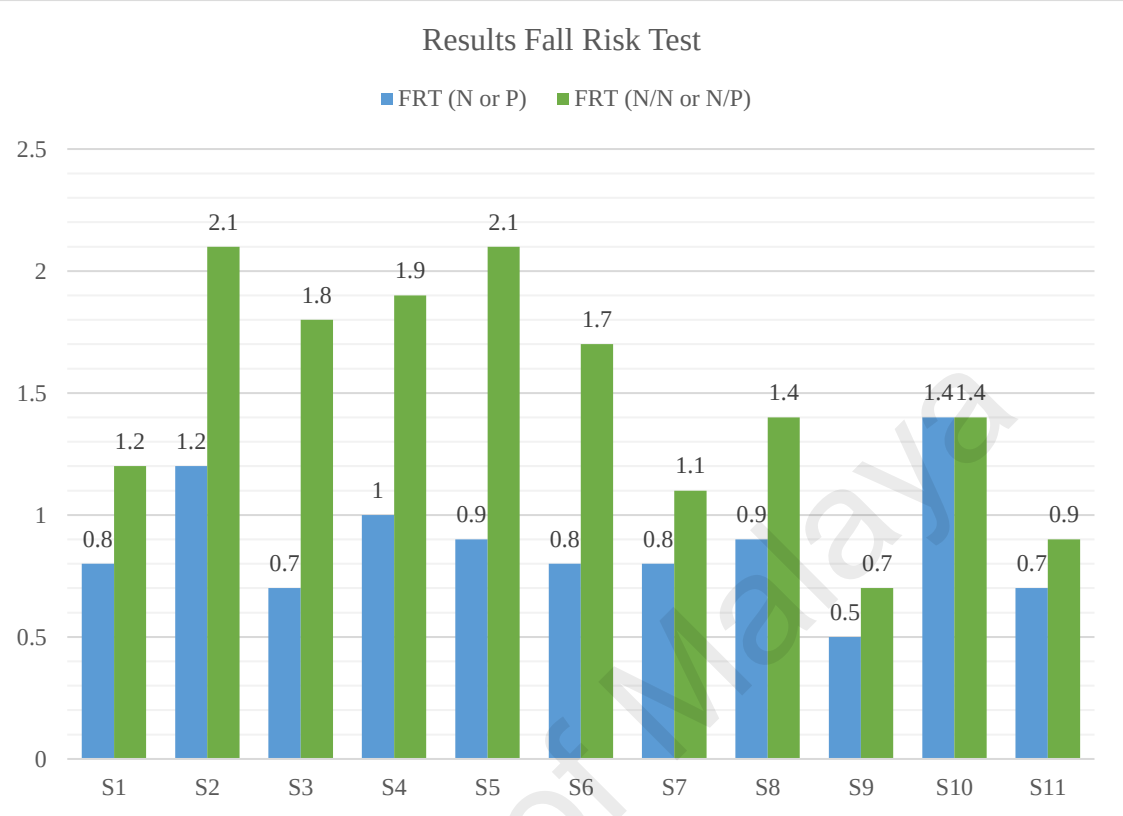
Table 4.7: Risk of fall data with standard deviation recorded during the procedure including normal subject and trilateral amputee subject. (Refer Appendices for Fall Risk Test results)

Condition	NS									TS
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
N or P	0.8 (1.32)	1.2 (0.48)	0.7 (1.1)	1 (0.54)	0.9 (1.24)	0.8 (0.47)	0.8 (0.31)	0.9 (0.72)	0.5 (0.36)	1.4 (0.52)	0.7 (0.3)
N/N or N/P	1.2 (0.42)	2.1 (0.94)	1.8 (0.93)	1.9 (2.78)	2.1 (2.51)	1.7 (1.03)	1.1 (0.57)	1.4 (0.58)	0.7 (0.34)	1.4 (0.54)	0.9 (0.32)

NS=Normal Subject; TS=Trilateral Amputee Subject.

Data from Table 4.6 summarize to Graph 4.4 to see the differences obviously. The graph shown that N/N or N/P condition comtibute higher value of stability means it has lesser stability than N or P condition.

Graph 4.4: The differences of Fall Risk Test result between N or P condition and N/N or N/P conditions.



From the data taken, average values are obtained to calculate the value of differences between 'N/N or P/N' and 'N or P' to show the comparison risk of fall that trilateral amputee has with normal person. Differences value recorded in Table 4.7.

Table 4.8: Value of difference with standard deviation in stability index between two conditions during the procedure for risk of fall test.

				NS						TS
S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
0.4 (1.39)	0.9 (1.06)	1.1 (1.44)	0.9 (2.83)	1.2 (2.80)	0.9 (1.13)	0.3 (0.65)	0.5 (0.92)	0.2 (0.50)	0 (0.75)	0.2 (0.44)

Obviously, all differences value is positive means data value during procedure with condition N or P are lower than value in condition N/N or P/N. This show that condition N and P is the most stable position and less risk of fall while condition N/N and N/P have low stability but high risk of fall.

Table 4.9: Average of Difference value for normal subjects and trilateral amputee subject

NS	TS
0.6 (1.35)	0.2 (0.44)

The average of normal subjects and trilateral amputee subject as Table 4.8 compared by calculation of data obtained during experiment. Trilateral Amputee subject have lower average than normal subject. The stability index data in postural stability tests also show that trilateral amputee subject have lower value than normal subjects. This is because trilateral amputees learn to balance themselves since amputation take place. They already used to imbalance condition and learn how to weight shifting at any condition with prosthetics and without prosthetic. The weight shifting also play important role in this study and become most reason that there are differences in results between condition N or P with N/N or N/P. During condition N and P, both feet on platform for normal subject or prosthetic equipped for amputee subject, make the weight shifting balance for each foot. To maintain the balance, muscles are constantly used to make tiny adjustments to posture. When only one leg can be used, the body weight shifts in a way that practically stabilizes the joints of standing limb (Sung Hwun Kang et al. 2013). This muscle can learn and adapt with the pressure when it used to it means amputee can train their muscle to shift their weight to maintain the postural balance as much as they can. The findings are directly in line with previous findings by Ágnes Mayer in her study Adaptation to altered balance conditions in unilateral amputees due to atherosclerosis which conclude amputation patients with vascular insufficiency gradually shifted their body weight over the non-affected leg while standing or walking and learned a compensatory balance strategy which manifested in less postural sway while standing on the non-affected leg. The study considers this shift in weight distribution as an early adaptation. There are several other studies that support this analysis are effect of Tai Chi exercise on postural stability study by Tsung-Jung Ho that

found that regular training resulted in significant decrease in postural sway standing on single leg, but no significant change was found standing on double leg (Tsung-Jung Ho et al. 2012). Study by Pérennou D. also concluded from their results that hemiparetic patients should learn a new balance strategy to improve postural stability accepting the remaining weight-bearing asymmetry (Pérennou D. 2005).

The procedure of study been analysed with prior study and almost similar pattern found with Postural Stability Characteristics of Transtibial Amputees Wearing Different Prosthetic Foot Types When Standing on Various Support Surfaces by Nooranida Arifin. The differences in procedure is prior study evaluate different prosthetic foot type while this study analysed certain amputation. In prior study, they concluded that for normal subjects, postural instability during quiet standing is resisted by muscle contraction to control ankle joint stiffness and counterbalance of the destabilizing gravitational torque in anterior-posterior and mediolateral directions while for amputee they suggested that postural stability requires more control in the mediolateral direction when standing on a compliant surface by utilizing the hip strategy (Nooranida Arifin et al. 2014).

CHAPTER 5: CONCLUSION

The project was set out to investigate the differences of postural stability between normal persons and trilateral amputee. Other than that, the project also compare the Fall Risk between two groups of subjects. The procedure done by using Biodex Balance System SD that provide postural stability test and risk of fall test. The reliability of the system is studied and compared with other way to measure the stability which lead that this system is most reliable and user friendly as operating the system is not complicated and just straightforward. After the procedure, the results recorded and analysed. The study found that trilateral amputees have less postural stability than normal persons. Knowing the results and conclusion of the study, it may help the rehabilitation procedure for new trilateral amputees to get the training protocol right.

Risk of fall data also recorded which conclude that trilateral amputees have higher risk than normal persons with normal condition because the data from experiemnt shown that trilateral amputation condition gave higher overall stability index than normal condition. This conclusion may give idea to normal person how hard it is for trilateral amputees to do their daily life with such condition. However, during the study procedure, trilateral amputee with 8 years experienced with amputation have better stability and less risk of falling than normal persons with trilateral condition. This may conclude that after training, long time experienced and get used to prosthetics assistant, amputees might adapt to stable themselves. The muscles of trilateral amputee can stand the pressure and weight shifting are balance during the test. By this conclusion, the postural stability is lesser, and risk of fall are higher for trilateral amputees, before they get used to assistance of prosthetics and manage to shift their weight to the point of body that make themselves stable.

5.1 Study Limitation and Future Work

Limitations of this study are acknowledged. As having 10 normal subjects and only on trilateral amputee indicates that the size of sample is small as preferred to be as many as normal subjects which can be influence the generalization of the study. Another unfortunate limitation is the repetitions of procedure by the same subject with different time to get more precise average data and results.

Further research is required to increase the number of amputee subjects by 10 subjects to be conducted the study and the repetition procedure. This may increase the accuracy by more than 80% of data and results as the subjects will be more familiar with Biodex Balance System and the average of results will be more precise.

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