GAIT STUDIES OF NORMAL AND HALLUX VALGUS AFFECTED INDIVIDUALS

A Thesis submitted in the

Partial fulfillment for the requirement for

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by

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CERTIFICATE

This is to certify that the thesis entitled **"Gait analysis of normal and hallux valgus affected individuals"** is a record of bonafide work done by UTSAV HANSARIA (110BM0449) which is submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology (B.Tech) in Biomedical Engineering at National Institute of Technology, Rourkela. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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ABSTRACT

This study investigated the gait patterns of volunteers affected by hallux valgus and compares the results with volunteers free from this or any other foot related deformity. The reason for this study was to analyze the differences in gait patterns from a strictly biomechanical perspective by studying the various forces acting on a foot during locomotion and to determine the factors which play a major role in the gait of hallux valgus affected people. The study also aims to determine the impact of this deformity on the gait patterns of affected individuals, the chances of injury, potential for adverse impact of this deformity as the person gets older and available remedial solutions. The primary action studied was a normal walk executed by the volunteers at a normal walking speed. The various forces generated by the volunteers were measured using a Kistler's force platform and the data generated was stored using a data acquisition board (DAQ). Further analysis of the graphs obtained was done using the Bioware software. The ground reaction forces, center of pressure, co-efficient of friction were the parameters which were analyzed and compared for both sets of individuals. The result of the investigation was that gait of hallux valgus individual gets altered, with a change in the center of pressure, ground reaction forces and co-efficient of friction as compared to normal healthy subject. The affected individuals walk was found to be less balanced and jerky. The people who have this deformity are most prone to ankle and knee injuries with increased risk of falling as the person gets older and the deformity is aggravated. The treatments methods available, their impact and after-effects are also considered. Only surgery is a long term solution and the diagnosis and treatment of the deformity requires a detailed study into every individual case.

Keywords: gait analysis, force platform, hallux valgus, ground reaction force

Chapter 1

Introduction

Introduction

1.1 Overview

Walking is the most convenient way to commute short distances. Appropriate muscle force and free mobility in the joints found in normal individuals increases efficiency in walking. Gait analysis is primarily the study of human locomotion to determine the impact of any deformity, disease, accidents or surgery and develop appropriate treatment for the same. A single sequence of movement/functions of a limb is known as gait cycle, which can also be termed as the fundamental unit of gait. The gait cycle has essentially two phases: the stance phase and the swing phase (Fig. 1). The stance phase of a limb is where the limb is in contact with the ground. The swing phase corresponds to the phase where the limb is advancing in the air [1]. The important requirements for a person during normal walking are equilibrium (the ability to assume an upright posture and maintain balance), locomotion (initiating and maintaining rhythmic stepping, and musculoskeletal integrity-normal functioning of bone, joints and corresponding muscles) and neurological (control-efficient transfer of messages to and from the nervous system movement of the body).

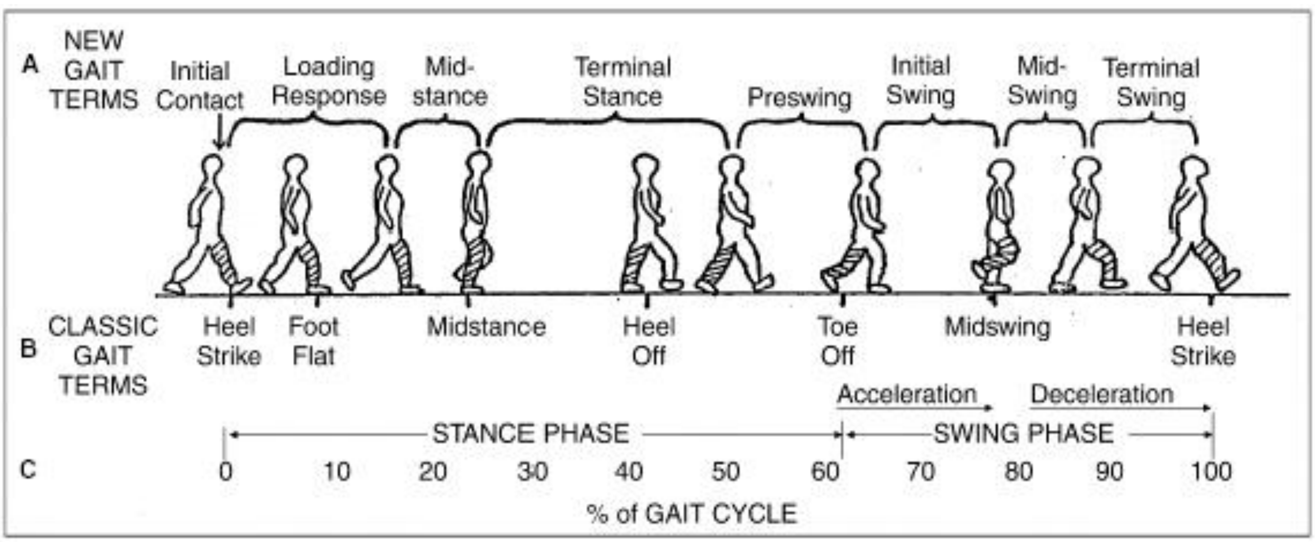

Figure 1: Different phases of a gait cycle.

1.2 Force plate

Force plates also known as force platforms are designed for use in the field of biomechanics to measure ground reaction forces, center of pressure, co-efficient of friction and a number of other parameters in states of rest and motion. A force plate can be described as a metallic plate with multiple sensors attached to it that produce an electrical output in response to force applied on the plate. Force plates are available in many different varieties depending on the types of sensors used to generate the electrical output in response to the force applied on it. For example strain gauge, capacitive gauge and piezoelectric sensors. The force plate used in this study uses four piezoelectric sensors at the four corners of the square force plate. The force plates using piezoelectric sensors are ideal for gait analysis because of the following reasons: (i) piezoelectric sensors do not require any local power source, (ii) they automatically generate electricity proportionally in response to mechanical stress, and (iii) they are sturdy; provide overload protection and long term stability. The output voltage of a piezoelectric sensor is given by

$$V=Q/C \qquad \text{.....Eq(1),}$$

where C represents the capacitance of the element and Q represents the charge induced by the force F in the direction perpendicular to the electrode surface.

Figure 2: Kistler multiaxial force plate (9260AA6)

1.3 Measuring Gait Parameters

1.3.1 Ground Reaction Force (GRF)

Ground Reaction Force is the reactionary force applied by the ground on the body in accordance with Newton's 3rd law of motion, "Every action has an equal and opposite reaction". Till the body is in contact with the ground, the system experiences a set of continuously varying equal and opposite action-reaction forces, the reaction force being provided by the ground [2]. The component of GRF perpendicular to the surface is the normal reaction force. The component of GRF parallel to the surface is the frictional force. The equation to determine ground reaction force in the z direction is,

$$GRF(z) = Ma(z) + Mg \quad \text{….. Eq(2)}$$

where GRF(z) stands for ground reaction force in the z direction, Mg stands for weight of the object and Ma(z) stands for moment about the z-axis. Similarly equations exist for ground reaction forces in the x and y directions.

1.3.2 Center of Pressure (COP)

The center of pressure is defined as the point on a body where the summation of a pressure field acts, resulting in a force and zero moment about that point [2]. Center of pressure is the line of action of the applied force which can be measured using the moments and forces measured by a fixed force plate where a force F is applied at a distance X and Y from the center of the force plate. The force plate with the help of a combination of four transducers will measure the force in the in the X,Y and Z directions and also the moments of the forces about the X,Y and Z axes. This information is sufficient to determine the X and Y positions of the center of pressure as follows:

$$X_{cp} = -M_y/F_z. \quad \text{…..Eq (3)}$$

Where X_{cp} is center of pressure on the X-axis, M_y is the moment of force in the y direction and F_z is the force of the body in the Z-direction.

$$Y_{cp} = M_x/F_z. \quad \text{….. Eq (4)}$$

Where Y_{cp} is center of pressure on the Y-axis, M_x is the moment of force in the x direction and F_z is the force of the body in the Z-direction.

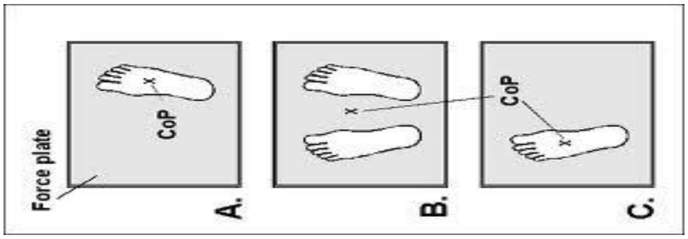

Figure 3: Center of pressure in a human when (a) standing on right leg, (b) standing on both legs, (c) standing on left leg

1.3.3 Co-efficient of friction (COF)

The co-efficient of friction is a dimensionless quantity which is the ratio of force of friction between two bodies and the normal reaction force between them. It is a scalar quantity. The co-efficient of friction is dependent on the material of the two interacting bodies. Co-efficient of friction is of two types: co-efficient of static friction and kinetic friction. Co-efficient of static friction can be defined the value which is a fraction of the maximum possible value such that it exactly counter-balances an opposing force which is acting on the body in the opposite direction parallel to the surface thereby keeping the body at rest. The value of co-efficient of static friction is variable and increases as the force acting on the body increases and reaches a maximum value of μ_0 (The maximum possible frictional force between the two surfaces just before sliding starts is equal to the product of coefficient of static friction and normal force). Co-efficient of kinetic friction is defined as the frictional force acting on the body as it moves along a surface. This force acts in a direction parallel to the surface but directly opposite the direction of movement [3]. The value of co-efficient of kinetic friction remains fairly constantly as seen in Fig. 4.

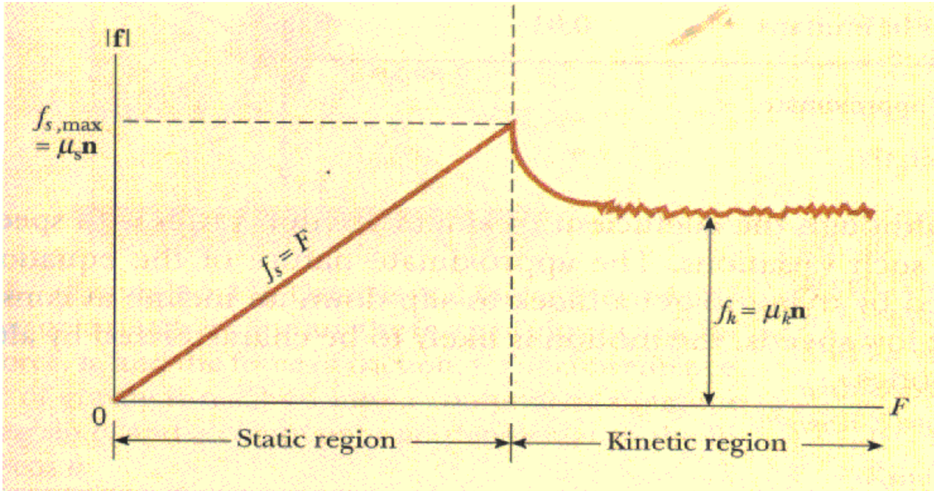

Figure 4: Graph showing the trajectory of co-efficient of static and kinetic friction.

1.4 Moment of force

The tendency of a force to cause a body to rotate about a particular axis is known as the moment of the force or torque. It is a vector quantity measured in N-m. The magnitude of torque is equal to the product of force the moment arm where the perpendicular distance between the line of action of force and the center of moments in known as the moment arm. A clockwise rotation about the center of moments is taken as positive by convention and an anti-clockwise rotation is given a negative sign.

$$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}. \qquad \text{.....Eq (5)}$$

Where τ stands for torque, r stands for the length of the moment arm and F stands for the force causing the rotational motion.

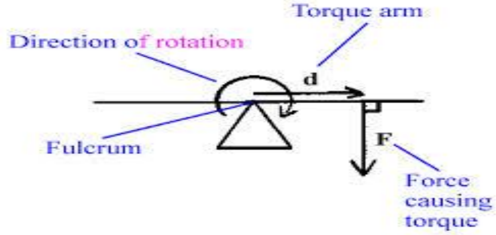

Figure 5: Schematic showing the moment of force.

1.5 Muscular activity

As we walk forward the thigh and hip of the leg in swing phase trail behind, the semi membranosus, semi tendinosus and biceps femoris muscles which make up the hamstring muscles at the back of the thigh help in the bending of the knee. The gluteal muscles help in the extension of the hip of the trailing during a stride. These muscles are worked more by the body while walking on an incline. Adductor magnus a small muscle at the located at the top of the inner thigh also becomes active. The force produced by a muscle depends on its length and a graph of the magnitude of force developed at different muscle contraction levels is shown here in Fig.6.

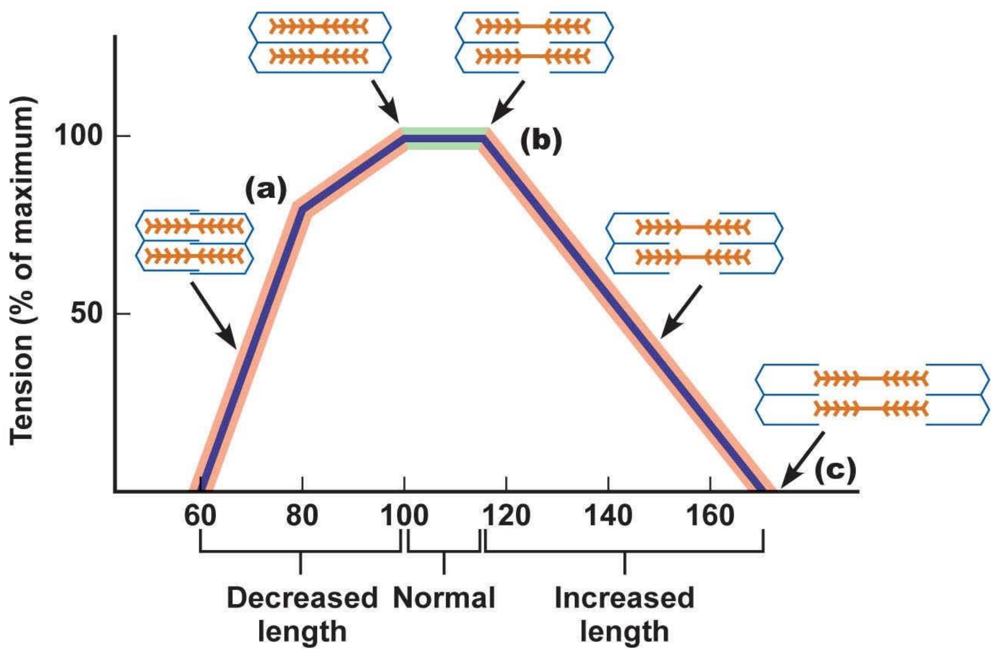

Fig 6: Graph showing the percentage of maximum force produced by the muscles at different lengths.

The structural unit of the skeletal muscle is the muscle fiber. Each muscle fiber is a cylindrical cell 1-30 cm in length and 10-100 µm in thickness. They are bundled together in hundreds and thousands to make one muscle. The muscle fibers are made up of myofibrils which adhere together by a plasma membrane called the sarcolemma. The contractile unit of a muscle is the sarcomere. The force generated by a muscle during contraction varies with its length and velocity. The graph clearly shows that at the maximum and minimum lengths the muscle produces a lower force compared to an optimal length at which maximum force is produced. The force produced is directly related to the degree of overlap between actin and myosin. Hence, the amount of overlap between the two filaments is responsible for the magnitude of force produced. At the longer lengths the thin and the thick filaments do not overlap resulting in formation of minimal number of cross bridges and low force. At the shorter length the length of the sarcomere gets too short as such the filaments are unable to slide past one another with ease resulting in a lower force [4]. The relation between the force produced by a muscle and its instantaneous rate of change of length is shown in Fig. 7.

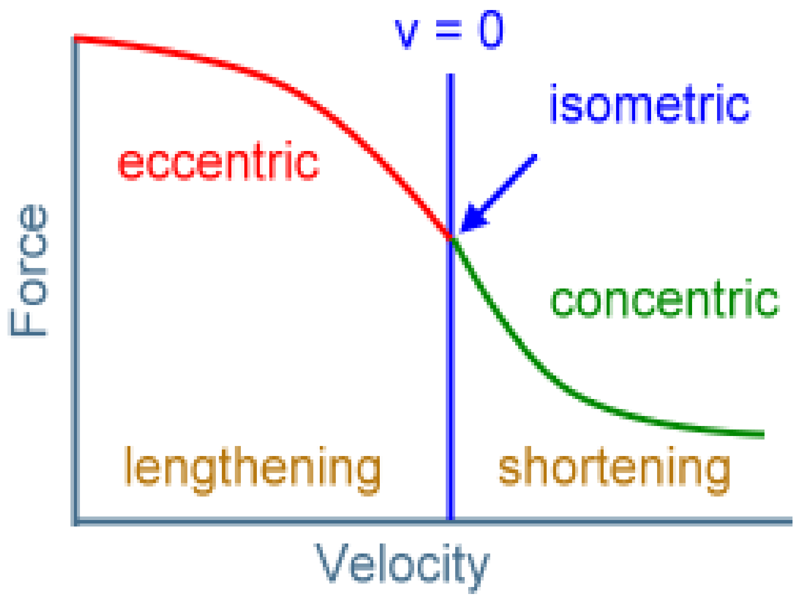

Fig 7: Graph showing force produced by a muscle against the velocity of the muscle shortening.

The graph was obtained by applying force to a muscle and measuring the velocity of shortening of its length. When a muscle lifts a weight which is less than its maximum capacity the muscle shortens. This action is called concentric. If the weight to be lifted decreases then the time taken for the muscles to contract decreases i.e. the velocity increases. However this lasts until the maximum contraction velocity is reached where no more force is generated. If the weight to be lifted is greater than the maximum capacity of the muscle the muscle will be activated but instead of contracting it will be forced to lengthen. This contraction is called eccentric. Most muscular injuries occur due to this overloading of the muscles.

The soleus, gastroenemius, plantaris, and tibialis anterior and posterior muscles are engaged as the foot completes a gait cycle on the floor from heel to toe. As weight of the body is shifted from side to side while walking the quadriceps, tibialis anterior muscle of the lower leg, the gluteus medius and minimus are also activated [4].

1.6 The metatarsophalangeal joint

The metatarsophalangeal joints (MPJ) are those found in-between the proximal bones and the metatarsal bones of the toes. The first metatarsophalangeal joint resembles a sliding or hinge joint i.e. ginglymoarthroidial joint. The first metatarsophalangeal joint is also known as the big toe joint. Similarly, the fifth metatarsal joint is known as the fifth toe joint. During the functioning of the forefoot the hallux/big toe dorsiflexes at the 1st MPJ. The head of the first metatarsal bone pivots against the base of the hallux's proximal phalanx for the first 20^0 resembling a hinge joint movement around its axis, known as the hinge action or the ginglymoidal action. When the foot is raised at an angle above 20^0 the first metatarsal bone has to slide against the base of the proximal phalanx. The head of the metatarsal has to plantarflex and then move backwards before the shaft of the metatarsal rises further and the foot proceeds towards toe-off [5]. The first metatarsophalangeal joint is very crucial to movement and as it is a major load-bearing joint any loss of movement in it causes severe disruption or distortion of biomechanical functions of foot, mainly locomotion.

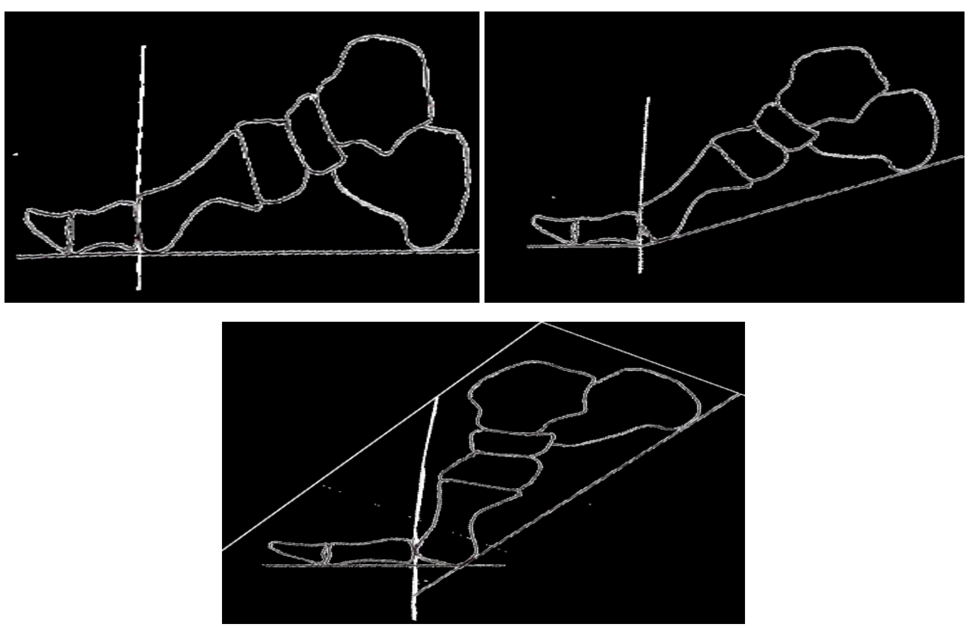

Figure 8: Metatarso-phalangeal joint at (a) 0^0, (b) 20^0 , (c)the first metatarsal has moved down and to the rear (plantar-flexed) to allow flexure of the 1st MPJ beyond 20^0 .

1.7 Hallux Valgus:

Hallux valgus (bunions) is a common foot deformity that can result in a lot of pain and can even restrict locomotion in severe cases. The defining feature of this condition is the inward lateral deviation of the big-toe, the first metatarsophalangeal (MTP) joint. A deviation of 15-20^0 upsets the foot biomechanics and hence is considered abnormal. The deviation of the big toe towards the smaller baby toe causes a bump to develop on the metatarsophalangeal joint of the big toe (metatarsal bone) [6]. The symptoms of hallux valgus are irritated skin around the bunion, redness of the joint, pain while walking and formation of blisters. An X-ray can clearly show the degree of deformity and also whether there is subluxation of the joint. The deformity can be caused by prolonged use of tight or ill-fitting shoes or can be congenital [7]. The treatment of the deformity can be both surgical and non-surgical. The decision to choose either one is dependent on the extent of the deformity or the discomfort caused. Surgery is generally recommended in cases where pain is acute and non-surgical procedures are not effective. Low wide fitting shoes with appropriate padding is a good remedy in most cases accompanied with physiotherapy sessions.

Figure 9: Hallux Valgus affected foot.

There is a lack of detailed study on the gait analysis of bunion affected individuals with most studies focusing on a select area of concern of this condition. The purpose of this study is to develop a general understanding of the problems affecting individuals affected by hallux valgus by analyzing their gait patterns with the help of a multi-axial force platform and comparing the results with the gait patterns of a normal healthy individual.

Chapter 2

Literature Review

Literature Review

Previous Works

Hallux Valgus (HV) can increase the risk of falling by impairing balance in older people. There is no much information about impact of gait pattern on upper body movements while performing normal activities like walking and stair ambulation. Data on the tempero-spatial parameters of head and pelvis during gait and acceleration were obtained in seventy-one people between seventy-five and ninety-three years old. Adjusting for confounders the study yielded the result that volunteers with average to extreme extent of hallux valgus show clear signs of reduced step length and velocity on simple and irregular walking surfaces compared to subjects with hallux valgus of mild proportions. The study confirms the detrimental impact of hallux valgus on older people making them vulnerable to falling especially when walking on irregular surfaces [8]. The direct impact of hallux valgus on mobility was studied in detail in another study. Validated physical examinations were performed by a trained professional on the volunteers and the data was recorded. The volunteers were divided into four groups having: i) no HV and no other foot disorder, ii) no HV but atleast one other foot disorder, iii) HV and atleast one other foot disorder, iv) HV only. Biomechanical data was obtained for both feet from the volunteers. The posture of the foot while walking or standing using center of pressure excursion index were calculated. The study confirmed the alteration of foot loading patterns and pressure profiles and highlighted the need for further work in the area [9]. Twenty women volunteers were selected as the subject of the experiment. Their gait pattern data was obtained with the help of magnetic resonance scanner. The participants simulated their gait movement and image reconstruction was done into virtual bone datasets. Foot posture was described using parameters such as arch angle, inter-metatarsal angle, hallux angle. Relative tarsal positional angles were calculated using image sequence which was registered across gait conditions. The intermetatarsal and hallux angles were found to be greater with deformity, the change in arch angle is not significant in the groups. Patients undergoing arthrodesis of the 1st metatarso-phallangeal joint have severe hallux valgus. A study reported the use of flexible titanium structures along with a titanium staple for immediate protected bearing of load. The number of patients selected in the study were 156 and the average age was sixty-seven years. Flexible crossed intermedullary titanium nails were inserted. The incidence of non-union after arthrodesis was 0.5% and only happened for cases of extreme deformity [10].

A sequence of twenty eight subjects with a moderate to extreme hallux valgus deformity and an intermetatarsal angle of 14° or greater were followed for an average of six years to determine whether any significant loss of correction occurred after surgery. All subjects were treated with a proximal metatarsal osteotomy and distal soft tissue procedure. The mean correction of the intermetatarsal angle was 13.2° (7–20°), and the mean loss of correction after surgery was 1.4°. The range of correction of the deformity hallux valgus was −2° to 48° with a mean of 26.7° [11]. The average loss of correction was 3.9°. In three cases, the deformity recurred in three other cases, a hallux varus deformity developed. The surgery success rate was 85%. This study is an indicator that in most patients affected by hallux valgus with an intermetatarsal angle of 14° or greater, there is sufficient inherent stability of the first metatarsophallangeal joint such that there is no requirement for stabilization to obtain a long term result [12].

Chapter 3

Materials and methods

Materials and methods

3.1 Force plate

The device used for the study is Kistler's multi-axial force platform, model number 9260AA6, Switzerland.

3.2 Data Acquisition Board (DAQ)

The process of sampling signals that measure real world physical conditions and convert these samples into digital numeric values which can be interpreted and manipulated using a computer is known as data acquisition. The components of DAQ/DAS are sensors which can convert electrical signals (physical parameters), signal conditioning circuitry to convert the sensor's signals into a form that can be converted to digital values. ADC's which can convert these conditioned sensor signals into digitized values. The device used is the DAQ system for Kistler's multi-axial force platform, type 5691, Switzerland.

3.3 BioWare software

The software is available for biomechanical applications provide by the Kistler group. BioWare is the interface for signal conditioning, data acquisition and force plate data analysis, A/D board and cabling. This software is used for gait analysis, sports training, ergonomics, neurology and general biomechanical research.

Volunteer1: The subject is suffering from Hallux Valgus.

Volunteer 2: The subject is free from Hallux Valgus or any other foot-related deformity.

Clearance for the project was obtained from the Institute Ethical Committee. The subjects were informed about the procedure and scope of the study and their consent was obtained.

The volunteers were instructed to walk on the 60 cm x 55cm Kistler's force platform at normal walking pace in a 10 second window. In the interest of obtaining greater sample data the volunteers were instructed to walk in repeated cycles for 10 seconds on the force platform. The ground reaction forces, center of pressure, co-efficient of friction and torque profiles have been analyzed. The governing equations fundamental in finding the result are as follows:

The experiment was conducted using two volunteers. Volunteer 1 suffers from Hallux Valgus whereas volunteer 2 is completely free from this or any other foot-related deformity. The volunteers were instructed to walk at self-selected normal walking pace on a Kistler's force platform in a 10 second window. Since walking involves an alternating sequence of single and double phase gait pattern, the volunteers were instructed to walk in repeating cycles during the 10 seconds. The data was recorded and saved. The volunteers performed the experiment under standard conditions on a level surface.

3.4 Governing equations:

Equation for Ground Reaction Force

$$F_y = f_{y14} + f_{y23} \quad \text{......(6)}$$

where f_{y14} Force in Y-direction measured by sensor 1 + sensor 4 and f_{y23} Force in Y-direction measured by sensor 2 + sensor 3 and F_y is the ground reaction force in the y direction.

$$F_x = f_{x12} + f_{x34} \quad \text{.....(7)}$$

where fx12 Force in X-direction measured by sensor 1 + sensor 2 and fx34 Force in X-direction measured by sensor 3 + sensor 4 and Fx is the ground reaction force in the x direction.

$$F_z = f_{z1} + f_{z2} + f_{z3} + f_{z4} \quad \text{.....(8)}$$

where f_{z1}, f_{z2}, f_{z3}, f_{z4} Force in Z direction measured by sensor 1,2,3,4 and F_z is the ground reaction force in the z direction.

Equation for Co-efficient of Friction

$$COF_x = F_x/F_z \quad \text{.....(9)}$$

where COF_x is the Coefficient of Friction (x-component), F_x is the ground reaction force in the x direction and F_z is the ground reaction force in z direction

$$COF_y = F_y/F_z \quad \text{.....(10)}$$

where COF_y is the Coefficient of Friction (y-component), F_y is the ground reaction force in the x direction and F_z is the ground reaction force in z direction.

Equation for Center of Pressure

$a_x = -M_{y'} / F_z$ …..(11)

where a_x is X-Coordinate of force application point (COP), My' is the plate moment about top plate surface and F_z is the ground reaction force in z direction.

$a_y = M_{x'} / F_z$ …..(12)

where a_y is Y-Coordinate of force application point (COP), Mx' is the plate moment about top plate surface and F_z is the ground reaction force in z direction.

Chapter 4

Results and Discussion

The objective was to analyze the difference in the walking patterns of the two volunteers by studying their ground reaction forces in the X, Y and Z directions. Previous studies on this subject lacking a clean gait curve indicated that hallux valgus hinders smooth uniform locomotion in the affected individual. The impact of the deformity increases with age and results in instability in walking pattern and risk of falling in older people specially when walking on irregular surfaces.

Further analysis of this deformity will be continued in subsequent experiments taking into account other important gait parameters such as co-efficient of friction, center of pressure and moment of force around ankle. However the basic experiment will remain the same, a volunteer executing a predetermined number of gait cycles on a Kistler's force plate during a period of 10 seconds. The data being recorded and stored in the system with the help of Bioware software, the DAQ (Data Acquisition Board) and studied in detail for further analysis.

4.1 Ground Reaction Force

The graph of the ground reaction force (GRF) vs time for the volunteer (Fig. 10) in the Z- direction (Fz) clearly shows the difference in walking patterns. Volunteer 2 has an expected two peak output but for volunteer 1, the reading shows aberration throughout the entire gait cycle (Fig 10). The anomaly as compared to a healthy gait is observed here. For hallux valgus subject the gait cycle shows at least three prominent peaks as opposed to two peaks in a standard gait cycle. This third peak arises due to the phenomenon of impact transient [13]. The result of this is the extended hallux valgus striking the force plate and the volunteer applying his weight through his deformity. This trait has been regularly observed among people with this deformity. This effect is magnified when the person is walking fast. The graphs of the volunteer for GRF in the y-direction (Fy) are analyzed to check for differences in the gait patterns in the anterior and the posterior direction (Fig. 11). As the body moves forward it also moves up and down. The mass of the body speeds up as it moves downwards and it slows down as it moves up. At the same time there are accelerations in the forward and backward direction.

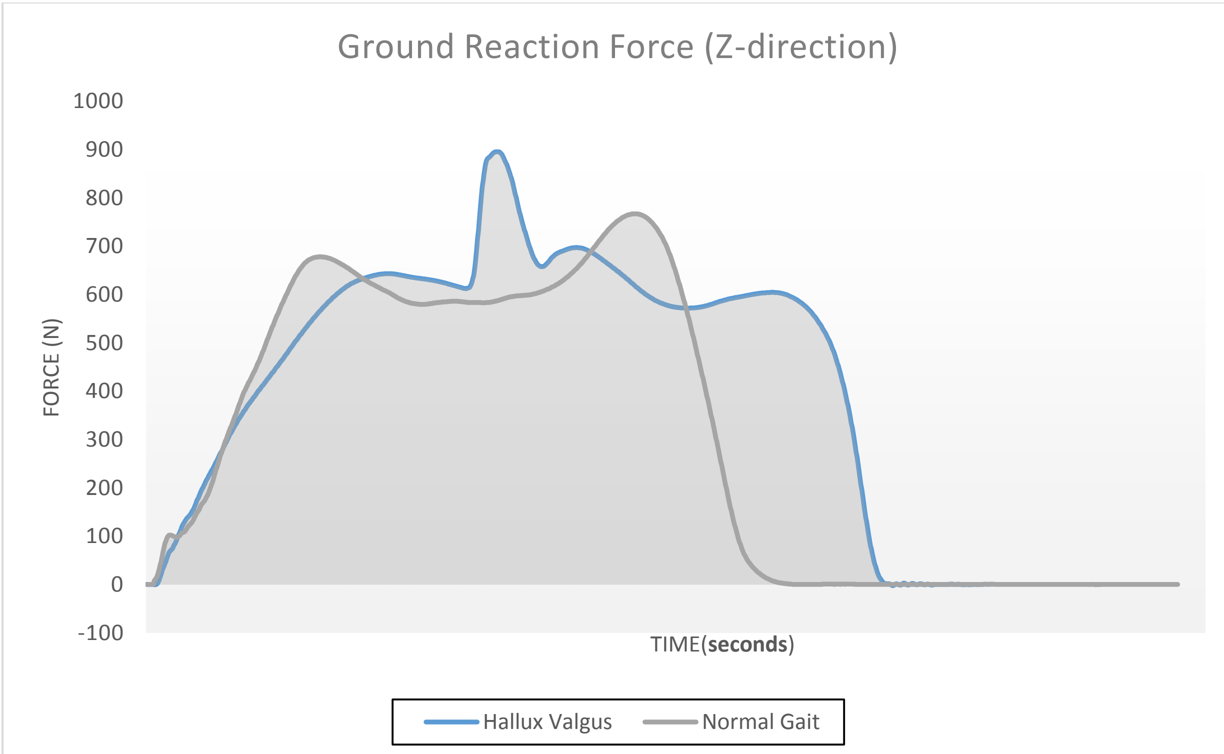

Figure 10: The graphs for ground reaction force (z) of the volunteers.

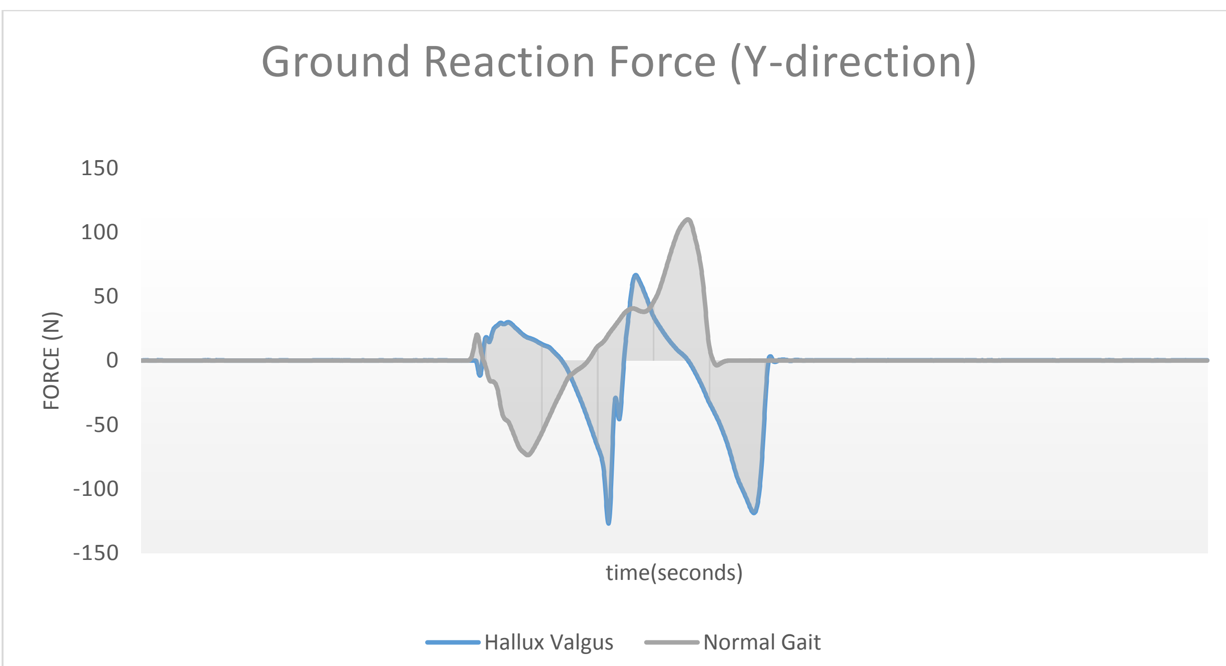

Figure 11: The graphs for ground reaction force (y) of the volunteers.

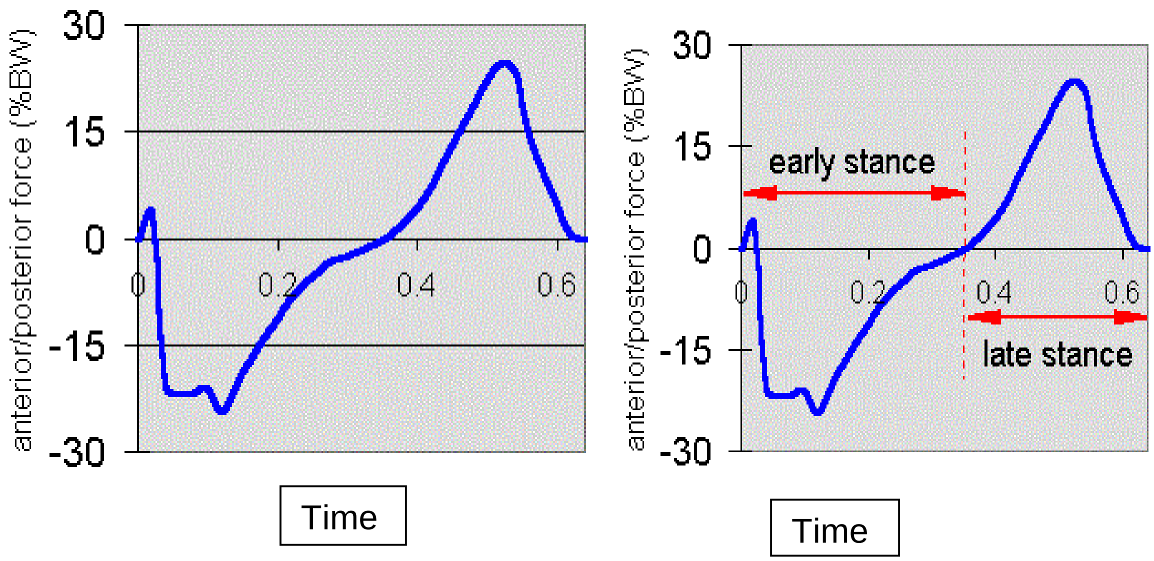

Fig 12: A graph showing the ideal waveform of the GRF of the anterior and posterior direction (Fy) [12].

The ideal scenario during the stance phase is that the force is applied to the foot is in the backwards direction and then in the forward direction in the late stance as the body moves forward with increasing speed. The graph of GRF in Fy direction for the hallux valgus affected individual shows the small peak which indicates that the body comes to a momentary halt unlike the normal gait pattern but instead of accelerating in the forward direction there is another negative peak which means the body again moves downward [14]. This is an indicator of a jerky gait action of the hallux valgus affected individual which is a common characteristic of this deformity. This has been suggested as the reason behind the number of people affected by hallux valgus suffering from arthritis in old age. This is unlike the waveform obtained from the unaffected individual which conforms to the pattern expected of a person free from such deformity. The positive and negative areas of each foot landing in this curve were also studied.. Equal positive and negative areas as those observed for volunteer 2 indicate a constant walking speed [15]. However the graph of volunteer 1 shows varying positive and negative areas for each foot landing which means the individual is not walking at a constant speed.

The lateral and medial analysis of gait pattern is done so as to check and characterize the loading and unloading patterns and postural balances. The graph of the hallux valgus affected individual shows that the volunteer takes more time than normal to stabilize. The greater stabilization time required shows that the bunion's affected individual find it difficult to balance and sways a lot more than a healthy individual.

4.2 Center of Pressure

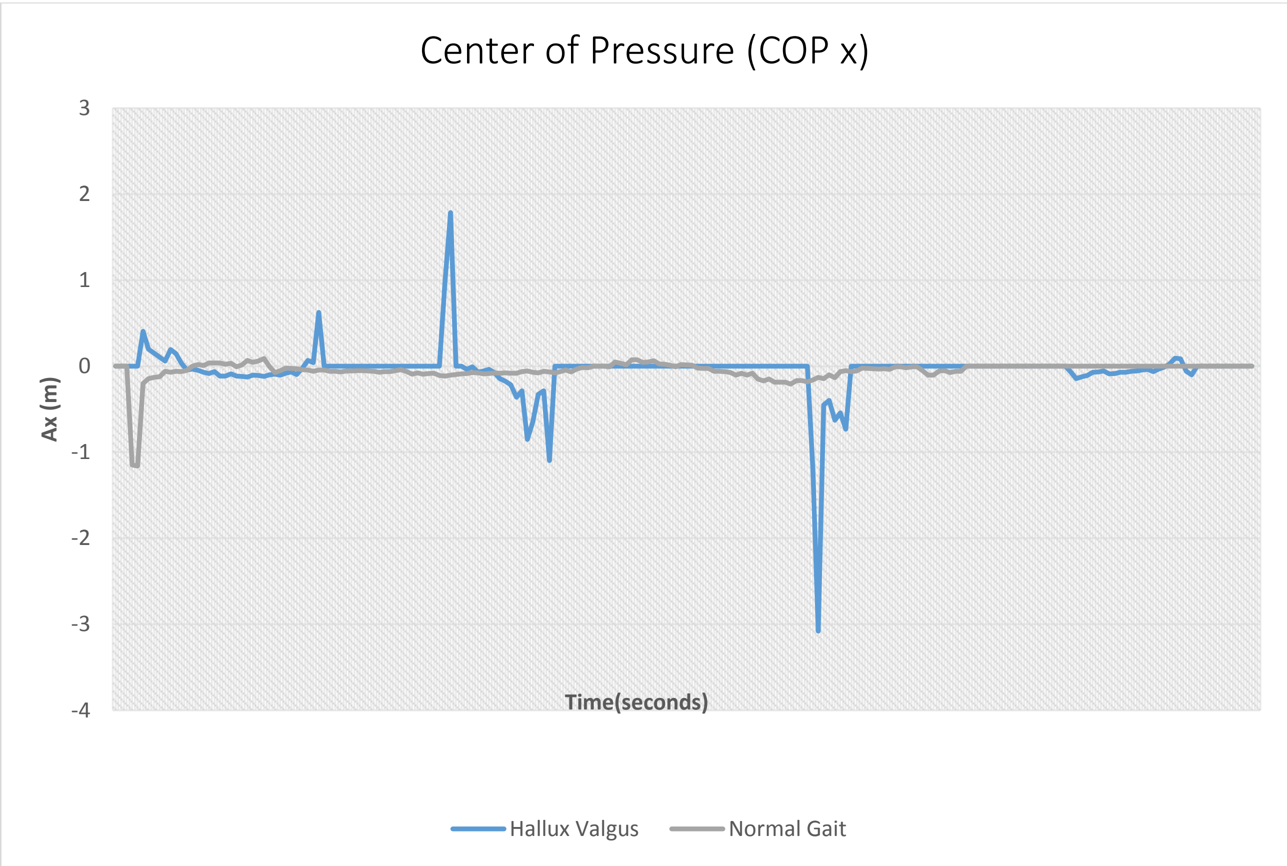

Figure 13: The graphs of center of pressure of the volunteers

The curve of center of pressure are analyzed to study the balance of the human body in the stable posture. A body is in mechanical equilibrium when the sum of the internal and external forces and the torques of the forces acting on the body are equal to zero. The ground reaction force acting on the plantar surface of the foot and the gravitational forces are the major external forces under consideration here.

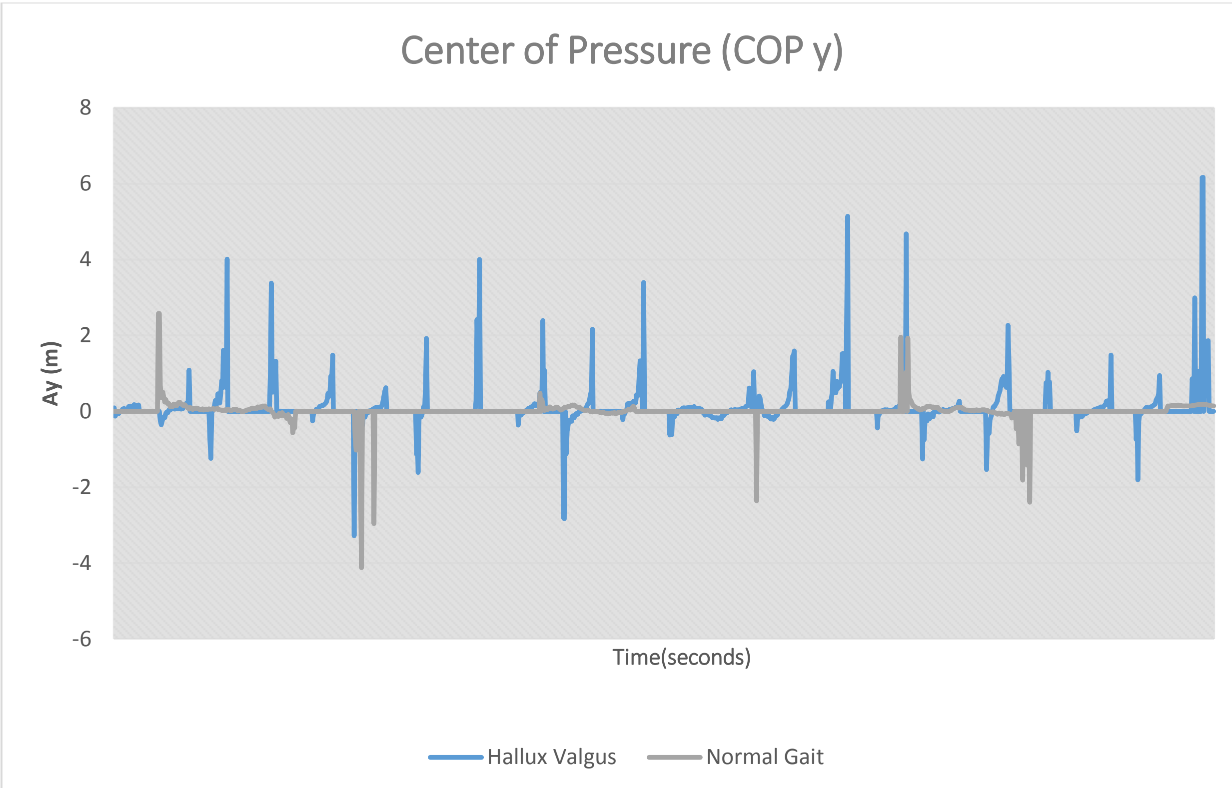

Figure 14: The graphs of center of pressure of the volunteers.

Muscle activations and heartbeats are the internal forces which cause perturbations and constantly vary even in equilibrium unlike the external forces. When no external force acts on the body these internal forces may cause the body to sway depending upon the intensity of the perturbations [16]. The center of pressure graphs of volunteer 1 are found to exhibit very high variation along the medial-lateral (X-axis) direction compared to the anterior-posterior (Y-axis) direction. The center of pressure graphs of both volunteers show a roughly linear tendency along the Y-axis (Fig 14) which is an indication of smooth transfer of weight from the heel to the toe, in the forward direction. The graph of the hallux valgus affected person is not completely linear but the reason for this might be obtained by looking at the lateral-medial graph more closely.

The graph of center of pressure in the medial-lateral direction is a clearer indicator of the differences in walking patterns between the volunteers. For volunteer 1 the graph records rapid changes in the vertical axis which means the person is having difficulty balancing as he puts each foot forward. Hence volunteer 1 will tend to sway from side to side while walking. This phenomenon is observed to be minimum for graph of volunteer 2. This is a natural outcome since volunteer 1 is suffering from the deformity. The pattern of walk of the hallux valgus affected individual is not the most comfortable and constantly puts pressure on his ankles and knees. This sort of gait pattern can cause bone injuries in ankle and knee joints if continued over a long period of time and as the person gets older.

4.3 Co-efficient of friction

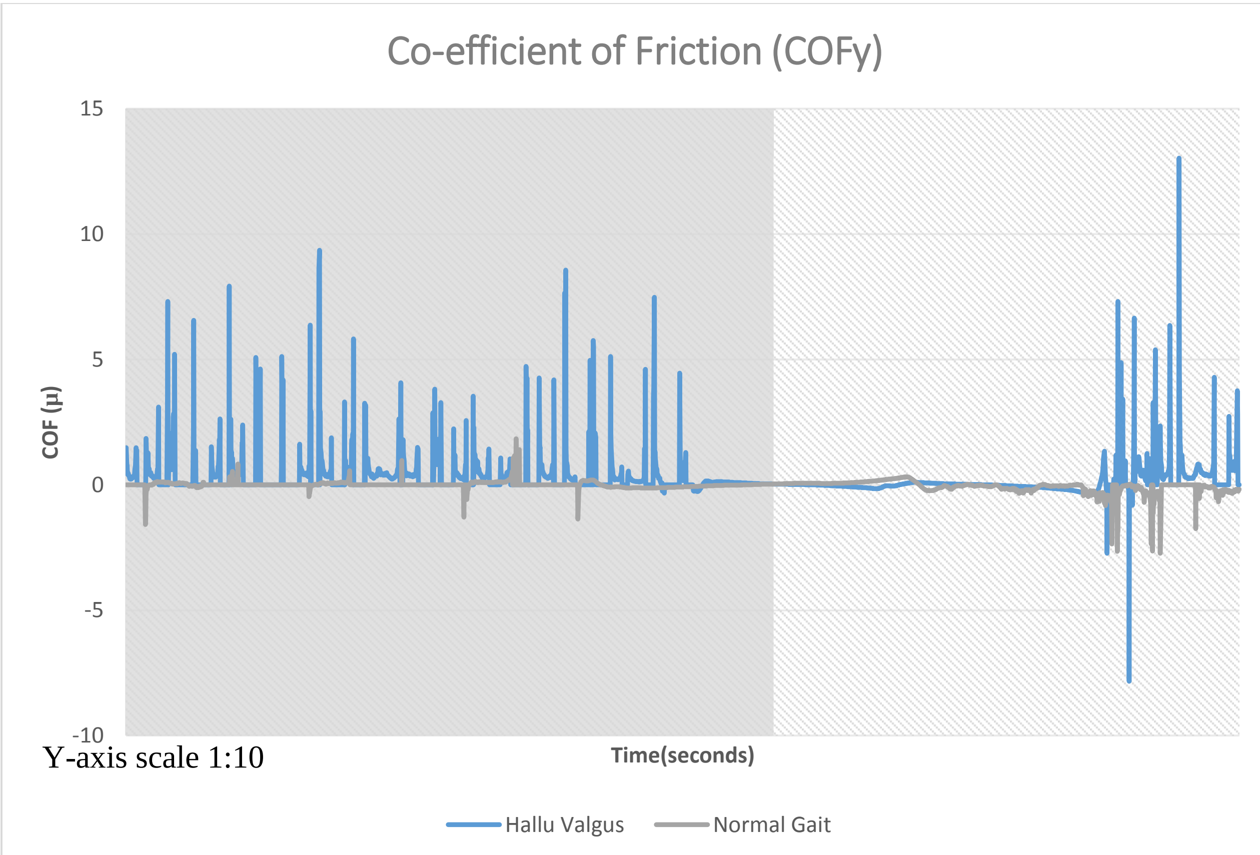

Figure 15: The graphs for co-efficient of friction of the volunteers.

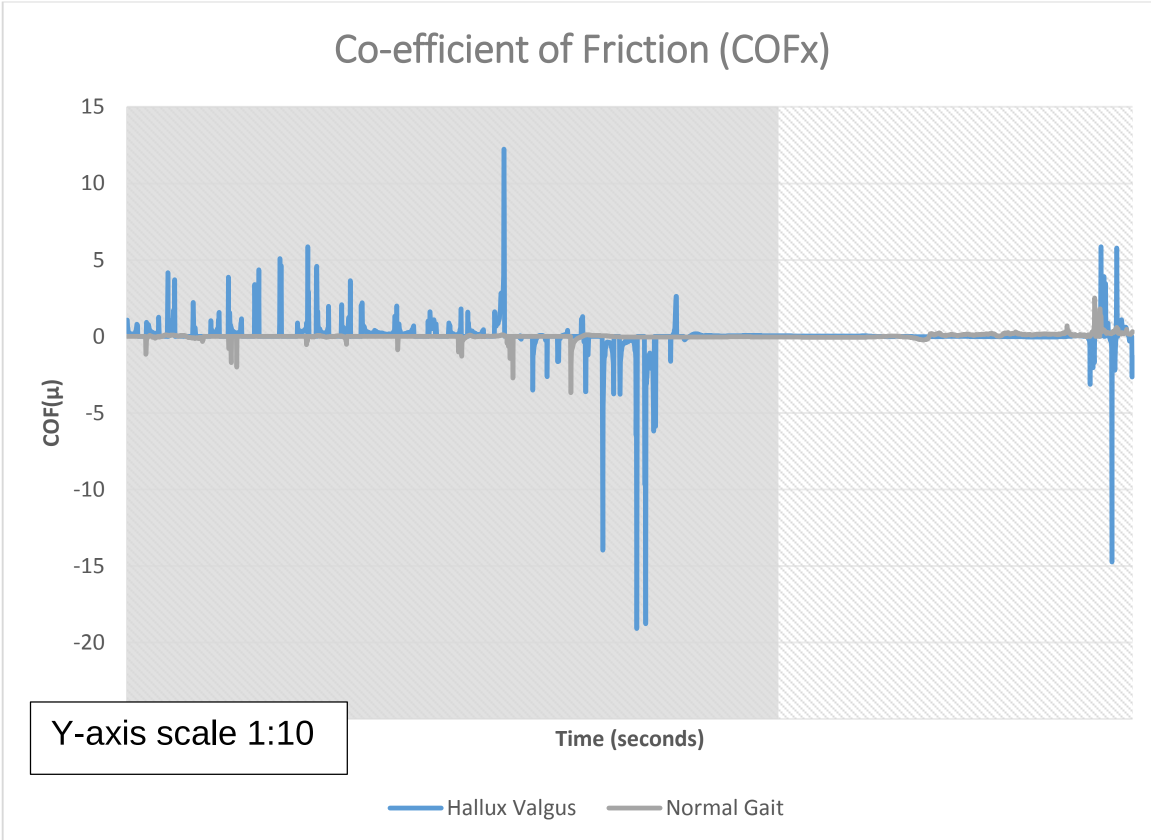

Figure 16: The graphs for co-efficient of friction of the volunteer.

The pronation and supination of the feet while walking is represented by the curves of co-efficient of friction. While moving forward the heel has to apply greater frictional force on the ground compared to that by the toe. During the load acceptance phase, the heel strikes the ground, overcomes the frictional force and moves forward swiftly to the toe-off phase [17]. This is the mechanism for a normal gait. The heel pushes on the ground, decelerates the swinging leg applying resistance to the ground reaction force. For a hallux valgus affected individual the coefficient of friction is found to be consistently high. This is because of the varying degree and rate of contraction and relaxation of the muscles which might have become stiff or weak from the abnormal pressure being put on them by volunteer 1. The value of co-efficient of friction for this person is found to be around 0.5 or more frequently. This indicates higher friction during propulsive loading. The lateral side of the foot is pronated as a result of which the ability of the volunteer to overcome the frictional force is limited [18]. The result is that the hallux valgus affected person takes longer time to lift his/her foot for moving forward.

4.4 Suggested Remedies

The permanent treatment of this deformity is possible only through surgery. First x-ray scans ae done to determine the extent of deformity as mild, moderate, or severe and after taking other factors into consideration such a age, health, daily activities etc the surgery goes ahead to restore the toe to a normal position through re-alignment of joints, ligaments, tendons and muscles. The procedure chosen for mild deformity is bunionectomy where the extended part of the bone is shaved off. Similar process follows for a moderate case but here the bone is cut closer to the metatarsal bone. Severe cases require the surgeon to make a cut at the base of the metatarsal bone. The complication rates vary with the different studies done in this area from 10% to 55% [19]. Non-invasive treatment involves wearing the right kind of shoe which has sufficient space in the toe-box to accommodate the deformity. Specially made gel-skinned pads or moleskins provide protection. Shoe insert help the foot in positioning correctly as it lands on the ground. Cortisone injections are also recommended for temporary relief from pain but they have some side effects if used frequently and at concentrated doses.

Conclusion

Conclusion

The gait analysis of the volunteers yielded the following results. The waveform of the ground reaction force of hallux valgus affected individual shows a small dorsiflexion moment shortly after contact. This moment prevents the foot from slapping down during initial contact with the ground. The walking action is not smooth. The body moves forward in a jerky motion. As the volunteer moves into the latter half of his stance, a sizeable plantar-flexion moment is generated as main contributor to the body's forward progression. Also the affected individual takes more time than the normal person to stabilize as seen from the graph of GRF in lateral-medial direction. Graphs of center of pressure also show high variations in the medial-lateral axis as compared to the anterior posterior direction. This is a clear indicator of difficulty while balancing, every time the volunteer walks. The graph of co-efficient show a varying rate and degree of contraction and relaxation of muscles which become stiff or weak from abnormal pressure being put on them. There is higher friction during propulsive loading and the lateral side of the foot is pronated as a result of which the ability of the volunteer to overcome the frictional force is limited. Hence a hallux valgus affected individual walks at a slower pace compared to a normal individual.

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