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AN ICT ORIENTED APPROACH TO IDENTIFY IMBALANCES OF LOWER BODY MUSCULOSKELETAL SYSTEM VIA GAIT AND POSTURE ANALYSIS USING KINECT

Charitha Paranamana*, Hiranthi Tennakoon, Damitha Sandaruwan,

Maheshya Weerasinghe and Kalpani Mahindarathne

Charitha Paranamana, University of Colombo School of Computing

ABSTRACT: *Repetitive usage of one body muscle sector than the other and incorrect postures a human body takes and practices on a regular basis may cause muscle imbalances in a human body. A muscle imbalance should be paid adequate attention since both neurological and physical performances can be severely affected due to imbalances as time progresses. Current clinical practices of imbalance identification as in gait and posture analysis, movement analysis, joint range of motion analysis and muscle length analysis require and 100% depend on domain expertise and experience. Technical methods of imbalance identification as in X-Rays and CT scans also require the assistance of domain experts to interpret the results and the cost and time an individual has to bear for this is excessive. To overcome cost, time and domain expertise constraints, this research propose a mechanism for an individual to self-identify body imbalances and track their progress with treatments. To analyse the imbalance, Kinect, a motion capturing device which is able to track human skeleton, its joints and body movements within its sensory range is used. Primary consideration is tracking the human gait cycle and posture via Kinect motion capture device and differentiating the deviation of standard gait and posture patterns. The outcome of this study will be a self-identification method of human skeletal imbalances initially for physiotherapy and physical fitness areas.*

KEYWORDS: Gait and Posture; Kinect; Musculoskeletal imbalance;

INTRODUCTION

To function properly as individuals, it is important to endow a healthy and a strong body. In order to provide the body with shape, protection and internal structure, human skeleton is a necessary component and for human skeleton to function, support of skeleton muscles is crucial. Human body consist muscles which mostly work as pairs to assist these functionalities. A muscle imbalance can be defined as an inequality of the strength, length and the stiffness between the agonist and antagonist where in a pair of muscle agonist is the carrier of a function and the antagonist is the muscle at rest. When usage of one of these muscles is at a higher rate than the other, strength, stiffness and length of the muscle deviates from the latter parameters of the other muscle. Repetitive usage, faulty postures and everyday routine activities can be described as the causes of such deviations. After effects of the causes are highly dependent on the associated muscle. Several after effects which are related with muscle imbalance are neuro musculoskeletal damages, lower back tightness, repetitive stress injuries (RSI), hamstring strains, altered movement patterns and postural dysfunction [1], [2], [4].

A muscle imbalance cannot be identified at its preliminary stage unless it causes pain or any kind of a symptom. Therefore at the time of determining a body imbalance, it may have already caused the individual a cost. The relationship of the lower body skeletal system components is

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at a stronger rate than the upper body skeletal system. Therefore, higher injury rates are associated with the lower body [6], [7] and applicability of this study to the upper body will be determined only if the approach can be applied to the lower body. So, the lower limb musculoskeletal system is examined in this study to determine body imbalances.

Gait analysis is a new biometric technique which can be used to identify behavioral specifics of different people [14]. Usage of marker-less systems is a technique which does not need physical contact between sensor and the subject to observe the gait cycle. Advantages of using gait analysis are its allowance for marker free identification and this biometric technique is hard to imitate or hide. Therefore, in this study the human gait cycle is analyzed via Kinect. According to recent cites, Microsoft Kinect which is originally used as a video gaming device can also be used as a tool to track human gait variables as well as gait kinematics. Kinect is capable of tracking and recording 3-D human motion without using markers [15], detects human motions in 3-D view real time and extract artificial skeleton with joints overtime.

Clinical Analysis Mechanism

Gait And Posture Analysis

Gait cycle, primarily can be defined as the way a human walks; the cycle containing phases from the initial contact of one foot with the ground and the next contact of the same foot with the ground. Posture can be defined as positions a human body can take; seated, standing. In gait and posture analysis, physiotherapist observes the gait and posture of an individual, analyses gathered information by comparing with standards and predicts the condition of the muscle.

Gait cycle can be mainly divided into two phases; stance and swing where 60% of the cycle is included in the stance phase and 40% includes in the swing phase. These two phases can then be divided into eight minor phases as shown in Fig 1.1.a. There is no one correct manner of assessing the gait [2]. Fig 1.1.a shows the events of a complete gait cycle.

A walkway of at least six meters or a treadmill is used to perform gait assessment and the best time to examine a patient's gait is as they are entering the examination room since they walk in naturally [2].

Optimal posture implies balanced distribution of body mass around the center of gravity and abnormal posture can be detected by visually observing the gait [3]. Elevation of shoulders, protraction of shoulders, head forward posture, increased cervical lordosis, hyperextension of

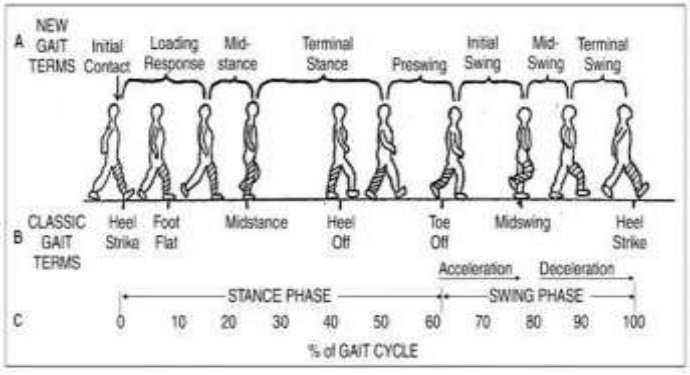

Figure 1.1.a – Gait cycle

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upper and cervical joints are the measurements of postures analysis which drives for identification of muscle imbalances [2].

Following figures (figure 2.1.b - figure 2.1.f) illustrate the ideal and imbalanced postures of a person [9].

movement Analysis

In movement analysis, a patient is requested by the physiotherapist to perform various activities to determine whether the patient holds a musculoskeletal imbalance or not by analyzing the behaviors and stances the patient's body takes. Requested stance is highly depended on the experience and knowledge of the observer. There are three main methods of movement analysis; movement phases, free body diagrams and deterministic models. In movement analysis phase, analysis of preparation, execution and follow-through is analysed. In preparation phase, movement preparation by the individual to perform a particular motion is analysed and in the execution phase, movement of the patient is analysed. All the behaviors of the individual after the movement is also analysed in this phase. In free body diagram analysis, a two dimensional or three dimensional diagram of the predicted movement is created but forces on the outer body is concerned. In deterministic model, biomechanical factors which determine a movement is analysed and one primary movement is divided into several secondary factors for further analysis of a muscle imbalance. Following characteristics of movement patterns are considered in this analysis [11].

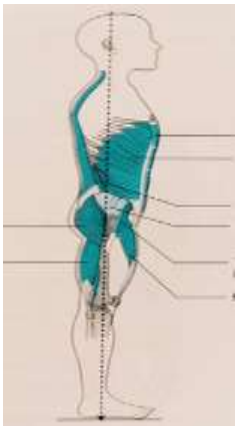

Figure 1.1.b - Ideal alignment (side view)

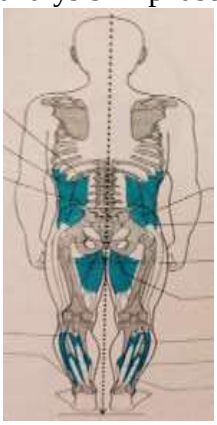

Figure 1.1.c - Ideal alignment (posterior view)

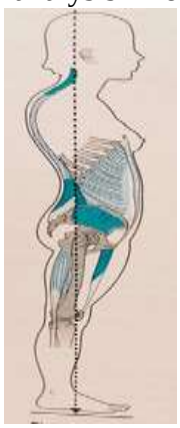

Figure 2.1.d - Kyphosislordosis posture

Figure 1.1.e - Sway-back posture

Figure 1.1.f – Flat back posture

View	Faulty Movement
Anterior	 Toe out  Knee moves inward (Valgus)

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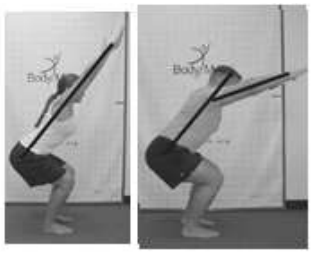
Lateral	 Arms fall forward  Excessive forward trunk lean
Posterior	 Flattening of medial longitudinal arch

Table 1.1.g – Movement pattern characteristics

Joint Range of Motion Analysis

In joint range of motion analysis, the range a human can perform his motions and movements is taken to consideration. Main considerations in this approach are; the plane of the movement occurrence, muscle used to produce the movement, function of the involved muscle; agonist [3]. There are mainly four planes a human body can be divided into;

- Sagittal plane
- Coronal plane
- Transverse plane
- Oblique plane

The three axis which are considered are;

- Frontal axis
- Sagittal/ Transverse axis
- Longitudinal axis

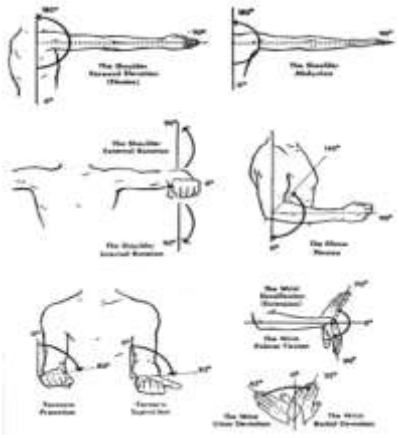


Figure 1.1.h – Movement pattern characteristics

In this analysis method all mentioned planes and axis and both active and passive range of motions are measured [3] and with the aid of Goniometer angles between the joints are

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measured and compared with the standard angles defined in the domain with respect to the person's age, weight and fat elements. A noticeable deviation of joint angles from the standards is determined as a muscle imbalance.

Muscle Length Analysis

Muscle length is analysed against the age and other physical parameters of the person which assesses the resistance to passive movement. In order to gain accurate result, muscle length should be performed when the patient is not in acute pain in order to avoid pain inhibition and muscle guarding [5]. Goniometer or a tape can be used to do the measurements and there are four steps in performing muscle length analysis [11].

- Ensure maximal lengthening of the muscle from origin to insertion
- Firmly stabilize one end (usually the origin)
- Slowly elongate the muscle
- Assess the end feel

Technical Analysis Mechanisms

Electromyoraphy

A needle is injected to the surface level of the human body and this stimulation is used to measure the reaction and activities of muscles to the mentioned electrical stimulation. Muscle activities grasped by the electrodes are displayed in a monitor called oscilloscope and an audio amplifier is also used to listen to the muscle activities. To determine a muscle imbalance, currently consultants analyse these muscle activities and their responses to the electric stimulation and a muscle imbalance is determined if found.

X-Ray and Ct Scans

In Computed Tomography a special X-Ray equipment is used to detect body conditions. This scanning produces multiple images of the inner body of a person. X-Ray beams and electronic X-Ray detectors rotate around the patient and different parts of the body absorb the produced X-ray in different degrees and it records in a special electronic recording plate [4]. These record and datasets create a two dimensional image of the body. In determining musculoskeletal imbalances, the domain experts analyse these scanned body images to conclude whether the patient is having a muscle imbalance or not.

Related Work

In the IT domain, researchers have done studies to identify muscle abnormalities using motion tracking sensors. In many studies they have considered sports domain to identify musculoskeletal issues since sport persons are often having issues in musculoskeletal system. Characteristics of the range of motions of the musculoskeletal system, muscles at risks and injury prevention strategies have been identified by using 3D motion tracking systems in a previous researches [2]. A nine-camera, 3D motion capturing system and 42 reflective markers on subject's each part of the body were used to track body movements and to identify muscles at risk. Using the raw 3D data captured from the nine-camera and 42 reflective markers, biomechanical modeling of the subject is produced and muscles and risks have been identified

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using this biomechanical model. Inertial tracking sensor which combines the signals from 3D gyroscopes, accelerometers and magnetometers and estimate the free orientation of human have also been used in previous studies [3].

When calculating human kinematics, it is required to define all joint orientation in its local frame so that local orientation can be easily converted into the angular values of each joint of musculoskeletal system [8]. In the inertial sensor, each individual sensor of the system provides orientation with respect to the global frame. The MVN motion capture system is consisted of body worn sensors which are having unique approach to estimate body segment orientation and position changes by integration of gyroscope and accelerometer signals which are continuously updated by using the biomechanical models of the human body which allows to track the human musculoskeletal system's motions [3]. This system is running real-time with maximum update rate. It is possible to observe, record and export the human muscle movements in 3D version with the MVN studio software. When sensors are placed in the body, the sensor to segment alignment and segments lengths can be re-estimated by using medical standard values about the distance between two points in kinematics. Using biomechanical model which assumes that a subject's body includes body segments linked by joints and that the sensors are attached to the subject's body segments, the inertial navigation system kinematics are translated to body kinematics. When calculating the joint angles, the origin values are defined in the center of the functional axis with the directions of the X, Y and Z related to the functional movements. MVN MotionGrid is an ultra-wideband based tracking technology complementary to the MVN system which is added a local GPS system to the sensor and capable of assessing all the kinematics of an athlete accurately even during high centripetal accelerations [3]. The sensor fusion scheme is capable to calculate the position, velocity, acceleration, orientation, angular velocity and angular acceleration of each body segment with respect to the global reference coordinate system.

Kinect, a markerless technology has been used to study the precision in the joint angles computation against a professional optical motion capturing device. The researches have obtained a guaranteed range of disparities to make validations on the used two devices regarding joint angles when the limbs are involved [9]. Motion tracking devices as in Kinect since it is relatively a cost effective motion capturing device, introduces the possibility of changing paradigms based on complex and expensive technologies and devices in the biomechanical domain [9]. Human musculoskeletal motions can be tracked using Kinect in model-based and appearance-based approaches [10]. In model based approach, it provides a continuum of solutions which are costly and also depending on the wealth of visual information provided by a multi camera system. When it comes to appearance-based method, it is associated with much less computational cost and the complexity of hardware is very less. This model [10] minimizes the inconsistency between the 3D structure and appearance of hypothesized 3D model and the actual visual observation comes from the Kinect sensor.

In recent studies gait cycles has been used for Human identification [19] , identify neurological diseases [20], Fall detection of elderly people [21] and at the same time in clinical domain gait analysis is used for muscle imbalance identification, monitoring and rehabilitation. [22]. Gait cycle is highly depending on the height, weight of the subject [23], injuries in the skeletal and diabetes [21]. Individual human recognition by gait cycle has been performed [19] via Gait Energy Image (GEI) mechanism. GEI is a spatio-temporal gait representation for individual recognition which represents human motion in a single image while preserving temporal information. This representation saves both storage and computation time for recognition

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compared to binary silhouette [19]. In recent studies gait cycle parameters have been used to be predictive of future falls and adverse events in older people using Kinect [24]. In this study height of the person, walking speed, average stride time, and average stride length, in addition to the time the walk occurred have been considered in their methodology. Impairments in gait and balance causes falling of adults basically. Identification of these gait abnormalities is essential to early initiation of fall prevention strategy [25].

Research Design

Kinect is able to capture body movements of people and it indicates the joint positions of the body. Kinect is consisted with a RGB camera. With the aid of the IR in the Kinect, it can capture people's positions, joints and track their movements. Motions only within the sensor's viewing limit are able to capture. Architecture of the proposed system is as follows.

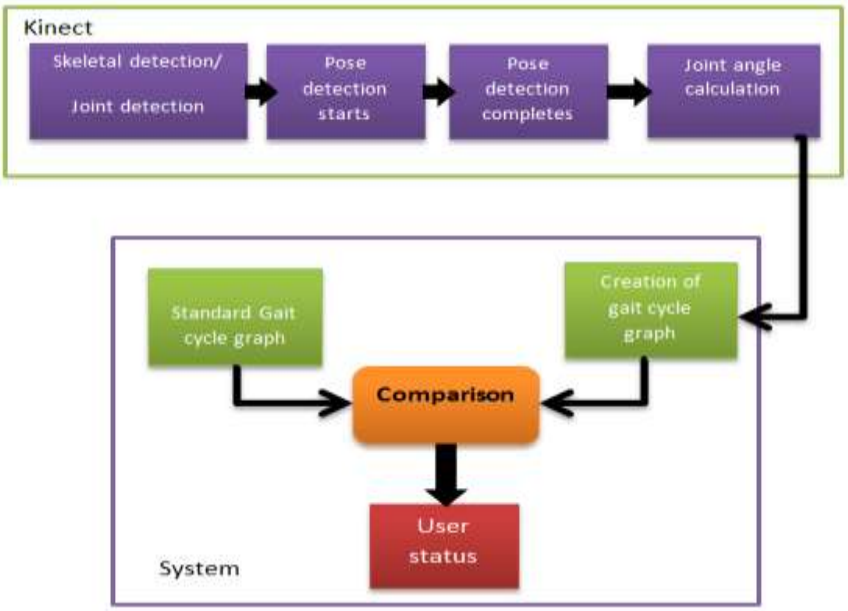

Figure 2.1.a – Research Design

The gait cycle is to be divided into its main eight phases (initial contact, loading response, mid-stance, terminal stance, pre-swing, initial swing, mid-swing, terminal swing) and the Kinect is used to track the phases. By the joint positions the Kinect capture, three parameter angles X, Y and Z can be captured to calculate the angle values between the joints.

Outcome of this calculation is then compared with the standard joint angles of a person according to his/ her age and gender. If the calculated value is deviating from the defined standards, it can be described as a skeletal imbalance. Sample taken to test the study will consist of both male and female who are currently in the age range of 25-40 skeletal cycle has three stages; gain, consolidation and loss. Peak mass of the skeletal system is achieved in between age of 20 - 30 which is called gain and consolidation period is up to age of 40. Thereafter the loss of bones are occurred in both men and women [12]. Therefore our sample will be consisted of subjects who are in the consolidation age period. The intended sample will be consisted of people who are/ are not currently having body imbalances. Sample will be drawn directly by patients whom a physiotherapist consults at the moment.

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Leg length, age, gender, stride length, walking speed, weight are some factors which affect the deviations of the gait cycle from its individual standard. Increase in leg length affect increase in the gait speed [16], old age affects decrease in gait speed and stride length, walking speed is higher in male gait cycles than in the female gait cycles [17], increase of weight result in longer gait cycles [18]. These factors and how they proportionally affect the gait cycle is also considered when conducting the research.

Assumption: All the objects in the sample will achieve the peak mass of the skeletal at the age of 25.

CONCLUSIONS & RECOMMENDATIONS

Previous identification of muscle imbalances is crucial for every individual to treat and overcome the situation in its early stages and avoid the occurrence of severe injuries. With the current mechanisms of identification lie many drawbacks. Muscle imbalances are not visible to the eye unless they rise with noticeable symptoms. Starting treatments for the imbalance in its latter stages will cause individuals to handle more developed neurological and physical dysfunctions.

A self-identification method is required in order to provide individuals with the ability to track their musculoskeletal system and treat it with proper care. Assessing muscle imbalances with the aid of technologies as in Kinect where human skeleton, gait cycle can be detected and by combining the medical domain with information technology and provide the physiotherapists and consultants with an aiding device, providing a self-identification mechanism for human body imbalances is the primary objective of this research.

This research only focuses on the gait analysis to examine and determine muscle imbalances. Other clinical and technical mechanisms currently in practice can be aided by ICTs and a combining method of evaluation and treatment can be stated as an extension of this study. In this study, the only consideration is the lower limb musculoskeletal system therefore in extensions, upper body musculoskeletal system can be used with ICTs. Other deceases can also be identified by these type of body behaviors and can be recommended as future extensions.

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