KINECT-BASED KINEMATIC GAIT ASSESSMENT FOR FILIPINOS VIA CROSS CORRELATION CALCULATION USING MATLAB

CUISON, Sherwin Kio I. [1]   DE BELEN, James Patrick P. [2]   RAMOS, Vince Kyle Y. [3]   ROXAS, Janrey A. [4]   TRAVILLA, Earl Floyd P. [5]

Electronics Engineering Department, Technological University of the Philippines
Ayala Blvd. Ermita, Manila, Philippines
[1] sherwinkio.cuison@tup.edu.ph   [2] jamespatrick.debelen@tup.edu.ph   [3] vincekyle.ramos@tup.edu.ph
[4] janrey.roxas@tup.edu.ph   [5] earlfloyd.travilla@tup.edu.ph

***Abstract* -- Gait analysis requires analyzing patterns while walking or running to scientifically assess irregular or atypical patterns of motion. Gait analysis is a vital instrument for the precise diagnosis of certain injuries, especially in the field of sports. Existing gait analysis technologies are considered costly, intrusive, or require well-controlled conditions. This paper presents kinematic walking gait analysis as a way to establish a normative walking gait database that will serve as reference for comparing the subject's gait and the normalize gait. Moreover, this paper focused on one ethnicity – particularly Filipinos – as the source of test subjects since the target application of the proposed database is for Filipinos. Test subjects that were recruited in the study have no history of any injury or gait abnormality and were divided according to age, gender, and Body Mass Index (BMI). All measured through kinematic parameters. We further improve over existing work by making a system that store and analyses the subjects' gait, it also compares different gaits to distinguish the variations from the normal gait and the subject's gait.**

***Index terms* -- Gait Analysis, Kinematic Walking, Normative Walking Gait, Gait Abnormality, Kinect sensor**

I. INTRODUCTION

Kinematic gait analysis is the study of the body, limbs, and joints' motion that takes place during walking. This method of research provides a non-invasive way of gathering patients' objective information on joint and limb motion.

Gait reference data are essential in determining the nature and severity of gait deviations in injured individuals and in helpful evaluation of the effect of clinical treatment [3]. This is used as a comparison between an impaired and a healthy unimpaired individual of same age, gender, and Body Mass Index (BMI). These normative data commonly come from control groups of studies involving pathological gait patterns. These are very useful indicators of gait abnormality and even the extent of abnormality without necessarily indicating the cause of problem [4].

Irregularities in the gait pattern of a person often stipulate symptoms of pathological gait. To identify pathology and track recovery, univariate parameters, such as step length, walking speed, stance, and swing time, are used to characterize asymmetries with symmetry indices and ratio [5]. Several corrective treatments are proposed that aims to control and improve the efficiency of pathological gaits based on the data obtained from gait analysis and clinical evaluation [6]. Gait patterns generally vary with ethnicity, racial, and cultural factors. Studies show that the use of other ethnicities' gait parameters can lead to both misdiagnosis and misinterpretation of clinical problems [3].

Asian and Non-Asian countries have different values on parameters that includes stride length, walking speed, vertical ground reaction force, step length, and step frequency [3][4][7]. Differences in parameters are also present between Asian countries which include cadence and stride length [3][8]. This shows that existing gait reference data are not generally applicable to all ethnicities because of the differences in gait kinematics. Filipinos, as part of the Asian group, embody unique gait characteristics. Therefore, there is a need for an ethnicity-specific walking gait database.

To perform accurately on gait analysis for Filipinos, a gait database for Filipinos was developed by utilizing a portable motion capture system the MS Kinect which consists of infrared projector, RGB camera and an IR camera. The Microsoft Kinect V2 is a camera-based sensor primarily used to directly control computer games through body movement. The Kinect tracks the position of the limbs and body without the need for handheld controllers or force platforms. Use of a depth sensor also allows the Kinect to capture three-dimensional movement patterns [9].

MS Kinect was used as an alternative low-cost gait analysis method. This research also aims to validate the capability of the sensor used and to assess the accuracy of Microsoft Kinect V2 sensor for the assessment of walking gait parameters of Filipinos. The outline of the paper is as follows: Section II discussed the methodology of the research which tackles about how the study was done, from the test subjects and experimental set-up, up to the process on how the data gathered were analyzed. Section III presented the data and results gathered from the study. Section IV discussed the trends of the parameters obtained. And lastly, Section V summarized the entire study and included the possible improvements of the research for the future work.

II. METHODOLOGY

The study was divided into six phases namely: the gathering of test subjects, setting up of the equipment, validation of the equipment, the actual testing or the gathering of data, the analysis of the gathered data, and the drawing of conclusion from the data based on statistical analyses

A. Subjects

The study involved the analysis of the natural gait of healthy Filipino men and women. To analyze Filipino gait characteristics using MS Kinect, 70 male and 40 female consenting subjects were recruited in the study. To categorize the different test subjects according to their gender, age, and BMI, the height and weight of each subject were measured. The age of each subject was also recorded. Table I shows the measured data.

TABLE I
MEAN (SD) OF AGE IN YEARS AND ANTHROPOMETRIC DATA WHICH INCLUDE HEIGHT IN METERS, WEIGHT IN KILOGRAMS, AND BMI IN KG/M^2

	Male Mean (SD)	Female Mean (SD)
Age (years)	1.03	1.15
Height (m)	0.05197817	0.05224407
Weight (kg)	10.3445159	6.54156726
BMI	3.4687902	2.3989945

The test subjects were at their early 20's or late teenage years – ages at which the development of gait is complete (considered to be of an adult) yet no degenerative factors related to aging are present [3]. In gathering the subjects of the study, a criterion that subjects should have no history of musculoskeletal, neuromuscular, neurological and any other type of abnormality concerning the lower part of the body that may cause abnormal gait [10].

B. Experimental Setup

Subject are composed of 21 males and 9 females with different weight and height. The subjects are asked to walk to the position of the Kinect. This is continued until all the height of the tripod are utilized. After the trial the proponents concludes that for the effective distance the tripod height must be 440cm producing a range of 1.5m being the minimum effective distance and 4m being the maximum effective distance, the group will be using the 3.5m – 4m distance in order to have a wider walking area for the assessment.

C. Data Collection

A Microsoft Kinect V2 camera was used to gather data using Software Development Kit (SDK) and a custom-built software created on Microsoft Studio. Microsoft Kinect camera was composed of an infrared sensor, RGB camera and IR camera to track human gait movement [11]. Microsoft Kinect's SDK provides tool used necessary to startup Kinect enabled applications for Microsoft Windows [12]. Custom-built software was used to track and acquire skeletal joint position data of the subjects. These joints are represented as X, Y, Z in the 3D coordinate system. As the subject walks on the pathway, key points are recorded for each frame the sensor grabs. Each key point that is represented by the coordinates corresponds to its distance from the (0, 0, 0) point in space. These key points are important in calculating different gait parameters. The skeletal data acquired at a rate of 30 frames per second is the output of the Kinect system saved in an external file [11].

D. Data Analysis

Data obtained from Microsoft Kinect v2 were exported to MATLAB (R2018a, The MathWorks Inc., Natick, MA, USA) for calculation of the biomechanical parameters. The parameters analyzed was kinematic parameters [13].

a. Kinematic Analysis

Kinematic parameters include ankle and knee flexion, and hip angle. Ankle flexion was determined by measuring the angle between the foot and the sagittal axis of the shank while knee flexion was determined by measuring the angle between the sagittal thigh axis and the sagittal shank axis. Hip angle was determined by measuring the angle between the projected sagittal thigh axis and the sagittal pelvic axis [14]. Table II shows the corresponding definition for each kinematic parameter.

TABLE II
OPERATIONAL DEFINITIONS FOR KINEMATIC PARAMETERS

Kinematic Parameter	Operation definition
Knee flexion (degrees)	Angular separation between the femur and tibia
Ankle flexion (degrees)	Angular separation of the foot with respect to the ankle
Hip angle (degrees)	Angular separation between the projected sagittal thigh axis and the sagittal pelvic axis

III. RESULTS AND DISCUSSION

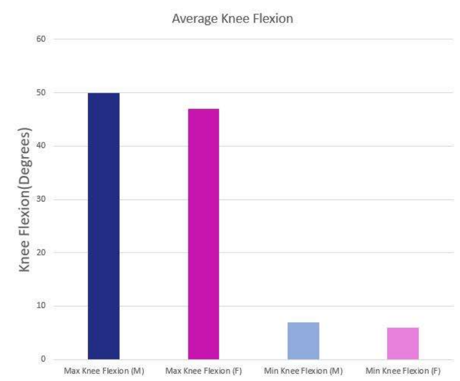

Fig. 1 Comparison of knee Flexion Minimum and Knee Flexion Maximum of male and female

The data from male and female subjects were gathered and compared. The data shows that the Male knee Flexion is slighty wider with a percentage difference of 6.18% as shown in Fig.1.

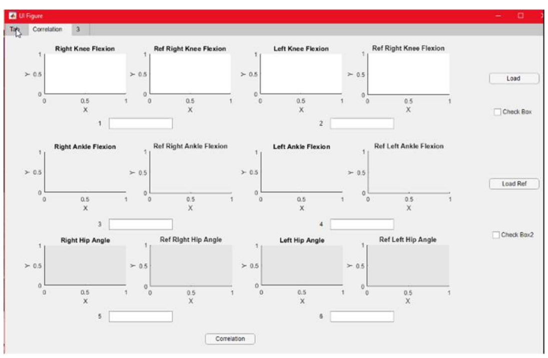

Fig. 2a GUI that shows correlation tab

Fig. 2b Showing an example of a GUI with the subject correlation to the normal gait is shown

Fig.2 shows the GUI through graph the angle of the kinematics with the use of x and y axis, provided by the virtual skeleton of the Kinect, wherein the comparison of different subjects by BMI and gender will find the normal gait and any irregularities on the system.

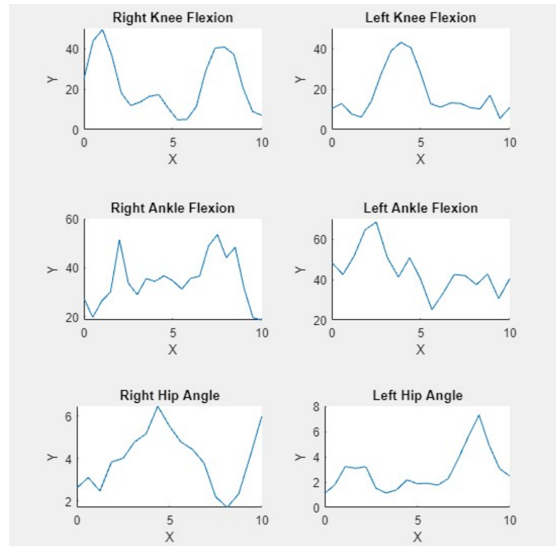

Fig. 3a Normal gait for Kinematic parameter for Female

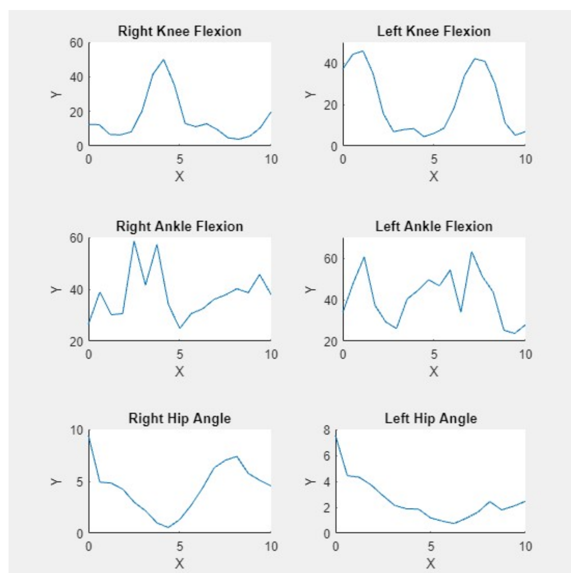

Fig. 3b Normal gait for Kinematic parameter for Male

After the collection of data within the subjects. The average kinematics parameter was considered to be the normative gait for the study. The normal gait for male and female is shown in Fig.3.

Overall, there were no significant trends observed when the BMI is considered. The data shows that there is no direct relation between the magnitude of the parameters and the BMI of the test subjects.
This study has several limitations. First, the data came from a relatively small number of subjects drawn from healthy controlled young-adult students from Technological University of the Philippines (ages from 18 to 22 years old). The results cannot be generalized to other age group such as teenager, adult, and elderly people. Further study should involve larger range of age group.

V. CONCLUSION AND FUTURE WORK

The coordinates of the virtual skeleton were utilized with the use of Kinect version 2.0 in order to calculate the subjects' kinematic parameters. Based on the subject's BMI and gender, the kinematic parameters were compared. The results show that when the data is compared on gender, some of the kinematic parameter yielded substantial difference. On the other hand, it does not display any noticeable difference when the data was compared based on the subject's BMI.

The future of this research will be a comparative study of Microsoft Kinect V2 and the Vicon Motion Capture. The validation will allow prospective researchers to use a cheaper alternative method that is comparatively cheaper, but sufficiently precise. A greater number of subjects of different age ranges should be included in more studies to prove its accuracy.

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