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Towards Design and Development of Post Elbow Surgery Rehabilitation Evaluator

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Abstract: This paper outlines the design and development of a novel elbow surgery evaluator. Overhead athletes are at great risks of elbow injuries or pain. Rehabilitation of the athletes often involves surgical procedures and related trainings. Athletes require fastest possible recovery after the injury in order to return to competition. The proposed solution in this work is to evaluate the elbow surgery and effectiveness of the rehabilitation progress. The system design comprises of design an inertial measurement unit based wearable band. The developed system calculates the elbow rotational movement that includes flexion/extension and supination/pronation. These parameters are primary requirements in the rehabilitation of elbow. The core aim of the study is to evaluate the rehabilitation progress of injured athletes. The implemented system is tested on three healthy subjects successfully with satisfactory result.

Keywords: Elbow surgery evaluator, IMU, overhead athlete, rehabilitation.

I. INTRODUCTION

The overhead athletes such as athletes of cricket, baseball, tennis, football, volleyball etc. are greatly at risk of elbow injuries and pain. These athletes are involved largely in throwing ball. Throwing a ball produces large amount of forces at elbow joint [1]. Repetitive large amount of forces are the major cause of injuries that leads to tissue damage and failures. The primary objective is the evaluation of treatment or rehabilitation process of player. It helps the bio-mechanist to quick fully restore normal joint flexibility and return athlete to the competition.

Numerous techniques have been previously employed for the analysis of elbow joint flexibility. Joint flexibility can be measured by goniometer. Two types of goniometer are available to detect joint flexibility. One is mechanical goniometer and the other is electro goniometer. Mechanical goniometer can be used when patient is stationary. In other words, it cannot measure dynamic movements. While electro goniometer has poor flexibility, and alignment problem with respect to joint axis and is restricted to measure one axis rotation only.

Optoelectronic goniometer is another type of goniometer that consists of a method that measures joint flexibility using specialized video capturing cameras. The results of this method are very précised and provide more accurate measurements of the angular movements of joints at every instant [2]. The drawback of this technique is that the data analysis using this system is time consuming, complex and requires calibration.

In order to overcome these limitations, a system for measuring joint flexibility and detection of rehabilitation progress is needed to measure angular movements in multiple directions. Inertial Measurement Units (IMUs) are one of the most widely used types of sensors in biomechanical analysis. It measures angular movements in multiple axis.

Multiple methods have been employed to analyze range of motion of joints using IMUs. A. Mohan et al. [3] designed a glove for monitoring of hand function in order to rehabilitate paralyzed hand. It detects elbow and wrist flexion and extension.

Alvin Jacob et al. [4] designed a mobile elbow movement measurement device for badminton players using single IMU. It records fastest movements of elbow of the player to improve the performance and tactics. The design is able to detect flexion, extension and hyperextension of elbow joint.

H. F. Maqbool et al. [5] reported that a rule based real time walking events detection system for amputees using single IMU and force sensitive resistors. The system is able to measure shank velocity and acceleration around sagittal plane only.

Ahmed F. S Alhajjar et al. [6] designed an upper limb rehabilitation system. The designed system comprises of IMU and electromyography to evaluate the improvement of Hemiparetic patients. It tends to encourage patients by using 3D virtual reality arm movements. Virtual arm movement is controlled by IMU.

Christopher L. Bennett et al. [7] has also designed an algorithm to estimate knee joint angle using artificial neural network. Two IMUs were used during investigation. It estimated knee flexion/extension angle during walking.

Hsin-Ta Li et al. [8] quantified the post stroke rehabilitation effectiveness. They address the issue of variation in assessment result.

According to previous studies, it measures joint flexibility using IMU in terms of flexion extension test. All previous studies ignores to measures pronation supination movement of the elbow joint. The current study focusses on fully restoration of athlete joint flexibility. Proposed system is able to detect both flexion/extension and pronation/supination movements of the elbow joint.

The remaining part of the paper is to arrange in to different sections. Section II demonstrates about biomechanics of elbow, section III describes about the current elbow evaluation method, section IV describes system design approach and section V describes the testing of the system and section VI is the data collection and result. In last section, conclusion has been elaborated.

II. BIOMECHANICS OF ELBOW

A. Structure of Elbow Joint [11]

Elbow joint is a stable joint that comprises of humeroulnar, humeroradial, and proximal radioulnar joints as shown in figure. 1. Humeroulnar joint is the hinge joint where ovular trochlea of the humerus articulates with trochlea fossa of the ulna. Secondly, humeroradial joint is a gliding joint that articulates between the capitellum of the humerus and the proximal end of the radius. Finally, the proximal radioulnar joint is a pivot joint that binds head of the radius and radial notch of the ulna.

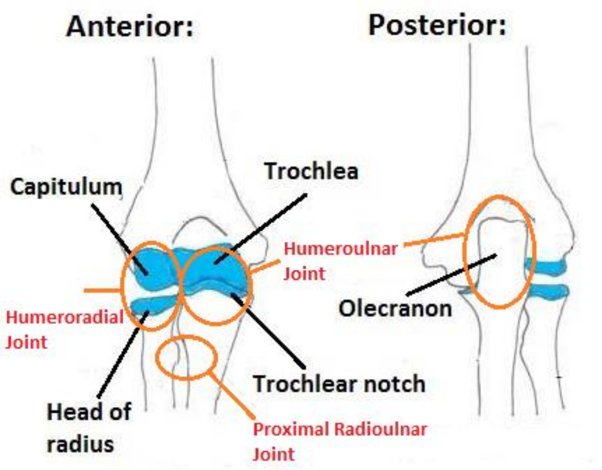

Figure 1: Structure of Elbow

B. Movements of Elbow Joint [11]

These three different joints forming two different aspects of movements. It allows flexion and extension of the arm as well as pronation and supination of the forearm as shown in figure. 2 and 3. Primary movement of Humeroulnar joint is flexion and extension. The joint is most stable when arm is fully extended. Humerordial joint is responsible for resisting movement in sagittal plane. It is most stable when arm is flexed at 90^{o} and forearm is supinated about 5^{o} from anatomical position. Proxiamal radioulnar joint is responsible for pronation and supination. It is most stable when forearm is supinated about 5^{o} from anatomical position.

Figure 2: Elbow Flexion/ Extension [9]

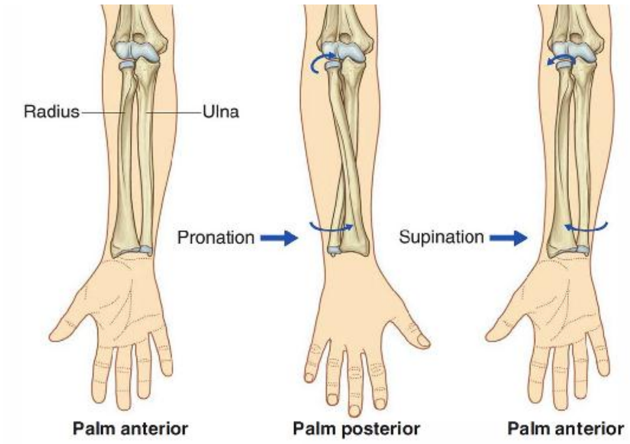

Figure 3: Pronation and Supination [9]

C. Elbow Range of motion

The normal range of motion (ROM) of healthy individual is 0 to 150 degrees for flexion/extension and 80 degree for both supination and pronation from neutral position as shown in figure. 4 and 5. It can vary athlete to athlete and in various health conditions.

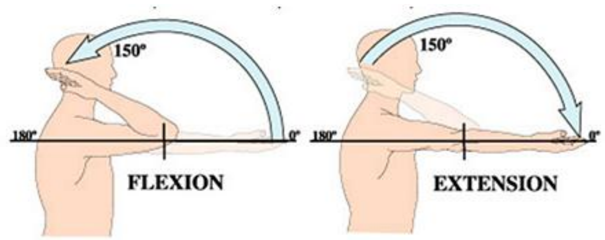

Figure 4: Flexion and Extension Range of motion [10]

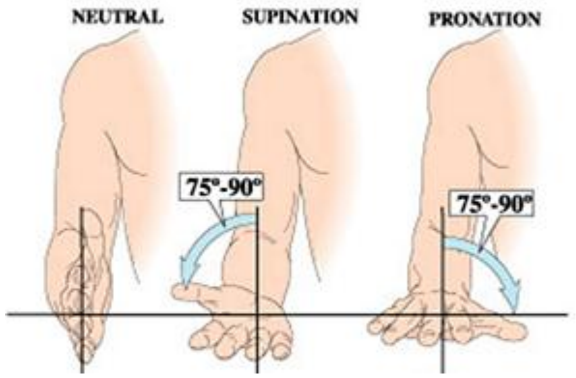

Figure 5: Pronation supination Range of Motion [10]

III. BENCHMARK ELBOW EVALUATION TEST

Not a single standard quantitative tool is available to access elbow function. Currently, Oxford Elbow Score (OES) is used for assessment of elbow rehabilitation [12]. OES is a highly qualitative method that essentially focusses on range of motion of elbow joint to analyze disorder.

IV. SYSTEM DESIGN APPROACH

The idea behind the study is to analyze the rehabilitation progress using wearable goniometer. System is equipped with single IMU (Inven Sense, MPU 6050) six axis motion tracking sensor. IMU is used to collect the raw data from the patients. The raw sensor data is fed in to Arduino Mega2560 which serves as a medium for importing data to LabVIEW 2016. In LabVIEW, an algorithm is implemented that converts IMU raw data, calculates and analyzes joint flexibility reliably as shown in figure. 6 and overall system is shown in figure. 7.

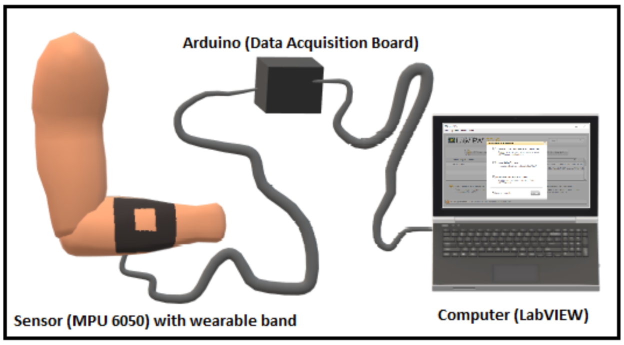

Figure 6: Block Diagram

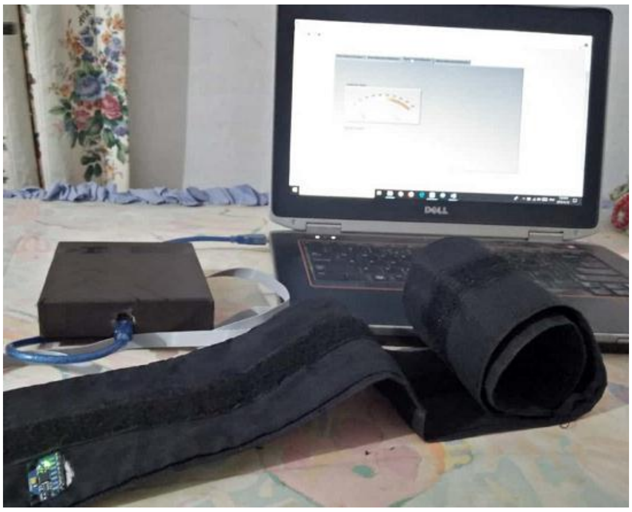

Figure 7: Overall System

V. TESTING

In order to verify the output of the system, IMU sensor is placed on PASCO Human Arm Model (PS-2611). The results of both IMU and Arm model elbow angle sensor were compared. The results of both IMU and Model are shown in table. 1.

Table 1: Comparison Result

PASCO Human Arm Model Readings (degree)	IMU Readings (degree)
0.0	-1.8
10.0	6.7
20.0	14.3
30.0	26.8
40.0	33.2
50.0	42.7
60.0	57.6
70.0	64.5
80.0	78.4
90.0	89.2
100.0	100.1
110.0	109.6
120.0	119.2
130.0	130.9
140.0	139.6
145.0	145.6

Table 1. Shows ±7 degrees variation in angle between 0 to 90 degrees of flexion. While from 90 to 145 degrees shows ±2 degrees variation.

VI. DATA COLLECTION AND RESULTS

Healthy participants were recruited from the Hamdard Institute of Engineering and Technology. An inclusion criterion was that all the participants were healthy and found no traces of upper limb injuries, orthopedic and neurological disorders. In this study, three (3) healthy subjects (2 males and 1 female) belonging to the age group of (25-55 years) were tested for the analysis of elbow.

Each subject was instructed to wear a band equipped with the IMU positioned at center of the forearm. After sensor positioning, the subject is asked to perform at least 20 trials for flexion/extension test of the elbow joint and pronation/supination of the forearm in both active and passive movements.

A. Flexion/Extension Test

Each subject was first instructed to stand in anatomical position and then fully flex his/her arm as shown in figure. 8. The data was recorded and it is shown in table 2.

A B

Figure 8: Flexion/Extension test; A. Anatomical Position, B. Fully flexed

Table 2: Elbow ROM measurement during flexion/extension

Gender	Age	Active ROM	Passive ROM
M	54	0^0-149.37^0	0^0-152.75^0
F	51	0^0-150.48^0	0^0-147.43^0
M	25	0^0-152.73^0	0^0-155.47^0

B. Pronation/Supination Test

In second test, each subject was instructed to flex his/her hand to 90° from anatomical position and then rotate elbow from full supination to full pronation as shown in figure. 9. The data was recorded and it is shown in table 3.

A B C

Figure 9: Supination Pronation test; A. Fully supination, B. Neutral position, C. Fully Pronated

Table 3: Elbow ROM measurement during pronation/supination

Gender	Age	Active Pronation	Passive Pronation	Active Supination	Passive Supination
M	54	78.74^0	80.08^0	73.56^0	76.76^0
F	51	74.72^0	79.46^0	72.31^0	78.43^0
M	25	81.46^0	83.42^0	78.73^0	80.56^0

Every system has few limitations. The proposed system is limited to measure joint flexibility of elbow joint only. Few of the injured overhead athletes require rehabilitation of shoulder joint along with elbow joint. Further, it is not a wireless system.

VII. CONCLUSION

An evaluator device has ability to improve bio-mechanist practices to recover athletes' range of motion and to improve their rehabilitation plans. Through designed and developed evaluator in this work, a bio-mechanist may quickly collects reliable data in repeatable range of motion comprising joint flexibility. This system allows bio-mechanist to rapidly start a right path to recovery, and validate treatment programs, and to record improvement over time.

The proposed system can be enhanced by connecting a wireless communication system in the wearable band. Also, it can enhance by develop for measuring multiple joint flexibility.

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