Musculoskeletal Modelling and Simulation for Upper Limb Muscle Activities

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***Abstract*—Musculoskeletal modeling and simulation are widely used in many areas of research including biomedical, sports, and engineering. In this study, the musculoskeletal model from an open-source platform, OpenSim software is used to simulate the upper limb muscle activities while performing the ADLs tasks using an assistive device. The upper limb musculoskeletal model was scaled down from the existing model to meet the motion requirement of the device. The device was remodeled in 3D using design software and imported into OpenSim environment and connected to the musculoskeletal model. The center of mass (COM) and inertia calculation were also conducted to adjust the model. Two experiments of ADLs task; the touching nose and moving object was conducted and simulated using the model. The simulation results showed that the muscle force values for the selected muscles (deltoid interior, pectoralis major, and teres major) were reduced during the simulated ADLs tasks when wearing the assistive device.**

Keywords—computer simulation, upper limb, muscle, OpenSim, activities of daily living

I. Introduction

Musculoskeletal modelling and simulation are widely used in many areas of research including biomedical, sports, and engineering. For example, Lee *et al.* [1] analyzed the ankle muscle activities during gait, Mahadas *et al.* [2] applied the musculoskeletal model to study the biomechanics of golf swing, Wang *et al.* [3] used a model to study the biomechanical characteristics of the gait, and Mohamaddan *et al.* investigated the musculoskeletal disorder caused by different tools design and technique towards harvesters' lower [4] and upper body [5].

Different types of software are available for musculoskeletal modelling and simulation such as SIMM (Software for Interactive Musculoskeletal Modelling), OpenSim, AnyBody and MSMS (MusculoSkeletal Modelling Software) [6]. SIMM and AnyBody are the commercial software while OpenSim and MSMS are the free software. In this study, OpenSim software is applied for musculoskeletal modelling and simulation. OpenSim software is an open-source platform for modeling, simulating, and analyzing the neuromusculoskeletal system [7]. OpenSim is being developed and maintained in Simtk.org where it serves as a public repository where researchers can share their research work. Many research were conducted using OpenSim software such in [8-11]. The research includes evaluation of upper limb musculoskeletal, modelling of upper extremity, full body musculoskeletal model and musculoskeletal dynamics of human and animal.

Besides using the existing model of musculoskeletal model by OpenSim, previous research such in [12-15] was conducted to develop a model for the upper limb especially the shoulder. The development was mainly based on shoulder joint kinematics using skin marker to achieve the bony landmarks. The optical motion capture and Magnetic Resonance Imaging (MRI) data was widely used to obtain the bony landmarks. However, it was mentioned that limited recommendations on the reference positions of the bony landmark by the International Society of Biomechanics (ISB) contributed to the non-standardized model [12].

The objective of this study is to investigate the usage of musculoskeletal model from an open-source platform, OpenSim with assistive device to perform upper limb movement during activities of daily living (ADLs) and to estimate the muscle activities with and without using the assistive device. The challenge of this study is on applying the existing OpenSim model with the existing upper limb assistive device developed in our laboratory. New method is developed to combine the two models for the simulation purposes and real-world experiment was conducted for the evaluation.

In this paper, the developed upper limb assistive device is presented. Next, the musculoskeletal model and the process involved in manipulating the model with the upper limb device within the OpenSim environment is discussed. Lastly, the ADLs experiment with and without using the assistive device is explained and the simulation results are presented and discussed.

II. Materials and Method

A. Upper Limb Assistive Device

The developed assistive upper limb device is shown in Fig. 1(a). The device is used to assist movement by providing the motor force to move the upper limb. The device considered the specific motion of the right upper limb. The device is developed to meet the right arm's kinematics and allow several ranges of motion (ROM) to be executed to perform the activities of daily living (ADLs). The kinematics of the right upper limb is based on the locomotion of the scapula, the shoulder, the forearm, and the arm. Each element involved in the kinematics definition is shown in Table I with the respective ROM. Details design and