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Assessment and Modelling of Elbow Joint for Analysing of Muscle moment and Reaction Force during Flexion Movement with ADAMS Software

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ABSTRACT

In this research elbow flexion has been analysed and the moment of muscles and the reaction force exerted on the elbow is calculated in the range of motion. The moment of muscles indicate the performance of movement and the reaction force of the joint is believed to be one of the most important causes of damage, something which hasn't been studied thoroughly enough in previous researches. To that end, we use ADAMS software which is one of the most powerful ones available in dynamics analyses. The results indicate that the maximum torque of the arm occurs at 96 degrees and it decreases in the beginning and the end of flexion. The reaction force of the elbow in the beginning of motion is at maximum amount and then decreases to 107 degrees, and from that point on it increases up to the end of the motion. These results indicate that the optimum range of elbow flexion occurs in the mid-range of flexion, approximately at 58-140 degrees.

Key Words: Modelling, Muscle Moment, Reaction Force, Elbow flexion.

INTRODUCTION

considering the progress in human sciences, it seems that, it is possible to use other sciences, specially engineering sciences, mutually. Nowadays, using software in the field of engineering is very common. Moreover, one of the important uses of these software is in modelling. Because of the developments of sport biomechanics it seems that making use of these kinds of engineering software can help to improve it. Some of the applications of sport modelling are sport equipment designing, kinematic and kinetic human movement analyzing, understanding the injury mechanism of joints and tissues, and finally the development of sport activities performances.

Previous research studies show that human movement modeling software has been rarely used and sometimes it shows a great difference in comparison to other analysing methods such as motion capture, electromyography and empirical research. The major advantages of this approach include reduction in terms of cost and time without needing to use human and equipment and increase the accuracy of research data. In our study, muscles moment and reaction force exerted on the elbow joint were studied. Joint torque help us determine the range of strengths and weakness of muscles and the reaction force of the elbow joint is potentially capable of causing harm to the joint. Figure 1 shows the elbow joint reaction force. This force is measured by the balance of forces and moments. This force represents the forces exerted on the ligaments and joint capsule.

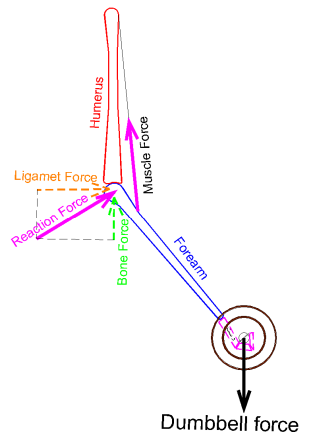

Figure1: reaction force in elbow joint

For more explanation of reaction force, we break up this force into two components. The horizantal force intends bones far away from each other and pressures on ligaments. The vertical component intends pressure bones on each other that cause cartilage damage which is one reason of arthritis. Therefore we conclude the reaction force is one of the important reasons of producing damage in exercise.

MATERIALS AND METHODS

the method of this study is to model the elbow joint using ADAMS software. The application is made by the MSC Software Corporation and is a powerful tool for analyzing kinetic & kinematic analysis and is widely used in science and engineering.

ADAMS simulation software and its add-on tool, Human Figure Modeler, developed and marketed by Mechanical Dynamics Inc., was, For the first time, introduced to bioengineering students at the University of Pittsburgh to enhance the learning of biomechanical principles. [1]. Based on their experience and the students' feedback, they believe that the integration of ADAMS into existing bioengineering courses can greatly improve students' understanding of biomechanical systems, while simultaneously adding to their engineering skills.

This software is used in analyzing human movement too. In one research ZHANG.lin-lin and et al 2011 modeled elbow flexion with ADAMS and in another research Ylikorpi and et al, 2011 modeled the walker with ADAMS and compared the results with MATLAB software [2].

For modeling process we should perform these steps. The first step for modeling the movement of flexion is to build the parts of the arm. These parts are made by the software toolbox and making use of appropriate geometric shapes and anthropometric data table1. In the second step the organs must be bound and in this research the connections between humerus and ulna are made using hinged joints. In the third step, the muscular forces obtained from the EMG data are applied with respect to the specified ratio in Table 2. Then, in the fourth step the software application is provided with the required information such as moment, the joint reaction force etc. And finally the motion is run in the range 0-150 degrees and as a result the software reports the results in the form of a chart that was requested in the last step. Addition the base of calculation of software is the laws of physics and dynamic. The process in like to manual calculation of laws dynamic that the software perform quickly and easily. Figure 2 shows the constructed shape of model in ADAMS software in this study.

Base of calculation of software is the motion& mechanic laws. When the model creates in the software completely and the motion is run. The software calculates the results. In the other hand the software performed the manual calculation relation to equilibrium force and moment quickly and the high accuracy. And it reports the results simultaneous. This software is powerful dynamic analyzing software. The important mechanic equations are the following.

$$\sum F_X=0$$
$$\sum F_Y=0$$
$$\sum M_Z=0$$

Table 1 Parameters evaluation for rigid body modelling [2]

Segment	Hummers	Ulna	Radius
m(kg)	1.81	0.79	0.79
h(cm)	27.4	38.253	38.253
r(cm)	4.165	2.365	2.365
Ixx (kg.m2)	121.089	97.438	97.438
Iyy(kg.m2)	121.089	97.438	97.438
Izz (kg.m2)	15.699	2.209	2.209

Ixx=Iyy=m (r2/4+h2/12) and Izz=mr2/2

Table2 Ratio of forces exerted by muscles during elbow flexion [2]

Muscle name	F(N) From EMG	Percentage of producing force for flexion
Biceps	137	39%
Brachialis	167	48%
Brachioradialis	45	13%

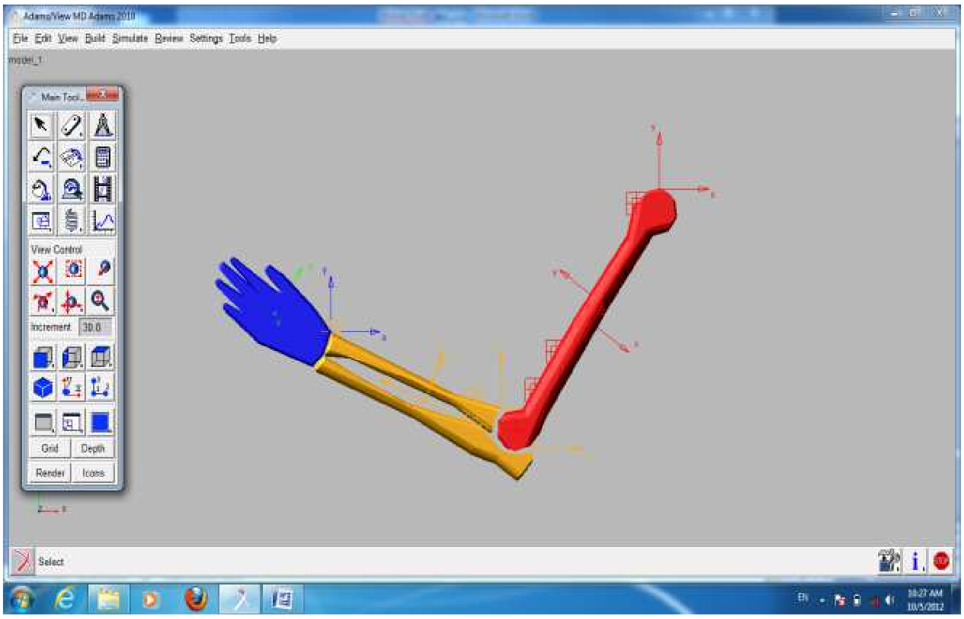

Figure2: Upper limb biomechanical model in ADAMS software

RESULTS

After constructing the model in the software we run the motion. The first result that calculates is the angular velocity of arm. Angular velocity indicates pressure on musculoskeletal system. When the velocity is low it means the pressure on musculoskeletal system is high and when the velocity is high it means the pressure on musculoskeletal system is low. Figure 3 shows the angular velocity of arm in the range of motion.

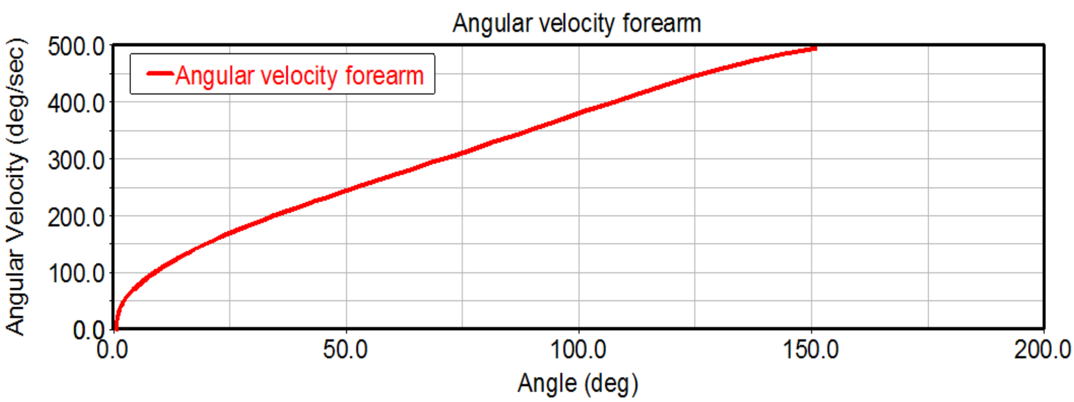

Figure3: Angular velocity of forearm in the range of motion.

Another result that calculates in the software is the moment of muscle in the range of motion. This moment is minimum in the beginning of motion and it increase to 96 degree of flexion and then decrease to end of motion. Figure 4 shows the moment of muscles in the range of motion.

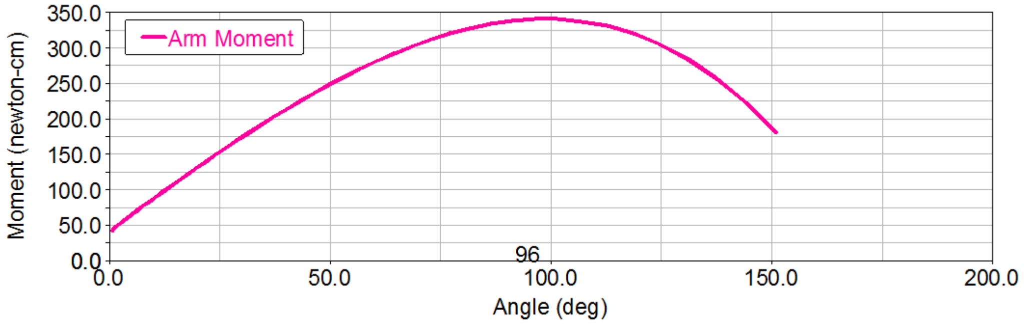

Figure4: The moment of muscles in the range of motion.

One important result of the study is to investigate the reaction force exerted on the elbow joint. This force is potentially capable of causing damage to the joint. The study showed that the reaction force is at maximum amount at the beginning and then reduces to a 107-degree angle and then increases toward the end of the motion. Figure 5 shows the reaction of force on elbow joint in the range of motion.

Figure5: The reaction of force exerted on elbow joint in the range of motion.

The figures above show different levels of velocity, moment and joint reaction force in the range of motion which is due to changes of muscle angle. For more explanation this issue If the two components of horizontal and vertical forces exerted on the forearm muscles are divided, we observe that only the component of motion perpendicular to the forearm is capable of producing motion And horizontal components of the muscle does not produce any work and compress bones together and as a result will produce a reaction force. For this reason we calculate vertical and horizontal component of each muscle force in the range of motion.

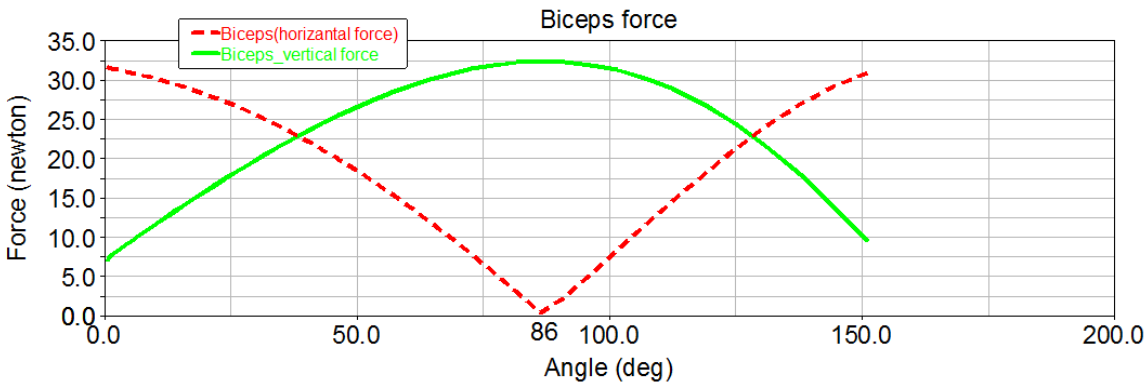

Figure6: break up Biceps force into vertical& horizontal components in the range of motion.

Figure 6 shows vertical and horizontal component of Biceps in the range of motion. This curve states the vertical component is maximum in the 86 degree of flexion. This component just produces moment.

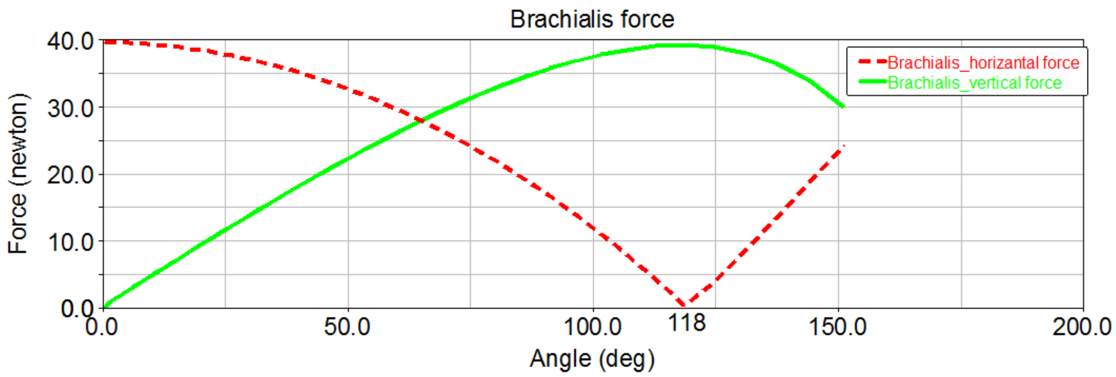

Figure7: break up Barachialis force into vertical& horizontal components in the range of motion.

Figure 7 shows vertical and horizontal component of Barachialis in the range of motion. This curve states the vertical component is maximum in the 118 degree of flexion. This component just produces moment.

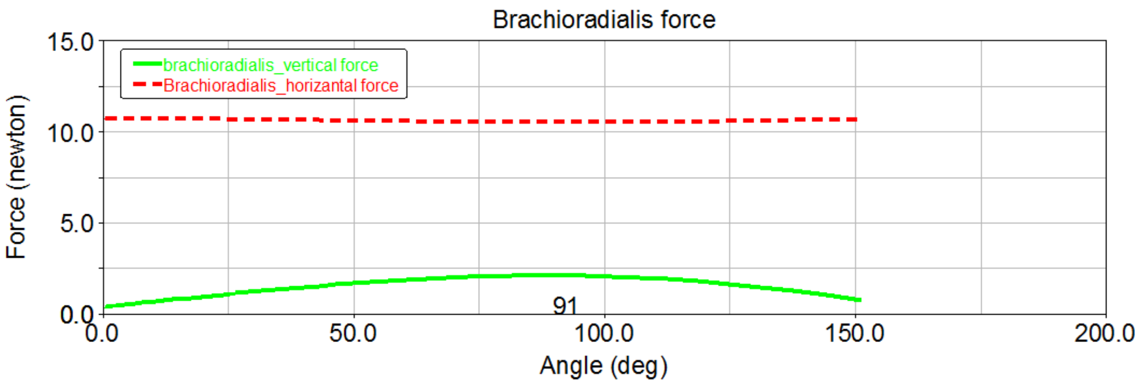

Figure8: break up Barachioradialis force into vertical& horizontal components in the range of motion.

Figure 8 shows vertical and horizontal component of Barachioradialis in the range of motion. This curve states the vertical component is maximum in the 91 degree of flexion. This component just produces moment.

Figure 9 shows vertical component of muscles in comparison to each other in the range of motion. These curves state the sum of vertical component is maximum in the 101 degree of flexion.

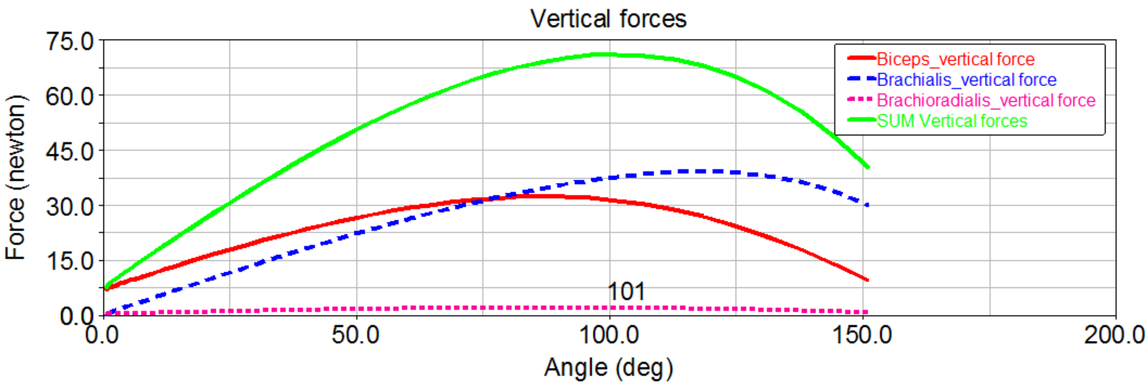

Figure9: the vertical force of muscles in the range of elbow flexion

Figure 10 shows horizontal component of muscles in comparison with each other in the range of motion. These curves state the sum of horizontal component is minimum between 86-118 degree of flexion.

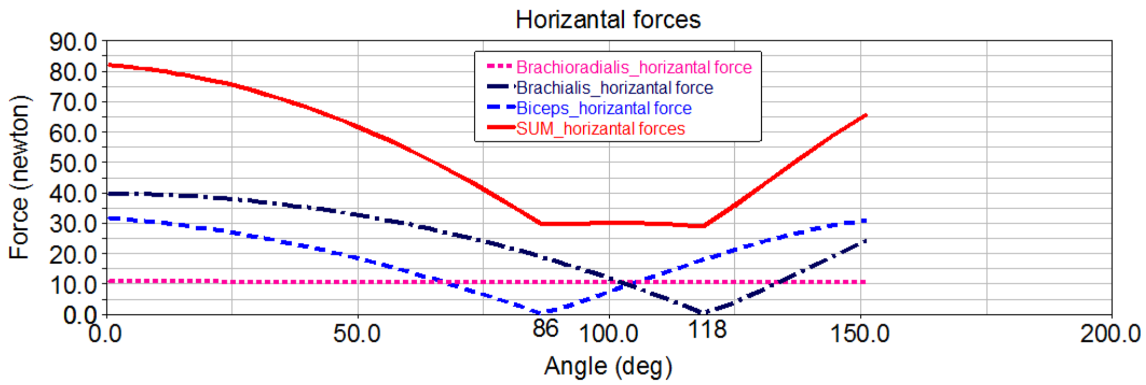

Figure10: the horizontal force of muscles in the range of elbow flexion

The moment of muscles is calculated multiple the vertical components to distance between central of elbow to exerted line of muscles. These moments are calculated in software in the range of motion. Figure 11 shows these moments. The maximum moment of biceps occurs at 86 degree and brachialis at 118 degree and brachioradialis at 91 degrees and therefore the sum of moment of three muscles was measured at an angle of about 96 degrees. This result will be compared with other researches in discussion part[2,3,4,5].

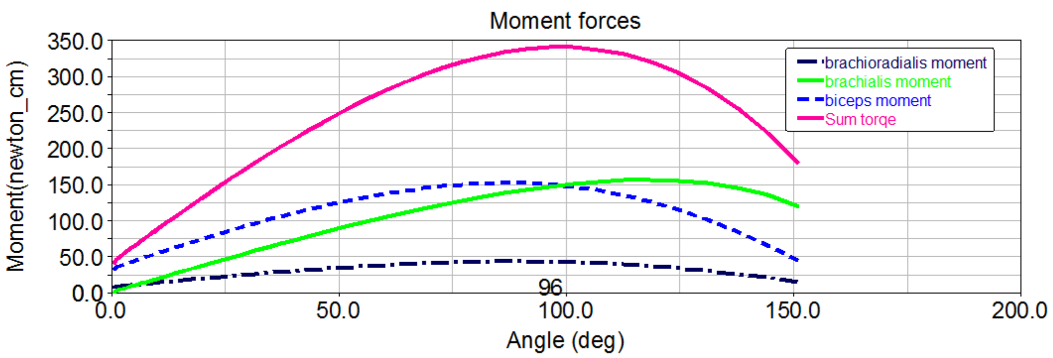

Figure11: the moment of muscles in the range of elbow flexion

In this research compare total of vertical and horizontal component in the range of motion too. Figure.12 shows the total vertical component muscle force, in comparison with horizontal component muscle force. This chart indicates that the vertical component is more than horizontal component in the mid range and the muscles of elbow flexion have high performance in the 58-140 degree of flexion so it is suggested for rehabilitation of arm after damaging and designing ergonomic conditions.

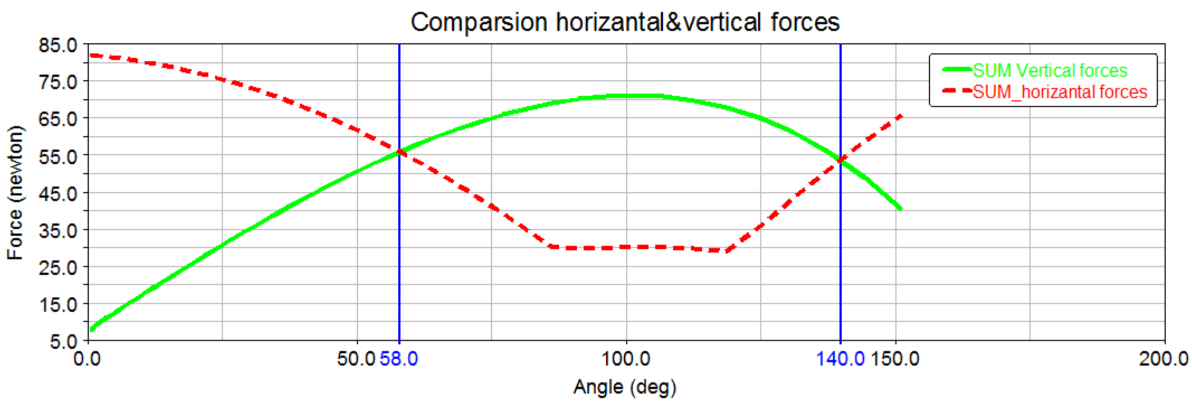

Figure12: Comparison of horizontal and vertical components of the muscle force of elbow flexion in elbow flexion range of 0 to 150

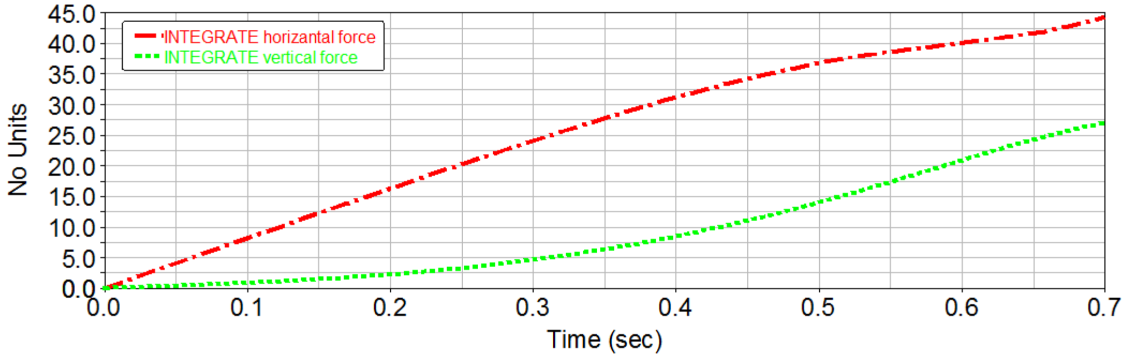

Figure13: A comparison of the overall sum of the vertical and horizontal muscle forces in flexion of the elbow. The total amount of vertical and horizontal force is 38 percent to 62 percent respectively.

The total amount of muscle forces in the vertical and horizontal components is the result of the integration of curve 12 in figure 13.

Figure 13 shows that the 38% of the energy of the muscles turn to work and the rest is wasted by turning into reaction force and other forms of energy such as heat and friction. In other words, only 38% of muscle force can produce motion and movement in the skeletal system.

DISCUSSION

This study shows that the maximum torque of the elbow occurs at an angle of approximately 96 degrees which is in agreement with the results of other researchers. ZHANG.lin-lin et al (2011) in their research obtained the approximate maximum moment at an angle of 90 degrees although their graph indicates that maximum moment occurs at an angle more than 90 degrees [2]. Felipe Pivetta Carpes et al (2012) evaluated asymmetries in elbow torque output between preferred and non-preferred limbs. They obtained moment curve in five angles with the maximum moment at 90 degrees. It should be noted that moment curve was calculated only at specific angles. And torque was not calculated at an angle between 90 and 120. If moment values had been calculated at more angles, moment curve and maximum angle could have been different. Figure 14 shows the moment of arm in various researches [3].

Another result of this study is the optimal range of elbow flexion which occurred at an angle between 58 and 140 degrees and the 38% mechanical efficiency of muscles can also be noted. It was so strange to us why the musculoskeletal system of the arm is so inefficient. Has the creator of the universe made a mistake? Morry's research answers this obscurity. Morry et al (1981) obtained the range of flexion for fifteen essential daily activities by using an electro goniometer. Most of the activities studied in this project were carried out at a mid-range of 100 degrees of elbow flexion (from 30 to 130 degrees). This indicates that the musculoskeletal system of the arm is optimally capable of performing essential daily activities [4].

In general this research is unique and difference with the other research. The previous researches were carried out mostly by using equipment such as electromyography, isokinetic set, and goniometer and motion caption. These methods are more reliant on research tools and the researcher only collects information and doesn't have a special role in the analysis of the data. However, this study is performed using an application and is analyzed using motion and mechanic laws, and the role of the researcher is highlighted in the process of analysis.

Some of the advantages of this study are as follows:
1- A new method of analysis using software that was rarely used in the past.
2- Less money and time is spent compared to other research methods.
3- Using kinematic and kinetic analysis,
4- Unlike other methods, where the results are measured at specific angles, in this method, the results are measured consistently throughout the range of motion.
5- Using a special method for calculating joint reaction force and determine damage mechanism.

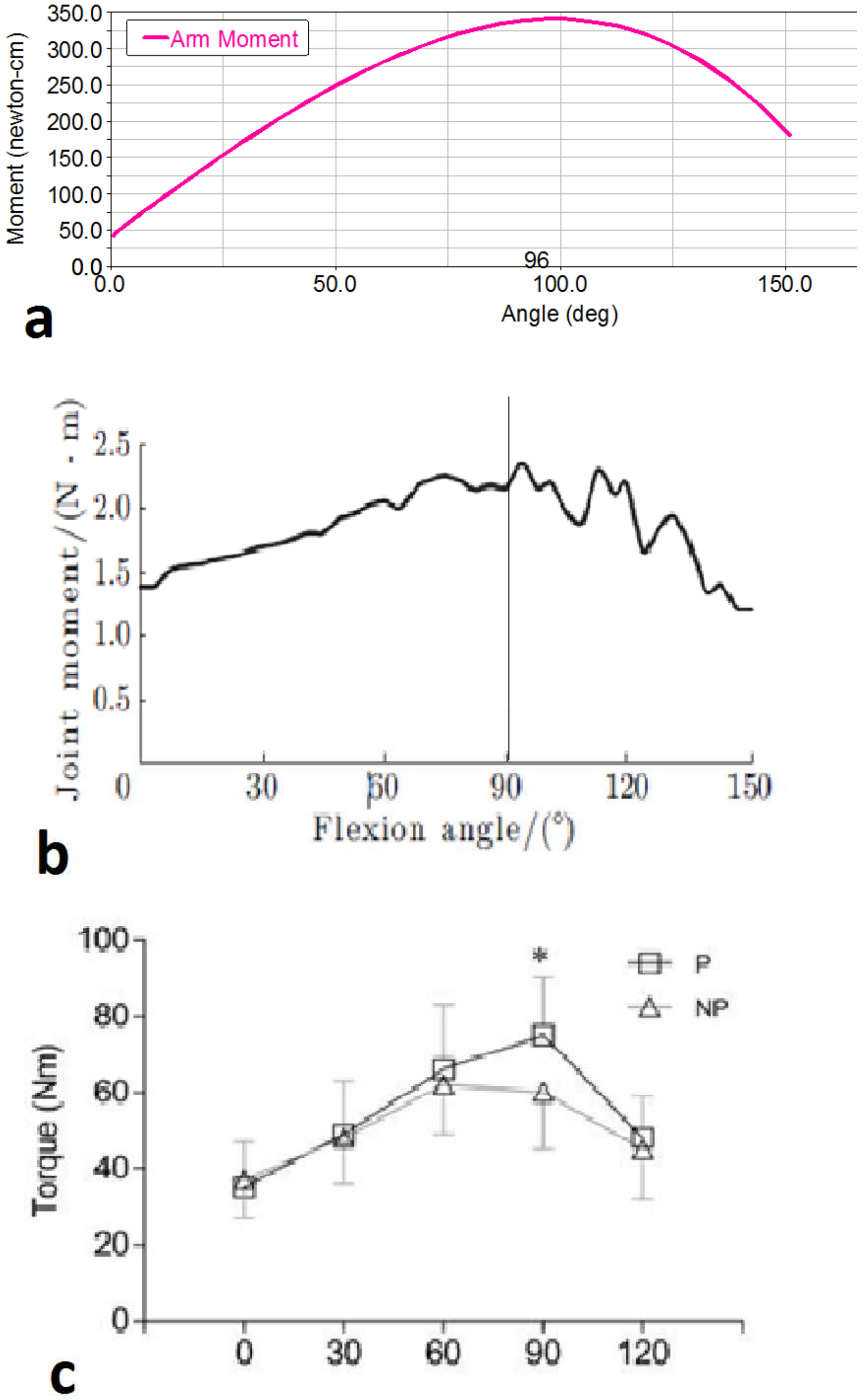

Figure 14: comparison moments in various researches. a) In this research b) in ZHANG.lin-lin et al (2011) research c) in Pivetta Carpes et al (2012) research.

CONCLUSION

The main results of the analysis and modelling of elbow flexion movement is the evaluation of the efficiency of the elbow flexion muscles in the range of motion, The results show that maximum muscle moment of the arm occurs at an angle of 96 degrees and at the start and end of the flexion is much less. Moreover, the reaction force of the elbow which is one of the most important potential damage to the joint is at the minimum in the mid-range of motion

(107degree). Therefore, combining these two results shows that the efficiency of flexion is in the range of 58 to 140 degrees.

Acknowledgments
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