THE DESIGNABILITY INVESTIGATION OF A SUPPORT SYSTEM BASED ON INJURY PREVENTION USING KINECT IN BODYBUILDING SPORT

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Abstract— As in all sports, injury and disability cases may occur in the bodybuilding sport. On the basis of this status, in general there are two factors. The first one is the wrong angle motion, as a result of this; muscle or muscle group is damaged. The second one is the wrong choice of weight (even excessive), so deterioration of the angles of motion leads to the damage of the muscle groups. Information technologies that can be used in this field are rapidly evolved and Kinect sensor is one of them. As a platform, Kinect has the ability of transforming human body movements to the digital environment via the sensors in its structure. So in bodybuilding sport, we can benefit from Kinect which forms a touchless interaction. In our study, "Dumbbell shoulder press" is selected as an example movement. Through the program written, using the Kinect the coordinates of the joints of the studied area during bodybuilding training is extracted. Then, by examining the data obtained from bodybuilding training, the designability of support system based on injury prevention using Kinect have been investigated.

Keywords— Applications in sport, Determination of injury risk, Exercise angles, Movement analysis, Skeletal tracking.

I. INTRODUCTION

The origins of strength training are based on thousands of years ago. According to the Ancient Chinese texts, potential soldiers were wanted to pass certain level of strength prior to being enrolled [1]. Bodybuilding uses many of the same techniques of strength training. But, the main goal in bodybuilding is much less about strength and more about adding size, symmetry, and muscular definition [2]. To achieve this, the training must be done within a short time and with high weight. As a result of this training, like as in all sports, injury and disability cases may occur in the bodybuilding sport.
The previous studies show that a shoulder shown in fig. 1 within the upper extremity has the highest musculoskeletal injury rate.

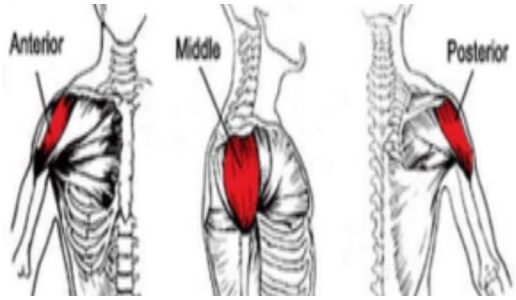


Fig.1. Shoulder muscles and joint

The previous study shows that more than 40 % of Bodybuilding or Strength training injuries are about shoulder muscles and joints in this sport. Other sites of elevated injury occurrences were the lower back part and the knee were. Muscular injuries (muscle pulls, tendonitis and sprains) were perceived to account for 83.6 % of all injury types [3].

1.1. Angle Related Injuries

Injuries related to angle of movement are also associated musculoskeletal injuries. On the basis of this status, in general there are two factors.
The first of these factors is the wrong angle motion, as a result of this, muscle or muscle group is damaged. The second one is the wrong choice of weight (even excessive), so deterioration of the angles of motion leads to the damage of the muscle groups.

II. KINECT USAGE

Kinect is both a product of the evolving information technology and a hardware device developed by Microsoft. Microsoft's Kinect technology was first introduced in the gaming industry [4], but one of the sensor types which Kinect includes became more popular for scientific applications.

Kinect contains internal RGB camera (red, green and blue), a depth sensor and microphones inside. The popular sensor is the Depth sensor; Kinect sends IR rays and gathers them back to recognize depth data.
Kinect send the IR rays and those rays are reflected by people or the objects in the view field of Kinect and allow depth data recognition process through scaling the distance from the Kinect to the reflection point.

As explained above, through depth data recognition process, Kinect gains an ability to track user skeleton using 3D depth information recognition and an algorithmic support process that works at the background. Tracked user skeleton is sketched over depth image stream, provided by Kinect [5].

Kinect supports to identify positional data up to the 25 body joints. In Fig. 2, these joints with their meridian labels are presented [6].

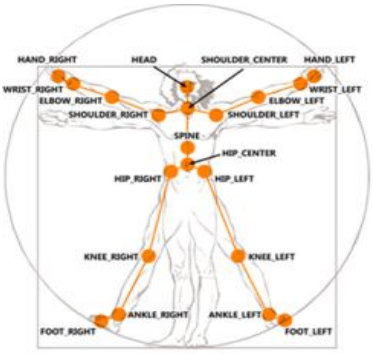


Fig.2. The Joint Distribution of the Skeleton

Algorithm of Kinect that works at the background allows skeleton tracking and it was investigated thoroughly in a research carried out by Shotton et al. that introduces a real time and accurate method of predicting body joints' 3D positions from only a depth image without using any temporal information [7].

In this work DepthFrame Class and CoordinateMapping Class were used for calculating joints positions. DepthFrame Class represents a frame where each pixel represents the distance (in millimeters) of the closest object seen by that pixel [6] and CoordinateMapping Class explains how to use data between coordinate spaces [8].

Through the program coded, joints coordinates were successfully gained. But using joint coordinates wasn't enough for calculating joints angles, so joints coordinate data has been converted to vectors in three-dimensional spaces as shown below.

Standard Cartesian coordinate system including x, y and z-axis is located in three dimensional space. Starting with a point called the origin, three mutually perpendicular axes, called the x-axis, the y-axis, and the z-axis were formed (Fig.3).

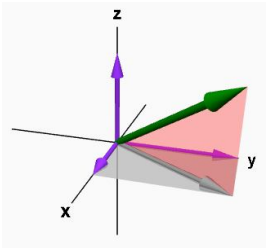


Fig.3. The Joint Distribution of the Skeleton

Using these axes any point "p" can be assigned three coordinates in space (1):

$$p = (p_1, p_2, p_3) \quad (1)$$

In this way, we wrote the vector as (2):

$$a = (a_1, a_2, a_3) \quad (2)$$

We often write $a \in \mathbb{R}^3$ to indicate that it can be explained by three real coordinates. Sums, differences, and scalar multiples of three-dimensional vectors are all performed on each component.

If $a = (a_1, a_2, a_3)$ and $b = (b_1, b_2, b_3)$, then (3):

$$a + b = (a_1 + b_1, a_2 + b_2, a_3 + b_3) \quad (3)$$
$$b - a = (b_1 - a_1, b_2 - a_2, b_3 - a_3)$$

We can also indicate three-dimensional vectors are in the standard unit vectors, i, j, and k. These vectors are the unit vectors in the positive x, y, and z direction, respectively. Explained in coordinate terms, they can be written *as i=(1,0,0), j=(0,1,0),* and *k=(0,0,1).* Any three-dimensional vector can be expressed as a sum of scalar multiples of these unit vectors as in formula 1.

$$a = (a_1, a_2, a_3) = a_1 i + a_2 j + a_3 k \quad (f.1)$$

As for final step, creating the dot product from vectors for calculate angles is done.

2.1. The Dot Product

The dot product (also called the inner product or scalar product) of two vectors $\mathbf{A} = [A_1, A_2, A_3, \ldots, An]$ and $\mathbf{B} = [B_1, B_2, B_3, \ldots, Bn]$ defined as in formula 2;

$$A * B = \sum_{i=1}^{n} A_i * B_i = A_1 * B_1 + A_2 * B_2 + \cdots + A_n * B_n \quad (f.2)$$

The dot product of vectors is shown formula 3;

$$A = a_1 i + a_2 j + a_3 k \quad \text{And} \quad B = b_1 i + b_2 j + b_3 k \quad (f.3)$$

Can be written as seen in eq. 4;

$$A * B = a_1 * b_1 + a_2 * b_2 + a_3 * b_3 \quad (4)$$

According to eq. 4, the angle between two nonzero vectors A and B is shown in formula 4:

$$\Theta = \arccos\left(\frac{A*B}{|A| * |B|}\right) \quad (f.4)$$

Given the geometric definition of the dot product along with the dot product formula in terms of components, we calculated the dot product of required pair of vectors.

2.2. Accuracy of Kinect V2

The previous studies show that, several properties of Kinect v2 which include accuracy distribution, depth resolution, depth entropy, edge noise and structural noise, has good accuracy if the replacement is right (2-3 meters away) [9]. Compared with other systems like Vicon system, upper body parts and joint angles displayed in higher accuracies with a difference of less than 7.2◦ [10].

III. EXPERIMENTAL DESIGN

Experiment was firstly carried out get movement angles during the exercise from Kinect, after that; investigate the systematic or random situations during training. The following sections describe the experiment and show the results.

3.1. Experimental Stage

The primary objective of the experiments with the Kinect is to determine whether the efficiency of detect injury risks depending from the joint information recorded by the program is adequate for use in bodybuilding training. For this purpose, we formed experiment stage as shown in figure 4.

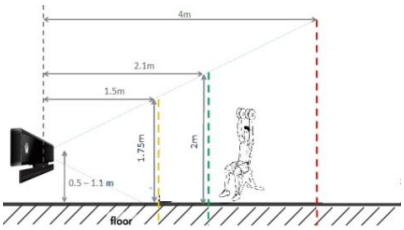


Fig.4. The Joint Distribution of the Skeleton

In the experiment, Six subjects of different age (21 to 36) and height under same experiment stage have performed "Shoulder Barbell Press" training with increased weights (5 kg, 7.5 kg, 10 kg, 12.5 kg, 15 kg) as 5 sets 12 reps.

3.2. Participants

Six male noncompeting bodybuilders attended our experiment and performed "Dumbbell Shoulder Press" workout. Two of them have 2 year of continuous weightlifting experiment and rest of them as weightlifting experiment change between 3 months to 8 months. Respectively, ages of participants are 21, 22, 28 and 35.

3.3. Collected Data

The data, collected from "Dumbbell Shoulder Press" are right shoulder angle, left shoulder angle, right elbow angle, left elbow angle and spine angle. In the program, all data for example movement saved into a database. The form design of program is shown in figure 5.

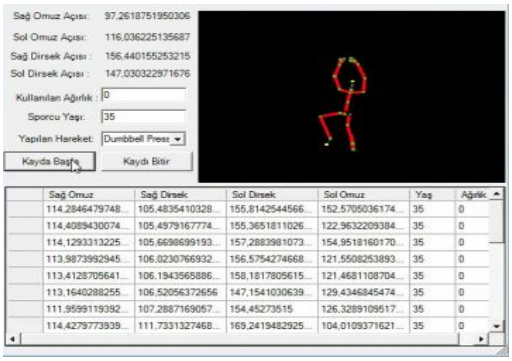


Fig.5. The Joints angles during "Dumbbell Shoulder Press"

As seen in table 1, it contains 3 rep's data which simplify to decide efficiency of training and injury risks.

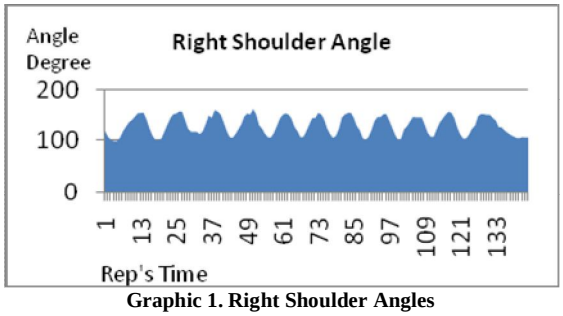
Table1. Partial experiment result of a participant (age 21) for 15 kg dumbbells.

Right Shoulder Angle	Right Elbow Angle	Left Elbow Angle	Left Shoulder Angle	Spine Angle
133,5568	128,1873	127,9367	132,8553	179,1961
127,8383	137,4449	134,3137	127,2952	179,0577
113,8435	141,8764	156,8214	113,6301	178,5861
115,7787	153,8243	158,4568	115,4579	176,7778
132,8099	110,2849	113,625	132,7473	177,6636
133,9004	120,9672	143,235	134,161	178,3797
125,4061	116,9382	110,4522	125,2934	177,3196
133,9434	129,2704	134,6534	133,9393	178,126

IV. RESULTS AND DISCUSSION

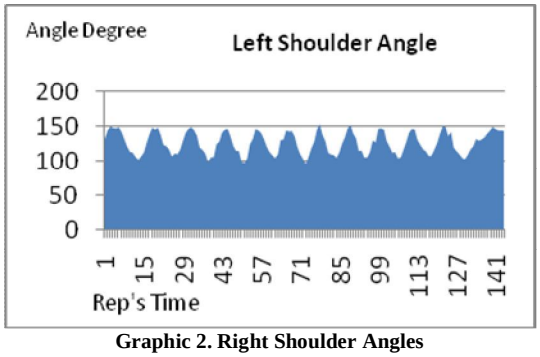
As seen in graphic 1 and 2, right and left shoulder angles during training recorded by our program. Using these angles, it is possible to understand risk factors of injuries, efficiency of training and how much power used in training.

When we compared the graphic 1 and 2, it is seen that left shoulder angles are slightly smaller between 5.5◦ to 7◦. The reason of this, the strength of the left shoulder seems to have a little less power than right shoulder. At this point of training session, it is advised that the weights should not be increased until shoulders angles become equal, so the injury risks would be eliminated.



Graphic 1. Right Shoulder Angles

In another way if we examine the muscular torque for mono-axis joints model shown in Fig.6 [11].



Graphic 2. Right Shoulder Angles

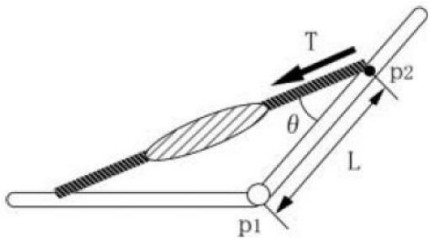


Figure 6. Mono-axis joints model

At the mono-axis joint model, torque of a joint (τ) calculated in formula 5 as shown below.

$$\tau = \sum \tau_i = \sum L_i * T_i$$
$$\tau_i = L_i * T_i = |T_i| * |L_i| * (\sin \theta_i) * e_i \quad \text{(f.5)}$$

In equation 5, ei is a unit vector in the same direction as τi. This equation explains that, if multiple muscles join in a joint action, then the joint torque can be found as a sum of the each muscle's torque vectors.
If we apply this procedure only for the deltoid muscle according to our data, where T is the muscle tension and L is the length from the rotation center (p1) to the action point (p2). According to our data, subject is holding a 15kg dumbbell in an isometric position with at 127, 8383 degrees of Right shoulder and at 134, 2952 degrees for left shoulder and the moment arm of the elbow is 14cm about the both of shoulder joints axis. The muscles torqueses are for right shoulder is 49,644 Newton and for left shoulder is 45,297 Newton are found. As can be seen, results obtained from both of methods show consistency with each other.

CONCLUSION

In this study, through the program we wrote, using the Kinect the coordinates of the joints of the studied area during bodybuilding training is extracted. Then, by examining the data obtained from bodybuilding training, the designability of support system based on injury prevention using Kinect V2 have been investigated. As discussed in previous section through the obtained data and using methods, it is highly possible to design a support system using Kinect V2. In our future works, we include other systems to fuse with our system for larger use in other sport areas.

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