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RISK OF INJURY COMPARISON BETWEEN REGULAR AND KNUCKLE PUSH-UP BASED ON KINEMATIC PARAMETER ANALYSIS

Nowadays, it is difficult to access physical exercise facilities because people spent most of their time at work. Therefore, physical exercises that could be done with less equipment and space are more likely needed, and a push-up is one of them. There are several kinds of push-up which two are regular push-up and knuckle push-up. Both of them differ in hand posture, which carries a different risk of injury. In this research, kinematic parameters of joints on both of the push-up method that was acquired from optical motion capture using 120 fps GoPro camera and six markers were compared to identify which method would lead to a higher risk of injury. From analyzing the elbow joints acceleration, it was observed that the maximum value of both the linear and angular acceleration of knuckle push-up was larger. This means that the elbow joints suffered more load during knuckle push-up, leading to a higher risk of injury.

Keywords: *Palm, Injury, Knuckle, Kinematic, Push-Up, Motion Capture*

1. INTRODUCTION

Stress management is one of the keys to maintaining our daily life productivity. For this reason, physical exercise plays an important role in it. Therefore, physical exercise is becoming more important nowadays, especially when stress is built more intensively. Physical exercise is any repetitive bodily movement from muscle activity which purpose is to maintain physical fitness [1]. However, since nowadays people spent most of their time working, it is difficult to spare time going to the gym. Consequently, physical inactivity occurs, and it could damage both our physical and mental health. Therefore, physical exercise, which involved fewer tools and space, is currently highly demanded, and push-ups are one of them. Push-up is one of the most popular physical exercises focusing on the upper extremity muscles [2-4] and is frequently used to train the upper body among athletes, the general population, and even military recruits [5]. Its popularity is due to simplicity and convenience where there is nothing needed to perform this activity.

The biomechanical analysis of push-up has been much conducted. One of the variant push-ups that was analyzed comprehensively was the plyometric push-up. In 2012, the kinematics analysis of four plyometric push-up variations was performed by Moore et al. [6]. In addition, Giancotti et al. also investigated the biomechanical aspect of suspension training push-up [7]. Although plyometric and suspension training push-ups have been explored, there is another variance of push-up that has not been studied yet, i.e., the knuckle push-up. The knuckle push-up is like the regular push-up. Both consist of upward phase and downward phase but differ in hand posture, shown in Figure 1 and

Figure 2. In knuckle push-up, both fists will be clenched, while in a regular push-up, the palm is stretched open, touching the floor. This variance leads to a different muscle activation [8] and also a different

risk of injury. From comparing the loads on the elbow, it was claimed that knuckle push-up resulting in a larger value than regular push-up ($0.35BW \pm 0.02 > 0.2BW \pm 0.04$) [9, 10]. There was also a report that a 19-years old soldier injured his wrist due to his daily knuckle push-up, and after further examination, it was believed to carry potential trauma for metacarpal and stress fractures [11], but there is no study to prove this claim [12]. Therefore, in this study, the kinematics analysis of knuckle push-up was conducted. At here, the regular push-up was also investigated as the control.

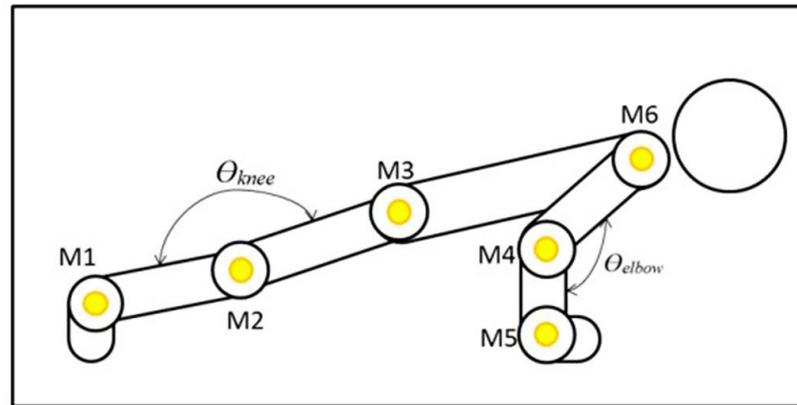


Figure 1 Illustration of regular push up

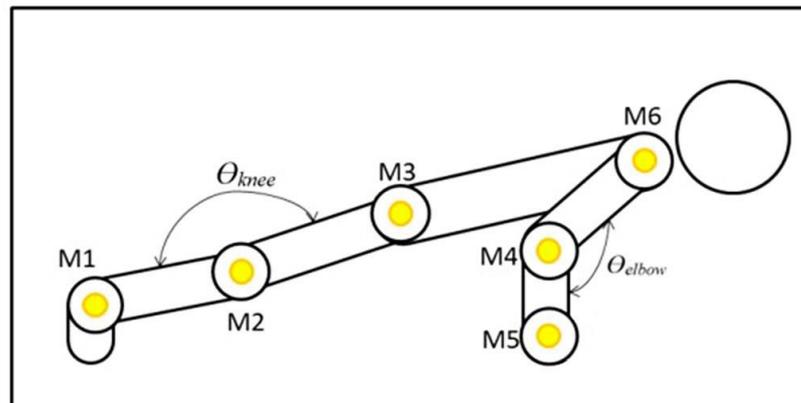


Figure 2 Illustration of knuckle push up

2. METHODOLOGY

The kinematics analysis of regular and knuckle push-ups was conducted by an optical motion capture system developed by FMAE Biomechanics Research Team [13]. The motion of push-ups was recorded using a 120 fps GoPro camera. The camera was set to take the sagittal plane image, which will describe the flexion and extension movement as shown in Figure 3. Before recording, the action camera was calibrated using the Direct Linear Transformation method to obtain the correlation between image and world coordinate systems [14]. The camera calibration was conducted using four LED markers, M1 – M4, which were attached to a calibration board with the dimension presented in Figure 4. The calibration process was conducted to find the DLT parameters which were used after the marker tracing process to transform the image to the world coordinate of markers on the subject. The DLT method was chosen as it is simple and reaches a very low uncertainty [15].

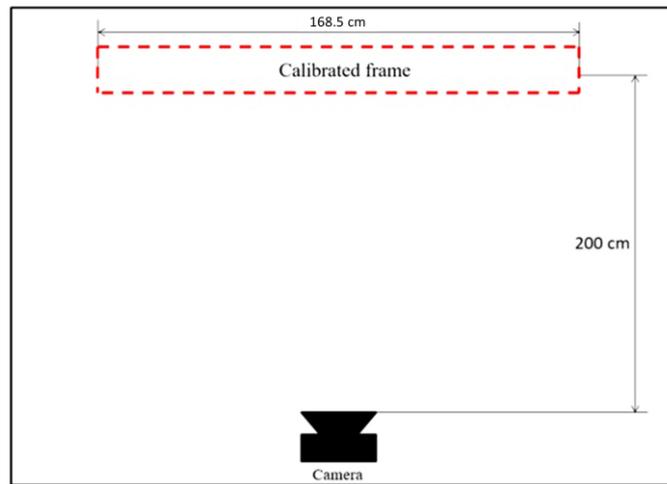


Figure 3 Experiment set up configuration

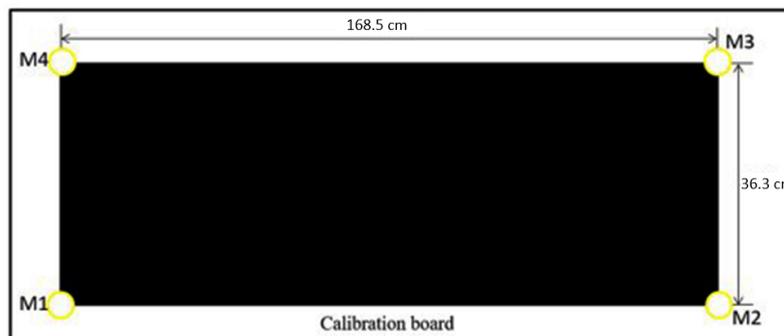


Figure 4 Calibration board configuration

During recording, six markers were placed on the subject, which represented the ankle, knee, hip, elbow, wrist, and shoulder, as presented in Figure 1 and Figure 2 **Error! Reference source not found.** The positions of all markers were the same in both push up method. The vector of M1-M2 and M2-M3 were used to construct the knee angle, while M3-M4 and M4-M5 were used to construct the elbow angle. A black cloth was also needed to cover the floor so that there was no reflection of markers on the floor. This was essential because the reflections could create a false marker detection in the image segmentation process, resulting in marker identification and follow-up tasks [16]. The false marker appears because the image segmentation was conducted based on the thresholding method, as it was modest and efficient [17]. In addition to the black cloth, the movement was also recorded in a dark room to contrast markers and background, making the image segmentation task easier.

In the present work, the push-up recording was performed twice, which was for the regular and knuckle push-up. Each of the push-ups was conducted in three cycles. The recorded video was then sent to MATLAB to be divided into frame images processed further for marker identification using the least squared distance method. In the least square distance method, the Euclidean distance by each marker from the current frame to all markers in the next frame was calculated. Then the minimum Euclidean distance determined the identity of the corresponding markers in the next frame, as presented in Figure 5. This method was used because it was observed that the horizontal order of the marker changed during push-ups. Therefore, marker numbering based on the horizontal order was not valid.

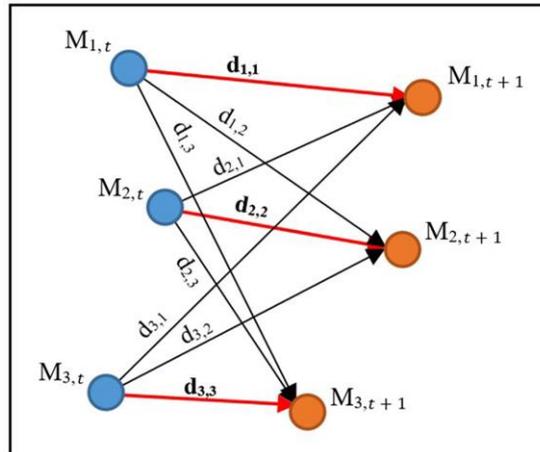


Figure 5 Marker tracking using least squared distance method

Lastly, data smoothing was conducted using the Smoothing Spline method to remove the noise of the data [18] before differentiated against time to get the linear velocity and acceleration of the markers. The smoothing parameter was decided by observing the MSE over the data points and reduced noise [19]. The elbow and knee angle were also evaluated by using the cosine rule, as shown in Figure 3. The angular velocity and acceleration were also obtained after data smoothing and differentiation from relative angle data against time.

3. RESULT AND DISCUSSION

One of the results in this present work was elbow and knee angle, as could be seen in Figure 6a and Figure 6b. From the relative angle presented in Figure 6a, both motions, regular and knuckle push-up, resulted in a parabolic curve during its early stage of the cycle, but a slight instability was noticed from the elbow angle graph in the late upward phase of knuckle push-up. The high pressure caused this during knuckle push-up due to the small area of force distribution. So, more strength on the wrist is needed to maintain the stability. This instability could also indicate muscular compensation [20], the activation of muscle groups that are not supposed to be used to help the subject maintain balance and complete the move. This muscular compensation can be dangerous without the supervision of a trainer [21]. Besides instability, the high-pressure concentration also led to a higher force acting on the knuckle. According to Newton's first law, the wrists suffer a higher load, which leads to a higher risk of wrist and knuckle injury. Moreover, the elbow range of motion during knuckle push-up is also not as wide as during regular push-up which is also caused by the difficulty that has been mentioned before. The instability again also makes the cycle time of knuckle push-up slightly longer than during regular push-up. However, from Figure 6b any significant difference is yet noticed from the motion of the knee.

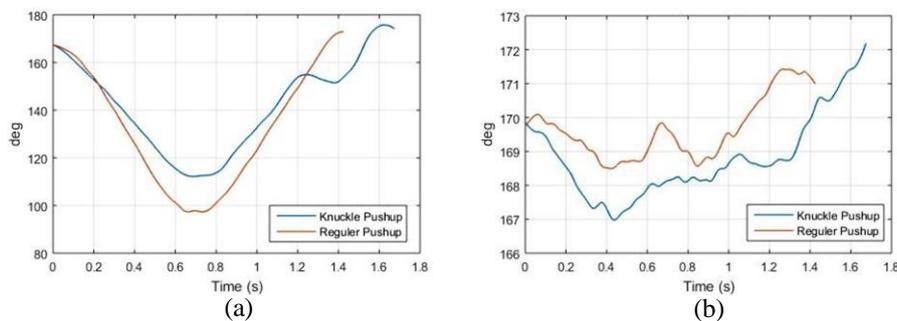


Figure 6 (a) Elbow angle and (b) knee angle during a cycle of knuckle and regular push-up

From the linear velocity graph in Figure 7a and Figure 7b, it could be seen that both push-ups are resulting in a similar profile of velocity. However, the value of velocity in knuckle push-up is mostly lower than regular push-up, except during the late stage of the cycle. This is caused by the instability of motion at

the end of the cycle, as shown in Figure 6a. Meanwhile, in Figure 7c and Figure 7d, the magnitude of angular velocity in knuckle push-up is also mostly lower compared to knuckle push-up. In Figure 6a, it also could be seen that in the same amount of duration, the subject can decrease the relative angle more during regular push-up than during knuckle push-up. The angular velocity of knuckle push-up during the late stage also suddenly increases due to the instability mentioned before.

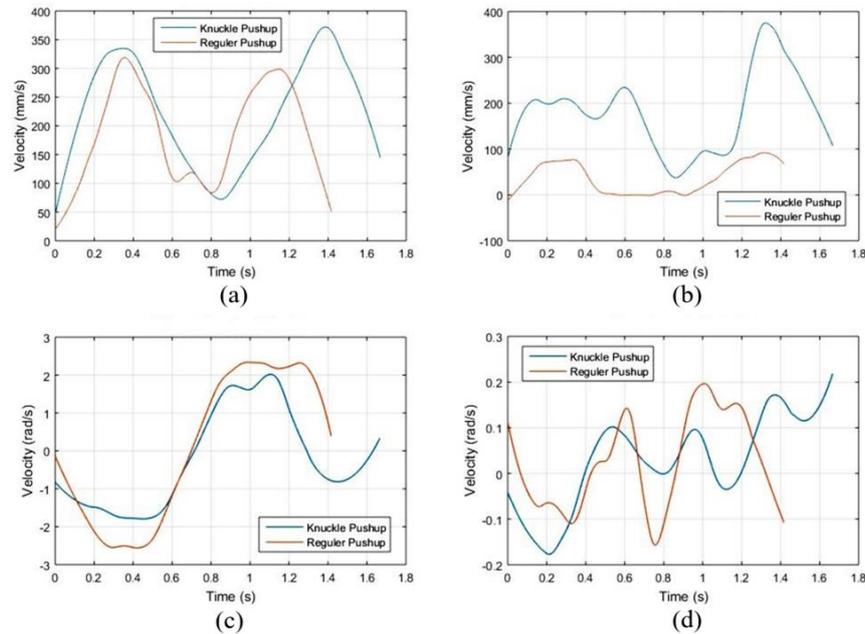


Figure 7 (a) Elbow linear velocity, (b) knee linear velocity, (c) elbow angular velocity and, (d) knee angular velocity during knuckle and regular push-up

The same phenomenon as in velocity could also be observed in the acceleration graph, where the magnitude of knuckle push-up linear acceleration gets larger at the late stage of the cycle. This is due to the instability (Figure 8a) according to Newton's second law, resulting in a higher force or load on the elbow (Figure 8a). Therefore, this higher load during knuckle push-up leads to a higher risk of elbow injury. In Figure 8c and Figure 8d, the angular acceleration during knuckle push-up in the late stage is also higher compared to regular push-up due to instability of motion. This will also be resulting in a higher torsion load and contribute to a higher risk of elbow injury. This result was in tune with the study by Chou et al. (2011) [9], and Polovinets et al. (2017) [10], which was the elbow suffered more load during knuckle push-up than a regular push-up.

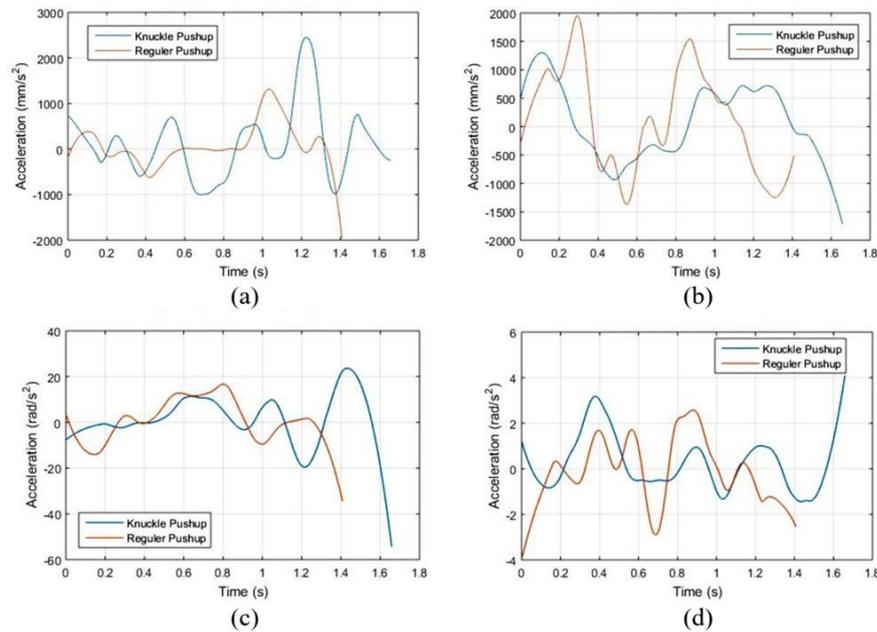


Figure 8 (a) Elbow linear acceleration, (b) knee linear acceleration, (c) elbow angular acceleration and, (b) knee angular acceleration during knuckle and regular push-up

4. CONCLUSION

From the analysis of all the data taken from the subject knuckle and push-up motion, knuckle push-up and regular push-up are quite different, especially in the late stage of the cycle of motion. There was instability during the late stage of the knuckle push-up cycle of motion. This instability resulted in a longer cycle time, the higher linear velocity of the elbow, and higher linear and angular acceleration, leading to higher force and torsion load suffered by the elbow. Besides, during knuckle push-up, the wrists and knuckles also suffer more load due to high-pressure concentration on a small area of force, leading to wrist and knuckle injury.

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