Comparison between Marker-less Kinect-based and Conventional 2D Motion Analysis System on Vertical Jump Kinematic Properties Measured from Sagittal View

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Abstract. Marker-less motion analysis system is the future for sports motion study. This is because it can potentially be applied in real time competitive matches because no marking system is required. The purpose of this study is to observe the suitability and practicality of one of the basic marker-less motion analysis system applications on human movement from sagittal view plane. In this study, the movement of upper and lower extremities of the human body during a vertical jump act was chosen as the movement to be observed. One skilled volleyball player was recruited to perform multiple trials of the vertical jump (n=90). All trials were recorded by one depth camera and one Full HD video camera. The kinematics of shoulder joint was chosen to represent the upper body extremity movement while knee joint was chosen as the representative of the lower body extremity movement during the vertical jump's initial position to take-off position (IP-TP) and take-off position to highest position (TP-HP). Results collected from depth camera-based marker less motion analysis system were then compared with results obtained from a conventional video-based 2-D motion analysis system. Results indicated that there were significant differences between the two analysis methods in measuring the kinematic properties in both lower (knee joint) and upper (shoulder joint) extremity body movements ($p < .05$). It was also found that a lower correlation between these two analysis methods was more obvious for the knee joint movement [38.61% matched, $r = 0.12$ (IP-TP) and $r = 0.01$ (TP-HP)] compared to the shoulder joint movement [61.40% matched, $r = 0.10$ (IP-TP) and $r = 0.11$ (TP-HP)].

Keywords: Motion analysis, marker less, depth camera, vertical jump

1 Introduction

The capture technique of human movement is one of the crucial parts recently used by biomechanics to study the musculoskeletal movement and is also being used by physiologists to diagnose an injury problem. According to Krosshaug et al (2007), analysis of human motion is very useful in establishing injury risks through joint position

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measurement and orientation of body segments, as well as analyzing the technique in sports (Lees, 2002). Thus, it is important to obtain the robustness and accuracy of the results in order to detect every single motion involved in particular human movements.

There are several approaches recommended for use as simple setup tools in order to obtain stable, accurate, and real-time motion capturing performances. The marker-based system tool has been proven to be suitable for in-vitro (laboratory based) studies where the subject has to wear an obstructive device, a marker which is more complicated, hard to maintain, and even quite expensive. Although the application demands to use these tools have increased during a real-time competitive sporting event, but it is difficult for athletes to do their normal routines with the marker placed on their body (Wheat, Fleming, Burton, Penders, Choppin, & Heller, 2012; Zhang, Sturm, Cremers, & Lee, 2012).

The marker-less based system tools have come out with attractive solutions to solve problems associated with marker-based system tools. Microsoft launched the low cost marker-less camera-based Kinetics which originally was used for Xbox 360 gaming, with the capability for tracking the users' body segment positions and 3D orientations in real situations. These cameras require minimal calibration by standing in a specific position only for a few seconds with no marker required on the body. However, this tool also has their own limitations resulting in low accuracy and less supported on motions with high speed (Choppin & Wheat, 2012). With a lower price compared to other depth camera, these cameras are only capable of capturing 30 frames per second. It means that these cameras have the capability only for capturing certain basic motions or movements like walking or jumping, rather than fast movements (Corazza et al., 2006; Zhang et al., 2012).

Therefore, this study was designed to observe the suitability and practicality of depth camera applications in vertical jump focusing on upper and lower extremity body movements when located at the sagittal plane with respect to the movement.

2 Method

2.1 Subject

One skilled amateur volleyball player (age 24 years, height 178 cm, weight 75 kg with 10 years of competitive volleyball playing experience) was recruited to participate in this study. Consent from the subject and approval from the research ethics committee from the research organization was obtained before the study was conducted.

2.2 Instrumentation

One depth camera (Microsoft's Kinect) and one Full HD video camera (Sony-60 FPS) were utilized in this study. The depth camera has the capability of depth data capture at 30FPS with a resolution of 640 x 480 pixels. It is capable of tracking various types of joint angles. Depth Biomechanics by Sheffield Hallam University (Depth Biomechanics, 2015) was the software utilized in this study to process the data captured by the depth camera. KINOVEA software (v. 0.8.15) (Kinovea, 2015) was used to analyze the video. Two units of reflective markers (d=14mm) were located at the right side of the subject's shoulder and knee joint. Subject was asked to perform warm up and stretching exercises for 5 to 10 minutes prior to performing the jump. All cameras were set at the sagittal view of the subject's body, as shown in Fig. 1. Typical calibration of the depth camera (front view calibration) was performed before the recording took place.

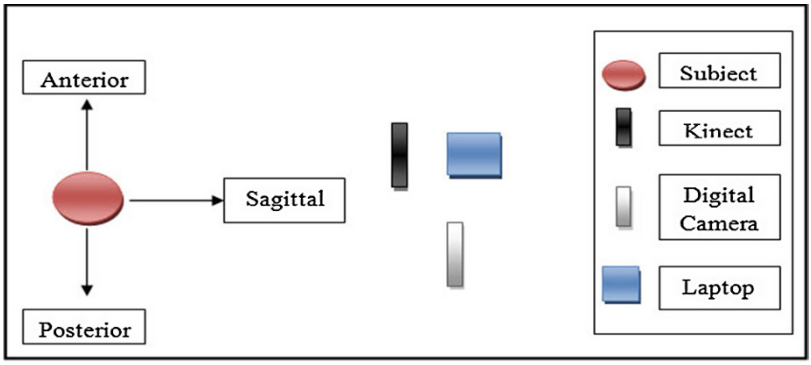


Fig. 1. Instrumentation setup (Top View)

2.3 Data collection and processing

In this study, the shoulder joint was chosen as a representative of upper body extremity, while the knee joint represents the lower body extremity. From these two major parts, each part consists of two different types of phases to be analyzed, which include initial position to take-off phase (IP-TP), and take-off position to the highest phase (TP-HP), as shown in Fig. 2.

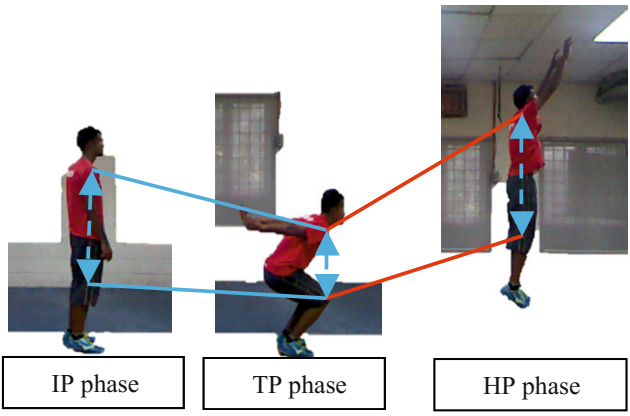


Fig. 2. Vertical Jump phases used to measure displacement

According to Adams and Beam (2008), proper jumping maneuver for the vertical jump was 3 trials with about 20 – 30 s of recovery between trials. Each of these 3 trials is considered as 1 set of jumps. Throughout this study, the subject performs 35 sets of jumps. Between each set, the subject will rest between 1-3 minutes. From all trials recorded, 90 trials were selected for further analysis.

Synchronization of the frame rate between the video camera-based and depth camera-based data were required prior to data analysis. In order to synchronize it, the time frame and joint displacement obtained from the video analysis by Kinovea were converted to coordinate system, to make it similar to the output obtained from Depth Biomechanics. This study tends to evaluate the two methods of analysis at its most optimum setting. Therefore the video camera was set at full high definition resolution (1920 x1080) with 60 FPS. Since the data from the depth camera was 30 FPS (resolution at 640 x 480), therefore the time-frame rate need to be adjusted for both sources to be in-sync before the results were analyzed. Finite forward difference method was utilized in order to calculate the joint displacement based on the coordinates obtained from both depth and video cameras. Independent t-test was used to compare data from the two methods of analysis. Lastly, correlation analysis was performed to observe how strong the results between the two methods of analysis were similar.

3 Results and Discussion

The result of the study showed that there were significant differences between the two methods analyzed in all jumping phases (Table 1). It was also found that a lower correlation between these two analysis methods were more obvious for the knee joint

movement [r= 0.12 (IP-TP) and r=0.01 (TP-HP)] compared to the shoulder joint movement [r=0.10 (IP-TP) and r=0.11 (TP-HP)]. This result can be explained based on the differences in speed in each of the phases. Although it was not shown here, but the speed of TP-HP was faster than the movements during the IP-TP phases. It is also worthwhile mentioning that based on point-to-point data comparison in each trial, the data for knee joint displacement (lower body movement) only achieved 38.61% matching results and the data from the shoulder joint displacement (upper body movement) achieved 61.40% matching results when compared between the two types of analysis methods.

Microsoft Kinect depth camera has its own limitation resulting in low accuracy and less support on motions with high speed (Choppin & Wheat, 2012). With a lower price than the other depth cameras, these cameras have capabilities only for capturing certain basic motions or movements like walking or jumping, rather than fast movements (Corazza et al., 2006; Zhang et al., 2012). This study shows that the accuracy level reduces when the depth camera measures a higher speed motion.

These types of depth camera with capturing capabilities of 30 frames per second at 640 x 480 resolutions are more accurate when used at the frontal plane. In gaming situations, the upper extremity is used more frequently rather than the lower extremity. Also, the camera is typically located in the frontal view, and not from the sagittal view. The calibration procedure was also only based on frontal view calibration and not the sagittal view.

Table 1. Comparison of Displacement Measurement between 2D Video-based and Marker-less Motion Analysis.

Segment	**Method**	**N** (**No. of trial**)	**Mean, cm (SD)**	**t** (**t-value**)	***Correlation*** (**r**)
Upper body IP-TP Displacement (Shoulder joint)	2D-Video	90	54.85 (3.21)	6.3*	0.10
	Marker-less	90	141.88 (131.27)		
Upper body TP-HP Displacement (Shoulder joint)	2D-Video	90	118.78 (3.87)	7.2*	0.11
	Marker-less	90	252.38 (175.42)		

Lower body IP-TP Displacement (Knee joint)	2D-Video	90	24.00 (5.65)	3.5*	0.12
	Marker-less	90	62.42 (104.80)		
Lower body TP-HP Displacement (Knee joint)	2D-Video	90	74.39 (16.48)	6.4*	0.01
	Marker-less	90	196.23 (179.79)		

**Mean values between the two method are significantly different ($p < 0.05$)*

If a depth camera is to be utilized from sagittal view in a motion analysis involving rapid movement, a higher specification of the camera in terms of the frame rate should be considered. There must also be a calibration procedure involving sagittal view. However, further studies are still needed to suggest that a higher frame rate and additional calibration steps could improve data captured from other viewing angles or planes, beside the frontal view. Also, the resolution of the camera could also be a factor that influenced accuracy. A depth camera with a higher resolution, higher than 640x480, might provide an improvement to the marker-less motion analysis method.

4 Conclusion

From this study, it can be concluded that video-based analysis and depth camera-based analysis have significant differences on the upper extremity and lower extremity towards the vertical jump motion, when captured from the sagittal view. In terms of accuracy between the upper body and the lower body based analysis by the Microsoft Kinect depth camera, the upper body was slightly more accurate than the lower body. A depth camera with 30 FPS was less suitable when capturing fast movements, especially from the sagittal view plane. It would be interesting to note whether these types of tools can come out with high level of accuracy towards other movements such as kicking or throwing if the frame rate was to be improved. In order to get higher accuracy, it is recommended that 2 or more Microsoft Kinect depth cameras be used to detect the full capturing angles; frontal plane and sagittal planes. By using more than one depth camera, the validity of the 3D data capturing ability can be observed from different viewpoints.

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