Biomechanics of the standard table tennis forehand drive using a low-cost motion capture software

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Abstract: we compared the biomechanics of the table tennis forehand drive of a beginner and an advanced player through a low-cost and easy to set up motion capture software that we have developed. The vertical and horizontal displacements of the three key points: wrist, elbow, and shoulder, were analyzed from the video footage of the players. Results show that the technique of the beginner is different from the advanced player, with the power of the beginner's stroke coming from the arms instead of the body. The novice player also lacks the follow through and the correct stance of an advanced player.

Keywords: low cost motion capture software, biomechanics.

1. INTRODUCTION

Motion capture systems have helped develop the understanding of the physics of moving bodies. They give a more in-depth analysis through the recording of the individual and collective movements of selected key points. These types of information gathering systems are widely used in other countries, but are not as widely available in the Philippines. According to Moeslund and Granum, as cited by Tiesel and Loviscach [2], available motion capture systems make use of hardware systems costing in the range of several hundred to several thousand US$.

We have developed motion-capture software that makes use of a normal digital video camera that is interfaced to the computer where our own software is installed. This software partially implements the proposed grid-based mean shift algorithm by Luo and Zeng [1] and uses frame differencing techniques. A specific video stream can be treated as a sequence of images. The subsequent images which are represented as matrices will then be subtracted from the preceding image to determine which pixels have changed, implying that motion has occurred. In order to reduce noise in the video (film grains, motion blurs) preprocessing (particularly foreground-background segmentation) is done to get accurate detections. Despite these efforts, the current system has the following disadvantages: 1) reflections from the background contribute greatly to noise; 2) it is extremely tedious to work with the generated data (to eliminate the noise contribution); it can only measure in 2D, i.e. depth is not taken into account. The biggest advantage, however, is the ease of use and the price – digital cameras that can record videos are available under 100 US$ and the software is compatible with Windows XP to Windows 7.

The standard forehand drive is a basic skill in table tennis. The initial position of the arm is extended and weight shifted to the racket arm. In executing the forehand drive, the armswings forward and slightly upward in the same direction as the ball. This action is simultaneous to the weight shift to the other leg while twisting the waist. The forehand drive is an aggressive attacking stroke; the ball is made to land close the opponent's sideline or baseline.

In this study, we analyzed the biomechanics of the forehand drive. Specifically, the forehand drive of a beginner and an advanced player were compared using the motion capture software.

2. MATERIALS AND METHODS

The major bulk of data collected came from the changes in the position of various points (reflecting stickers) relative to a pre-determined reference frame. The said points were strategically positioned on key areas of movements in the body: shoulder, elbow, and wrist. In order to reduce the effect of noise and to ensure that the motion capture will only detect the movement of the key points (and not other body parts), subjects wore black tight-fitting long sleeved clothing during data acquisition. A black backdrop was also necessary to ensure accuracy of data (Fig. 2).

The two players, a beginner (who has never played table tennis or any other racket sport, Fig. 1) and a varsity player (advanced, Fig. 2), were instructed to simulate the forehand drive using a metronome which was set at a pace of 120 beats per minute (the ball then was struck every 2 counts) as dictated by their instructor. The beginner underwent the shadow practice technique used in a previous study [3] where participants were designated to swing and point their racket diagonally opposite the crosscourt when shadow practicing, and hitting the ball crosscourt at a designated area opposite the crosscourt when doing many-ball practice.

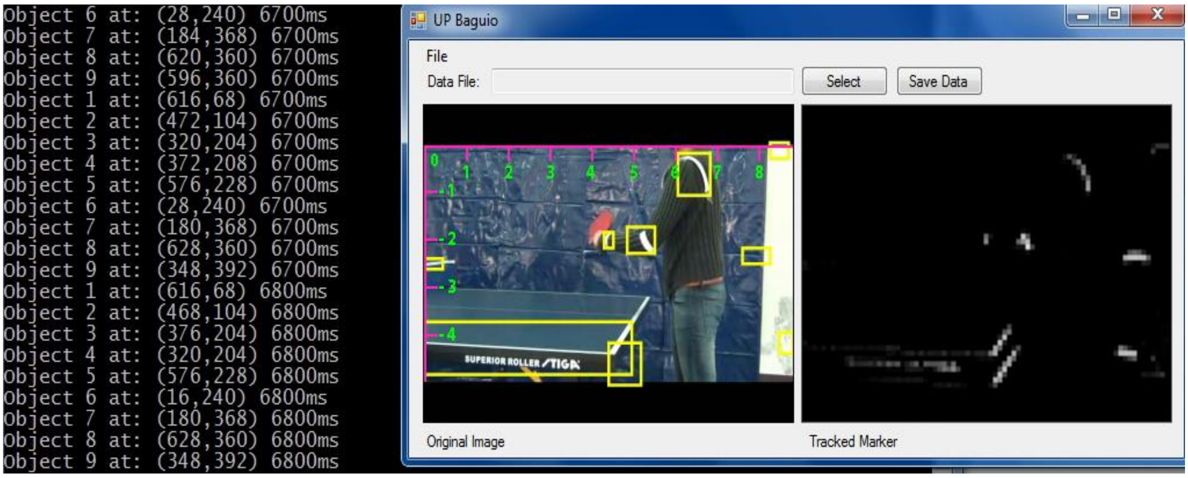

Fig.1. The software user interface as it is used to detect the motion of the novice table tennis player. Each scale appearing in the middle frame, multiplied by 100, corresponds to the x- and y-coordinates enclosed in parenthesis in the leftmost frame. The said values are arbitrarily assigned. In the leftmost frame, the coordinates of each marker in the middle and right frame can be seen for specific times. White markers were used but this turned to be a disadvantage because noise from other sources of reflected white light is evident.

The two participants were filmed using a regular digital video camera that shoots at 30 frames per second; analysis could be made given 30 data points per second for a specific key point. The film was subsequently interfaced with the motion capture software and the popular technical computing software MATLAB for data interpretation.

3. RESULTS

In Fig. 1 and Fig. 2, the numbers on the left frame correspond to the coordinates of the markers at specific times (with an interval of 100 ms). Each of the white objects in the actual video footage (middle frame) is defined by the software as Object 1 through Object 9. The right frame is how the software perceives the markers after image processing.

The origin of the coordinate system used to assign the coordinates of the markers is at the upper left corner of the frame for the video with yellow markers, while it is at the lower left corner of the frame for the video with white markers. The positions of the coordinates were changed simply for convenience; thus, all of the values of the displacements shown have arbitrary units. The positive values are to the right and downward for the video with yellow markers, while it is right and upward for the video with white markers.

In Fig. 1, the shoulder, elbow and wrist markers correspond to object 5 at (576,228), object 3 at (376,204), and object 4 at (320,204), respectively, at t = 6.8 s. Thus, for the beginner, the forward swing corresponds to decreasing values of the horizontal displacement (also seen in Fig. 3).

In Fig. 2, the shoulder, elbow and wrist markers correspond to object 1 at (252,216), object 2 at (364,284), and object 3 at (456,240), respectively, at t = 5 s. Thus, for the advanced player, the forward swing corresponds to increasing values of the horizontal displacement.

A. Beginner level – horizontal motion (Fig. 3A)

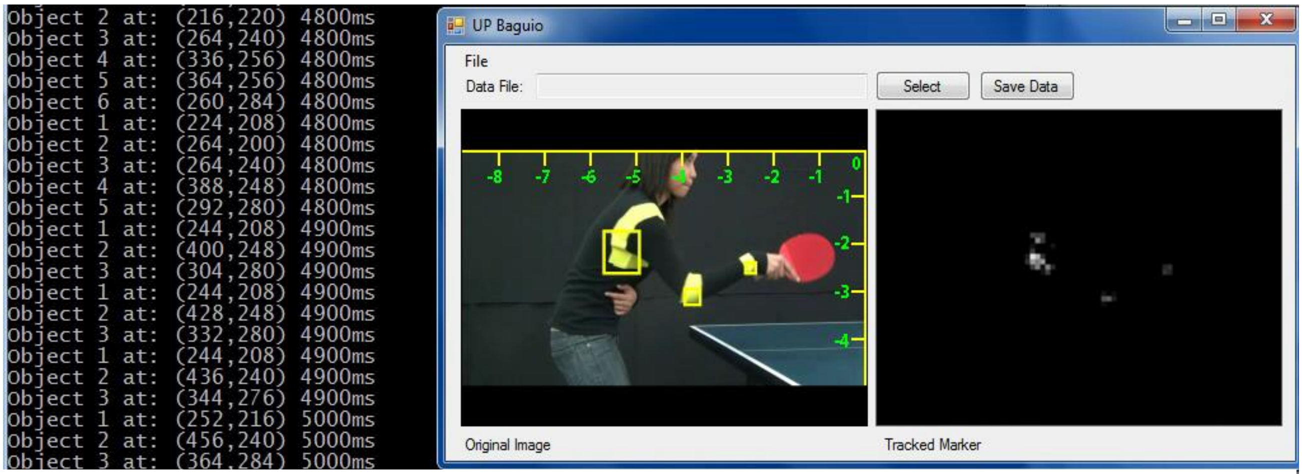

Fig. 2. The software as it is used to detect the motion of the advanced (right-handed) table tennis player. Each scale, multiplied by 100, corresponds to the x- and y-coordinates enclosed in parenthesis in the leftmost frame.The said values are arbitrarily assigned. Yellow markers were used; this gave less contribution to noise.

The relative positions of the elbow and the wrist for the novice player was not constant. It increased just when the forward swing reached its full amplitude (e.g. at t = 7.6 s), almost intersected at the full amplitude (e.g. at t = 8 s), and then increased again after the full amplitude (e.g. at t = 8.3 s) as the arm returned to its 'ready' position. This implies that the novice rotated the arms around her body when doing the forehand forward swing, and swung the wrist almost inward towards her body. The amplitude of the forehand swing (see wrist amplitude: square boxes) of the beginner considerably varied with time; the same was true for the elbow swing. Using the slop of the best fit line for a single stroke, a horizontal wrist velocity was determined to be 750 units

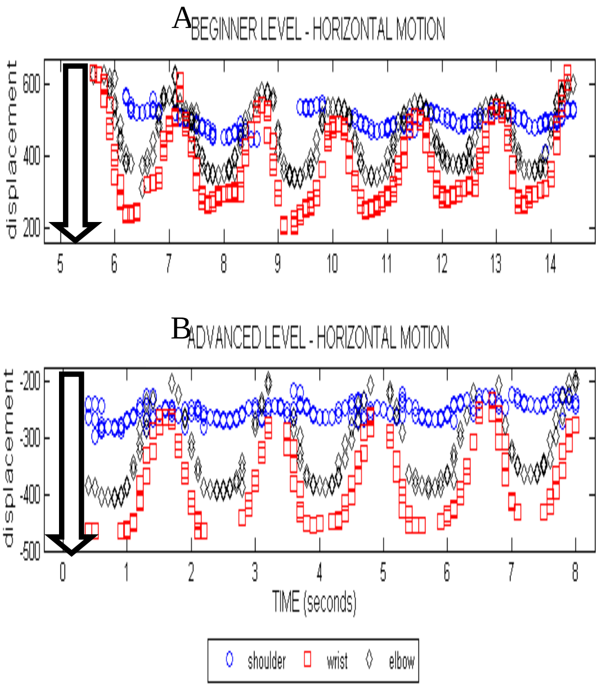

Fig. 3. Horizontal displacements of the shoulder, wrist and elbow for both players.Six forehand strokes are shown. Arrows indicate the forward swinging motion of the arm of the players; the values and signs of the displacements are arbitrary.

/ second. The shoulder of the beginner did not return to its initial position or to the 'ready' state (see level of blue circles through time). It was also seen in the video that during the forehand stroke, the beginner used little to no twisting of the body.

B. Advanced level – horizontal motion (Fig. 3B)

The relative positions of the elbow and the wrist for the advanced player was constant (see red boxes and black diamonds).The horizontal displacement of each forehand swing for the advanced player was practically the same, showing consistency in the technique. The same was also observed in the motion of the elbow during each swing. This implies that the forehand forward swing of the advanced player moves forward (following through in the direction of the ball) and not inward towards her body. Using the technique described earlier, the horizontal wrist velocity of the advanced player was found to be a comparably more controlled 450 units /second.

C. Beginner level – vertical motion (Fig. 4A)

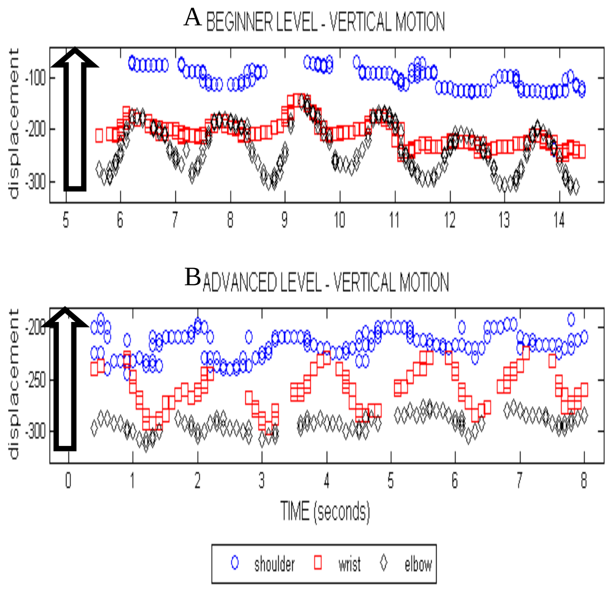

Fig. 4.Vertical displacements of the shoulder, wrist and elbow for both players. Six forehand strokes are shown. Arrows indicate the upward swinging motion of the arm of the players; the values and signs of the displacements are arbitrary.

The novice only moved her forearm forward and wrapped the whole arm around her body as the arm moved towards the maximum swing amplitude (red squares never intersect with the blue circles). The shoulder level almost never changed (see blue circles) indicating a relaxed stance. Her elbow level had large amplitude level changes (see black diamonds) indicating up and down motion of the elbow while there was barely any up and down motion of the wrist (see red squares). Using the slope of the best fit line of the wrist amplitude for a single stroke, it was determined that there was only a 25 units / second vertical motion of the wrist. All these indicate that the power of the swing of the novice is delivered solely by the arm.

D. Advanced level – vertical motion (Fig. 4B)

The forehand swing of the advanced player came from the level of the wrist to the level of the shoulder consistently (red squares alternately intersect with blue circles and black diamonds).Simultaneous to the upward forehand swing of the advanced player, the shoulder dropped down a little bit (see blue circles). Simultaneous to the dropping of the shoulder was the raising of the elbow level (see blue circles in relation to black diamonds). This shows that the upper arm simply follows the motion of the body, and that the power is transferred from the body to the forearm. In contrast to the beginner, the graphs indicate that the power of the swing of the advanced player comes directly from her body. The wrist had a vertical velocity of 43 units / second.

It is evident from the results of the motion capture that the advanced player's forehand drive biomechanics was consistent with the recommended motion, i.e. arm should move forward and slightly upwards in the same direction as the ball (with a follow through of the motion) and the force of the stroke came from the body. Using the horizontal and vertical components of the velocity, it was determined that the advanced player drove the racket with a 452 units / second velocity. However, the beginner's biomechanics was different – the power came from the arm's inward-toward-the-body motion and the wrist had a velocity of 750 units / second for each drive. The advanced player readily returned to the ready stance after the stroke while the beginner was in a generally steady stance all throughout.

It is therefore recommended for beginners to practice the proper form with video analysis and a coach who would then point out the mistakes to be corrected. This can be done without an actual ball (shadow practice*) so the player can consciously practice the correct technique and develop what is termed as muscle memory. For future related researches, it is recommended to use green reference markers (instead of white) to reduce noise (as seen in Fig. 2) since the motion capture software is color-sensitive. Future researches can also look into the development of the biomechanics of a player's forehand stroke from being a beginner to intermediate to advanced using techniques taught in class. This may be further quantified by devising a scoring system to gauge performance.

* *In table tennis, shadow play is when a player practices his stroke technique without the ball. It is like a form of role playing wherein the stroke is played just as it would in a normal rally. The absence of the ball allows the player to concentrate on getting his technique correct, and what the correct technique feels like [3].*

4. DISCUSSION

We had demonstrated that our motion capture software is capable of acquiring enough data for analysis of the biomechanics of the standard forehand drive (and other similar motion-based studies) despite its simplicity. This was all done with minimal expense and set-up compared to the expensive and bulky (albeit more sophisticated and powerful) professional motion capture systems. Our inexpensive and simple software can eventually be shared to high schools and some state universities and colleges in the Philippines so that other studies of biomechanics can be made.

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