Biomechanical analysis using Kinovea for sports application

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Abstract. This paper assesses the reliability of HD VideoCam–Kinovea as an alternative tool in conducting motion analysis and measuring knee relative angle of drop jump movement. The motion capture and analysis procedure were conducted in the Biomechanics Lab, Shibaura Institute of Technology, Omiya Campus, Japan. A healthy subject without any gait disorder (BMI of 28.60 ± 1.40) was recruited. The volunteered subject was asked to perform the drop jump movement on a preset platform and the motion was simultaneously recorded using an established infrared motion capture system (Hawk–Cortex) and a HD VideoCam in the sagittal plane only. The capture was repeated for 5 times. The outputs (video recordings) from the HD VideoCam were input into Kinovea (an open-source software) and the drop jump pattern was tracked and analysed. These data are compared with the drop jump pattern tracked and analysed earlier using the Hawk–Cortex system. In general, the results obtained (drop jump pattern) using the HD VideoCam–Kinovea are close to the results obtained using the established motion capture system. Basic statistical analyses show that most average variances are less than 10%, thus proving the repeatability of the protocol and the reliability of the results. It can be concluded that the integration of HD VideoCam–Kinovea has the potential to become a reliable motion capture–analysis system. Moreover, it is low cost, portable and easy to use. As a conclusion, the current study and its findings are found useful and has contributed to enhance significant knowledge pertaining to motion capture–analysis, drop jump movement and HD VideoCam–Kinovea integration.

1. Introduction

In this era, gradually plyometric exercises are also being used in rehabilitation, but some coaches are used as a platform to elevate the potential sport performances of their athlete. Plyometric movements arise during sports such as in running, jumping and throwing. The focus on developing the efficiency of the stretch-shortening cycle is what discriminates plyometric exercise from normal strength training [1]. As a part of plyometric exercises, drop jump involves a person dropping to the ground from a raised platform then immediately jumping up [2]. Subsequently, there are research results of jumping up height appear to continue to increase with lighter knee flexion [3].

The usage of motion analysis is expanding due to high demand of accuracy in biomechanics field. It is essential to get relatively similar result based on exact measures. Therefore, countless free motion analysis software developed to accomplish the level where established motion analysis systems such as Cortex are considered as the precise methods for analyses of human movements. However, the
methodology of the system is complex and intricate for simple movement analysis [4]–[6]. Nonetheless, every one of these techniques, experiences the ill effects of the 3 potential disadvantages, which they are somewhat costly, which makes them hard to obtain excluding supported college research centres and first class wear, clubs and they are hard to transport, particularly on account of overwhelming stages, which, thusly, limits their applicability [7].

The study presented in this paper examines whether Kinovea software is reliable to analyse the drop jump perform by athletes. The analysis will be done by using motion capture software, Cortex 6.0.0.1645 and Kinovea 0.8.25. The cortex is motion analysis software for handling all phases of motion capture within a single program for initial setup, calibration, tracking and post processing [8] whereas Kinovea is a video analysis, which is a free software application for the analysis, comparison and evaluation of sports and training, especially suitable for physical education teachers and coaches. Some advantages of this software are: observation, measurement, comparison of videos, etc. This software also can perform the analysis without use physical sensors or by means reflective markers and it is uncomplicated to use. The overview function is a summary image of the video. It creates a composite picture where you can see the motion at a glance by sample images from the video at regular interval. Accordingly, this study is directed to verify Kinovea as one of that solid software that can be utilized in this research field. The aim of this project is to explore the reliability of Kinovea for detection and analysis of the movement focused on drop jump movement, its repeatability test and the relation of knee flexion angle due to the drop jump exercise with the maximum jumping up height achieved.

2. Materials And Method

2.1. System Validation
The main focus of this study is to produce a good quality of recording that is motion capture of drop jump movement, simultaneously using an established infrared cameras motion capture system and HD VideoCam. Then, the same motion data are tracked and analysed using Cortex and Kinovea. The relative angle of knee during drop jump phases are measured and analysed. These angles are compared to the angles measured using the established motion capture system. Basic statistical analyses are carried out to compute mean, standard deviation and variance. These data are also used to compute the percentage difference and variance. To produce a reliable system, both values should be less than 10% [9]–[11]. Finally, by comparing both results and the outputs from the basic statistical analysis, the reliability and accuracy of HD VideoCam–Kinovea are measured and assessed. In addition, the advantages and limitations of both HD VideoCam–Kinovea and Hawk–Cortex systems are discussed and summarised.

2.2. Parameters and Experimental Setup
As for HD Video Camera and Kinovea Software parameters and experimental setup, a Sony VideoCam was used to record the drop jump movement by the subject. The camera was placed on a level tripod at the height of 0.060m to allow a good capture of a jump from a 0.040m stage height perpendicular to the centre of the pathway at a distance of 3.568m. This setting ensured that the calibration area covered the lower limb of the subject (field of view). Focus and aperture were adjusted until the system produced clear and sharp 2D images [4], [12]. While for HAWK Cameras and CORTEX Software parameters and experimental setup, the 3-dimensional motion data was recorded using 6 Hawk digital infrared motion capture cameras; with a recording speed of 100 Hz, for a duration of 10 sec. Marker #1 of the calibration L-frame was set at the desired origin of the capture volume. A relationship was established between real-world positions (object-coordinates) and the corresponding image-coordinates from the camera view. The 6 Hawk cameras positioned as illustrated in Figure 2. F-Stop, a number of ratio of the focal length of the lens to the diameter of the aperture [13]. F-stop on a Motion Analysis camera was locked at its optimum value. The camera was fully operated in order to see most of the markers.
2.3. Experimental Protocols
Only one subject was used in this case. A healthy subject without any gait disorders, age 26 years (BMI mean 28.60 ± 1.40) was recruited. Markers were placed on lower limb parts of each subject as shown in Figure 3. The subject was asked to drop from a level platform and jump up at his own natural pace and repeating the movement 5 times. The motion was recorded simultaneously using both HD VideoCam–Kinovea and Hawk–Cortex systems. Results and data collected from the two different motion capture systems were compared.

![Figure 1](image1.png)

**Figure 1.** Illustration of the calibrated plane, camera position and field of view.

![Figure 2](image2.png)

**Figure 2.** The drop jump movement phases.

![Figure 3](image3.png)

**Figure 3.** The markers’ position on a subject.
Figure 4. Heel up position captured by the HD digital camera and displayed in Kinovea.

2.4. Motion Tracking Using Kinovea
Kinovea was used to retrieve all of the outputs (images and videos) from the Sony VideoCam camera. All of the recorded video (video files) was first playbacked to check for any obvious error. Low quality captures were also discarded. For the accepted videos, Kinovea was used to locate and specify all the five main markers (Figure 2), which the process was very similar for tracking markers using the infrared motion capture system. Kinovea kept track of the marker movement for the whole capture (drop jump movement). The example procedure for tracking and the example output at jump is shown in Figure 4.

2.5. Angle Measurement
Figure 4 shows a sample instance (image) from a complete cycle of a drop jump phase. Using Kinovea, three points (markers) were selected in order to measure the relative angle of ankle [14] for any instance. The main marker under consideration was the knee. The other two markers include the two markers adjacent to the knee. From these 3 points (markers), the relative angles of knee were determined. During drop jumping, the relative angles of knee change with respect to the motion. Instead of time, the important parameters determined in this study are angle changes with respect movement phase [15]. The data is stored according to subject and trials. Since the subjects performed 5 trials, in general 5 videos have been analysed and the data is stored for Repeatability Analysis.

2.6. Repeatability Analysis
To measure the repeatability of the system, the protocol is repeated for ten times, where each for time, the walking gait (motion of walking) was recorded. The percentage difference, mean values, standard deviation (S.D) and variance were computed using Eq. (1) to Eq. (4).

\[
\text{Percent Difference} \% = \left( \frac{\text{Value}_1 - \text{Value}_2}{\frac{1}{2} (\text{Value}_1 + \text{Value}_2)} \right) \times 100\% \tag{1}
\]

\[
\text{Mean} (\bar{x}) = \frac{\sum x}{n} \tag{2}
\]
Standard deviation (SD) = \sqrt{\frac{\sum(x - \bar{x})^2}{n}} \tag{3}

Variance (SD^2) = \frac{\sum(x - \bar{x})^2}{n} \tag{4}

3. Results And Discussion

Motion data captured using both systems are tracked and analysed using Cortex and Kinovea. Figure 5 shows the sample of out the capture as could be viewed in the Cortex’s interface. In general it displays the skeleton and walking motion.

![Figure 5. Jump position captured by the 6 Hawk cameras and displayed in Cortex interface.](image)

Figure 4 shows the sample of out the capture as could be viewed in the Kinovea’s interface for the same instance as shown in Figure 5. The relative knee angles comprised of 7 gait phases for the total of 5 trials were measured from the analysed videos; and the data are tabulated in Table 1 and Table 2. The associated graphs (Measured Relative Knee Angle,°) of walking gait cycle of Cortex and Kinovea are as shown in Figure 6 and Figure 7.

| PHASES | HEEL UP | 1ST LANDING | SQUAT | PUSH OFF | JUMP | 2ND SQUAT | 2ND LANDING |
|--------|---------|-------------|-------|----------|------|-----------|-------------|
| TRIAL 1 | 156.99 | 137.08 | 34.60 | 119.81 | 158.93 | 128.73 | 158.16 |
| TRIAL 2 | 155.83 | 132.93 | 39.01 | 114.43 | 170.88 | 113.97 | 155.39 |
| TRIAL 3 | 156.91 | 138.93 | 33.12 | 119.82 | 155.55 | 117.16 | 156.12 |
| TRIAL 4 | 159.12 | 137.50 | 44.11 | 102.08 | 157.54 | 125.65 | 158.79 |
| TRIAL 5 | 158.96 | 133.70 | 40.68 | 111.51 | 160.27 | 123.20 | 160.06 |
| AVERAGE | 157.56 | 136.03 | 38.30 | 113.53 | 160.63 | 121.74 | 157.71 |
| S.D | 1.28 | 2.31 | 4.01 | 6.56 | 5.35 | 5.44 | 1.72 |
| VARIANCE | 1.63 | 5.34 | 16.08 | 43.00 | 28.67 | 29.54 | 2.95 |
Table 2. Basic Statistic - Kinovea (Relative Knee Angle).

| PHASES | HEEL UP | 1ST LANDING | SQUAT | PUSH OFF | JUMP | 2ND SQUAT | 2ND LANDING |
|--------|---------|-------------|-------|----------|------|-----------|-------------|
| TRIAL 1 | 153.12  | 175.41      | 55.74 | 115.82   | 169.88      | 149.19    | 151.72     |
| TRIAL 2 | 157.83  | 171.83      | 55.97 | 113.92   | 169.88      | 131.48    | 147.80     |
| TRIAL 3 | 166.46  | 175.06      | 55.24 | 121.29   | 163.46      | 140.13    | 148.36     |
| TRIAL 4 | 154.51  | 176.37      | 58.79 | 109.08   | 162.98      | 149.14    | 149.48     |
| TRIAL 5 | 154.26  | 176.58      | 55.43 | 118.55   | 169.59      | 146.61    | 157.49     |
| AVERAGE | 157.24  | 175.05      | 56.23 | 115.73   | 167.16      | 143.31    | 150.97     |
| S.D    | 4.87    | 1.71        | 1.30  | 4.16     | 3.22        | 6.78      | 3.53       |
| VARIANCE | 23.72   | 2.91        | 1.69  | 17.29    | 10.37       | 45.92     | 12.44      |

Figure 6. Measured Relative Knee Angle (°) of walking gait cycle (Cortex).

Figure 7. Measured Relative Knee Angle (°) of walking gait cycle (Kinovea).
A graph comparing the measured relative knee angles of drop jump movement using both systems are shown in Figure 8. From the graph, it can be observed that both Kinovea and Cortex display similar pattern of walking gait cycle but show a slight differences in their peak values at each walking gait phases.

On the other hand, the toe off phase peak values shows the most prominent height difference between Kinovea and Cortex that are 56.23° and 38.30°. As the objective of this study for case study 1 is to compare the results of relative ankle angle between Kinovea and Cortex, a tabulated percentage difference, % concerning all the 7 gait phases is shown in Table 3.

From Table 3, four out of seven phases of walking gait proved to have percentage difference less than 10%. The percentage difference should be less than 10% of error. The criterion for repeatability is the variance should be less than 10% [10]. The lowest percentage values is 0.21% occurred at heel up phase, the highest value is 37.93% at squat phase followed by 25.09% at 1st landing phase. These indicate that most of the errors are small and acceptable. Reviewing from the result obtained, the high error values at the 1st landing phases, the squat phase and the 2nd squat phase are might be due to the time taken to pull off the phases are quite shorter than others hence affecting the video recorded. The slow movement of the limb during stance reduces blurriness, which should make it easier to digitize the picture as the speed of capture by HD Camera is lower than Hawk Camera [16], [17]. Based on the graph, the Cortex plotted line of relative knee angle is slightly lower than Kinovea at most of the phases. It is may be contributed by the difference number data obtained where Cortex produces data from 200 frames per second where Kinovea are producing data from 50 frames per second thus the coordinate produced by Cortex are more accurate. For that reason, it is denoted that Cortex produced higher accuracy and precision in analysing motion.

Table 3. Average of Measured Relative Knee Angle (°) of drop jump movement.

| PHASES           | HEEL UP | 1ST LANDING | SQUAT | PUSH OFF | JUMP | 2ND SQUAT | 2ND LANDING |
|------------------|---------|-------------|-------|----------|------|-----------|------------|
| AVERAGE KINOVELA | 157.24  | 175.05      | 56.23 | 115.73   | 167.16| 143.31    | 150.97     |
| AVERAGE CORTEX   | 157.56  | 136.03      | 38.30 | 113.53   | 160.63| 121.74    | 157.71     |
| PERCENTAGE       | 0.21    | 25.09       | 37.93 | 1.92     | 3.98 | 16.27     | 4.37       |


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4. Conclusion
In short, this paper focussed on drop jump movement analysis using Kinovea. The acquired results have shown good implications of using Kinovea as a tool to analyse the drop jump movement. The motion capture-analysis system combining HD VideoCam-Kinovea has been validated [18]. The percentage difference between Kinovea and Cortex, an established motion capture system are relatively small thus concluded Kinovea reliability.

Results also show that in general, the protocol is repeatable and when compared to an established motion capture system, Kinovea is reliable. Therefore, it is found that Kinovea has the potential to be used as a motion capture-analysis tool. The capability of Kinovea is currently being further investigated to confirm it accuracy and repeatability for other applications. It could be concluded that this study has contributed significant and new knowledge about drop jump movement analysis using HD VideoCam-Kinovea system.

For future amends, the subject might undergo pre-scheduled training or time range studies are included to generate more consistent results. In other hand, high speed camera is also suggested to be used to obtain a highly digitized camera. It is recommended further exploration on this topic to be made in order to strengthen these findings.

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![Study Case 1 - Cortex and Kinovea](image)

**Figure 8.** Measured Relative Knee Angle (°) of walking gait cycle (Cortex).
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