Biomechanics Analysis of Combat Sport (Silat) By Using Motion Capture System

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Abstract. 'Silat' is a Malay traditional martial art that is practiced in both amateur and in professional levels. The intensity of the motion spurs the scientific research in biomechanics. The main purpose of this abstract is to present the biomechanics method used in the study of 'silat'. By using the 3D Depth Camera motion capture system, two subjects are to perform 'Jurus Satu' in three repetitions each. One subject is set as the benchmark for the research. The videos are captured and its data is processed using the 3D Depth Camera server system in the form of 16 3D body joint coordinates which then will be transformed into displacement, velocity and acceleration components by using Microsoft excel for data calculation and Matlab software for simulation of the body. The translated data obtained serves as an input to differentiate both subjects' execution of the 'Jurus Satu'. Nine primary movements with the addition of five secondary movements are observed visually frame by frame from the simulation obtained to get the exact frame that the movement takes place. Further analysis involves the differentiation of both subjects' execution by referring to the average mean and standard deviation of joints for each parameter stated. The findings provide useful data for joints kinematic parameters as well as to improve the execution of 'Jurus Satu' and to exhibit the process of learning a movement that is relatively unknown by the use of a motion capture system.

1. Introduction

Biomechanics is an application of mechanical laws to living structure, specifically to human locomotion system [1]. Biomechanics can also be defined as the study of the structure and capacity of biological system of biological by means of the methods [2]. Mechanically, biomechanics is the study of forces acting on the object and what its impact on the movement, shape, size, and structure [3]. It can also be associated with the study of the internal and external forces acting on the human body and the effects produced by action [4]. The role of biomechanics in life is to grasp the concept of mechanical cause and effect relationships that determine the living organism's motion. Sport biomechanics is a use of biomechanics concept that underlines the comprehension of exhibition on athletic event through mechanical modeling, simulation and calculation. In sport, biomechanics helps to analyze and improve an athlete performance as well as reducing the risk of injuries during any sporting events.

   "Silat" or "pencak silat" is the traditional Malay self defense art. "Pencak" or "pentjak" is a self defense training method: it consists of myriads range of regulated body movements directed to training while "silat" is the application of the training method which is the combat [5]. Based on the advancement of the science of biomechanics in sports arena, there are numerous studies and

examinations were completed. Among them is to choose the distinction in kinematics between the individual contenders who have speedy and moderate acceleration in sports [6]. The study of the golf swing kinetics and kinematics (3-dimensional) also was created. From the data acquired will be separated in purpose of interest and the relationship made is firmly associated with four swing types. This study communicates that the golf swing is included with the movement of individuals. Four athletes were taken a gander at in perspective of their swing. It is revealed that the golf swing is encouraged with the movement of individuals and subjected to the assortment of the individual strokes. This study focuses on the significance of wrist in creating velocity the head of the club and the club face orientation [7].

By using Ergonometric for rowing sports, three types of studies have been finished. The first is the examination of the nerve coordination rowing cycle, the second is a study on the attributes of kinematics and dynamics paddle, while the third is to choose the maximum power of muscle limit in the midst of rowing [8]. All things considered, a vast part of the studies related to the kinematic parameters and motor coordinated together to ensure the advancement of control capacities for each sport discipline. Normally, analysis of motions in 'silat' is limited to qualitative evaluations both in amateur and professional levels.

The purpose of this project is to conduct the biomechanics analysis on the "bunga silat'" execution by several person by using Kinect motion capture system. The movement execution will be recorded and numerically analyzed in three session. The analysis is aimed to investigate and evaluate the effect of joint displacement before and after execution, to provide descriptive kinematic factors that correlates with the movement speed and acceleration during motion between experienced and new practitioners.

2. Methodology

2.1. Subject
The study involves a 14-year experienced Seni Silat Gayong practitioner as benchmark and a new practitioner with no martial art experience. The subjects are a 28 years old male and a 25 years old male, 173cm of height and weight 65kg, 165cm of height and weighs 57kg, respectively. Motions of these subjects are compared specifically for selected 'silat' movements. The "bunga silat" that will be used are from the "Seni Silat Gayong Jurus Satu" as shown in Figure 1.
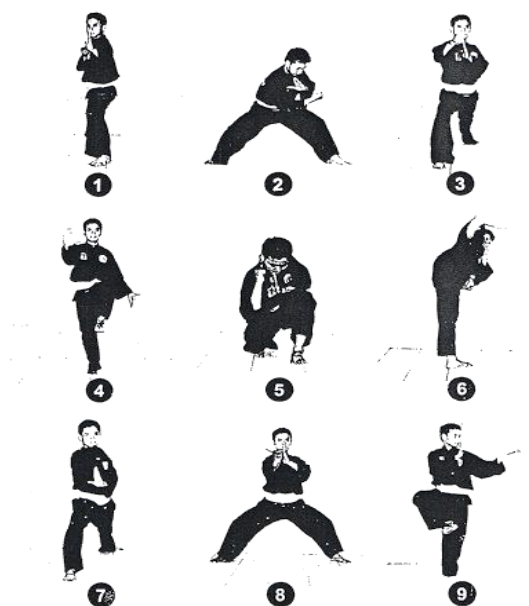

Fig.1 Nine primary steps in "seni silat gayong jurus satu"

There are nine steps in "jurus satu" execution. The first step is to establish "kekuda" or footing stance whereas the left foot at the front and the right foot at the back with right fist clenched to the front. The second step is right arm parry or deflection with the "kekuda" in the middle (both foot is parallel to each other). Third step is right side hit with the right foot advances forward. The fourth step is left foot advances forward with hands in capture like posture. The fifth step is the right elbow parrying downwards with the left foot forward and in crouching position. The sixth step is right foot T-kick to the front. The seventh step is right elbow to the front. The eighth step is the right hand and leg advances forward. The last step is the right leg move the side, open palm right hand and leg rose up to the left knee.

2.2. Motion Capture System Protocol

The Kinect motion capture system is able to capture motion operating at 30 fps with a distance between the sensor and the subject is approximately 1.5m minimum and 5m maximum. The Kinect motion capture system and its sensor are able to detect 20 body joints and the data extracted from the sensor are in the form of .txt file per frame captured. The subjects were asked to repeat the execution of ' Jurus Satu' three times and as well as to teach the inexperienced subject on the 'Jurus Satu' execution. The post-processing data were compiled in a Microsoft spreadsheet after being analyzed by the Kinect server software. The kinematic parameters are calculated using these equations:

$$Displacement(m) = \sqrt{\left(x_f^2 - x_i^2\right) + \left(y_f^2 - y_i^2\right) + \left(z_f^2 - z_i^2\right)} \qquad (1)$$

$$Velocity \left(\frac{m}{s}\right) = \frac{d_f - d_i}{t_f - t_i} \qquad (2)$$

$$Acceleration \left(\frac{m}{s^2}\right) = \frac{v_f - v_i}{t_f - t_i} \qquad (3)$$

The temporal simulation of the 3D coordinates obtained were also reconstructed to cross reference with the video obtained visually.

3. Results and Discussion

Tables 1 shows a subject data retrieved during the execution of 'Jurus Satu' by the first subject. The mean and standard deviation of the displacements of each joints, obtained by the kinematic equations were tabulated based the data obtained throughout the three sets of executions. The relatively small values of standard deviations for all joints of subject number one exhibit the consistency of movements by the 14-year experienced 'silat' practitioner. Throughout the execution of 'Jurus Satu', the subject maintained the same level of consistency hence became the benchmark for the movement by the inexperienced subject number two.

Table 1 Mean and standard deviation for joint displacements per joint of 'Jurus Satu' taken from subject 1 and set 1

	Displacement	
Type of Joint	Mean (m)	Standard deviation
Spine	0.02779473	0.04445259
Head	0.03080678	0.04644384
Shoulder left	0.02671781	0.04434403
Elbow left	0.03476577	0.04152885
Wrist left	0.04541242	0.04412944
Hand left	0.0526389	0.04297978
Shoulder Right	0.03368637	0.04709784
Elbow right	0.04389255	0.04474416
Wrist right	0.05492126	0.04423981
Hand right	0.06407865	0.04580653
Hip left	0.02931514	0.04395879
Knee left	0.02623266	0.04409291
Foot left	0.03579723	0.04819077
Hip right	0.03064572	0.04453037
Knee right	0.03654757	0.04491509
Foot right	0.0564036	0.05640314

Figure 2 shows the joint displacements versus frame number taken from the experienced, first subject. The pattern shows clearly the variations in 'silat' movements that involve both slow motions and fast motions. The huge range of displacement magnitudes also shows that 'silat' has both smooth and aggressive movements.
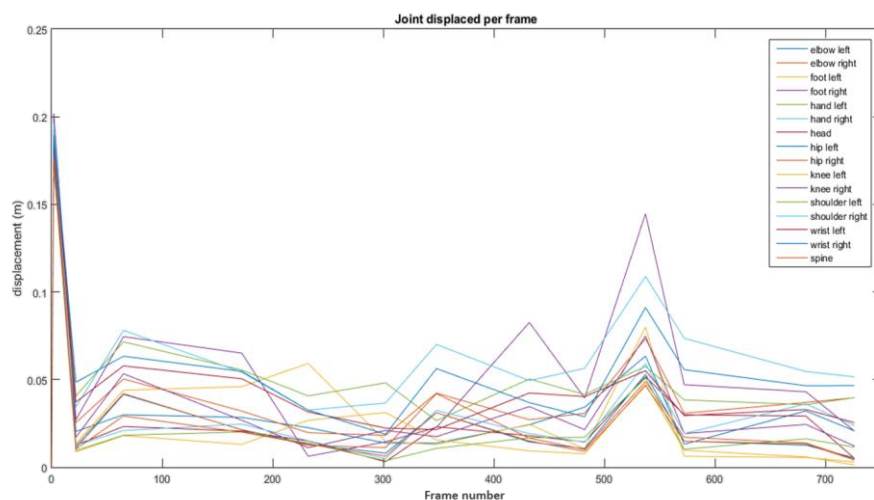
Fig.2 Joint displacement throughout execution of set 1 for subject number one

In order to differentiate the two experienced and inexperienced subjects, a table of average mean values are tabulated and the difference of mean values are calculated. Table 2 shows the average mean values of joint displacement and velocity between the two subjects and its differences:

Table 2 average mean of displacement and velocity between two subjects and its difference

	Average mean of displacement			Average mean of velocity		
	Subject 1	Subject 2	Difference	Subject 1	Subject 2	Difference
Spine	0.0246	0.0253	0.0007	0.2716	-0.0096	-0.2813
Head	0.0264	0.0299	0.0035	0.2935	-0.0075	-0.301
Shoulder left	0.0236	0.0276	0.004	0.2714	-0.0075	-0.279
Elbow left	0.0294	0.0344	0.005	0.2637	-0.0076	-0.2713
Wrist left	0.0379	0.0459	0.008	0.2953	-0.0069	-0.3022
Hand left	0.044	0.0547	0.0107	0.2983	-0.0069	-0.3052
Shoulder right	0.0291	0.0309	0.0018	0.2919	-0.0083	-0.3002
Elbow right	0.038	0.042	0.004	0.294	-0.0082	-0.3022
Wrist right	0.0502	0.0543	0.0041	0.2962	-0.007	-0.3032
Hand right	0.0601	0.0623	0.0021	0.3084	-0.0055	-0.3139
Hip left	0.0254	0.0274	0.002	0.2688	-0.0085	-0.2774
Knee left	0.0224	0.0248	0.0024	0.2674	-0.0073	-0.2747
Foot left	0.0316	0.0322	0.0006	0.2816	-0.0082	-0.2897
Hip right	0.0259	0.0276	0.0016	0.2743	-0.0089	-0.2832
Knee right	0.0313	0.036	0.0047	0.2769	-0.0095	-0.2864
Foot right	0.0488	0.0519	0.0031	0.3083	-0.0083	-0.3166

The mean and standard deviation values were used in this research due to the continuous nature of the data obtained. In addition to the large number of data obtained during capture, the mean and standard deviation helped to generalize and compare the data between two subjects much easier. The table above shows that the closer the difference between two subjects and as the values closing towards zero it can be said that the subject number one movement is relatively identical to subject number two movement. This confirm the fact that both subjects, eventhough had a different level of experience were actually executing the same 'Jurus Satu' if 'Seni Silat Gayong'.

4. Conclusion

Biomechanic analyses of 'silat' as both combat and art sports are proven to be feasible via Kinect-based Motion Capture System. Among others, initial capture of the subjects' motions showed that 'Jurus Satu' has interestingly good variety of slow and fast motions, trivial and aggressive motions throughout the execution. The results also illustrated that both subjects were doing the same 'Jurus Satu' where the mean displacements and accelerations throughout the practice were relatively identical in its patterns. The patterns of displacements and velocities during the course of the executions will never be alike if the subjects were doing dissimilar motions. In order to distinguish the quality of the

motion between the two subjects, further analyses on the smoothness of the motion, timing of each movements withing the jurus, exact positioning of each joints, angles of joints and also the precision of the motions must be taken into considerations. More comprehensive analyses are expected in the future via the same motion capture system used in this work.

Acknowledgment

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