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Hand Speed Measurements in Boxing

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Abstract

Hand speed is particularly important in boxing both for protection against incoming blows and delivering blows. Sixteen amateur boxers (10 male, 6 female) with varying levels of experience from a boxing gym performed 20 jabs and 20 cross punches in air. The movement was recorded with a small wrist mounted accelerometer under the glove. The maximum velocity of each punch was determined from the RMS acceleration profile. The mean values of the jab maximal velocity was higher than the cross maximal velocity for 9 participants. The cross showed some dependence on reach (Spearman's correlation coefficient r = 0.57) and the jab dependence on experience (Spearman's correlation coefficient r = 0.56). The accelerometer technique has some promise for routine assessment of fist speed.

*Keywords:*boxing; hand speed, accelerometer, jab, punch

1. Introduction

Modified rules in boxing which reduce the risk of concussion (known as Box'tag) has resulted the sport regaining popularity (http://boxing.org.au/development/development-programs/boxtag/). Shadow, punch ball and punch bag boxing (known as boxercise) is a very common cross-training exercise for a variety of sports and exercise classes (http://www.boxercise.co.uk/). While the hand velocity is important in offensive action in boxing, the speed of retraction is particularly important for defensive protection of the scoring areas on the body. The measurement of hand speed is usually determined from a multi-camera video system and so is restricted to a finite volume of motion capture. Commonly the force of a punch is determined from an instrument that is hit and the momentum transfer is recorded [1] however, some preliminary studies have been conducted using accelerometers to determine reaction times [2]. The hand can achieve a peak velocity as high as 9 m/s depending on the type of punch - jab, cross, lead hook and reverse hook [3]. While the wrist has maximum velocity, the movement of the upper body contributes to

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the kinematic chain to achieve maximum speed. This is common in many sports where the radius of rotation of the wrist can be much larger than the length of the arm [4, 5].

A powerful punch is a full body movement, driven off the back foot, whilst rotating the trunk of the body on its central axis. It starts with leg extension, followed by hip rotation and then the arm extension (see Fig 1). At the end of a punch, the palm of the hand should face downwards. Not every punch has to be as fast as possible. Sometimes fast lead hand punches are used to break through the opponent's defence in order to strike him with a powerful rear hand punch. With regards to technique the lead hand punch (jab) is different from the rear hand punch (cross). The jab is a fast but weak blow, delivered from the front hand. The elbow stays close to the body for as long as possible. Starting with an initial turn of the front hip, the jab extends from the shoulder. No twisting on either foot is applied. The cross is a more powerful punch, because it has the bodyweight turned into the punch. The punch starts with slightly bent knees, a push off the ball of the rear foot, while simultaneously rotating the hips. The torso follows that movement, with extension of the rear shoulder and arm.

Figure 1: The acceleration sensor is fixed to the inside of the wrist with a velco band. The boxing glove covers the sensor. (a) Sensor position and axis definition, (b) guard position of the boxer (c) full extension of the lead hand for a punch.

2. Experimental

Small wrist-mounted inertial accelerometers can be used in normal training environments and are biomechanically neutral to the athlete. The technology is relatively low cost and wireless. In this research, a micro-electro-mechanical-systems (MEMS) based accelerometer was used to collect wrist acceleration data. The sensor was modified for high accelerations and had a resolution of 200g. For the data collection trials the sensor was attached to the athlete's wrist with a Velcro wristband (see fig 1a). The sensor is an application specific device developed in the SABEL Labs at Griffith University [6]. Fig. 1a defines the axis orientation with respect to the wrist where the x axis is parallel to the lower arm.

A set of (10 male and 6 female) athletes from different experience levels was asked to perform a series of lead hand punches (jab) and rear hand punches (cross) in air. The age range was 18 to 49 years (mean age was 27 years) and experience ranged from 0.5 to 15 years. The mean value of the arm span was 174 $\pm$ 24 cm. All participants were current members of a dedicated boxing gym and were currently in regular training. The trials were conducted in accordance with the Griffith University's ethics research committee (ethics approval number ENG/14/13/HREC).

Before undertaking the measurements on the volunteers, a video analysis was used to verify the phases of the punch from one participant. However, the trials did not routinely use video recordings. Before the trials, the athletes were asked to complete a survey form, which included their boxing experience and recent boxing training. Their physical attributes, such as height, weight and arm span were measured at this time. For the trials the athletes performed about 20 punches to the air with the lead and the rear hand, starting in a stationary regular guard position. All boxers wore a standard weight boxing glove and self-regulated their punches with a pause between each punch.

The acceleration data from punches from different athletes showed that either the x- or the y-axis acceleration component dominates. This is due to differences in technique and style. In addition, all axes contribute some acceleration to the overall punching movement. The most effective way to take all axes into account is to calculate the Root Mean Square (RMS) acceleration a_{rms} of all three axes. There will be an error included in the calculation due to the static gravitational acceleration g which has components present in all three axes. As the punch is a highly accelerated movement, $a_{rms} >> g$, the static g can be ignored as the dynamic acceleration dominates.

For the hand speed investigation, the RMS acceleration data were converted to velocity data using numerical integration in the form of the trapezoidal rule. This method was chosen because it is a sufficient approximation and requires a relatively small computational effort. To verify the results obtained with the accelerometer, a video camera was used to record each punch from every participant. With the help of the video data, the key moments of a punch were located on the punch acceleration profiles.

3. Results

Fig. 2 shows a typical acceleration profile and the corresponding movements identified by video. There is a good match between the key moments for the punch out movement and the positive acceleration curve segment with the x axis acceleration reaching almost +6 g over 0.148 s. There is a momentary pause at maximum extension as the muscles prepare for the retraction movement. The large negative x directed acceleration represents the inertial jolt followed by the retraction sequence. It is clear that the retraction acceleration profile is not simply an inverse of the punch out sequence and video evidence demonstrates that the fist follows a different path. Therefore, the sensor data seems unable to accurately detect and record the retraction of a punch. The end point of retraction cannot be determined accurately as the torso rotates slightly so that the boxer rapidly returns to the protective configuration.

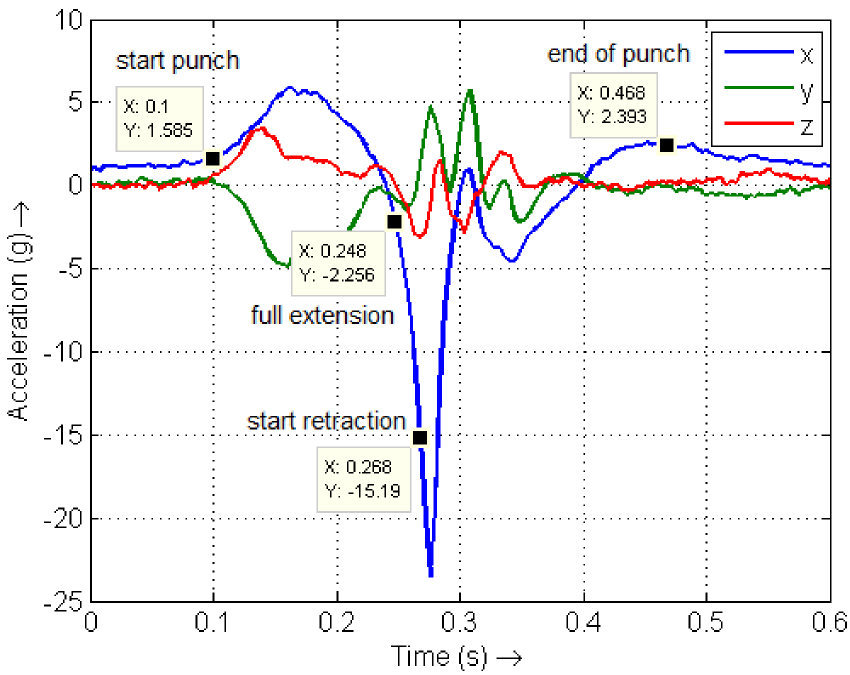

Figure 2: The three axis acceleration profile of a typical jab. The start of the punch, the start of retraction and the end of the punch were identified from the video record.

The mean velocity values for all participants are shown in Table 1. For 56% of the athletes the jab recorded a higher maximum velocity. The average velocities were slightly higher for the male boxers, however this is significantly influenced by the level of experience and recent training.

Table 1: The mean fist velocities for all 16 boxers.

	Jab Out (m/s)	Cross Out (m/s)
Males (n=10)	8.1 ± 1.4	7.7 ± 1.5
Females(n=6)	6.6 ± 1.6	5.7 ± 1.5

A paired, two-tailed student t-test was performed for mean value of the jab and cross velocities for every athlete. For the male athletes, the jab-out and cross-out velocities showed a p-value of $p = 0.37$, and $p = 0.26$ for female athletes. There is no significant difference between the velocities of the different hands. Figure 3 shows the mean values of the maximum recorded velocity for both jab and cross. The horizontal axis has the boxers ranked by experience.

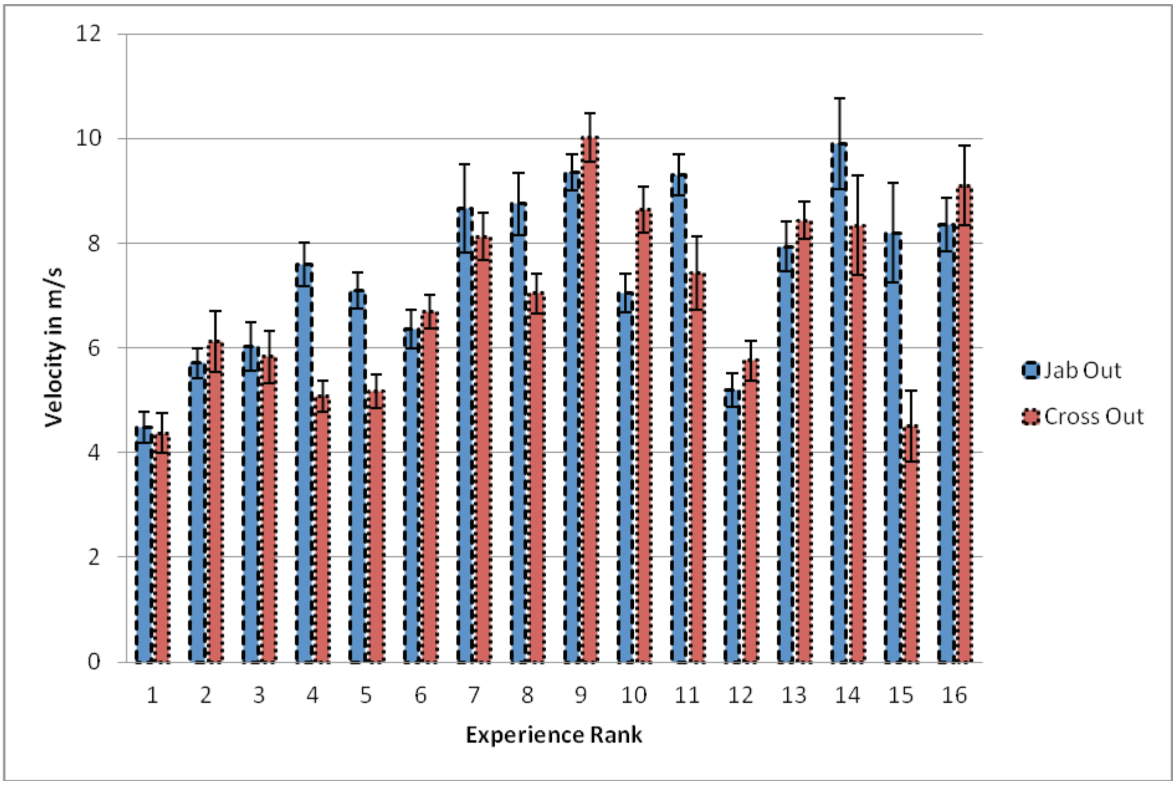

Figure 3: The maximum velocity of the jab and cross for each boxer ranked by experience. The error bars indicate the standard deviation for each set of 20 punches. The velocity values were determined from the integrated RMS acceleration.

The correlation coefficients between experience and velocity for all participants regardless of gender are given in Table 2. Both the Pearson product-moment correlation coefficient and the Spearman's rank correlation coefficients were calculated. The effect of reach on the jab velocity is unremarkable ($r < 0.35$) although slightly stronger for the maximum velocity during the cross (Spearman's correlation coefficient $r = 0.56$). The relationship between the maximal velocity and years of experience (Spearman $r = 0.56$) indicates that there is more than a 50% contribution of experience to the maximum hand velocity irrespective of gender, age and reach. The smaller Pearson coefficient ($r = 0.37$) indicates that the relationship is strongly nonlinear.

Table 2: Spearman's correlation coefficients comparing fist velocity, experience and reach for all boxers.

	Jab Out vs. Experience	Cross Out vs. Experience	Jab Out vs. Reach	Cross Out vs. Reach
Pearson	0.37	0.24	0.32	0.59
Spearman	0.56	0.47	0.33	0.57

4. Conclusions

A total of 16 athletes were asked to perform both jab and cross hand punches. In most cases, jabs had a higher velocity than the cross. A comparison between video and sensor data suggests that it is not possible to determine the full retraction movement with an inertial accelerometer. The retraction movement is thought to start in the inertial jolt that occurs at full extension.

It can be concluded that (Spearman's correlation coefficient of $r_s = 0.56$ for the jab and $r_s = 0.47$ for the cross) the overall hand speed improves with experience regardless of gender or age. Research on aging effects on peak performance suggest that the peak performance is usually achieved between ages 20 and 30. The decline in peak performance can be attributed to physiological aging or a decrease in training extent and intensity [7].

The correlation between reach and velocity suggests that athletes with a greater reach can generate faster punches. This is plausible, because the further the hand travels, the more time there is to accelerate even though the fist may take a longer time to reach its target.

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