AMATEUR BOXER BIOMECHANICS AND PUNCH FORCE

Jacob Mack, Sarah Stojsih, Don Sherman, Nathan Dau, Cynthia Bir

Biomedical Engineering Department, Wayne State University, Detroit, Michigan, USA

The current study investigates the correlation between punch biomechanics and punch force in amateur male boxers (n=39). A Hybrid III 50th percentile male dummy was used to gather punch force values. TrackEye Motion Analysis (TEMA) was used to measure the velocity of each boxer's punch. Lower body force values were determined using the Functional Assessment of Biomechanics (FAB) system. Two types of punches, hooks and straights, were analyzed. It was determined that punch forces correlated more strongly to hand velocity than to lower body forces. Punch force correlated to hand velocity with R^2 values of 0.380 and 0.391 for hook and straight punches, respectively ($p<0.001$). Punch force correlated to lower body forces with R^2 values of 0.103 and 0.099, respectively ($p<0.05$).

KEYWORDS: boxing, biomechanics, punch force.

INTRODUCTION: Boxing is a physically and mentally demanding contact sport. Boxers are required to possess a combination of endurance, strength, stamina, agility, coordination, and speed. Amateur boxing is based on a scoring system where the main objective is to impact the opponent while protecting one's self from impacts. The most desirable outcome is to knock out one's opponent, ensuring a win. In the process boxers sustain numerous punches to the head causing minor or even severe injuries. Dedication and intense training is vital for both amateur and professional boxers to establish effective technique.

Previously published studies have focused on boxing related injuries (Porter and O'Brien 1996; Zazryn *et al.* 2006) and the effects of punch biomechanics on the recipient (Sherman *et al.* 2004; Walilko *et al.* 2005). Few studies have evaluated the dynamics that occur throughout the body prior to impacting the opponent (Whiting *et al.* 1988). This knowledge may provide insight relevant to both boxers and trainers regarding effective technique, improving the athlete's skills, and decreasing the number of injuries.

This study evaluates the biomechanics of a punch and its correlation to punch force. Hand velocity and lower body forces were analyzed. To accomplish this goal, male amateur boxers were instructed to impact a Hybrid III (HIII) 50th percentile male dummy. Boxers threw two types of punches—hook and straight. The punch force was calculated using data gathered by the HIII. Pre-impact hand velocity was measured using TrackEye Motion Analysis (TEMA). Functional Assessment of Biomechanics (FAB), a novel motion analysis system, calculated the force values generated by the lower body.

METHODS: A total of 42 adult male amateur boxers participated in this study, which took place at the 2009 Ringside World Championship Boxing Tournament (Kansas City, MO). From the data collected, a total of 39 boxers provided reliable data for analysis. Boxer mass ranged from 54 kg to 118 kg (mean of 77±15 kg). Boxer height ranged from 1.60 m to 1.98 m (mean of 1.77±0.08 m). Prior to recruiting participants, approval was granted from Wayne State University's Human Investigation Committee.

A HIII 50th percentile male dummy (head, neck, and torso) with a frangible face was used in a manner similar to a previous study (Walilko, *et al*. 2005). The frangible face provides boxers with a compliant impact surface that was used to prevent participant injuries. The headform was attached to the dummy neck, which was mounted to the surrogate upper body to ensure a biofidelic headform motion (Viano and Pellman 2005). The upper body was mounted to an adjustable height metal table. Weights were used on the table top and at the bottom of the table legs to prevent the table from lifting off the ground or sliding across it.

Three Endevco (San Juan Capistrano, CA) 7264-2K accelerometers were mounted mutually orthogonal at the center of gravity of the headform. Three 12000 deg/sec angular rate sensors (DTS, Inc., Seal Beach, CA) were also mounted orthogonally at the center of gravity of the headform. A six-axis upper neck load cell (Denton ATD, Rochester Hills, MI) was utilized to measured neck forces and moments. The data acquisition system for the HIII dummy was TDAS PRO (DTS, Inc., Seal Beach, CA). Data were collected at 10 KHz and processed according to SAE J211-1 (SAE 1995).

A Redlake HG 100K camera (Integrated Design Tools, Inc., Tallahassee, FL) was placed 1.5 m from center of the surrogate head at a lateral plane view. The camera was kept stationary throughout the testing. The surrogate was moved such that the dominant hand of the boxer was always closer to the camera. The video was collected at 500 frames per second.

The FAB system (Biosyn Systems, Surry, British Colombia, Canada) was used to analyze the motion of each boxer's punch. Anthropometric measurements of the participant were entered into FAB for accurate kinematic data. The FAB system consists of 13 wireless sensors, which contain accelerometers, gyroscopes, and magnetometers. The gyroscopes and accelerometers collect data at 100 Hz and the magnetometers collect data at 25 Hz. The sensors use internal processing and filtering to provide data output at 25 Hz. FAB is rated to collect acceleration up to 5 g and angular velocity up to 1200 degrees per second. The FAB is capable of collecting: foot sole pressure and weight; angle and position of each body segment (excluding the phalanges); and velocity and acceleration of body segments. It utilizes this data to calculate force, power, and torque of the cervical, trunk, shoulders, elbows, hips, and knees. For purposes of the current research, the force production of the lower body was examined.

Boxers were instrumented with FAB. Hand wraps and certified gloves were provided for all participants. The height of the HIII dummy was adjusted to the height of the boxer. Boxers were instructed to punch the dummy a total of four times—two times with a hook and two times with a straight—in their normal fashion. In this test, the hook punch was delivered with the dominant hand to the side of the dummy's head. A straight punch, also known as a cross, was delivered with the dominant-hand starting near the jaw of the boxer and travelling straight to the jaw of the recipient. The order of the punches was randomized between boxers. Boxers were instructed to use maximum effort for all four punches. Boxers had a total of 20 seconds to throw all punches. This allowed the boxers adequate time to recover after each punch and prepare for subsequent punches.

The data from the surrogate were processed using Diadem 11.0 (National Instruments, Austin, TX). Sensor offsets were removed from all channels and the data was filtered according to SAE J211-1. The angular rate data were converted to angular acceleration by calculating the derivative. Linear and angular resultant accelerations of the headform were calculated using the resultant of the three axes. The linear acceleration in each axis was multiplied by the mass of the headform (4.54 kg) to calculate force, and added to the upper neck force in the same axis. The resultant force (Punch Force) was calculated by the vector sum of the forces in the three axes.

TrackEye Motion Analysis (Photo-Sonics, Inc., Burbank, CA) 2.6 was used to measure pre-impact hand velocity. Marker tape was placed on the dorsal side of the distal forearm. This tape was used for 2-D video tracking. Each video was calibrated using marker tape of a known width (5.08 cm).

Data from the FAB system were used to calculate a Sum of Lower Body Forces (SLBF) for the dominant side of the body. The force output data from the FAB at the hips, knees, and feet at each data point were added to create the SLBF. The individual force values were added to form the SLBF because the maximum of these forces occurred at the same time value. Statistical analysis was conducted using PASW Statistics 18 software (SPSS, Chicago, IL). The data was divided into two groups by the type of punch (hook and straight). For both groups, correlations were conducted to compare punch force with SLBF and hand velocity. The data was analyzed using a p value of 0.05. If correlations were found to be significant, R^2 values were used to compare the correlations.

RESULTS: For each boxer, two punches were analyzed: the hook and straight with the greater punch force. This method ensured that the analyzed data most accurately represented the maximum effort of each boxer.

Correlations were conducted comparing SLBF and hand velocity to punch force for both punch types. All of the correlations were found to be statistically significant ($p < 0.05$). Figures 1 and 2 show the correlation between punch force and hand velocity for hook and straight punches respectively. R^2 = 0.380 and 0.391, respectively. Figures 3 and 4 show the correlation between punch force and SLBF for hook and straight punches, respectively. R^2 = 0.103 and 0.099, respectively. A summary of the R^2 and p values are contained in Table 1.

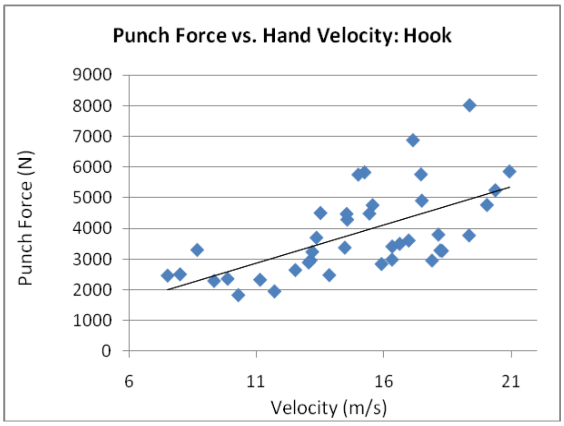

Figure 1. Correlation between punch force and hand velocity for hook punch.

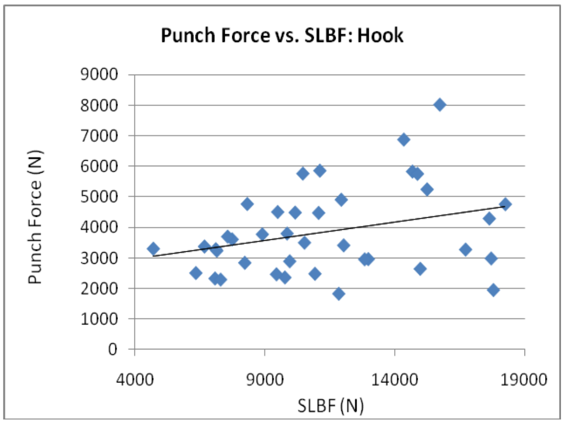

Figure 3. Correlation between punch force and SLBF for hook punch.

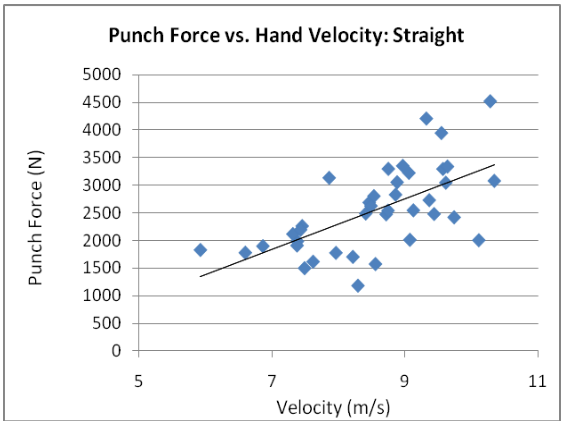

Figure 2. Correlation between punch force and hand velocity for straight punch.

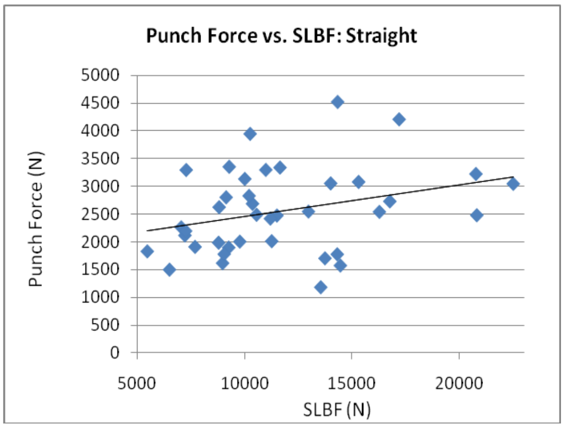

Figure 4. Correlation between punch force and SLBF for straight punch.

Table 1. Correlation Results

Variable	Hook		Straight	
	R^2	P	R^2	P
Hand Velocity	0.380	< 0.001	0.391	< 0.001
SLBF	0.103	0.043	0.099	0.048

DISCUSSION: This study evaluated the correlation between boxers' biomechanics and their punch force for two different punches. It was determined that punch force correlated more closely to hand velocity than to SLBF.

The FAB forces for the upper body were not used in this analysis because the maximum of these forces occurred at or near the time of the punch impact. Data within 80 ms of the event could not be analyzed due to a sensor-skin motion artefact apparent in visual observations and data evaluation. If the accelerometer range and the system sampling rate were increased the system could be greatly improved for impact conditions. Modifications to the sensor attachment systems could limit sensor-skin motion artefact and allow upper body forces to be measured with the FAB.

The SLBF values generated by FAB did not correlate well to punch force. It is unknown if another data collection technique (force plates and multi-camera motion capture system, for example) could provide an improved correlation with punch force. It is possible that there is a limited correlation between lower body forces and punch force regardless of how the measurement is performed. Lower body forces may not be uniformly transferred to upper body forces due to differences in technique.

Although the FAB did not provide the best correlations, its uniqueness was intriguing to prospective test subjects. It proved invaluable for recruiting participants to the study. Many participants joined the study because of their interest in the FAB system.

CONCLUSION: These data indicate that the pre-impact velocity of a boxer's punch provides a more reliable indication of punch force than the pre-impact forces generated by a boxer's lower body as measured by FAB. Punch force correlates to hand velocity with an R^2 value of 0.380 and 0.391 for hook and straight punches, respectively. However, punch force correlates to SLBF with an R^2 value of 0.103 and 0.099, respectively. Boxers and boxing trainers may benefit from an understanding of these correlations to improve performance.

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