Design and Development of a Device for Performance Analysis and Injury Prevention in Boxing

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ABSTRACT

Aim: The present work focuses on the design and development of a device for performance analysis and injury prevention in boxing.

Materials and methods: A boxing glove embedded with tri-axial accelerometers and 3-axis gyroscope connected through Aurdino board is developed. In addition, a punch force analysis target system embedded with pressure sensors has also been developed.

Results: Boxing performance parameters such as reaction time, punch force, fist’s angular rotation, acceleration, and velocity in 3D space are analyzed for nine college athletes. Boxing parameters such as acceleration, fist rotation, and the force generated involved in hook punch vs straight punch is analyzed. Moreover, the effect of shorter and longer reach length on boxing performance has also been observed. Greater punching power is observed during hook punch. Increase in fist rotation during hook punch resulted in greater punching power. Correlations are observed between punching powers and reach length and between acceleration and punching force.

Conclusion: The key feature of this device is its low cost for Indian boxing and other developing nations’ affordability. Ultimately, this device can also be useful in athlete selection, objective performance assessment, and improvement in boxing skills.

Clinical significance: This information will help medical practitioners to understand the mechanics of injury and help the athletes to prevent and manage injuries resulting from these motions.

Keywords: Acceleration, Boxing, Device design, Performance analysis, Punch force.

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INTRODUCTION

The combat sports, such as boxing, karate, kickboxing, etc., expose athletes to severe impacts and make them susceptible to injury.¹ Head and neck are two commonly injured body regions along with increased rate of injuries related to concussions.² However, the exact mechanism of injury is still not known completely. One of the reasons for this incomplete information on the injury mechanism is the nonavailability of kinematics and kinetics related to the movement causing the injury. For simplicity, an example of boxing is taken in the rest of the article. Boxing is an exciting combat sport. The successful performance in boxing depends on many interrelated factors, such as motoric ability, boxing technique, tactics, and physiological capacity.³ Coaches and boxers judge performances based on real-time visual inspection and past experiences. Accordingly, boxing technique is improvised to improve the athlete’s performance. Nevertheless, this does not provide a full proof performance analysis of the subject. The subjective observations may sometimes be insufficient to be implemented for performance improvement. Boxing mainly involves punches that typically damage the opponent and scores the point. The movement of arm, trunk, leg, etc. decide the effective punching.⁴ Kinematic and kinetic analysis provide a way to analyze these parameters and may be useful in concluding the reason behind successful or unsuccessful performance during boxing. Substantial scientific research has been conducted to understand the biomechanics of boxing. Punch analysis systems such as punch bag dynamometers have been developed over the years to analyze the punch forces. Dynamometers act as a tool to assess the weakness and the strength of boxers and proposed water-filled punch bags to measure the punch forces as a function of rise in fluid pressure.⁵,⁶ In addition to punch force analysis, kinematic parameters such as accelerations has also been analyzed simultaneously. A strong correlation between punch force and accelerations is observed. A boxing simulator was developed to estimate punch force, count, frequency, and impulse characteristics.⁷ The cost of this device was quite low and considered as a cheap aid training device. A good-quality device must give accurate measurement, must be reliable, and good in resolution so that it can differentiate the performance of the sports persons. A triaxial force dynamometer was developed to estimate the punching force induced due to straight punches.⁸ This device has been able to discriminate the elite, intermediate, and novice boxing performances; analyzed the straight punch biomechanics in Olympic boxers; and concluded that they deliver the punch with a high impact velocity and energy transfer.⁹ The ballistic pendulum-based system to quantifies the maximum punch force; however, these systems do not allow the quantification of forces for series of punches, as the pendulum has to returned

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back to its original position before the next punch. Attached accelerometer with punching bags developed a boxing glove with accelerometer; nevertheless, this device does not measured the impact force, since the hand effective mass may vary with the athletes.

In addition to punch force measurement systems, kinematic analysis systems are also developed to understand acceleration, velocity, and gyroscopic moment associated with punch. It is noticed that these parameters are key components in deciding the boxing performance. A gyrosensor-based device is presented to differentiate the four different types of punches, and a device was developed for 3D kinetics and kinematics of maximal effort punches. There are studies and devices that either focused on punch force analysis or attempted to assess the kinematic parameters. Nevertheless, kinematic parameters also influence the punch force. This aspect is investigated in very few studies. Accordingly, the present work aims to design and develop a device for analysis of kinematic parameters, such as velocity, acceleration, and angular rotation, during boxing and in extended applications for various combat sports, such as karate. This work also develops a punch force analysis system to measure the punching force. Ultimately, a correlation between kinematic parameters and the punch force has been studied for different punch types to evaluate the punching performance. The findings will provide a novel descriptive data for coaches and boxers for performance analysis during boxing. In addition, the system will provide the medical practitioners with the kinematic and kinetic data during practice and help them to understand the mechanism of the injury. The device will provide a low-cost technique for performance analysis for combat sports and help in optimal management of the resulting injuries.

**Materials and Methods**

**Design**

A set of sensors are used to develop the kinematic parameter analysis. A triaxial accelerometer is mounted on the boxing glove. This accelerometer provides the acceleration in all the three directions associated with the incident punch. In addition to accelerometer, a gyroscopic sensor has also been attached on the boxing glove which allows the measurement of the boxer fist’s rotation during the punch. Thus, the accelerometer calculates the accelerations in x, y, and z directions, whereas gyroscopic sensor mounted on boxing glove provides the information about the fist rotation/angular velocity about the three Cartesian axes. Both of these sensors are connected to Arduino board for data acquisition using a customized computer code (Fig. 1).

A punching pad is developed using the square pressure sensor with resolution of 0 to 25 kg. Two circular wooden pad of 20 cm diameter and mass 350 g is packed with foam on the outside periphery to absorb shock. All the four square pressure sensors are placed at the center of the circle with a diameter of 5 cm. This pad is calibrated with known weights. Force sensors are connected to Arduino to extract the real-time data (Fig. 1).

**Experimentation**

Kinematic parameters, such as acceleration and rotation, and punch force analysis are assessed for the following punch type:

- Hook vs straight punch
- Core form vs straight punch
- Long vs short reach

Nine college male athletes volunteered to punch the device, and the data have been recorded for the same.
Results and Discussion

Hook vs Straight Punch

Figure 2(A) indicates that acceleration pattern in z-direction (direction of attack) was significantly high in case of hook punch when compared to straight punch. Punch force achieved in case of hook punch was higher when compared to straight punches [Fig. 2(B)]. A clear difference between the angular velocities can also be observed for hook punch (higher) and straight punch (less) [Fig. 2(C)]. This information can be utilized to understand the mechanism of injury in the boxer executing a hook or straight punch. The kinematic and kinetic information will help us to understand the location of the different joints and the magnitude of forces involved, which in turn help us to understand the joint loading at respective joints. This detailed joint loading information will help us to understand the mechanism of injury.

Core Form vs Straight Punch

Acceleration achieved however lies within the same range for core form punch and straight punch. Punch force achieved in case of core punch was only slightly higher when compared to straight punches (Fig. 3). The results indicate the similarity between acceleration profiles for both the punch types; however, the kinematics of various joints might be different. This added information will provide more information on the kinematics at various joints during the execution of these punch types. Punch force and acceleration was found greater for the boxer who has greater reach length (Fig. 4).

The present work studies the link between the biomechanics of boxers in terms of kinematic parameters, such as acceleration, reaction time, and angular rotation. The strikes of nine volunteers college-level athletes are analyzed. The average contact time was found 25 milliseconds which is deduced from punch force-time curves. The peak forces ranged from 90 N to 220 N. In our view, this difference in peak force is primarily due to the level of novice athletes. The linear acceleration during the punch was found between 18 and 35 m/s². The reaction time that the experiment obtained ranged from 190 to 370 milliseconds.

The test sequence or striking frequency ranged from 1.75 to 4.0 punches. The connection between span length and punch speed shows that athletes with a larger reach length can attain quicker punches. This is sensible because the further the hand travels the longer it needs to accelerate. Accordingly, the punch force was evaluated, and a greater punching power is observed for the boxer who has greater reach length.

Conclusion

A new device has been developed for kinematic parameter analysis and punch force analysis to evaluate the performance and
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mechanics involved in the sport of boxing. The device provides a real-time measurement of acceleration, fist rotation velocity, contact time, and the punch force during the boxing. The further analysis of these parameters can provide information on the causes of injury at various skill level combat sports athletes. This will not only help the medical practitioners to understand the cause of injury but also help them to understand the mechanism of the injury. This will lead to improvement in the rehabilitation of the injured athletes by providing optimally selected rehabilitation protocols informed by the information available to the service providers. These parameters may also be useful in determining the overall performance of the athlete. The device can also be helpful in novice boxer training. Based on such analysis, coaches can provide informed recommendations to improve the overall performance of the boxers. The cost of this device is quite low and can be useful for boxing coaches and athletes in India and other developing countries. The future work involves the testing of the device on the professional athletes along with the follow-up for the injury if any to understand the mechanism of injury and then optimizing the rehabilitation process.

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