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# Evaluating the Effectiveness of Boxing Headguards in Mitigating Head Impact Accelerations That Cause Concussions by Using a Dynamic Head Model

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## ABSTRACT

Boxing headguards offer a form of head protection to minimize the risk of head injuries for athletes. Existing literature, however, lacks information regarding the protective capabilities of boxing headguards. This study examined the protective capacity of three boxing headguards in minimizing impact accelerations to the head that cause concussions using a dynamic head model. The researchers implemented thermoplastic polyurethane (TPU) inserts in one of the headguards and conducted static tests to examine the material properties of the headguards. The researchers also conducted dynamic testing using a surrogate headform to compare the three boxing headguards in minimizing the risk of concussion for measures of linear and rotational accelerations across different head impact locations. The results of this study revealed that TPU significantly mitigated the magnitude of linear and rotational accelerations when compared to the other headguards. This study offers an avenue to improve athlete safety.

## KEYWORDS

Angular Acceleration, Boxing Headguard, Concussions, Headgear, Impact Testing, Linear Acceleration, Static Testing, Thermoplastic Polyurethane

## INTRODUCTION

Giza and Hovda (2001) described a concussion as "any transient neurologic dysfunction resulting from a biomechanical force" (p.1). More specifically, a concussion is a "clinical syndrome of biomechanically induced alteration of brain function typically affecting memory and orientation, which may involve a loss of consciousness" (Giza et al., 2013, p. 2250). Concussions or mild traumatic brain injuries (mTBI) that occur while playing the sport of boxing, for example, cause short and long-term traumatic neurologic impairments on athletes and represent one of the major occurrences of head injuries for athletes at the amateur and professional levels.

In the sport of boxing, athletes scores points by landing finishing shots on their opponents with the intention to disable them (World Boxing Association, 2012). Consequently, the magnitude of the

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acceleration induced to the athlete's head plays a significant role in the risk of concussions, brain injuries, and the severity of the damage (Rowson et al., 2016).

Boxing headguards provide a mean to reduce the risk of concussion on athletes by mitigating the magnitude of linear accelerations induced to the athlete's head while playing the sport (McIntosh & Patton, 2015). There is a need to understand, however, the behaviour of boxing headguard materials in minimizing not only the magnitude of linear impact accelerations induced to the head but also rotational accelerations caused by oblique impacts to the head. Oblique impacts generate shear forces and consequently rotational accelerations producing a "jarring" effect to the head, which deforms the brain tissue and causes a concussion (Meaney & Smith, 2011). Furthermore, there is a lack of information in the literature regarding the effect of linear and rotational accelerations causing concussions on athletes in the sport of boxing.

Based on the need to further investigate the protective capabilities of boxing headguards, this study examined the static and dynamic properties of two commercial boxing headguards (Adidas→ and Century→ Drive) and a modified TPU liner insert model implemented into a Century→ Drive headguard. The TPU material has become attractive in helmet design for its elastic, high tensile, and flexural strength properties (Lin et al., 2017). The first objective of this study was to determine the energy absorption capacity of boxing headguard materials across different locations during static testing. The second objective was to examine the combined effect of headguard type and impact location on measures of linear and rotational accelerations during simulated dynamic impacts.

## BACKGROUND

Meaney et al. (1995) stated that during a head impact, the combination of linear and rotational accelerations causes the brain to accelerate and decelerate inside the skull, which may result in a concussion. Linear accelerations produced during a head impact cause the brain to elongate and deform by putting a stretch on various structures of the brain including neurons, glial cells, and blood vessels. This elongation and deformation of the brain alters membrane permeability and decreases blood flow (Mckee & Daneshvar, 2015), which in turn can lead to a variety of symptoms affecting the physical and cognitive performance of the athlete (Giza & Hovda, 2001). Symptoms of concussion may include confusion, disorientation, unsteadiness, dizziness, headache, and visual disturbances (Giza & Hovda, 2001).

Rotational accelerations, on the other hand, cause shear brain injury. This type of brain injury disrupts the white matter and its connections in the brain, disturbing the axons of the neurons, which may result in a concussion (Rush, 2011). Indeed, several studies have suggested that shear brain deformation resulting from rotational acceleration represents the predominant injury mechanism in concussions (Adams et al., 1982; Gennarelli et al., 1982; Meaney & Smith, 2011; Unterharnscheidt & Higgins, 1969). More specifically, the disturbances of the white matter induced by shear forces result in cell death, causing symptoms related to slow cognitive speed, and decreased motor coordination on the affected individuals (Rush, 2011). Other symptoms related to rotational accelerations may include loss of consciousness due to impact "rotational forces at the junction of the midbrain in the thalamus," which is the region of the brain responsible for all input for motor and sensory information (Mullally, 2017, p. 886).

The location of the impact on the head also plays a role in the cause of the brain injury and the occurrence of concussions (Meaney & Smith, 2011). Impacts to the side, front, or back of the head show significantly different linear and rotational accelerations induced to the brain and consequently, cause different levels of impairment on the athlete (Gennarelli et al., 1982; Meaney & Smith, 2011). Gennarelli et al. (1987), for example, found that impact accelerations induced to the side of the head produced more axonal damage in the brainstem and more frequently a concussion than other head impact locations (Gennarelli et al., 1987). Liao, Lynall, and Mihalik (2016) found that concussed athletes experienced more impacts to the side of the head than non-concussed athletes did. Kerr et al. (2014), on the other hand, found that concussions occurred more frequently from impacts at the front than the side of the head.