

# THE EFFECTS OF IMPACT AVOIDANCE TECHNIQUES ON HEAD INJURY RISK

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The purpose of this study was to determine the influence of impact deflection and neck compliance on peak linear and peak angular accelerations during a front impact to a Hybrid III head using a pneumatic linear impactor. Impact deflection was done by translating the headform laterally and showed to be effective at reducing linear and angular accelerations as well as GSI. Neck compliance was altered using one Hybrid III 50th percentile neck and two modified Hybrid III necks. A less compliant neck increased linear acceleration but decreased angular acceleration. When compared to estimated injury thresholds, the results demonstrated that an increase in lateral translation or a decrease in neck compliance resulted in a significant decrease in the risk of head injury as reflected by peak linear and angular accelerations.

**KEY WORDS:** sports, biomechanics, mTBI, linear acceleration, angular acceleration.

**INTRODUCTION:** Unanticipated impacts to the head occurring in a sporting event can have particularly devastating consequences. In fact, it is common for athletes to suffer from mild traumatic brain injuries (mTBI) following such collisions (Pellman et al., 2004). Athletes unaware of an imminent collision are unable to properly execute protective techniques placing them in a vulnerable position. Conversely, athletes aware of an impending collision prepare themselves to avoid, deflect or resist forces generated by an impact.

**Impact Deflection:** Athletes have the capacity to diminish head injury risk by deflecting a portion of the force resulting from an impact. When two bodies collide, the force transmitted is in part related to the angle of transmitted force vector during contact. As a result, the impacts closer to the center of gravity of the head are more severe. Athletes anticipating the hit are able to either avoid the hit altogether or deflect the blow by adjusting their head position; thus, reduce the force transmitted to their head.

**Neck Compliance:** When forces are transferred from one body to another, the resulting accelerations can be reduced by increasing the effective mass of the receiving body (Aubry et al., 2002). Athletes unaware of an impending collision are not prepared to resist the shock; thus, the force transmitted is resisted mostly by the mass of the head. In contrast, athletes anticipating the hit have sufficient time to contract their neck muscles, allowing them to resist the impact with the mass of their head, neck and upper torso. Assuming that the impact forces sustained by both players are equal, the lower impact mass of the unaware player will result in higher head peak acceleration of the head post-impact (Viano & Pellman, 2005). Linear and rotational acceleration of the head are common predictors of mTBI; hence, when they increase, there is an associated increase in risk of injury. Thus, it was proposed in this study that a noncompliant neck will mitigate head injuries.

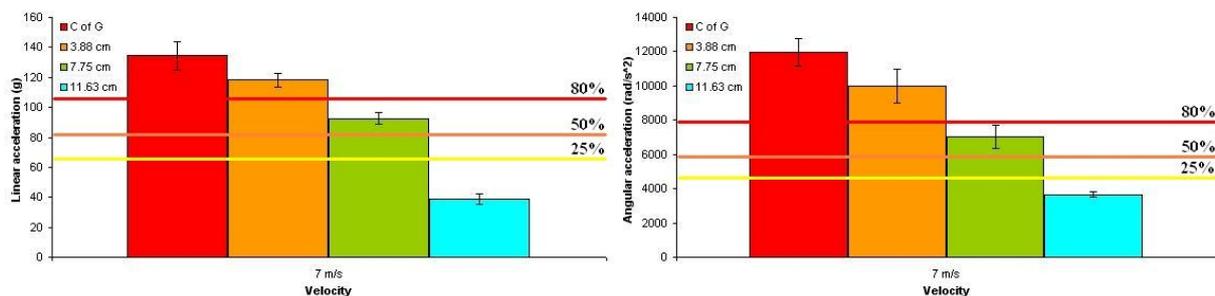
**METHODS: Data Collection:** The effect of impact deflection was evaluated by impacting a 50th percentile Hybrid III head with a linear impactor. The headform was hit nine times per impact location at the following two velocities: 5 and 7 m/s, which are comparable to impact velocities seen in football (Pellman et al., 2003). Impact locations were chosen using the width of the headform as a reference (15.5 cm) and were the following: through the center of gravity; 3.875 cm lateral displacement; 7.75 cm lateral displacement; and 11.625 cm lateral displacement. All impacts were located  $30 \pm 1$  mm above the reference plane of the headform.

The effect of neck compliance was evaluated by impacting a 50th percentile Hybrid III head attached to three different Hybrid III necks with a linear impactor. The impacts were located  $30 \pm 1$  mm above the intersection of the longitudinal plane and the reference plane of the

headform (centre of gravity). Three sets of three impacts were performed for each neck at the following velocities: 5 m/s, 7 m/s and 9 m/s.

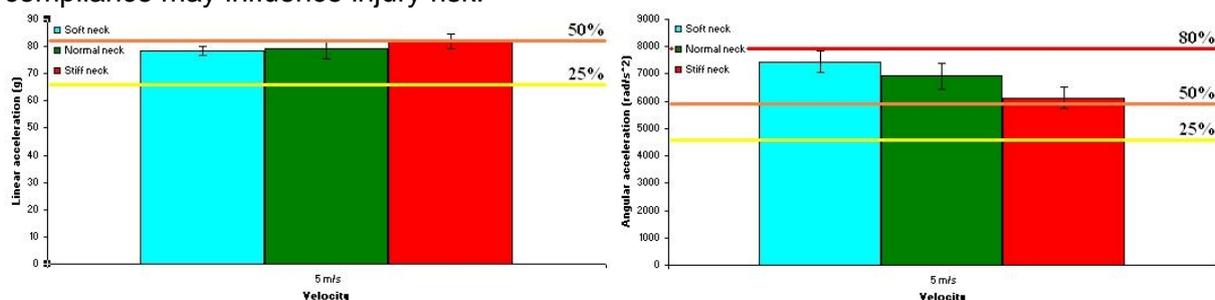
**Data Analysis:** To determine the effects of impact location, an analysis of covariance (ANCOVA) was performed on each dependant variable, using velocity as a covariate. Further analysis was performed at each velocity (5 m/s and 7 m/s) using simple one-way analysis of variance (ANOVA), followed by a post hoc test using Tukey's method. The same process was performed to determine the effects of neck compliance on each dependant variable. All statistical analysis will be performed using SPSS software (SPSS Inc., Chicago IL, USA).

**RESULTS: Impact Deflection:** The results showed that an increase in lateral displacement caused a decrease in peak linear acceleration and peak angular acceleration as demonstrated on Figure 1. This signifies that impact deflection can successfully reduce injury risk.



**Figure 1: Peak linear acceleration and peak angular acceleration measured during front impacts through the centre of gravity plus three displacements at 7 m/s. The lines represent a 25%, 50% and 80% probability of sustaining an mTBI.**

**Neck Compliance:** The results showed that under the conditions studied in this research an increase in neck compliance caused a decrease in peak linear acceleration but an increase in peak angular acceleration as demonstrated on Figure 2. This signifies that neck compliance may influence injury risk.



**Figure 2: Peak linear acceleration and peak angular acceleration measured during a direct impact to the front of a Hybrid III head attached to necks with three different compliances at 5 m/s. The lines represent a 50% and 80% probability of sustaining an mTBI.**

**DISCUSSION: Impact Deflection:** As expected, peak linear acceleration and peak angular acceleration decreased when the impacts got further from the centre of gravity. This was expected because these types of collisions do not engage the headform fully, meaning that the total momentum from the impactor was not fully transferred to the head.

Figure 1 shows a comparison of peak linear and angular acceleration using estimated brain injury thresholds reported by Zhang and his colleagues (Zhang, Yang & King, 2004). At 7

m/s, impacts through the centre of gravity and with a 3.875 cm displacement were above the 80% risk of injury.

Impacts with a 7.75 cm and an 11.625 cm lateral displacement were slightly above 50% and below 25%, respectively. This means that even a small head movement away from the centre of impact can effectively reduce the risk of sustaining a head injury.

**Neck Compliance:** Contrary to what has been previously reported in the literature (Pellman et al., 2008; Johnston et al., 2001), a stronger, less compliant neck did not reduce peak linear acceleration of the head. It was expected that the higher effective mass generated by a less compliant neck would help absorb the impact, yet these results presented a negative relationship between neck compliance and linear acceleration. However, a positive relationship was found between neck compliance and angular acceleration. In other words, more compliance will lead to higher angular acceleration, while less compliance will produce more linear acceleration. This implies that forces acting on the head upon contact need to somehow be dispersed as linear and angular acceleration, with the neck compliance determining its distribution.

Figure 2 shows a comparison of peak linear and angular acceleration as well as thresholds published by Zhang and colleagues (2004). It shows that peak linear accelerations measured when using the stiffer neck were associated with a probability of 50% of sustaining an mTBI at 5 m/s. This would suggest that players with tense neck muscles prior to an impact would be at a higher risk of sustaining a head injury than those who have not contracted their muscles. Conversely, peak angular accelerations measured when using the softer neck were near an 80% probability of sustaining an mTBI. Even though a compliant neck produces lower linear accelerations, it can produce high angular accelerations that may put a player at a higher risk of sustaining a head injury.

**Injury Prevention:** The data presented in this study provides a better understanding of the relationship between risk of brain injury and strategies for injury prevention. Training methods (strength and training), administrative intervention (rules and regulations) and protective equipment design (helmet) all benefit from a better understanding of the mechanism of injury. These results support training neck muscles to improve strength in order to reduce the risk of mTBI (Bailes & Cantu, 2001; Barthe et al., 2001). Impact deflection or avoidance should be considered as a strategy to prevent brain injuries resulting from head impacts. Skill training contributes to better ball tracking, helps avoid contact and increases the chance of impact deflection, thus reduces the risk of mTBI (McIntosh & McCrory, 2005).

Awareness of an impending collision is crucial because of the time required by the neck muscles to achieve full contraction, between 130 and 263 ms (Stemper et al., 2005). This indicates that athletes initiating neck muscle contraction as a result of an impact cannot protect themselves appropriately. Thus, efforts should be made to protect them through the establishment of rules and regulations, which have already shown to be effective at reducing injuries (Cantu & Mueller, 2003).

**CONCLUSION:** The objective of this paper was to determine the influence of impact deflection and neck compliance on head injury risk. As expected, an increase in lateral displacement caused a reduction in peak linear and angular accelerations, meaning that any head motion away from the impacting mass will reduce risk of head injury. Furthermore, a reduction in neck compliance caused a decrease in peak angular acceleration; however, it also resulted in an increase in peak linear acceleration. Considering that the peak angular accelerations were much higher, it is fair to say that a decrease in neck compliance will reduce risk of head injury. Hence, players should be encouraged to use both strategies as they showed effective at reducing the risk of suffering from a concussive injury.

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