THE RELATIONSHIP BETWEEN NECK STRENGTH AND HEAD ACCELERATIONS IN A RUGBY TACKLE

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The purpose of this study was to investigate the relationship between neck strength and head accelerations during a rugby tackle. Ten elite rugby players had their neck strength assessed and head accelerations tracked using a three dimensional motion analysis system during a rugby tackle. Higher levels of strength were related to lower head accelerations. Significant relationships were found between coronal plane accelerations and flexion and extension strength. The findings support those in the literature suggesting that increasing neck strength is a potential target to reduce sport concussions.

KEY WORDS: concussion, injury, neck strength.

INTRODUCTION: Over recent years there has been an increase in interest in understanding and moving towards prevention of concussion in sports. This interest arises from both the management of the initial incident and return to play, but also with regards to the long term effects of concussion, in particular repeated concussions (McCrory et al., 2013; Pearce et al., 2014). A recent systematic review has estimated the incidence of concussion in rugby union to be 4.73 per 1000 player match hours (Gardner, Iverson, Williams, Baker, & Stanwell, 2014).

Much of the work undertaken to identify the aetiology of the injury has focused on the assessment of head accelerations in game during American Football using in helmet accelerometers (Broglio, Martini, Kasper, Eckner, & Kutcher, 2013; Young, Rowson, & Duma, 2014). We are only aware of one study that has investigated head accelerations in a controlled contact situation (Hasegawa et al., 2014). Recently it has been identified that increased neck strength may reduce concussion risk in high school sports (Collins et al., 2014). The aim of this study was to investigate the relationship between neck strength parameters and head accelerations during a rugby tackle.

METHODS: Ten elite Rugby Union players (height 1.89 (SD 0.07) meters, weight 98 (SD 10.5) kilograms) were recruited to undertake this study. Four players were current professional players with a Super 15 team with the remainder being drawn from the wider training squad and academy. All procedures were approved by the Murdoch University Human Research Ethics Committee.

All testing was performed in the Performance Laboratory at Murdoch University. Peak isometric neck strength was assessed using a load cell (HBM 2007 S40 100kg) connected to the player using a head harness made of seatbelt webbing and velcro. All measurements were done while the participant was lying and strapped to a bench to minimise movement.

The tackle situation was designed to mimic a “one off the ruck” hit up. The attacking player was located four meters in front of two opposing defenders holding a regulation rugby ball. On the command to start, the attacking player moved forward to be met by one of the two defenders. The attacker was instructed to run to the centre of the two defenders and attempt to drive past the defenders. The defender used their inside shoulder to attempt to drive the attacker back and to the side where large mats were located. For instance the defender on the attacker’s right would drive the attacker to the left. Prior to the start of the trial the attacker was not aware of which defender would make the tackle, and initially both defenders were instructed to move forward, however only one would make contact. This was done to increase the similarity of the tackle scenario to the game. See Appendix 1.

The following markers were placed on the attacking players head, torso and pelvis: left and right forehead, left and right behind head, C7, sternal notch, left and right acromioclavicular joints, left and right anterior and posterior superior iliac spines. An additional two makers were located inferiorly to the left and right of C7, with a further maker located superior to and mid-way between the left and right posterior superior iliac spines. These markers were used to enable tracking of the torso and pelvis segments during the dynamic trials, as makers on the anterior body were occluded at contact. All motion was captured using a 12 camera (Oqus 3+, Qualysis, Gothenburg, Sweden) with 11 cameras capturing marker data 200Hz and with one capturing high speed video at 100Hz to identify contact. Data was recorded in Qualysis Track Manager (Qualysis, Gothenburg, Sweden).

Data was transferred to Visual3D where head, torso and pelvis segments were created based on a static posture. Head angular acceleration relative to both the lab and torso were calculated as well as the linear acceleration of both the torso and head along the anterior-posterior and medial lateral axes of the relevant segment. The peak values for linear accelerations following contact identified on video was used for further analysis. For flexion/extension and lateral flexion angular accelerations, two peaks were identified, one positive and one negative. Both peaks were identified and the range between two peaks also calculated.

Subject means for all data were calculated. Following this Pearson correlations were identified between neck strength data with head linear and angular accelerations using SPSS Version 21. P was set at 0.05.

RESULTS: Subject means for all data is presented in Table 1. In general, an increase in neck strength variables were correlated with a reduction in head accelerations (Table 2). Increased neck flexion strength was significantly correlated to a reduction in the range of lateral flexion angular acceleration (r = -0.671) and peak medial/lateral acceleration (r = -0.911). A decrease in peak medial/lateral accelerations were also significantly related to an increase in neck extensor strength (r = -0.843) and right lateral flexion strength (r = -0.754). Finally an increase in right lateral flexion strength was significantly correlated to a decrease in peak lateral flexion angular velocity away from the direction of travel (0.722). A number of other correlations approached significance.

DISCUSSION: All correlations indicated relationships in the expected direction, specifically an increase in neck muscular strength is related to a decrease in head accelerations. Only a few variables indicated significant relationships, despite a number showing moderate relationships around r = 0.6. It would appear that currently the study is underpowered and we are currently seeking to increase our participant numbers. The findings of the current study support previous work indicating that increased strength can reduce concussion risk (Collins et al., 2014). It also supports controlled laboratory based studies that have found that there is a relationship between neck strength and head accelerations in all three planes during controlled head perturbations (Eckner, Oh, Joshi, Richardson, & Ashton-Miller, 2014).

What is intersting in this study is the fact that the strongest correlations were found between neck flexion and extension strength and medial/lateral angular and linear accelerations. This may be indicative of the fact that muscles utilised in lateral flexion unilaterally are utilised bilatteraly duing flexion and extension. Thefore if participants were to preactivate their flexors and extensors in preperation for contact they may be protecting from movement more than a reactive lateral activation. Increase pre-activation has been shown to reduce head acclerations in a controlled experimental situation (Eckner et al., 2014). Instuctions to clench

Table 1 Mean and standard deviation of all measured variables

Variable	Mean (Standard Deviation)
Flexion Strength (N)	293.8 (65.1)
Extension Strength (N)	222.0 (49.3)
Left Lateral Flexion Strength (N)	221.9 (38.8)
Right Lateral Flexion Strength (N)	216.6 (43.2)
Peak Positive Flexion/Extension ω (rad/s^2)	89.8 (48.2)
Peak Negative Flexion/Extension ω (rad/s^2)	-73.7 (39.1)
Peak Lateral Flexion ω in direction of travel (rad/s^2)	55.0 (18.9)
Peak Lateral Flexion ω away from the direction of travel (rad/s^2)	-51.5 (18.9)
Flexion/Extension ω range (rad/s^2)	172.7 (87.3)
Lateral Flexion ω range (rad/s^2)	114.1 (45.8)
Peak Anterior/Posterior acceleration (g)	-2.6 (0.6)
Peak Medial/Lateral acceleration (g)	2.1 (0.5)
Peak Superior/Inferior acceleration (g)	1.7 (0.6)

Table 2 Correlation of strength and neck anthropometics with head accelerations. * indicates significance a p<0.05.

	Flexion Strength	Extension Strength	Left Lateral Flexion Strength	Right Lateral Flexion Strength
Peak Positive Flexion/Extension ω	-0.294	-0.430	-0.209	-0.348
Peak Negative Flexion/Extension ω	0.346	-0.554	0.401	0.476
Peak Lateral Flexion ω in direction of travel	-0.628	-0.668	-0.405	-0.476
Peak Lateral Flexion ω away from the direction of travel	0.470	0.309	0.416	0.772*
Flexion/Extension ω range	-0.416	-0.521	-0.364	-0.474
Lateral Flexion ω range	-0.671*	-0.531	-0.508	-0.431
Peak Anterior/Posterior acceleration	0.551	0.259	0.509	0.277
Peak Medial/Lateral acceleration	-0.911*	-0.843*	-0.629	-0.754*
Peak Superior/Inferior acceleration	0.365	-0.605	-0.418	-0.522

the jaw prior to contact, and therfore inducing pre-activation have also been shown to reduce head acclerations in a contact situation (Hasegawa et al., 2014). While we have collected muscle activation for this study it has yet to be analysed. Coronal plane acclerations may also be subsequent to sagittal plane acclerations following contact, allowing for increases in muscle activation post contact to mitigate the magnitude of the coroal accelerations in stronger participants.

Finally further investigation is required to identify what other factors influence head accelerations during the tackle situation. While this and previous studies have identifed muscle strength and muscle activation, factors such as applied tackle force and direction have yet to be assessed. In part this is due to these variables being technically difficult to assess, however moving foward, this should be considered either through direct measurement or derrived values such as assesing full body center of mass velocity changes and calculating applied frouce via the impulse-momentum relationship.

CONCLUSION: Increases in neck strength are related to reductions in head accelerations during a rugby tackle. The greatest relationship was to coronal plane accelerations, however further work is require to understand the difference between relationships of neck strength to sagittal and coronal plane accelerations. This study supports the proposition that increasing neck strength may reduce concussion risk in contact sports.

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