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THE EFFECT OF TACKLING TRAINING ON HEAD ACCELERATIONS IN YOUTH AMERICAN FOOTBALL

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ABSTRACT

Background: Many organizations have introduced frameworks to reduce the incidence of football related concussions through proper equipment fitting, coach education, and alteration of tackling technique.

Purpose: The purpose of this study was to examine the effects of training in a vertical, head up tackling style on the number of head accelerations experienced while tackling in a controlled laboratory situation. The authors hypothesized that training in a head up tackling technique would reduce the severity of head acceleration experienced by participants.

Design: Controlled Laboratory Study.

Methods: Twenty-four participants (11.5 ± 0.6 years old, 60.5 ± 2.2 in, 110 ± 18.4 lbs.) with previous playing experience completed a one-day training session on tackling technique utilizing a tackling dummy. A subgroup of these participants completed an additional two days of training with a 48 hour retention test. Head accelerations were analyzed at baseline and end of training. Feedback consisted of verbal feedback utilizing the Qualitative Youth Tackling Scale (QYTS) and video tackling playback.

Results: A significant reduction in the number of peak linear head accelerations over 10 g and peak rotational head accelerations over 1885 deg/s^2 were found in dummy tackling after training in both the one day and three day training regimens. A significant change in QYTS tackling form score was found between pretest and post-test ($p = 0.004$). Participants with larger steps had a 2.28, 4.42 and 4.14 increased odds ratio of sustaining head accelerations over 10, 15 and 20 g respectively.

Conclusions: Training in a vertical, head up tackling style decreased the number of head accelerations over threshold values sustained while tackling; decreased step length may be the driving factor in the effectiveness of this tackling form.

Level of Evidence: Level 3b

Key Words: Biomechanics, concussion, head injury, prevention

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INTRODUCTION

Concussions in high school football occur at a rate of 6.71 injuries per 10,000 athlete exposures, this number jumps to 30.07 injuries per 10,000 athlete exposures in competition.¹ Head contact during blocking and tackling are the most prevalent mechanism of injury or activity associated with concussion in American football.¹ Despite continued efforts to reduce the occurrence of concussion the incidence continues to increase.² Recent research has indicated the effectiveness of Heads Up Football (HUF) framework in reducing head accelerations and injury rates in youth football athletes.³ However, previous research does not separate the effectiveness of the coaches' education program, practice restrictions and the vertical, head up tackling technique instructed in these programs.

Concussion rates for youth football athletes per the Youth Football Surveillance Network accounted for 9.6% of all injuries in youth football.⁴ The injury rate at this level during game play was 2.38 to 6.16 per 1000 athlete exposures and 0.24 to 0.59 per 1000 exposures in practice.^{4,5} The median and 95th percentile linear acceleration and rotational acceleration for 9-12 year old athletes was significantly different between games and practices, with game accelerations being higher.⁶ This trend does not carry forward into 12-14 year olds, who show no difference in accelerations experienced between practice and games.⁷

Recent research may indicate the effectiveness of the HUF program in reducing head accelerations and injury rates in youth football athletes. The HUF program provides league coaches receive hands on training regarding proper equipment fitting, didactic and participant demonstration of proper tackling technique and instruction in drills that reduce head contact, as well as general player safety.³ The HUF tackling framework provides coaches with a progression of drills designed to implement a head up, vertical tackling style. Participants in HUF leagues experienced fewer head impacts during practice registering both 10 and 20 g when compared to non-HUF leagues.³ A 10 g head impact cut off value is often utilized in the literature for counting of number of head contacts. However, a count of number of impacts rather than measurement of impact values has also

been utilized due to concern over the accuracy of the measurements provided by current technology.³ In Pop Warner football leagues that also utilized the HUF program also saw a decrease in practice concussion rates (0.14/1000 athlete exposures) when compared to non-HUF leagues (0.79/1000 athlete exposures) though it is unclear whether these changes are due to contact restrictions or tackling style.⁸

The Qualitative Youth Tackling Scale (QYTS) is a visually observed, objective based scale created to instruct a vertical, head up tackling form that mimics the form recommended by USA Football (Figure 1). This scale is designed to provide feedback on the components of the technique believed to be most related to safety while maintaining performance. This system applies quantifiable, objective actions during the tackle to a subjective feedback mechanism that aligns with the overall form requirements of the HUF tackle. To determine an overall score participants are subjectively assigned a point for successful completion of the movement measure. Item 1, short steps, is a measureable variable to represent the "Breakdown" and "Buzz" phases in which the tackler comes under control after pursuit but remains able to adapt to the opponents movements. Item 2, posterior to anterior movement of the arms, aligns with the "Rip" phase of movement which encourages wrapping up as well as using the arms to encourage an upright posture. Item 3, low center of mass, is the first phase of the "Shoot" parameter. Starting low allows the player to extend the hips on contact and initiate a rising blow on contact. Item 4, head across the front, establishes the head outside of the contact zone and encourages tacklers not to lead with the head. Item 5, contact with the front of the shoulder, was again an encouragement to remove the head from contact by encouraging an alternate first point of contact. Item 6, maintain and extended neck position, is part of standard safe practices as contact with the crown of the head increases the risk of cervical spine injury. Items 4, 5 and 6 do not align directly with stated HUF goals but are implied within the tackling methodology and are well known safe tackling procedures.

Utilization of HUF practice recommendations has been indicated to have the potential to decrease injury risk in youth athletes, though the effect of the tackling

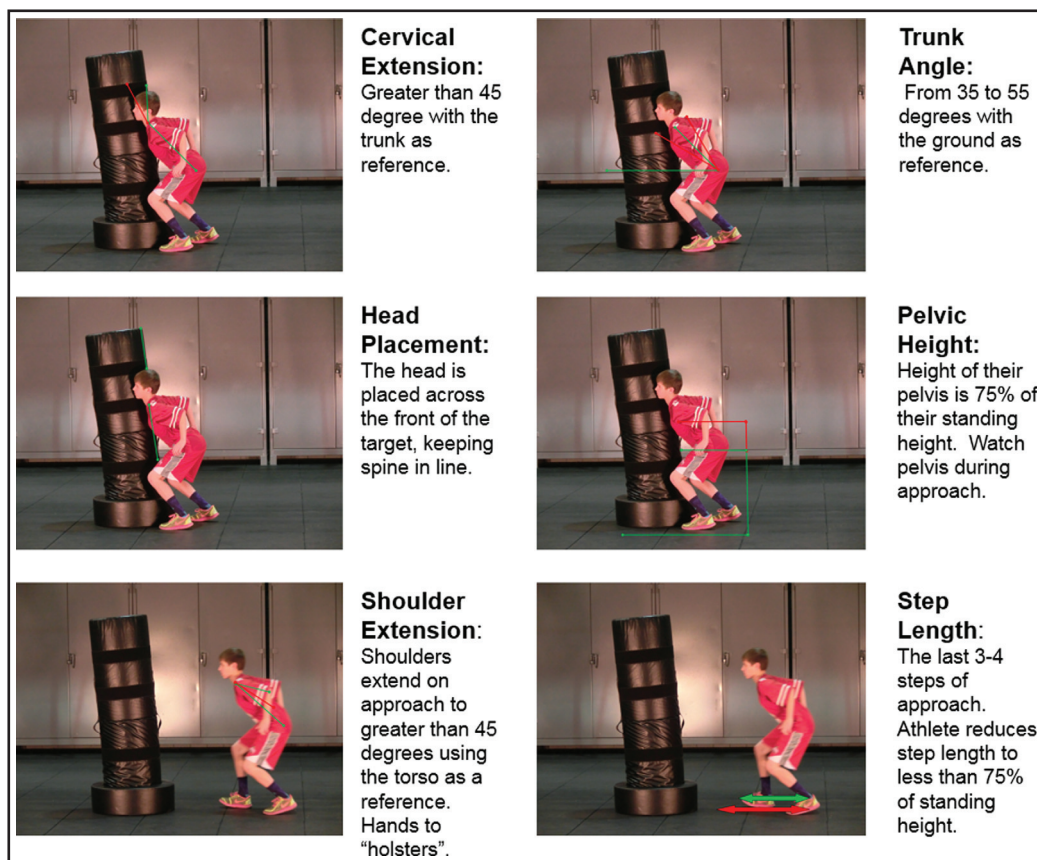


Figure 1. The six portions of the Head Up Football tackle form given as instruction and feedback to the participants.

technique may not be the primary driver or may not translate to game performance. The purpose of this study was to examine the effects of training in a vertical, head up tackling style on the number of head accelerations experienced while tackling in a controlled laboratory situation. A reduction in the head accelerations experienced by the tacklers may indicate a decreased risk for sports related concussion. The authors hypothesized that achieving the proper body position would reduce the number head accelerations over 10g experienced by participants when tackling.

METHODS

Participants with previous football experience were recruited from youth football organizations in the local area. The study procedures were approved by the university institutional review board and participants and their parents signed appropriate parental informed consent and assent forms prior to participation. Demographic data were collected including: age, height, weight, gender, school level, and seasons playing tackle football. Twenty-four participants

(11.5 ± 0.6 years old, 60.5 ± 2.2 in, 110 ± 18.4 lbs.) were enrolled in the study. All 24 participants completed at least a one day training session on tackling technique. Of these 24 participants, 14 participants (11.5 ± 0.5 years old, 60.4 ± 2.3 in, 109 ± 18.5 lbs.) agreed to attend an additional two days of training and a 48 hour retention test. There were no significant differences between those who participated for one day and those who participated for three days in terms of age, height, weight or experience. Overall, participants had 3.3 ± 1.5 years of football experience and were all male. The target was a 90 pound stand-up tackling dummy with the center of mass three feet from the ground in order to more closely represent a human target. This was done to improve the fidelity of the head accelerations measured. The dummy was placed five yards in front of the participant and offset one yard. The offset was utilized to create a far side of the target.

Day one tackling training included five baseline tackles and four training blocks of three tackles each in

the motion capture laboratory. At the baseline time point, the participants were instructed to “tackle the dummy as they typically do when playing football.” After five baseline tackles, participants were then given instruction on the six standard components of a heads up, vertical style tackle which are contained in the QYTS (Table 1) and allowed three practice trials. Reflective verbal feedback and video feedback utilizing the QYTS was then provided in four blocks of three trials. For the reflective verbal feedback, the participants were given 15 seconds to indicate with a check mark the portions of the tackling movement they performed correctly. They were then provided with the rater’s evaluation of their performance on the same six variables over an additional 15 seconds. Video feedback consisted of one tackle from the previous block of practice played four times at half speed during which participants were instructed to focus on the portions of the QYTS which they did not perform correctly. Playback of the video would occur over 10 seconds with a 10 second break between viewings. The verbal and video feedback were completed over two minutes at the end of each of the training blocks.

Participants in the three day feedback group completed two additional practice sessions with a rest day between sessions. Training during this period consisted of four blocks of three trials with feedback

as provided on day one. The participants then returned to the lab after a 48-hour retention time period. During the retention testing the participants performed five additional tackles in the same manner as training with no feedback given before or during testing.

Head acceleration data were collected utilizing data captured by the xPatch system. Two xPatch systems were applied bilaterally to the participant’s mastoid processes utilizing manufacturer provided adhesive patches. The threshold for recording impacts was set at 6 g for each device to allow for data collection below the 10g cut off. Previous reporting of head impact data has routinely utilized the 10g recording activation of these devices to determine the number of head impacts received during participation.⁸⁻¹⁰ Data were downloaded from the xPatch device into the X2 Impact Monitoring system (X2 Biosystems; Seattle, WA) using the manufacturer’s procedure. The data were uploaded and processed utilizing the system software which adjusts measures based on right and left head side device placement, making right and left side data comparable, and translates the measurements to the center of mass of the head. Peak linear acceleration (PLA) and peak rotational acceleration (PRA) measures as calculated by the system were downloaded to an Excel spreadsheet. Also included in this spreadsheet were: the time of

Table 1. *The Qualitative Youth Tackling Scale, including objective measures. Subjective information was provided as verbal feedback to participants.*

Subjective Feedback	Objective Measure
1. The athlete to maintain body control with short steps.	Step length less than 75% of standing pelvic height over last 250 cm to target.
2. Utilize the arms in a posterior to anterior motion during the tackle.	Shoulder extension greater than 45 degrees during last 0.5 seconds prior to contact.
3. Lower the body center of mass by bending at the knees.	Average Pelvis height less than 75% of standing pelvic height over last 0.25 seconds prior to contact.
4. Keep the head across the front of the target and not allow it to make contact with the target.	Visual verification of head placement on opposite side of approach on contact.
5. Contact the target with the front of the shoulder to keep the head away from the target.	Trunk angle between 35 and 55 degrees relative to ground on contact.
6. Keep the neck in an extended position by seeing the target to avoid contact with the crown of the head.	Cervical extension over 45 degrees on contact

impact, location, duration, and Clack measurement. The Clack measurement is an algorithm utilized by the monitoring system to distinguish true impacts from accidental bumping or dropping of the device. The xPatch system has been found to have a high correlation to the forces experienced by the wearer but routinely over estimates the measure of these forces.¹¹

Impacts were identified by comparing the timestamp reported by the xPatch device with the video recording of the data collection. The time stamp on the xPatch and the monitor were synced immediately prior to initiation of data collection. The monitor and the xPatch were both capable of displaying the time to within 1/100th of a second. Because impacts were aligned by time stamp on the device and video recording all impacts were utilized regardless of the Clack measurement, as it was independently verifiable the measure was not from a dropped device. Impacts from the left and the right xPatch were identified from the full list of all 6 g and above PLA recordings and were averaged. If two impacts took place in rapid succession, the first of the impacts was utilized. The second impact was likely caused by contact with the ground at the completion of the movement which is not the focus of this study.

Physical movement data was collected utilizing a 10 camera Vicon motion capture system (Vicon;

Oxford, UK) and a modified Helen Hayes marker set. A 58 marker set was used over bilateral lower extremities, upper extremities to the elbow, pelvis, torso and an adapted wrestling head gear to provide stable marker placement on the head (Figure 2).

Statistical analyses consisted of Wilcoxon Signed Ranks Tests to determine the effect of training on participant counts of PLA and PRA over threshold levels at baseline and the last training block for one day training (n = 24) and between baseline and 48 hour retention testing for the three day group (n = 14). For the one-day training group the first three baseline tackles were compared to the final three tackles of the day's training. For the three-day group all five baseline tackles were compared to the five tackles performed during retention testing. A median split was calculated for PRA data during baseline tackles for all participants. This number was then utilized as a threshold. An additional Wilcoxon Signed Ranks Test was performed to determine the effect of training on all training participant scores of the QYTS at one day pretest and post-test time points. A Mann-Whitney *U* test was performed to evaluate if a difference exists between QYTS scores of those who experienced head accelerations greater or less than 10g between one day time points. Statistical significance values were set at *a priori* $p \leq 0.05$ for all tests. Odds ratios comparing the successful performance of the individual skills of the QYTS to

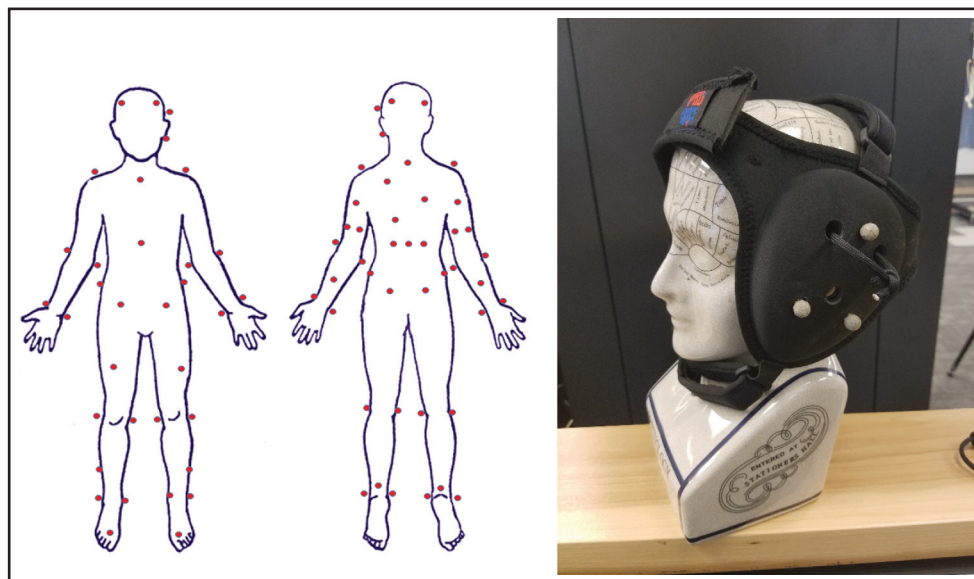


Figure 2. A fifty-eight marker set was utilized to determine neck, trunk, pelvis, hip, knee, ankle, shoulder and elbow angles. The modified wrestling headgear minimized head marker movement during contact drills.

head accelerations over 10, 15, and 20g were also completed.

RESULTS

In the 72 tackles (three tackles each, in 24 participants) performed during the baseline testing the mean impact count was 1.2 ± 0.9 and ranged from zero impacts to three impacts per participant. After training the mean impact count was 0.6 ± 0.7 per participant ranging from zero impacts to two impacts per participant. Individual change scores are indicated in Figure 4A. Results of the Wilcoxon Signed Ranks Test indicated a significant difference between these two timepoints ($p=0.027$, $Z=-2.216$,

$df=18$). In the three-day training group ($n=14$) PLA counts over 10g averaged 1.9 ± 1.6 and ranged from zero to five per participant at baseline. After training this number decreased to 0.5 ± 1.2 and ranged from zero to five. Individual change scores are indicated in Figure 4C. Results of the Wilcoxon Signed Ranks Test indicated a significant difference between these two time points ($p=0.021$, $Z=-2.313$, $df=10$).

Peak Rotational Acceleration (PRA) data was median split to create a threshold measure of 1885 deg/s^2 . The mean impact count was 1.2 ± 0.9 and ranged from zero impacts to three impacts per participant. After one day of training, the mean impact count

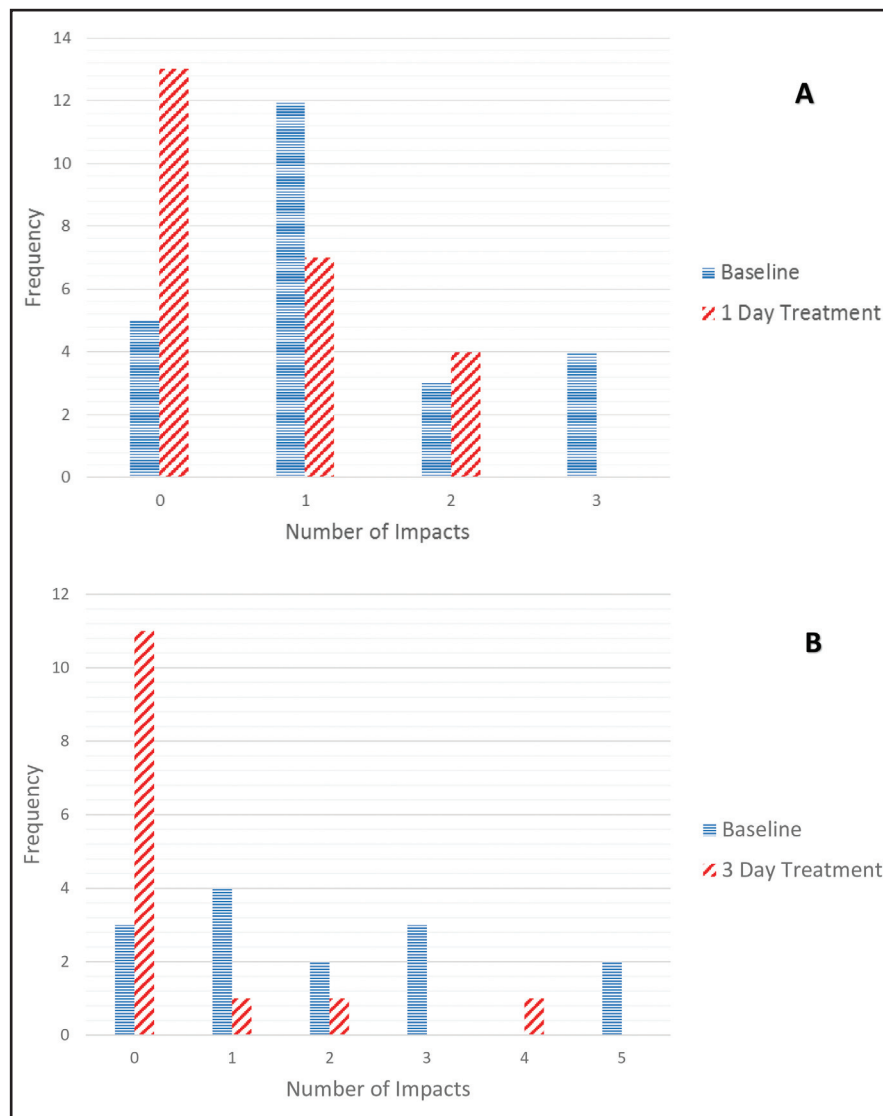


Figure 3. Number of impacts over 10g for each participant in the 1 day treatment group, chart A ($n=24$) and 3 day treatment group, chart B ($n=14$).

was $0.5 \pm .7$ per participant. This number ranged from two impacts to zero impacts per participant. Individual change scores are indicated in Figure 4B. Results of the Wilcoxon Signed Ranks Test indicated a significant difference between these two time-points ($p=0.038$, $Z=-2.079$, $df=19$). In the three-day training group PRA counts over 1885 deg/s^2 averaged 1.9 ± 1.7 and ranged from zero to five per participant at baseline. After training this number decreased to 0.6 ± 1.2 and ranged from zero to four. Individual change scores are indicated in Figure 4D. Results of the Wilcoxon Signed Ranks Test indicated a significant difference between these two time-points ($p=0.042$, $Z=-2.038$, $df=11$).

To assess change in performance between baseline and after one day of training, the participant's movement profile from motion capture data was dichotomized for along the criteria for each aspect of the QYTS. The dichotomized score was summed to create an overall score for each tackle. A Wilcoxon Signed Rank Test was performed between the two time points. This test indicated a difference in the total score between the baseline and end of one day training time points ($p=.004$, $Z=-2.915$, $df=17$). The average QYTS score improved from 1.50 ± 1.10 to 2.46 ± 1.31 .

In an examination of all head acceleration data points regardless of time point, a Mann Whitney U test found no significant difference ($p=.281$, $z=-1.079$, $df=261$) in QYTS scores during tackles in which the participant's head acceleration measurement was over 10g when compared to those tackles that were below the 10g threshold. Odds ratios (Table 2)

calculated for all movements found increased odds of having head acceleration greater than 10g when participants had an average step length greater than 75% of standing pelvis height (2.28, 95%CI: 1.29-4.05). Similar tests for trunk inclination greater than 55 degrees or less than 35 degrees (1.09, 95% CI: 0.61-1.96), cervical extension less than 45 degrees (0.96, 95%CI: 0.57-1.62) pelvis height greater than 75% of standing pelvis height (1.68, 95%CI: .93-3.01) and shoulder extension on approach less than 45 degrees (0.61, 95%CI: .35-1.08) were non-significant. The odds of sustaining an impact over 15g (4.42, 95%CI: 1.80-10.80) and 20g (4.14, 95%CI: 1.40-12.29) were also increased with a step length greater than 75% of pelvis height and for pelvis height over 75% of standing pelvis height at 15g (3.10, 95%CI: 1.26-7.6 1)

DISCUSSION

The results of this study indicate that training in a head up, vertical style tackle reduces the number of head accelerations over 10 g and 1885 deg/s^2 experienced by the tackler. Previous research has indicated the effectiveness of the USA Football Heads Up program overall to decrease the number of head accelerations experienced by tacklers.⁸ The USA Football Heads Up program provides coaches with a prescribed tackling form along with instructions to reduce the number of high contact drills which may be responsible for the decrease in head accelerations experienced in this previous study. Concurrently with the decrease in head accelerations, the participants' form scores on the QYTS improved from baseline to post training. Results indicated

Table 2. Odds ratios of experiencing head acceleration over 10, 15 and 20g's by failed performance of Qualitative Youth Tackling System items. Significant odds ratios indicated by darkened sections.

	10G	15G	20G
Cervical Extension	0.96 95%CI:0.57-1.62	1.46 95%CI:0.73-2.89	0.89 95%CI:0.41-1.98
Trunk Inclination	1.09 95%CI:0.61-1.96	1.88 95%CI:0.80-4.41	2.20 95%CI:0.74-6.55
Head Placement	1.46 95%CI:0.59-2.59	0.63 95%CI:0.14-2.79	0.5 95%CI:0.65-3.90
Pelvic Height	1.68 95%CI:0.93-3.01	3.10 95%CI:1.26-7.61	2.2 95%CI:0.82-6.02
Shoulder Extension	0.61 95%CI:0.35-1.08	0.32 95%CI:0.13-0.75	0.37 95%CI:0.14-1.01
Step Length	2.28 95%CI:1.29-4.05	4.42 95%CI:1.80-10.80	4.14 95%CI:1.40-12.39

those who took shorter steps toward the target had decreased odds ratios of receiving an impact greater than 10, 15 and 20g in one day of training. Participants decreased the head accelerations experienced both immediately during a one day training session and in a 48 hour retention with three sessions of training.

Analysis of changes in form indicates the training program was successful in improving the QYTS scores of the athletes over a one day period. Of these changes in form, a significant increase in the odds ratio of suffering an impact over 10, 15 and 20g was found in those who failed to reduce their step length to less than 75% of standing pelvis height. This result may indicate that slowing the body in general decreases the head accelerations experienced¹² or increases the time of approach, allowing the tackler to achieve better form as they apply the tackle.¹³ Other portions of the QYTS may show higher odds of head accelerations above 15 and 20g, however these data were limited to few impacts above those levels possibly due to the laboratory design as well as the age of the participants.

Linear accelerations and rotational acceleration/velocity have been proposed as the causative factors of concussive injuries,¹⁴ with a significant relationship between linear and rotational components.¹⁵ Previously only impacts that resulted in a concussion were seen as dangerous.¹⁶ As knowledge regarding head injuries increases, the role of subconcussive blows in long term health effects has become better known.¹⁷ Some research has indicated the effect of subconcussive impact includes increased risk of mild cognitive impairment and chronic traumatic encephalopathy (CTE).¹⁸ Providing a form structure that limits both high level impacts and subconcussive blows may lead to reduced concussive injury rates and long term cognitive issues. The results of this study indicate a training program in tackling form is capable of significantly decreasing the number of head contacts over 10g.

The goal of many programs and rule changes has been the reduction of the number and severity of head contacts¹⁰ through decreasing the number of contact practices,¹⁹ coach's education,⁸ and implementation of form instruction²⁰ and cervical

strengthening.²¹ These studies have utilized a number of mechanisms including conducting drills with helmets removed to create a risk adverse environment²² and a comprehensive coaches' education framework to limit the head impact exposure of football players.^{3,23} The 2016 Berlin Consensus Statement on Concussion in Sport recognizes prevention as a key component of concussion management, but also references the limited scope and the need for "A clear understanding of potentially modifiable risk factors is required to design, implement and evaluate appropriate prevention interventions to reduce the risk of SRC."²⁴,p.8 To date both coach education and helmetless tackling programs have shown promise in reducing the impact exposure of players.

Limitations to this study include a restricted age range and the use of a laboratory environment. Additional work should expand the scope both in number of participants and age range. The translation of these results to both a controlled dynamic and real life environment should be completed. Additional regression analysis could identify the components of the tackling form that influence the head accelerations experienced by the tackler in order to determine the source of changes in head accelerations found in this study.

CONCLUSION

The performance of a tackle that minimizes head accelerations is critical to the safety of the athletes in youth football. The results of this study indicate training in a head up vertical style tackle reduces the head accelerations experienced by tacklers in a laboratory setting against a stationary target. These results are critical to determining a form that minimizes the head accelerations experienced. These results provide a baseline from which additional research should be planned to translate these results to a field based dynamic environment.

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