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Associations of Tackling Characteristics, Player Position, and Head Contact Risk During Game Play in College Football

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ABSTRACT

Context: Sport-related concussion is a common injury among National Collegiate Athletic Association football athletes. Beginning with the 2016 season, Ivy League Conference coaches voted to ban player-on-player tackling from all in-season practices. BLINDED have enforced a no-tackle approach in practices since 2010.

Objective: To examine the association between tackling technique and head contact risk, and compare base rates of techniques used in the 2016 season between an Ivy League team with a longstanding no-tackle practice policy vs. the rest of the league.

Design: Cross-sectional study.

Setting: Ivy League College Football Conference.

Patients or Other Participants: Two-hundred-thirty-seven Ivy League defensive football players that participated in the 2016 season.

Main Outcome Measure(s): Tackles (*N*=3,701) across 237 Ivy League defensive football players in the 2016 season were coded based on predetermined classifications, which were combined to create unique tackle combinations/techniques. Associations among tackling techniques, head impact risk, and team (BLINIDED vs. other Ivy League teams) were evaluated using logistic regression, yielding odds ratios (OR) for head contact.

Results: Low-risk tackle characteristics for head contact during a tackle were neutral neck position (OR=0.1), back contact area (OR=0.3), pursuing momentum (OR=0.5), and quarterback sack momentum (OR=0.3). Low-risk tackle techniques were high-back-neutral (OR=0.1), low-back-neutral (OR=0.2), and medium-back-neutral (OR=0.1). High-risk tackle characteristics were flexion (OR=14.2) and extension (OR=3.8) neck positioning, front contact (OR=2.2), blowup (OR=2.5), and cut (OR=3.0). High-risk tackle techniques included low-side-flexion (OR=4.9), low-front-flexion (OR=9.9), medium-side-flexion (OR=15.5), and medium-front-flexion (OR=11.4). Relative to BLINDED, other teams demonstrated higher odds of using high-risk techniques (low-side-flexion OR=3.5; low-front-flexion OR=3.9; medium-side-flexion OR=6.3; medium-front-flexion OR=2.3) and reduced odds of using low-risk tackle combinations (high-side-neutral OR=0.4; high-back-neutral OR=0.6; medium-side-neutral OR=0.8).

Conclusions: Tackling techniques are associated with head contact risk, and by extension, player safety. BLINDED, who have a longstanding policy of practicing without player-on-player tackling, showed reduced use of high-risk tackling techniques.

Key Words: concussion, head injury, college football, safety, prevention

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Key Points:

- Tackling techniques with low (neutral neck position; back contact area; pursuing and quarterback sack momentums) and high (flexion and extension neck positioning; front contact area; blowup and cut tackle types) risk of head injury were identified.
- A team with a well-established no-tackle practice policy (BLINDED) showed lower prevalence of high-risk tackling techniques relative to other Ivy League teams.
- Teaching specific tackle techniques rather than focusing on player-on-player tackling, in tandem with safe practice policies, may be promising avenues for preventing football-related head injuries.

INTRODUCTION

Approximately 1.6-3.8 million sport-related concussions occur in the United States each year[1]. In the National Collegiate Athletic Association (NCAA), sport-related concussion (SRC) accounted for 6.2% of all injuries reported during the 2009-2010 and 2013-2014 academic years[2]. Football accounts for the greatest number of concussions compared to other sports in the NCAA and within the Ivy League, with a notable increase in incidence over time[2,3]. Level of play and physical contact increases risk of concussion, with a rate of 1.26 concussions per 1,000 athletic exposures in the Ivy League and Big Ten Conference between the 2013-2014 and 2017-2018 academic years[3,4]. Beyond SRCs, mere head contact is ubiquitous among athletes. To illustrate, epidemiologic head impact telemetry data from six Division I NCAA football programs (N=658 collegiate football players) recorded 528,684 incidents across the 2015 and 2019 seasons[4]. On average, players sustained over 400 recorded head impacts (*Med*=415, *IQR*=190-727) each season[4].

Critically, repetitive head impact exposure confers increased risk of SRC. One study of 50 concussed NCAA Division 1 football athletes found that 72% of these players had the highest or second highest cumulative head impact exposure than team- and position-matched controls[5]. A separate biometric study of 502 Division I college football players across the 2015 and 2017 seasons found that those who sustained SRCs experienced nearly 100 (M=93.7) more recorded head impacts (including more high-magnitude impacts) than physically matched controls[6]. Thus, as expected, athletes who sustain the highest number of head impacts (relative to their peers) have the greatest risk of SRC, even when controlling for player-level traits (e.g., height, weight, age, race, SRC history) thought to impact to *concussion tolerance* (i.e., predisposition or vulnerability to sustaining SRCs). Other risk factors for head and neck injury among football players (and by extension, SRC) include level of player physical maturation and quality/skill-level of coaching[7].

Epidemiological studies of concussion in college football published in the last decade found rates are higher in game play than during practice, but the majority of concussions occur during practice[2,3]. Indeed, large-scale data from six NCAA football teams spanning five seasons (2015-2019) observed that nearly half of the incident SRCs across the study period occurred during preseason (despite preseason only encompassing about one-fifth of the football season)[4]. Relatedly, the same observational cohort study revealed a twofold increase in head impact incidence in the preseason compared to the regular season (325 vs. 162 head impacts per team per day), and that most head impact exposures (67%) and SRCs (72%) occurred during practices[4]. In this context, preseason training and practices across the football season are important targets for intervention.

Given the robust evidence implicating repetitive exposure to head impacts as a predisposing factor for incident SRC, there have been efforts to increase player safety over time through refinement of tackling techniques and rule changes, which are aimed to reduce head impact exposures, as well as improvements in equipment to reduce the effect of head impact[7–9]. Some of the rule changes at the professional (2017) and collegiate (2016) levels included modification of the kickoff rule, which resulted in a significant reduction in concussions[10]. Research has also informed suggestions made for helmet modifications based on force transference during tackling[9].

Moreover, considering the compelling evidence of disproportionately high incidence of head impacts and SRCs sustained in preseason and football practices, prevention efforts have targeted these exposure periods. BLINDED discontinued player-on-player tackling in practice in 2010 in an effort to reduce the risk of head injuries occurring in practice. They also incorporated a mobile tackling dummy into practices in 2015 to reduce head contact exposure and resultant injuries[11]. While the NCAA issued new football practice guidelines limiting the number of scrimmages and contact practices in 2014, the Ivy League implemented a more stringent rule in 2016 that uniformly banned player-on-player tackling during practice. In this context, the BLINDED football program had ample experience (i.e., a four-season "head start") implementing the no-contact practice guidelines relative to when the other Ivy league teams adopted this policy.

A recent cohort study investigated trends in SRC frequency across 14 seasons (2006-2019 and 2021) in BLINDED's team, and across seven seasons (2013-2019) for other teams in the Ivy League football conference[12]. Keeping in mind the practice policy changes detailed above, a robust inverse association was observed between season year and frequency of SRCs sustained in-game for BLINDED and other Ivy League teams, such that SRCs trended downwards in later vs. earlier seasons. Follow-up analysis revealed reduced in-game SRC frequency for BLINDED in seasons with no-contact and tackle dummy practice policies compared to seasons without these guidelines/rules. Analysis of in-game SRC frequency among other Ivy League teams showed a similar trend of lower in game SRCs sustained for seasons with the no-contact practice policy vs. contact in practices. Finally, for BLINDED, both practice policies accounted for 51% of variance in SRCs sustained in games across the 14 seasons analyzed, though the tackle dummy intervention was a superior predictor in the model compared to the no-contact rule. Keeping with the epidemiologic literature[2,3], no consistent effects of the practice policies were observed for SRCs sustained in-practice[12].

While this Ivy League study[12] provided preliminary evidence of reduced recorded SRCs possibly in relation to practice policy changes, several limitations hindered the strength of such findings. Critically, the study focused on large-scale outcomes without consideration of more granular covariates such as tackling mechanics/techniques and player position. As such, their findings were limited by unmeasured player- and team-level variables which would have helped contextualize their observed effects (e.g., by way of prevalence of and changes in tackling techniques used by players). Here, we sought to address these limitations by conducting a follow-up study of detailed player-level variables, particularly tackling characteristics and player position in relation to risk of head contact, and comparing these in BLINDED vs. other Ivy League teams.

The goals of this study were two-fold. First, we sought to characterize defensive football player tackling techniques in relation to head contact risk in the Ivy League during the 2016 season. Second, considering BLINDED's early adoption of banning player-on-player tackling during practice (i.e., a "no-tackle" practice policy), we examined differences in base rates of tackle characteristics and combinations between BLINDED and other Ivy League teams. A priori, we refrained from making predictions regarding the association between tackle characteristics and head contact but broadly hypothesized that BLINDED would show lower base rates of utilizing high-risk tackling characteristics/combinations.

METHODS

Design

This cross-sectional study utilized a comprehensive sample of video footage from all 2016 games played across the Ivy League Conference accessed as part of a joint agreement among Ivy League teams. Plays were parsed within DV Sport (DV Sport Inc., Pittsburgh PA) game and practice data video analysis software. The provided footage encompassed two distinct vantage points for each play: an elevated position of the side of the field from the press box and an elevated position behind the end zone. The quality of the video was comparable among teams and plays. Only tackles from Ivy League players were analyzed. All extracted retrospective data were deidentified.

Participants

Data presented in this project is at the level of defensive tackles. That is, we analyzed characteristics of tackles (*N*=3,701) from 237 defensive football players across the eight Ivy League conference teams. While games involved both conference and non-conference opponents, only tackles made by Ivy League players were coded and analyzed. Each game in which an Ivy League team participated during the 2016 fall football season was included (10 games in total, seven of which were against another Ivy League team).

Procedures

Our method for identifying and labeling tackle combos was rooted in an informed observational approach. A series of preset classifications were determined from an analysis and characterization of all in-game tackling patterns of BLINDED football players during the 2016 season. Data included head and neck position at contact, how the tackler approached the ball-carrier, and the way in which the tackler completed the tackle. Tackle characteristic categories were selected a-priori by a subject-matter expert (author BLINDED) with over 30 years of coaching Division I college football. Using those criteria, each play was then classified by members of the football staff. Each tackle was then re-reviewed by a special assistant to the subject-matter expert and approximately 25% of the most-difficult-to-classify cases were discussed with the expert for additional expert opinion. Cases where the contact was not discernable enough to classify were excluded. In total, a minimum of five trained individuals reviewed tackles from each play. One of the staff members who reviewed tackles had years of experience in football coaching. Four additional team members were students trained by the subject-matter expert mentioned above.

Tackle Characteristics and Combinations

Expanded details for each tackle characteristic coded are presented in **Table 1**. Briefly, tackles were coded according to whether there was head contact (directly attributable to the tackle action rather than, for instance, a player hitting their head on the ground after the tackle), defensive player position of the tackler (defensive backfield [DB], defensive line [DL], or linebacker [LB]), neck position (neutral, flexion, or extension), contact area (side, front, or back of player), strike zone (high, low, or medium), tackle momentum (attack, blocked, multiple tacklers, follow-through, gathering, pursuing, quarterback sack), and tackle type (blowup, cut, follow-through, roll, swipe, or wrap). In addition, we computed tackle combinations based on an amalgam of neck position, contact area, and strike zone (27 possible permutations). The present data yielded 26 unique combinations. We retained the most frequent tackles combinations (defined as those with a base rate of >2% relative to all tackles that occurred in the 2016 season) for analyses. Thirteen distinctive tackle combinations (which, collectively, represented 93% of all tackles from the 2016 season) were analyzed: high-side-neutral, high-front-neutral, high-back-neutral, low-side-neutral, low-side-flexion, low-front-neutral, low-front-flexion, low-back-neutral, medium-side-neutral, medium-side-flexion, medium-front-neutral, medium-front-flexion, and medium-back-neutral.

Analysis Plan

First, we examined the association of broad tackle characteristics (e.g., neck position) with head contact via omnibus chi-squared (χ^2) tests of independence. Next, individual elements of tackle characteristic categories (e.g., flexion neck position) were dummy coded and entered into binary logistic regression models to predict head contact tackle outcome (i.e., 0=no head contact; 1=head contact). We conducted an identical set of analyses on the 13 unique tackle combinations mentioned above to determine their association with odds of resultant head contact. We then compared the base rates of the 13 tackle combinations between BLINDED College and the other Ivy League football teams aggregated (*note*: data were weighted according to total number of tackles within each team). That is, binary logistic regression models were constructed to determine whether respective tackle combinations predicted group membership (i.e., football team, coded as 0=BLINDED, 1=other teams). Finally, we conducted post-hoc exploratory analyses to determine whether defensive player position was associated with tackle variables (i.e., broad tackle characteristic categories, such as neck position, and any of the 13 computed combinations) using χ^2 tests.

Importantly, tackle characteristic categories and computed tackle combinations are orthogonal, or mutually exclusive, from one another. To illustrate, tackles were coded such that they could not possess *both* neutral *and* flexion neck position, and each tackle could only have one unique combination (e.g., high side neutral). For χ^2 analyses, effect strength was determined by Cramér's phi (φ_c; small=.20, moderate=.50, strong≥.80).[13] Odds ratios (OR) and 95% confidence intervals (CI) were computed to evaluate effect strength for logistic regression models (small=2.0, moderate=3.0, strong≥4.0)[13]. We also followed Ferguson's recommended effect threshold for what may be considered a "practically" significant effect ($\varphi_c \geq .20$; OR≥2.0 or ≤0.5). To control for α inflation due to multiple comparisons, all *p*-values were adjusted using the Benjamini-Hochberg False Discovery Rate (FDR) method. Significance threshold α_{FDR} was set to .05 (two-tailed).

Results

Descriptive information for tackles analyzed (e.g., player position, tackle characteristics, rate of head contact), stratified by team, is presented on **Table 2**. Notably, the base rate of head contact outcome (i.e., the tackler hitting their head) was 28.1% across all tackles (*N*=3,701). **Table 3** shows supplementary analyses of tackle characteristics and combinations as a function of defensive position. Briefly, defensive positions were broadly equally represented across tackles. Base rates of head contact were likewise broadly commensurate across positions. The only "clinically meaningful" effects were observed for broad tackle momentum (φ_c=.34) and tackle combination (φ_c=.22). Greatest differences according to position type were observed for attack momentum tackle (DB=52.2%, DL=8.0%, LB=35.0%) and quarterback sack (DB=0.8%, DL=11.4%, LB=3.4%) characteristics, and low front flexion tackle combination (DB=12.9%, DL=0.6%, LB=3.4%). Statistical assumptions of binary logistic regression were evaluated and upheld. Thus, we proceeded with our planned models.

Tackle Characteristics and Head Contact

Table 4 displays base rates (%) of specific tackle characteristics, as well as respective rates and ORs of head contact, across all tackles aggregated (N=3,701). Broad and specific neck position characteristics were strongly associated with head contact. Notably, neutral neck position was associated with 14.7-times (95% CI=12.3, 17.5) lesser odds of head contact, whereas flexion neck position was associated with 14.2-times (95% CI=11.8, 17.2) higher odds of head contact. A moderate to strong effect for extension neck position was also observed, such that odds of head contact were 3.8-times (95% CI=2.6, 5.5) higher for tackles with this characteristic. Smaller relations with head contact were observed for broad and specific contact area and strike zone characteristics. Front contact and back contact areas were associated with 2.2-times (95% CI=1.9, 2.5) greater and 3.2-times (95% CI=2.5, 4.0) lesser odds of head contact, respectively. Clinically meaningful relations were only observed for pursuing and quarterback sack tackle momentums, which were associated with 2.2-times (95% CI=1.7, 2.8) and 3.4-times (95% CI=2.0, 5.6) lower odds of head contact, respectively. Blowup and cut tackle types were related to 2.5-times (95% CI=1.7, 3.6) and 3.0-times (95% CI=2.3, 4.0) higher odds of head contact, respectively, whereas roll and swipe were both associated with 2.1-times lower odds of head contact (95% CI=1.6, 2.6 and 1.3, 3.2, respectively).

Tackle Combinations and Head Contact

Table 5 displays base rates (%) of tackle combinations, as well as respective rates and ORs of head contact, across all tackles aggregated (N=3,443). The omnibus test indicated a considerable association between tackle combinations and head contact (φ_c=.55). At the individual level, particularly robust (strong) ORs were observed for several combinations. Tackle permutations associated with markedly higher odds of head contact included low-side-flexion (OR=4.9; 95% CI=3.3, 7.2), low-front-flexion (OR=9.9; 95% CI=7.2, 13.4), medium-side-flexion (OR=15.5; 95% CI=9.6, 25.0), and medium-front-flexion (OR=11.4; 95% CI=8.0, 16.2). Conversely, high-back-neutral, low-back-neutral, and medium-back-neutral were associated with 7.8 (95% CI=2.9, 21.3)-, 5.0 (95% CI=10.2, 2.4)-, and 7.7 (95% CI=4.8, 12.5)-times lower odds of head contact, respectively.

Tackle Combinations Reflected in BLINDED vs. Other Ivy League Teams

Table 6 displays base rates (%) of tackle combinations, stratified and compared by team. Broadly, tackle combination was weakly associated with football team (BLINDED vs. other; φ_c=.16). Nevertheless, several tackle combinations appeared to differentiate BLINDED from the other Ivy League teams in this sample. Largest effects were observed for low-side-flexion, low-front-flexion, and medium-side-flexion, such that odds of these tackle combinations were 3.5 (95% CI=1.4, 8.6), 3.9 (95% CI=2.0, 7.6), and 6.3 (95% CI=2.0, 20.0)-times higher for other Ivy League teams vs. BLINDED. Worth mention, analyses identified these three combinations as being associated with considerably higher odds of head contact. To add, while effects were smaller in magnitude, other Ivy League teams showed lower odds of using several "safer" tackle combinations compared to BLINDED: high-side-neutral (OR=0.4; 95% CI= 0.3, 0.7), high-back-neutral (OR=0.6; 95% CI=0.3, 0.9), and medium-side-neutral (OR=0.8; 95% CI=0.6, 0.98).

Discussion

The overarching aim of our study was to expand upon a recent pilot study reporting preliminary evidence of lower documented SRCs among Ivy League teams for seasons where practice policies (such as no-tackle) are implemented[12]. Specifically, here, we captured finer player-level variables within teams (as opposed to gross metrics such as SRC frequency across teams). We first sought to examine characteristics of tackling and their association with head contact. Examination of individual tackling characteristics demonstrated lower odds of head contact associated with neutral neck position, making contact with the back, tackling momentum of pursuing and quarterback sack, and proceeding through the tackle using a roll or swipe technique. Similarly, tackling combinations with the neutral neck position and contact in the back regardless of strike zone were less likely to result in head contact. Conversely, tackling characteristics that lead to higher odds of head contact included a flexion neck position, making contact in the front, and blow up or cut tackle types. Tackling combinations with high odds of head contact all involved the flexion neck position with low or medium strike zone in the front or side contact areas. Notably, DBs were more likely to use a low-front-flexion tackle combination than other positions, a technique with third-highest risk of head contact (OR=9.85). Further, while head contact did not vary significantly by position, tackling momentum reflected variation in position characteristics where attacking was more common for DBs and quarterback sacks for DLs.

Consistent with our observing higher odds of head contact related to flexion neck positioning, multiple studies indicate neck flexion prior to contact in rugby and football is associated with a broad range of adverse outcomes including concussion, cervical spine injury, quadriplegia, and mortality[7,9,14,15]. In a similar vein, Suzuki et al.[15] investigated the relation between tackling characteristics and concussion in rugby and found that head down position prior to contact increased risk of concussion by a factor of 4.67. The flexion neck positioning not only increases the risk of concussion in the defensive player, but also the player being tackled due to more momentum being transferred in a head-down tackling position[9,16]. In recognition of the dangers associated with this neck positioning, rules prohibiting the deliberate spearing and use of the top of the helmet as initial point of contact were first instituted in 1976 in the NCAA and National Federation of State High School Association[9]. Further, use of helmet rules (e.g., initiating contact with the helmet) were instituted in the NFL in 2018 and have been recently re-emphasized during the 2021 season[17]. Finally, the dangers of this neck position are clearly reflected in the 2022 National Athletic Trainers' Association position statement, which includes 14 recommendations for equipping American football athletic training/coaching personnel with tactics for reducing such "head-first" contact[18]. Some examples include developing compulsory up-to-date education on harmful effects of head-first contact to the head and neck for players, intensive evidence-based instruction that teaches players "progressive techniques for avoiding head-first contact behavior" prior to the exposure of tackle football (e.g., in preseason), and eliminating or modifying drills in football practices that go against the ethos of "proper and safe tackling and blocking behaviors or techniques[18]."

Regarding other aspects of tackling, tackling techniques taught by the 2012 USA Football's Heads Up program emphasizes primary contact be made to the mid-section while maintaining the neutral neck position. This tackling technique is based on those used in collegiate rugby, leading to reduced incidence of concussion when performed correctly[14,15]. Our results demonstrate striking a player in the mid-section did not increase their odds of head contact if the tackler maintained a neutral neck position, and the odds of head contact decreased further when contact was made with the ball carrier's back. Nevertheless, the broad neutral neck position characteristic was related to a 93.2% reduction in odds of head contact in our data, one of the most robust findings in this study. Heads Up also teaches that the player should grab the jersey and continue through the tackle (consistent with a wrap or roll tackle type), which along with a wrap tackle type was found to reduce the likelihood of head contact. Similarly, in rugby, making contact with the ball carrier's back and using a roll tackle type was found to reduce the likelihood of concussion compared to tackles where the head was positioned in the front or to the side of the ball carrier, or tackles that did not involve pulling, gripping or wrapping the ball carrier with their arms[15]. Therefore, it follows that there is an increased risk of head contact associated with cut block or blow-up tackles as these do not involve wrapping or gripping the ball carrier.

The second purpose of our study was to compare BLINDED tackling to that of other Ivy League teams. This goal was motivated by the findings of a recent pilot study that observed strong effects of practice policies in attenuating SRCs sustained across 12 seasons (2009-2019, 2021) for BLINDED, particularly those in game[12]. We sought to compare identified high-risk and low-risk tackle characteristics/combinations between BLINDED and other Ivy League football conference teams to further clarify whether a team who have been engaged in specific preventative measures for SRC longer than other teams demonstrates any systematic differences in tackling techniques in game. That is, BLINDED has been implementing a no-tackle practice policy since 2010, whereas at the time of this study's data collection (2016), other teams were just beginning to incorporate this rule change into practices[11]. The results indicated that BLINDED used the three tackling combinations associated with the highest odds of head contact (low-side-flexion, low-front-flexion, and medium-side-flexion) significantly less than other Ivy League teams. Further, BLINDED showed evidence of using several "safe" tackle combinations (high-side-neutral, high-back-neutral, and medium-side-neutral) more than other Ivy League teams.

One possible explanation for these findings is that BLINDED implemented no-tackle practices six years prior to the other Ivy League teams. That is, BLINDED focused on teaching proper tackling techniques without tackling other players. Therefore, the coaches and players had more time to adjust to and experience using this method of practicing more than other teams. In this sense, the concept of not tackling in practice may translate best to gameplay and player safety when it is part of a culture of safety, rather than simply thought of as a rule or policy initiative. Another explanation is BLINDED introduced a mobile tackling dummy into their practice approach in 2015, which recent literature suggests predicted reduced SRC frequency above-and-beyond the no-tackle policy[12]. Thus, their unique access to this technological innovation may have contributed to enhanced skills in the context of the no-tackle practice approach. Conceptually, the key focus in practice is on tackling form rather than brining other ball-carrying players to the ground, which is espoused in formal league games. Epidemiologic findings underscore the importance of teaching and practicing safe (with respect to reducing odds of head injury-related sequela) as the majority of concussions occur amidst practices (despite actual gameplay having highest rates)[2,3]. Ideally, experiential learning that occurs across practices will transfer over to gameplay and contribute to reduced odds of head injuries.

Limitations

The current study was limited by the lack of concussion diagnostic data to contextualize our findings as head contact does not inherently lead to head or neck injury. While lack of corroborating evidence regarding concussion incidence in relation to the tackles we analyzed limits the breadth of inferences we can draw from our data, this was out of the scope of the current project, which focused on head impact exposure (in relation to defensive tackle characteristics and player position). Conversely, a strength of the study is the inclusion of head contact, rather than only concussions. Head contacts may be easier to visually observe in a game than *bona fide* concussions, which often go undiagnosed and under-identified[19]. However, the objectivity of our methods of documenting player head contacts was weakened by lack of concurrent head impact sensor system to confirm observer ratings of head contact. While sensors are useful in head impact research as they provide a variety of force parameters (e.g., peak linear acceleration, angular velocity, angular acceleration magnitude) to grade impact severity, some limitations have been noted. One study found instances of a mouthguard sensor missing up to ~30% of helmet contact events classified by video, while also detecting too many impacts at times (i.e., which far exceed those cross-verified in video)[20]. Next, our study did not use a previously validated methodology for establishing the predetermined tackling characteristics and combinations. Observer training for counting head impacts may also differ across programs. Indeed, tackling instructions, associated nomenclature, and key performance metrics (and their measurement) more likely than not vary among coaches and football programs. Future studies should investigate tackling techniques by examining both incidence of head contact and concussion as it may provide a more comprehensive picture.

Additionally, the scope of the study was limited to tackles performed by defensive players on Ivy League teams during the 2016 football season. In this context, our data was limited to a cross-sectional (vs. longitudinal) sample of an Ivy League football season. As such, we advise cautious interpretation of the relation between the no-contact practice regulation change and tackling techniques used in games. The conclusions that can be drawn from our findings would be strengthened (in either direction) if expanded tackle data from seasons before and after the uniform ban on player-on-player tackling during practice in the Ivy League in 2016 were available. We unfortunately did not have such pre-post tackling data to study change in tackle techniques in relation to the no-tackle practice policy. Future investigations of tackling techniques and their association to head contact should span across seasons and include offensive and defensive players.

Next, we were unable to quantitatively index the degree of inter-rater reliability/agreement (e.g., intra-class correlation and Cohen's kappa statistics) as requisite data to do so were not available to us. Nevertheless, five or more trained athletics personnel reviewed tackles from each play, and therein, inter-rater discrepancies were carefully processed and rectified. In a separate vein, we were unable to quantitatively analyze various idiosyncratic team-level variables (e.g., quality of teams, coaching staff, athletic programs, and training facilities; player size, talent level, position, and experience; overall team ability; team cultural differences and other in-house practice/game policies) that may differ from team-to-team and perhaps influence tackling techniques players use. Such nuanced team- and player-level variables may play a role in head injury/contact-related outcomes. As such, future studies should consider empirically incorporating these elements. Next, we did not consider, nor had access to, additional biometric assays such as in-helmet accelerometers to analyze additional metrics of head impacts resulting from various tackle tyles. Future lines of research may wish to evaluate measured biomechanical and actual concussion-diagnostic outcomes of the high-risk tackle combinations identified from our analysis. In a separate vein, we also did not code information on play type (e.g., runs, passes). We recommend future studies examine the relation between play type and base rates of high/low-risk tackles.

Finally, we were unable to formally assess whether tackling characteristics and combinations were associated with team success/win-loss record and odds of winning games. This was out of the scope of the aims of the current project but a promising topic for future investigations to consider. However, two recent studies analyzed tackling techniques in relation to their effectiveness (i.e., success of the tackle). The first of these examined 1,000 defensive tackle attempts that occurred in the NCAA Southeastern Conference 2021 season and found that head-down tackles below the offensive player's waist yielded lower success rates than head-up tackles and at or above the waist[21]. These findings were mirrored in a study published a year later that assessed 1,000 defensive tackle attempts that occurred across six English Rugby Premiership matches in the 2022 season[22]. Interestingly, the tackle characteristics linked with poorer success rates in these two recent studies were linked with higher odds of head contact in our data (i.e., head-down = flexion neck position and below waist = low strike zone in the present study's classification system). Next, our data revealed lower odds of head contact for the characteristics linked with higher tackle success rates (i.e., head-up = neutral neck position and at or above waist = medium or high strike zone). Thus, it remains possible that promoting safe (i.e., low risk for head injury) may have indirect (downstream) effects on tackle success, and by extension, team success. Anecdotally, BLINDED averaged 6.6th place in Ivy League standings in the 10 seasons (i.e., 2000-2009) before they banned tackling from practices. In contrast, their average team standing within the conference increased to 3.3 across the 13 seasons (i.e., 2010-2019, 2021-2023) after setting the no-tackle practice policy in place (with adjunctive implementation of mobile tackling dummies in 2015). Moreover, across these later 13 seasons, they won/shared four division titles juxtaposed with zero titles from the earlier 10 seasons. We stress that additional data are needed to clarify whether practice policies are associated with changes in tackle techniques as well as defensive (and team) success before anecdotes like the one we presented above can be given weight.

Conclusions

Our study echoes prior literature thereby suggesting that the use of proper tackling technique may reduce the chances of head contact, and by extension, subsequent head and neck injury[2,3,11,12,17]. Reducing the chance of head impact in organized football through refinement of tackling technique and rule changes is important for player safety. While our results suggest a relation between the elimination of player-on-player tackles in college football practices and reduced chance of head contact in games, additional longitudinal studies are necessary to clarify whether this is attributable to changes in tackle technique. Future studies will also be important for determining whether our results generalize to other levels of play, such as high school and youth sports. Indeed, the majority of football injuries presenting to emergency departments occur in children under 14-years-old, with the primary diagnoses being concussion[23]. Notably, this likely reflects coaching experience, ongoing physical development of the player, and fewer resources (e.g., athletic trainers) available to assess and manage injuries in youth sports. However, it also highlights the need for more teaching of proper tackling techniques at younger ages and implementation of rules that reduce injury risk. Implementing a no-tackle practice approach for developing players may control more injury-risk variables. Learning safe tackling techniques would increase player safety in practice but may also lead to players maintaining better form during gameplay.

References

1. Langlois JA, Rutland-Brown W, Wald MM. The Epidemiology and Impact of Traumatic Brain Injury: A Brief Overview. *undefined*. 2006;21(5):375-378. doi:10.1097/00001199-200609000-00001

2. Zuckerman SL, Kerr ZY, Yengo-Kahn A, Wasserman E, Covassin T, Solomon GS. Epidemiology of sports-related concussion in NCAA athletes from 2009-2010 to 2013-2014. *American Journal of Sports Medicine*. 2015;43(11):2654-2662. doi:10.1177/0363546515599634

3. Putukian M, D'Alonzo BA, Campbell-McGovern CS, Wiebe DJ. The Ivy League–Big Ten Epidemiology of Concussion Study: A Report on Methods and First Findings. *American Journal of Sports Medicine*. 2019;47(5):1236-1247. doi:10.1177/0363546519830100

4. McCrea MA, Shah A, Duma S, et al. Opportunities for Prevention of Concussion and Repetitive Head Impact Exposure in College Football Players: A Concussion Assessment, Research, and Education (CARE) Consortium Study. *JAMA Neurol*. 2021;78(3):346-350. doi:10.1001/JAMANEUROL.2020.5193

5. Stemper BD, Shah AS, Harezlak J, et al. Comparison of Head Impact Exposure Between Concussed Football Athletes and Matched Controls: Evidence for a Possible Second Mechanism of Sport-Related Concussion. *Ann Biomed Eng*. 2019;47(10):2057-2072. doi:10.1007/S10439-018-02136-6/FIGURES/2

6. Rowson S, Campolettano ET, Duma SM, et al. Accounting for Variance in Concussion Tolerance Between Individuals: Comparing Head Accelerations Between Concussed and Physically Matched Control Subjects. *Ann Biomed Eng*. 2019;47(10):2048-2056. doi:10.1007/S10439-019-02329-7/TABLES/2

7. Obana KK, Mueller JD, Zhong JR, et al. Targeting rule implementation decreases neck injuries in high school football: a national injury surveillance study. *https://doi.org/101080/0091384720211932630*. Published online 2021. doi:10.1080/00913847.2021.1932630

8. Swartz EE, Myers JL, Cook SB, et al. A helmetless-tackling intervention in American football for decreasing head impact exposure: A randomized controlled trial. *J Sci Med Sport*. 2019;22(10):1102-1107. doi:10.1016/J.JSAMS.2019.05.018

9. Viano DC, Pellman EJ. Concussion in professional football: Biomechanics of the striking player - Part 8. *Neurosurgery*. 2005;56(2):266-278. doi:10.1227/01.NEU.0000150035.54230.3C

10. Wiebe DJ, D'Alonzo BA, Harris R, Putukian M, Campbell-McGovern C. Association Between the Experimental Kickoff Rule and Concussion Rates in Ivy League Football. *JAMA*. 2018;320(19):2035-2036. doi:10.1001/JAMA.2018.14165

11. Kramer A. The Future of Football Practice: What a "No-Tackle Practice" Looks, Feels and Sounds Like. Bleacher Report. 2016. Accessed August 21, 2022. https://thelab.bleacherreport.com/the-future-of-football-practice/

12. Aita SL, Muchintala R, Suresh A, Patel S, Schuler B, Lichtenstein JD. The use of a mobile tackling dummy is associated with reduced sport-related concussions beyond that of banning tackling in college football practices: Results of a pilot investigation. *Orthop J Sports Med*. Published online 2024.

13. Ferguson CJ. An Effect Size Primer: A Guide for Clinicians and Researchers. *Prof Psychol Res Pr*. 2009;40(5). doi:10.1037/a0015808

14. Sobue S, Kawasaki T, Hasegawa Y, et al. Tackler's head position relative to the ball carrier is highly correlated with head and neck injuries in rugby. *Br J Sports Med*. 2018;52(6):353-358. doi:10.1136/BJSPORTS-2017-098135

15. Suzuki K, Nagai S, Iwai K, et al. Characteristics and factors of concussion events for tacklers in collegiate rugby union. *Scand J Med Sci Sports*. 2020;30(1):185-192. doi:10.1111/SMS.13553

16. Heck JF, Clarke KS, Peterson TR, Torg JS, Weis MP. National Athletic Trainers' Association Position Statement: Head-Down Contact and Spearing in Tackle Football. *J Athl Train*. 2004;39(1):101-111. Accessed August 24, 2022. https://www.ncbi.nlm.nih.gov/pmc/articles/pmid/15085218/?tool=EBI

17. NFL Rules Digest | NFL Football Operations. Accessed August 21, 2022. https://operations.nfl.com/the-rules/nfl-rules-digest/

18. Swartz EE, Register-Mihalik JK, Broglio SP, et al. National Athletic Trainers' Association Position Statement: Reducing Intentional Head-First Contact Behavior in American Football Players. *J Athl Train*. 2022;57(2):113-124. doi:10.4085/1062-6050-0062.21

19. Bookbinder HA, Houston MN, Peck KY, et al. Factors Associated With Delayed Concussion Reporting by United States Service Academy Cadets. *J Athl Train*. 2020;55(8):843-849. doi:10.4085/1062-6050-362-19

20. Kuo C, Wu L, Loza J, Senif D, Anderson SC, Camarillo DB. Comparison of video-based and sensor-based head impact exposure. *PLoS One*. 2018;13(6):e0199238. doi:10.1371/JOURNAL.PONE.0199238

21. Hirase T, Bondar K, Doucet D, Moore B, Saifi C, Marco RAW. At-Risk Tackling Techniques and Effectiveness in NCAA Division I Collegiate Football. *Orthop J Sports Med*. 2023;11(7). doi:10.1177/23259671231182968/ASSET/IMAGES/LARGE/10.1177_23259671231182968-FIG2.JPEG

22. Moore BP, Doucet D, Dow B, Vemu SM, Hirase T, Marco RAW. At-Risk Tackling Techniques and Effectiveness in English Premiership Rugby. *Orthop J Sports Med*. 2024;12(7). doi:10.1177/23259671241255097/ASSET/IMAGES/LARGE/10.1177_23259671241255097-FIG3.JPEG

23. Richardson J, Stanbouly D, Moynihan H, Reynolds RM, Recker MJ, Markiewicz MR. The Most Dangerous Game: A Review of Head and Neck Injuries in American Football and Rugby: *https://doi.org/101177/19433875211073437*. Published online January 13, 2022:194338752110734. doi:10.1177/19433875211073437

Table 1. Description of Defensive Tackle Characteristics.

Tackle characteristic	Description
Neck position	*Position of tackler's neck position during tackle initiation*
Neutral	►Neck in neutral alignment with cervical vertebral column extended; dissipates axial force with greater ease
Flexion	►Neck in flexed anterior/forward position; cervical spine straights out and is colinear with axial force
Extension	►Neck in extended posterior/backward position; cervical spine is hyperextended and nonlinear with axial force
Contact area	*Position on the body of the ball carrier where contact was made*
Side	►Contact made in the sagittal plane
Front	►contact made in the frontal plane with ball carrier moving toward the tackler
Back	►contact made in the frontal plane with ball carrier moving away from tackler
Strike zone	*Vertical position on the body of the ball carrier where contact was made*
High	►Contact made at the shoulder or above
Low	►contact made below the knee
Medium	►contact made between the knee and shoulder
Momentum	*How the tackler approaches the ball carrier*
Attack	►Tackler identified ball carrier, changed direction and moved toward ball carrier with intent
Blocked	►Tackler was blocked by an opposing player into the direction of the ball carrier which caused a collision leading to a tackle
Multiple tacklers	► More than one tackler identified the ball carrier and converged on the BC in a collective manner
Follow-through	► Tackler continued his motion through the opponent's body as he completed the tackle
Gathering	►Tackler uses outstretched arms to corral the ball carrier
Pursuing	►Tackler approached ball carrier in pursuit of the play
Quarterback sack	►Tackler brought the quarterback to the ground behind the line of scrimmage
Tackle type	*The way in which the tackler finished the tackle*
Blowup	►Tackler raises his body and that of the ball carrier in an upward motion
Cut	►Tackler or blocker struck around the knees of the opponent
Follow-through	►Tackler continued his motion through the opponent's body as he completed the tackle
Roll	►Tackler rolled across the ground in the act of bringing the ball carrier down
Swipe	►Tackler used a sweeping motion with his arms to bring the ball carrier down
Wrap	►Tackle was secured by wrapping both arms around the ball carrier

Table 2. Defensive Tackle Characteristics Stratified by Ivy League Team.

	Team							
Variable	Team 1	Team 2	Team 3	BLINDED	Team 4	Team 5	Team 6	Team 7
Games played (*n*)	10	10	10	10	10	10	10	10
Number of players (*n*)	28	31	30	29	30	29	33	27
Total tackles (*n*)	418	458	508	501	422	461	442	491
Player position (%)								
Defensive backfield	45.2	32.1	46.7	40.7	32.1	33.3	33.3	45.6
Defensive line	24.9	29.0	15.6	26.5	27.1	17.4	28.7	24.2
Linebacker	29.9	38.9	37.8	32.7	40.7	49.3	38.0	30.1
Head contact tackle (%)	27.3	20.5	21.1	24.2	28.2	40.8	23.3	39.3
Neck position (%)								
Neutral	83.7	87.8	74.6	87.4	66.1	58.4	85.3	64.8
Flexion	13.9	10.0	13.8	8.0	32.2	41.0	12.0	35.0
Extension	2.4	2.2	11.6	4.6	1.7	0.7	2.7	0.2
Contact area (%)								
Side	36.1	33.6	40.9	37.5	30.8	30.6	38.0	38.9
Front	45.7	45.6	48.0	45.1	44.5	51.4	38.2	44.2
Back	18.2	20.7	11.0	17.4	24.6	18.0	23.8	16.9
Strike zone (%)								
High	15.8	15.3	17.9	23.6	9.2	12.1	8.2	16.7
Low	37.9	27.3	40.4	22.8	28.9	33.8	30.9	25.5
Medium	46.3	57.4	41.7	53.7	61.8	54.0	60.9	57.8
Momentum (%)								
Attack	35.4	43.9	42.5	17.8	37.9	40.6	36.9	28.1
Blocked	13.9	17.7	17.3	15.0	16.8	15.0	17.0	23.0
Multiple tacklers	14.4	16.8	7.9	23.4	19.0	15.8	20.6	7.5
Follow-through	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
Gathering	12.2	3.7	13.0	23.2	5.7	10.2	6.3	27.3
Pursuing	18.7	14.0	15.9	17.0	14.5	15.0	13.1	10.6
Quarterback sack	5.5	3.9	3.3	3.0	6.2	3.5	6.1	3.5
Tackle type (%)								
Blowup	2.6	1.7	2.0	3.6	4.7	2.2	1.6	5.7
Cut	4.3	5.2	6.5	3.8	5.2	8.5	5.7	6.7
Follow-through	1.0	3.5	2.2	17.4	8.1	6.9	5.4	.6
Roll	13.4	13.1	22.4	21.8	19.9	14.3	16.8	11.6
Swipe	3.6	4.6	6.9	4.6	1.2	2.8	2.9	4.9
Wrap	75.1	71.8	60.0	48.9	60.9	65.3	67.6	70.5

Note. Percentages (%) displayed are based within columns (i.e., teams).

Table 3. Comparison of Defensive Tackle Characteristics (N=3,699) across Ivy League Football Teams as a Function of Defense Position.

	Defensive position				
Variable, *n* (%)	DB	DL	LB	p_{FDR}	φ_c
Total tackles	1,436 (38.8)	889 (24.0)	1,374 (37.1)	<.001	.198
Head contact	500 (34.8)	155 (17.4)	384 (27.9)	<.001	.149
Neck position	--	--	--	<.001	.108
Neutral	998 (69.5)	767 (86.3)	1,046 (76.1)	<.001	.151
Flexion	375 (26.1)	111 (12.5)	277 (20.2)	<.001	.130
Extension	63 (4.4)	11 (1.2)	51 (3.7)	<.001	.069
Contact area	--	--	--	<.001	.089
Side	418 (29.1)	366 (41.2)	547 (39.8)	<.001	.115
Front	745 (51.90	342 (38.5)	594 (43.2)	<.001	.109
Back	273 (19.0)	181 (20.4)	233 (17.0)	<.001	.035
Strike zone	--	--	--	<.001	.138
High	200 (13.9)	180 (20.3)	178 (13.0)	<.001	.082
Low	572 (39.9)	154 (17.3)	415 (30.2)	<.001	.188
Medium	663 (46.2)	554 (62.4)	780 (56.8)	<.001	.132
Momentum	--	--	--	<.001	.337
Attack	749 (52.2)	71 (8.0)	481 (35.0)	<.001	.356
Blocked	96 (6.7)	336 (37.8)	198 (14.4)	<.001	.323
Multiple tacklers	158 (11.0)	174 (19.6)	242 (17.6)	<.001	.101
Follow-through	1 (0.1)	3 (0.3)	0 (0.0)	.058	.040
Gathering	228 (15.9)	74 (8.3)	181 (13.2)	<.001	.086
Pursuing	193 (13.4)	130 (14.6)	225 (16.4)	.101	.036
Quarterback sack	11 (0.8)	101 (11.4)	47 (3.4)	<.001	.204
Tackle type	--	--	--	<.001	.161
Blowup	60 (4.2)	9 (1.0)	43 (3.1)	<.001	.071
Cut	164 (11.4)	8 (0.9)	41 (3.0)	<.001	.197
Follow-through	80 (5.6)	37 (4.2)	94 (6.8)	.035	.044
Roll	224 (15.6)	145 (16.3)	251 (18.3)	.170	.032
Swipe	70 (4.9)	25 (2.8)	54 (3.9)	.058	.041
Wrap	838 (58.4)	664 (74.8)	891 (64.8)	<.001	.132
Tackle combination	--	--	--	<.001	.220
High-side-neutral	35 (2.6)	46 (5.5)	38 (3.0)	.002	.063
High-front-neutral	85 (6.4)	90 (10.7)	95 (7.5)	.002	.063
High-back-neutral	49 (3.7)	23 (2.7)	21 (1.7)	.008	.054
Low-side-neutral	109 (8.2)	51 (6.1)	115 (9.1)	.053	.043
Low-side-flexion	53 (4.0)	18 (2.1)	42 (3.3)	.074	.040
Low-front-neutral	166 (12.5)	34 (4.0)	129 (10.2)	<.001	.112
Low-front-flexion	172 (12.9)	5 (0.6)	43 (3.4)	<.001	.216
Low-back-neutral	34 (2.6)	37 (4.4)	50 (3.9)	.054	.043
Medium-side-neutral	159 (11.9)	214 (25.4)	268 (21.1)	<.001	.143
Medium-side-flexion	35 (2.6)	27 (3.2)	58 (4.6)	.032	.047
Medium-front-neutral	202 (15.2)	173 (20.6)	210 (16.5)	.006	.056
Medium-front-flexion	74 (5.6)	25 (3.0)	82 (6.5)	.003	.061
Medium-back-neutral	158 (11.9)	98 (11.7)	119 (9.4)	.099	.038

Note. Two tackles (0.1%) removed for equivocal player position. Base rates (%) are anchored within columns (i.e., each defense position). φ_c=Cramér's phi (effect size); p_{FDR}=false discovery rate adjusted *p*-value via the Benjamini-Hochberg FDR method; DB=defensive backs; DL=defensive line; LB=linebacker.

Table 4. Base Rates of Tackle Characteristics across all Ivy League Team Defense Tackles in a Season (N=3,701), and Odds Ratios of Head Contact for each Tackle Characteristic.

					95% CI *OR*		
	n	Base rate of characteristic	Base rate of head contact	*OR*	Lower	Upper	p_{FDR}
Tackle outcome							
Head contact	1,039	28.1%	--	--	--	--	--
No head contact	2,662	71.9%	--	--	--	--	--
Tackle characteristics							
Neck position	--	--	--	.544*	--	--	<.001
Neutral	2,812	76.0%	14.4%	0.068	0.057	0.081	<.001
Flexion	764	20.6%	73.4%	14.217	11.779	17.158	<.001
Extension	125	3.4%	58.4%	3.793	2.638	5.454	<.001
Contact area	--	--	--	.198*	--	--	<.001
Side	1,331	36.0%	25.2%	0.801	0.688	0.932	.006
Front	1,681	45.4%	36.6%	2.172	1.877	2.513	<.001
Back	689	18.6%	12.8%	0.317	0.250	0.402	<.001
Strike zone	--	--	--	.065*	--	--	<.001
High	558	15.1%	24.7%	0.817	0.664	1.005	.064
Low	1,141	30.9%	32.3%	1.346	1.156	1.567	<.001
Medium	1,999	54.1%	26.6%	0.853	0.739	0.984	.038
Momentum	--	--	--	.156*	--	--	<.001
Attack	1,302	35.2%	32.7%	1.417	1.222	1.642	<.001
Blocked	630	17.0%	25.2%	0.840	0.691	1.023	.094
Multiple tacklers	575	15.5%	32.5%	1.286	1.062	1.558	.014
Follow-through	4	0.1%	0.0%	1.00	1.00	1.00	1.00
Gathering	483	13.1%	33.1%	1.318	1.074	1.618	.011
Pursuing	548	14.8%	16.4%	0.456	0.360	0.579	<.001
Quarterback sack	159	4.3%	10.7%	0.295	0.178	0.491	<.001
Tackle type	--	--	--	.187*	--	--	<.001
Blowup	112	3.0%	48.2%	2.460	1.686	3.590	<.001
Cut	213	5.8%	52.1%	3.001	2.270	3.967	<.001
Follow-through	211	5.7%	31.3%	1.177	0.872	1.589	.306
Roll	620	16.8%	17.4%	0.487	0.390	0.608	<.001
Swipe	149	4.0%	16.1%	0.480	0.308	0.747	.002
Wrap	2,395	64.7%	28.2%	1.021	0.878	1.186	.799

Note. OR=odds ratio. p_{FDR}=false discovery rate adjusted *p*-value via the Benjamini-Hochberg FDR method.
*Omnibus tests for the association between the tackle characteristics (e.g., neck position types) and head contact effect size reflected by Cramér's phi (φ_c).

Table 5. Base Rates of the 13 Most Frequent Tackle Combinations across all Ivy League Team Defense Tackles in a Season (N=3,443), and Odds Ratios of Head Contact for each Tackle Combination.

					95% CI *OR*		
	n	Base rate of combination	Base rate of head contact	*OR*	Lower	Upper	p_{FDR}
Tackle outcome							
Head contact	874	25.4%	--	--	--	--	--
No head contact	2,569	74.6%	--	--	--	--	--
Tackle combination	--	--	--	.549*	--	--	<.001
High-side-neutral	*119*	*3.5%*	*13.4%*	*0.446*	*0.262*	*0.760*	*.005*
High-front-neutral	270	7.8%	22.2%	0.828	0.615	1.115	.233
High-back-neutral	*93*	*2.7%*	*4.3%*	*0.128*	*0.047*	*0.350*	*<.001*
Low-side-neutral	*275*	*8.0%*	*12.7%*	*0.405*	*0.282*	*0.582*	*<.001*
Low-side-flexion	**113**	**3.3%**	**61.1%**	**4.919**	**3.342**	**7.239**	**<.001**
Low-front-neutral	*329*	*9.6%*	*16.4%*	*0.549*	*0.406*	*0.743*	*<.001*
Low-front-flexion	**220**	**6.4%**	**73.6%**	**9.850**	**7.216**	**13.447**	**<.001**
Low-back-neutral	*121*	*3.5%*	*6.6%*	*0.201*	*0.098*	*0.413*	*<.001*
Medium-side-neutral	*641*	*18.6%*	*12.8%*	*0.372*	*0.291*	*0.476*	*<.001*
Medium-side-flexion	**120**	**3.5%**	**82.5%**	**15.499**	**9.613**	**24.990**	**<.001**
Medium-front-neutral	*585*	*17.0%*	*21.9%*	*0.793*	*0.641*	*0.981*	*.042*
Medium-front-flexion	**181**	**5.3%**	**76.8%**	**11.378**	**7.980**	**16.224**	**<.001**
Medium-back-neutral	*376*	*10.9%*	*4.8%*	*0.130*	*0.080*	*0.210*	*<.001*

Note. *OR*=odds ratio; Base rates adjusted for infrequent tackle combinations (i.e., those of n<90) removed from analyses (i.e., 13 combinations; n=258, 7.0% of all tackles). p_{FDR}=false discovery rate adjusted p-value via the Benjamini-Hochberg FDR method. *Omnibus test for the association between the tackle combinations and head contact effect size reflected by Cramér's phi (φ_c). Combinations significantly associated with greater and lesser odds of tackler head contact appear in **bolded** and *italicized* text, respectively.

Table 6. Comparison of Base Rates of Defensive Tackle Combinations between BLINDED and Other Ivy League Football Teams.

	Team				Comparison			
	BLINDED		Other teams			*95% CI OR*		
Variable	*n*	BR	*n*	BR	*OR*	Lower	Upper	p_{FDR}
Tackle combination	--	--	--	--	.156*	--	--	<.001
High-side-neutral	*31*	*6.6*	*88*	*3.0*	*0.429*	*0.281*	*0.653*	*<.001*
High-front-neutral	56	12.0	214	7.2	0.569	0.416	0.777	<.001
High-back-neutral	*20*	*4.3*	*73*	*2.5*	*0.562*	*0.339*	*0.931*	*.033*
Low-side-neutral	*39*	*8.4*	*236*	*7.9*	*0.945*	*0.664*	*1.346*	*.771*
Low-side-flexion	**5**	**1.1**	**108**	**3.6**	**3.479**	**1.412**	**8.575**	**.010**
Low-front-neutral	*42*	*9.0*	*287*	*9.6*	*1.080*	*0.769*	*1.517*	*.678*
Low-front-flexion	**9**	**1.9**	**211**	**7.1**	**3.883**	**1.978**	**7.622**	**<.001**
Low-back-neutral	*13*	*2.8*	*108*	*3.6*	*1.315*	*0.733*	*2.358*	*.378*
Medium-side-neutral	*103*	*22.1*	*538*	*18.1*	*0.780*	*0.615*	*0.989*	*.050*
Medium-side-flexion	**3**	**0.6**	**117**	**3.9**	**6.329**	**2.004**	**19.994**	**.003**
Medium-front-neutral	*88*	*18.8*	*497*	*16.7*	*0.863*	*0.672*	*1.110*	*.272*
Medium-front-flexion	**12**	**2.6**	**169**	**5.7**	**2.283**	**1.261**	**4.134**	**.009**
Medium-back-neutral	*46*	*9.9*	*330*	*11.1*	*1.141*	*0.825*	*1.580*	*.443*

Note. BR=base rate; *OR*=odds ratio; p_{FDR}=false discovery rate adjusted *p*-value via the Benjamini-Hochberg FDR method. *Omnibus test for the association between the tackle combinations and head contact effect size reflected by Cramér's phi (φ_c). Combinations significantly associated with greater and lesser odds of tackler head contact (according to analyses summarized in Table 5) appear in **bolded** and *italicized* text, respectively. High-front-neutral is not italicized as it was not significantly associated with head contact risk.