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Data-informed Intervention Improves Football Technique and Reduces Head Impacts

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ABSTRACT

CHAMPAGNE, A. A., V. DISTEFANO, M.-M. BOULANGER, B. MAGEE, N. S. COVERDALE, D. GALLUCCI, K. GUSKIEWICZ, and D. J. COOK. Data-informed Intervention Improves Football Technique and Reduces Head Impacts. *Med. Sci. Sports Exerc.*, Vol. 51, No. 11, pp. 2366–2374, 2019. **Introduction:** Although sport participation is a key contributor to the physical and mental health of children and youth, exposure to subconcussive head impacts in football has raised concerns about safety for athletes. **Purpose:** To demonstrate the efficacy of incorporating targeted football drills into a team's practice routine with the goal of improving players' technique and reduce exposure to subconcussive head impacts. **Methods:** Seventy high school football players (age, 16.4 ± 1.1 yr) were tested PRE season using a sport-specific functional assessment. Results from the testing were used to inform the design of a prepractice intervention aimed at improving tackling and blocking techniques while reducing exposure to head impacts. The assessment included drills which evaluated the players' ability to safely tackle, and block while simulating game-like situations. Testing was repeated at MID season (internal control) without an intervention, and again at POST season (experimental), after introduction of the prepractice intervention between these timepoints, administered twice weekly. All testing sessions were recorded, and subsequently reviewed by trained graders based on selected criteria defined by football coaches. A subset of 19 participants wore in-helmet accelerometers to assess the effectiveness of the intervention in decreasing head impacts during practice. **Results:** Significant improvements in blocking and tackling techniques were observed after the introduction of the intervention ($P < 0.0001$). Participating athletes also showed better techniques when evaluated in new game-like situations, postseason, providing evidence for proper acquisition and generalizability of these safer habits. Finally, frequency of head impacts (>15*g*) per practice was significantly reduced by ~30% after 1 month of training. **Conclusion:** Our results suggest that data-informed methods can be used to improve coaching practices and promote safer play, which can have a positive public health impact moving forward. **Key Words:** BEHAVIOR MODIFICATION, SPORT SAFETY, FOOTBALL, COACHING, INJURY PREVENTION, SUBCONCUSSIVE IMPACTS

Sport participation is a key contributor to the physical and mental health of children and youth (1). However, in recent years, rising rates of sport-related concussion (SRC) in contact sports like football, hockey and rugby (2) have raised concerns about the effects of repeated head injuries on brain health. As a result, rates of youth and high school football registration have fallen, with many parents citing concerns regarding safety (3), and requesting that changes be implemented to reduce injury risk. This is in concordance with increasing evidence suggesting that repetitive exposure to subconcussive head impacts may lead to structural and functional changes in the brain, similar to the ones observed after SRC (4), along with possible effects on long-term cognitive health (5). A subconcussive impact is characterized as a head contact that does not produce clinical symptoms, such as headaches, short-term memory loss, or dizziness, which are common in SRC (6). Despite the lack of concussion-related signs and symptoms, repeated mechanical loading from subconcussive impacts has been proposed to induce pathologies and functional sequalae that may be associated with chronic neurodegenerative diseases (7–9). Although no prospective studies have established a cause and effect relationship, wisely, there is a new emphasis on reducing exposure to such impacts over the span of an athlete's career.

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It is known that high school football athletes can experience up to 1000 subconcussive head impacts in a single season (10,11), and that this may vary based on position (11,12), session type (i.e., games vs practices; (13,14)), and starting status (10), as well as style of coaching and play. Furthermore, it has been shown that head-to-head contact with another player is the most probable mechanism for SRC among football players (15), likely because these collisions result in greater impact magnitudes (14). In light of findings from both neuroimaging studies and helmet kinematic assessments, growing efforts have been focused on improving player safety through federal, state and provincial legislation (16), changes in sporting rules (17), and a variety of commercial products, such as redesigned helmets and jugular compression collars (18,19). Regulations intended to limit and/or eliminate contact during practices help to reduce the total number of head impacts sustained by athletes over the course of an entire season (20,21). However, such changes fail to provide athletes with opportunities to practice and develop proper skills, such as blocking and tackling techniques, to learn how to play the game more safely. Recently, the use of specific technical training principles to teach players proper and safer fundamental football skills have shown promise for reducing head impacts (22). In particular, the implementation of helmetless tackling and a focus on proper technique led to a reduction in the frequency of head impacts per athlete exposure among college athletes (22). Despite this success, however, limited studies for team-wide interventions have been conducted in youth or high school programs. Arguably, the long-term effects of limiting head impacts through safer play may be of greater significance in younger players, given the remaining years of play in their career, and their vulnerable stage of neurodevelopment (23). Thus, despite the current initiatives enacted to make youth and high school football safer, there remains a knowledge gap regarding proper methodological approaches to reduce the number of head impacts incurred during practice, and games while helping players develop proficiency in delivering and/or engaging in contact on the football field. Optimal neuromuscular performance is achieved and more likely retained when training is initiated during preadolescence (24). This would suggest that earlier interventions may be most beneficial. As well, existing literature on behavior modification has yet to consider ways to improve blocking events in football, where a player is required to protect and/or deliver contact to make way for a teammate, which should be addressed given the large number of head impacts sustained by offensive and special team players in both games and practices (21).

The purpose of our study was to investigate the introduction of a data-informed behavioral intervention designed to improve both blocking and tackling techniques among high school football players. We aimed to demonstrate the efficacy of incorporating targeted fundamental football drills into a team's practice routine with the goal of improving players' technique throughout a season. We hypothesized that this data-informed intervention would enhance the players' ability to execute safer tackling and blocking drills while also reducing the number of head impacts sustained during practice, on a per-session basis. Finally, we hypothesized that the players' improved technique and acquired fundamental skills would translate to new game-simulating situations, as evidence of acquisition and generalizability of these safer habits.

METHODS

Participants and Ethics Approval

A total of 70 high school football athletes (age, 16.4 ± 1.1 yr; range, 14–19 yr; height, 180.9 ± 7.0; mass, 86.0 ± 18.4 kg; position group: 13 defensive backs, 9 offensive linemen, 10 defensive linemen, 1 kicker, 6 linebackers, 2 quarterbacks, 12 running backs, 17 wide receivers) were enrolled in this study. The study protocol was approved by the Queen's University Health Sciences Research Ethics Review Board (Kingston, ON, Canada). Before data collection, all subjects (and legal guardians) reviewed and signed the informed consent form approved by the institutional review board. Additionally, a subset of subjects selected by the participating football team's staff agreed to wear helmet accelerometers (see below; $N = 19$). Of the 70 players enrolled, 9 reported a previous history of SRC (range, 1–3).

Experimental Protocol

Preseason football-specific assessment of tackling and blocking technique. During the first practice of the season (baseline testing; PRE), all players participated in four football-specific drills (Fig. 1), designed to assess tackling (Fig. 1A–B, drills 1 and 2) and blocking (Fig. 1C–D, drills 3 and 4) technique. All drills were filmed using GoPro HERO five cameras (GoPro 2018, Inc.), attached to standing static tripods. Players were assigned a testing number, and this was used to track them throughout the remainder of the season.

All football drills were performed with no equipment (e.g., shoulder pads or helmet). Upright padded shields held by teammates were used for the contact component of each drill. Drills were repeated twice to assess the players' ability to execute the exercise in both directions. Each drill involved a tackling, or a blocking component preceded by an agility section. The agility section was incorporated to stimulate game-like athletic movements and force players to come into the contact with momentum after a change in direction. This was done to enhance the drill's ability to simulate a game-like situation, and thus, provide a more accurate index of the players' technique.

Drill 1 and drill 2 were designed to assess the athletes' ability to execute a good tackle in space using proper technique. In drill 1 (Fig. 1A), athletes were asked to side shuffle through stepover bags, changing directions three times, before redirecting and exploding toward the bag holder, making a linear tackle in a confined space while staying up and safe. Drill 1 was designed to assess the player's ability to move laterally while keeping their eyes up and making a proper forward tackle. In drill 2 (Fig. 1B), the athletes were asked to run back

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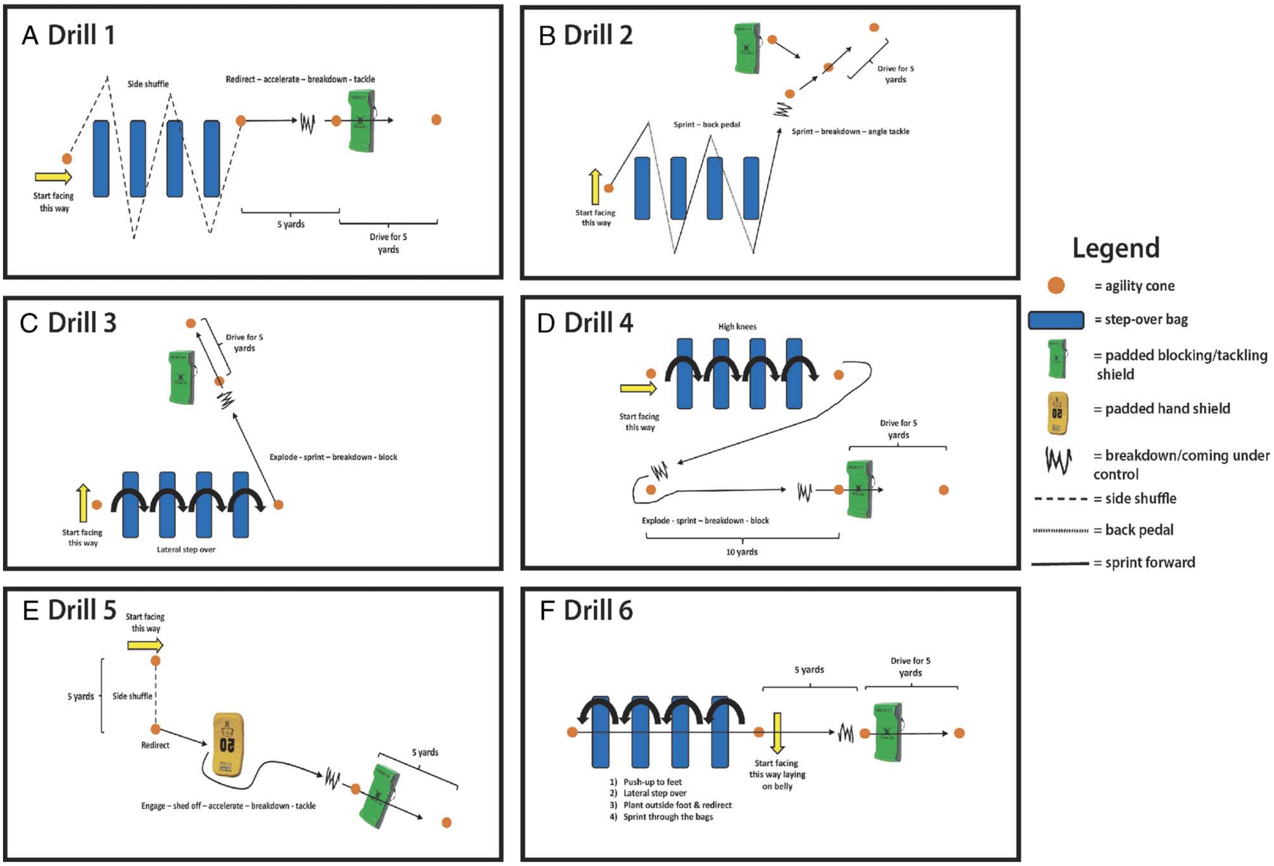

FIGURE 1—Football-specific tackling and blocking drills used to assess the players' technique throughout the season. Tackling drills 1 (A) and 2 (B), along with blocking drills 3 (C) and 4 (D) were repeated twice (one per side) at each data collection timepoint (PRE, MID, POST season). Tackling drill 5 (E) and blocking drill 6 (F) were used only at the POST season timepoint to assess the effectiveness in the intervention to translate proper skills to new game-like situations.

and forth in the "W" drill, around the step-over bags, after which they were required to make a cut at a cone and tackle a moving target. The bag holder was asked to take a step forward when the active player reached the cone, and made his cut. Drill 2 was designed to assess the players' ability to maintain proper tackling technique on an angle and place their head behind the target, which is more challenging than the requirements of drill 1. This is a common scenario in games when players are out-of-position, and/or are chasing down the ball carrier. Both tackling sections of drills 1 and 2 were scored using the same criteria, which were generated by a team of collegiate and high school football coaches based on important features required for an effective tackle.

Drill 3 and drill 4 were designed to assess the athletes' ability to execute a good block in space using proper technique. In drill 3 (Fig. 1C), players were asked to step laterally over the bags, plant their outside foot in the ground to redirect, and explode off that foot in an angle to make a block on a padded shield. Drill 3 simulates a player having to quickly change direction and regain proper footing to make a good technical block. Similarly, in drill 4 (Fig. 1D), athletes were required to run through the step-over bags with high knees (one foot over each bag), after which they were asked to make two speed-cuts around cones (spaced approximately 10 yards apart), and then explode, sprint, and come under control to make a block in space. Drill 4 simulates a special team event where athletes are required to accelerate and decelerate rapidly to make plays in space.

Mid- and postseason testing interleaved with internal control and team-based intervention. Testing sessions with all four stations described above were repeated 6 wk (MID) and 14 wk (POST) after the baseline PRE season combine (Fig. 2). All testing sessions took place in an indoor turf facility to provide a consistent environment for players and to reduce bias among video coders by eliminating recognizable differences in conditions across testing sessions.

For the first half of the season, practice sessions between the PRE and MID season timepoints were preceded by 10 to 15 min of drills focused on position-specific football skills. The use of position-specific drills at the beginning of training sessions is common practice in most youth, high school and collegiate football teams. These drills consisted of practice skills regularly implemented by position coaches and served as an internal control (Fig. 2, gray) for the participating team to quantify the magnitude of players' improvement in blocking and tackling technique without having access to assessment feedback or exposure to the proposed data-informed intervention.

After completion of the MID season testing session, a team-wide, prepractice, 10- to 15-min behavior modification program

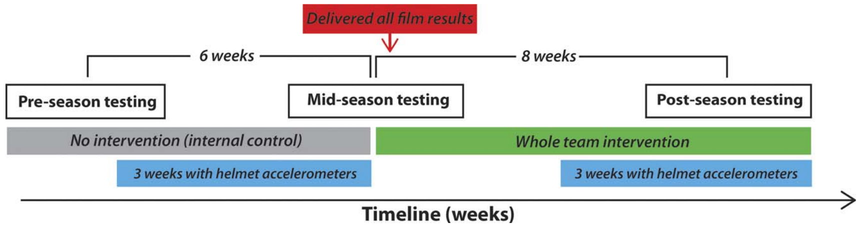

FIGURE 2—Schematic of experimental study design. The study design where players were tested PRE, MID, and POST seasons using the drills presented in Fig. 1. A biweekly (twice a week) data-informed team intervention (*green*) was introduced after the MID season testing session. Evaluated film clips from baseline performance were shared with all athletes and coaches, after the MID season testing (*red*). A subset of 19 athletes also wore helmet accelerometers (*blue*) 3 wk before, and 1 month after the MID season testing, to assess possible reduction in head impacts per practice.

was introduced twice a week (Fig. 2, green). One practice each week was focused on improving tackling, whereas the other was dedicated to blocking skills. Intervention drills were designed by a team of high school and collegiate football coaches after observations from the PRE season testing, which allowed our research team to highlight core features (i.e., fundamental skills) that required additional attention. Prepractice intervention drills were executed with the players wearing their helmet and shoulder pads and supervised by members of the research team and the football team's coaching staff. All drills were conducted using padded hand-shields, and no player-to-player contact was ever required. A member of the research team (A.A.C) was present for each control and intervention session to ensure treatment fidelity, and to provide standardized instructions across all practices.

Postseason assessment of skill translation using novel football-specific drills. To assess whether skills acquired through the behavior modification intervention could be translated to new game-like situations, two new football drills (one tackling, Drill 5, Fig. 1E; one blocking, Drill 6, Fig. 1F) were introduced for the first time at the POST season testing time point. The introduction of contextual interference in the postintervention evaluation is a valid method of increasing drill difficulty to match the learner's acquired skills and provide an added layer of analysis to confirm that players successfully consolidated and generalized desired skills learned through the intervention.

In drill 5, players were asked to shuffle laterally for five yards, followed by a forward acceleration toward a secondary target. When reached, the player needed to engage and shed the blocker, and accelerate toward the primary bag holder to make a tackle. Drill 5 was designed to simulate game-like situations where players get away from blocking opponents in their path to make a play on the ball carrier. In drill 6, players started laying prone on the ground. On the "go" signal, players were required to stand up and take lateral steps over the bags, redirect once they reached the cone, explode back to the starting point, and then continue straight ahead to engage in a proper block on the padded-shield. Again, drill 6 provided another way of assessing the players' ability to change directions rapidly and engage in a short-range blocking situation, in a confined space.

Data preprocessing, randomization, and scoring of the footage from each drill. All GoPro film data were imported into an automated program developed in-house to split the film into individual clips, for each player and each drill (Fig. 3). For every repetition of each drill, a specific identification code was assigned based on the drill (1–6; Fig. 1), the timepoint (PRE, MID, POST), and the player's ID. Once labeled, all frames were randomized and assigned a new temporary ID which was derived from a random array of numbers, without replacement (Fig. 3).

After randomization, clips for each drill were assigned to two of the study investigators (V.D. and B.M.) who were blinded from the randomization process. Both graders scored the tackling and blocking components of each drill using a predetermined standardized scoring scale that counts the number of errors, or deviations from the proper technique, accumulated by each subject. This scoring system was developed through a collaborative effort between high school and collegiate football coaches, along with former players, to incorporate important features that make up a good and safe tackle, or block (i.e., reduces the risk of head injury). Types of errors for the scoring system included parameters related to head placement at contact, arm position errors, body control, position of the feet, and more, which allowed the graders to characterize the quality of each tackle, or block. Final *safety scores* for each athlete in each drill were then computed based on the difference between the total score (1 point per feature) and the cumulated error score. Thus, a higher safety score reflects better (i.e., safer) technique.

Characterizing exposure to head impacts using helmet accelerometers. Players' daily exposure to repeated subconcussive impacts was quantified in a subset of 19 participants from various offensive and defensive positions. These players included three defensive backs, one defensive lineman, three linebackers, four offensive linemen, five running backs, and three wide-receivers. Head impacts were monitored during practices using helmet-based accelerometers (gForce Tracker, GFT; Hardware version GFT3S ver4.0, Artaflex Inc., Markham, ON, Canada), which provided measures of linear acceleration and rotational velocity by impact location. GFT sensors were mounted inside the helmet shell, to the left of the crown air bladder. Data collection was triggered at a threshold of 15*g* for consistency, similar to previous studies (25). The head impacts were categorized as "front," "right," "left," "back," "bottom," and "top" (13). Data from the accelerometers were collected for a 3-wk period before

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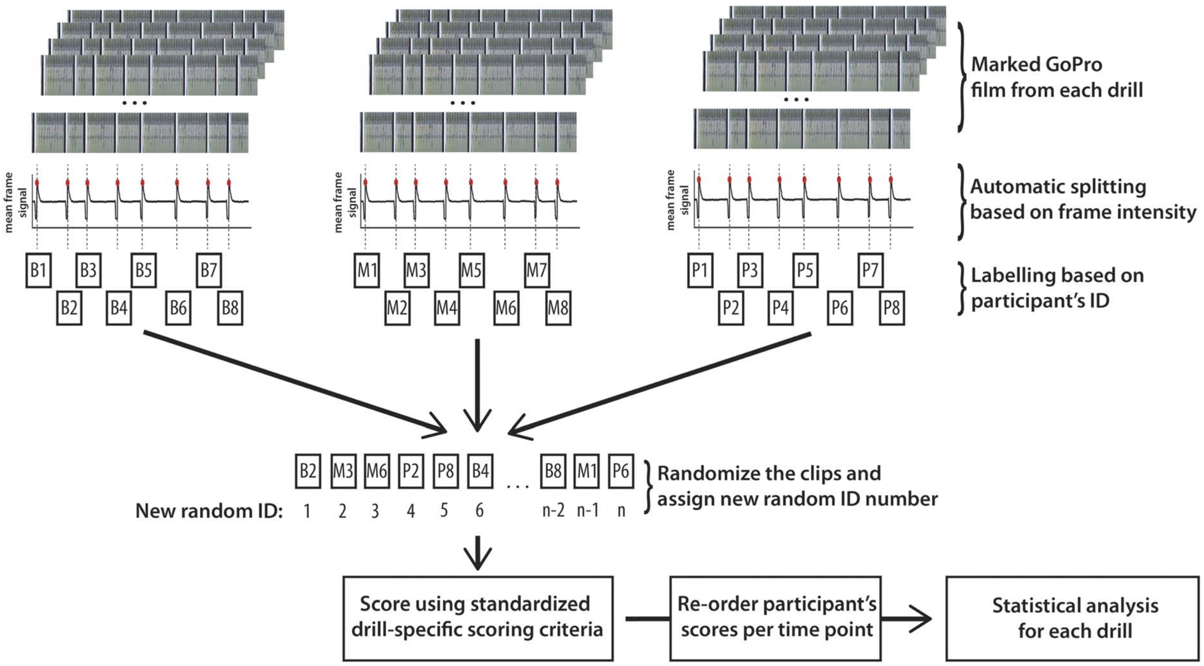

FIGURE 3—Methodology for randomization and scoring of the footage acquired at each time point. The methodological approach used to score the movie clips while blinding the graders on the time point of interest. B, baseline testing, P, postseason testing.

the MID season testing, and 1 month after the introduction of the intervention (Fig. 2, blue).

Data analysis. Statistical differences between cumulative safety scores for drills 1–4, were assessed across all time points using a linear mixed model for repeated measures, to account for missing data between subjects. In this model, time was labeled as a fixed factor, and subject was set as random.

To assess the players' performance on the new tackling and blocking drills at POST season, as an index for skill acquisition, safety scores from drill 5 (tackle) and 6 (blocking) were compared using a univariate ANOVA against the average scores from drills 1–2 (tackling) and drills 3–4 (blocking) from the PRE season assessment, respectively. This is possible because the same scoring criteria for tackling and blocking were used to score drills 1, 2, 5 and 3, 4, 6, respectively. Thus, an analysis of the tackling and blocking skills at the first exposure to each drill (PRE season for drills 1–4 and POST season for drills 5–6) may provide an indicator of whether or not the athletes had acquired safer tackling and blocking techniques.

Finally, helmet kinematic parameters including the total number of practices, the frequency of impacts per session, and the average cumulative linear acceleration and rotational velocity per session were assessed in a subset analysis using a paired *t*-test. All helmet kinetic data were processed using in-house scripts designed in Matlab (MATLAB 2018a, The MathWorks, Inc., Natick, MA).

All statistical analyses were conducted using IBM SPSS statistics (version 24.0; SPSS Inc., Chicago, IL), with a set threshold of $P < 0.05$ for statistical significance.

RESULTS

Significant differences in safety scores were documented over time across all four drills, repeated at each time point ($P < 0.0001$; Fig. 4), suggesting an improvement in blocking and tackling techniques, within the group. More specifically, for all drills, *post hoc* analyses revealed no significant differences between the PRE and MID season timepoints. However, safety scores at POST season were statistically higher than both previous testing sessions, indicating improved tackling and blocking technique after the implementation of the data-informed intervention.

In addition to improvement in drills 1 to 4 at POST season, significantly higher safety scores for tackling and blocking were observed in drill 5 ($P < 0.0001$; Fig. 5A) and drill 6 ($P < 0.0001$; Fig. 5B), compared with average combined PRE season scores from drills 1 to 2 (i.e., tackling) and 3 to 4 (i.e., blocking), respectively. Figure 5C illustrates two representative examples for improvements in tackling technique postintervention. In example one (Fig. 5C; example 1, top), a player is shown at PRE season performing a tackle with poor (i.e., unsafe) technique. His head is down, his eyes are looking down, he is not coming under control before the contact point and he is swinging his arms to make the tackle, which is causing his head to go down further. Postseason, in drill 5 (Fig. 5C; example 1, bottom), the same player comes under control before contact, keeps his head up and maintains a proper wide-base at contact, which allows him to make a safe tackle on the padded shield. Similarly, a second player is shown tackling the shield in Example 2 (Fig. 5C; bottom), where he, in

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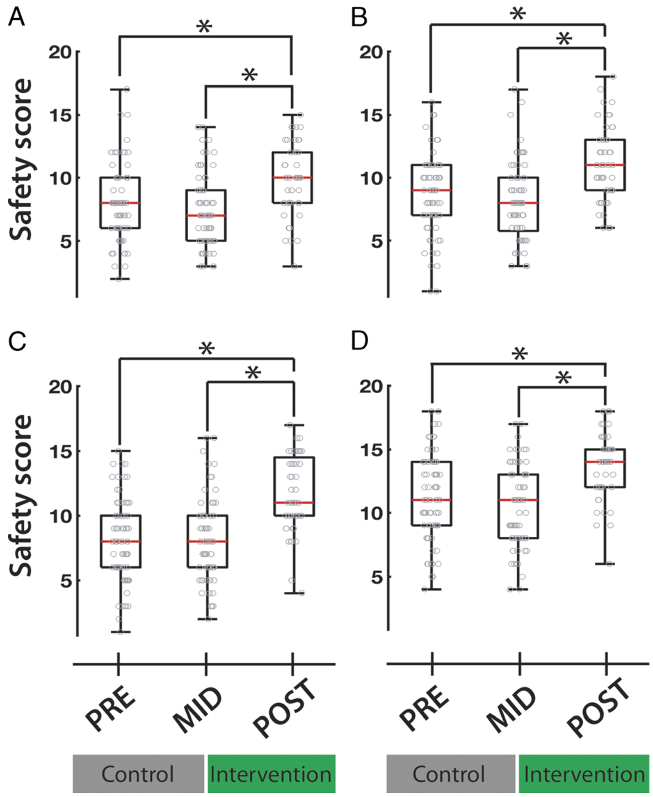

FIGURE 4—Boxplot from *post hoc* results from statistical analysis of safety scores throughout the season. Boxplots for each time point in drill 1 (A), 2 (B), 3 (C) and 4 (D) showing the minimum, maximum, median (*red*) along with the interquartile range. Differences across time points were assessed using a linear mixed model for repeated measures, and *post hoc* pairwise comparisons, upon significant differences over time (P* < 0.05).**

addition to features noted in example 1, also places his head on the wrong side of the tackle, increasing his risk of injury. After the intervention, in drill 5 (Fig. 5C; example 2 bottom), the player maintains proper control throughout the contact while placing his head on the inside of the tackle (i.e., behind the moving player), as recommended (26).

Similar block-specific observations can be made using examples 1 and 2 in Figure 5D. In both preintervention examples, the players are running at full speed towards the blocking point without coming under control. They both swing their arms out before contact, forcing their bodies to fall forward, and make contact with their head on the padded shield. Both players also fail to use their hands and arm extension to control their opponent, almost to an extent to which the player in example 1 (Fig. 5D, top) falls to the ground. At POST season, both players show efforts to come under control before engaging in their block and use good hand positioning to keep their heads away from contact. They initiate the block with their thumbs up and use their arms to properly extend the blocking point away from their bodies, creating good separation, and gaining leverage against their simulated opponent.

In addition to the film results, the subset analysis of the exposure data from the GFT helmet accelerometers showed a significant 30% decrease in the total frequency of impacts per session, 1 month after the introduction of the prepractice intervention (Table 1). Similarly, average cumulative linear acceleration per session was also decreased, though no difference in cumulative rotational velocity was observed. These differences were controlled for the total number of practices, which did not differ between the data collection blocks (Table 1).

DISCUSSION

Main findings. Our study introduced a novel, data-informed intervention designed to assess, modify and improve the safety of on-field behaviors among high school football players, and decrease exposure to head impacts on a per-practice basis. Our key findings are threefold: 1) significant improvements in blocking and tackling techniques were documented at the end of the second half of the season, after introduction of the behavior modification intervention at the MID season time point, 2) skills acquired through the prepractice drills were generalized to new game-like simulations presented to the participants at the POST season evaluation using drills 5 to 6, and 3) a 30% decrease in head impact frequency per practice was observed 1 month after the introduction of the intervention, suggesting that such an approach was effective in improving contact techniques on the field while objectively reducing exposure to subconcussive head impacts.

Making football safer using evidenced-based preventive measures. Understanding the mechanism of injury is key for the development of effective injury prevention initiatives in sport (27). Improvements in tackling and blocking techniques at the end of the season (POST) were concordant with evidence that players sustained fewer head impacts per practice, after the introduction of the football-specific prepractice intervention. This intervention aimed to address football-specific weaknesses identified using information collected during the preseason functional baseline assessment. Based on previous studies in rugby (28), better overall technique may subsequently reduce risk of head injuries in players exhibiting skill improvements. These findings may provide further incentive for athletes, parents, and coaching staffs, to incorporate similar approaches in their local practices.

The primary kinematic outcomes measured in this study to test differences in head impacts PRE and POST interventions included frequency per session, linear acceleration, and rotational velocity, which are often related to head injury in sports. Decreases in the per practice exposure to impacts and cumulative linear acceleration were observed 1 month after the introduction of the intervention. However, no differences in cumulative rotational velocity were identified, suggesting that although players' helmets were hit less often, they still sustained, on average, impacts with high rotational momentum. Whether these differences in exposure after the intervention minimize the effects of subconcussive head impacts on brain integrity (29), and cerebrovascular physiology (30), however, will require additional research that combines individual-specific behavior modification interventions and noninvasive neuroimaging tools.

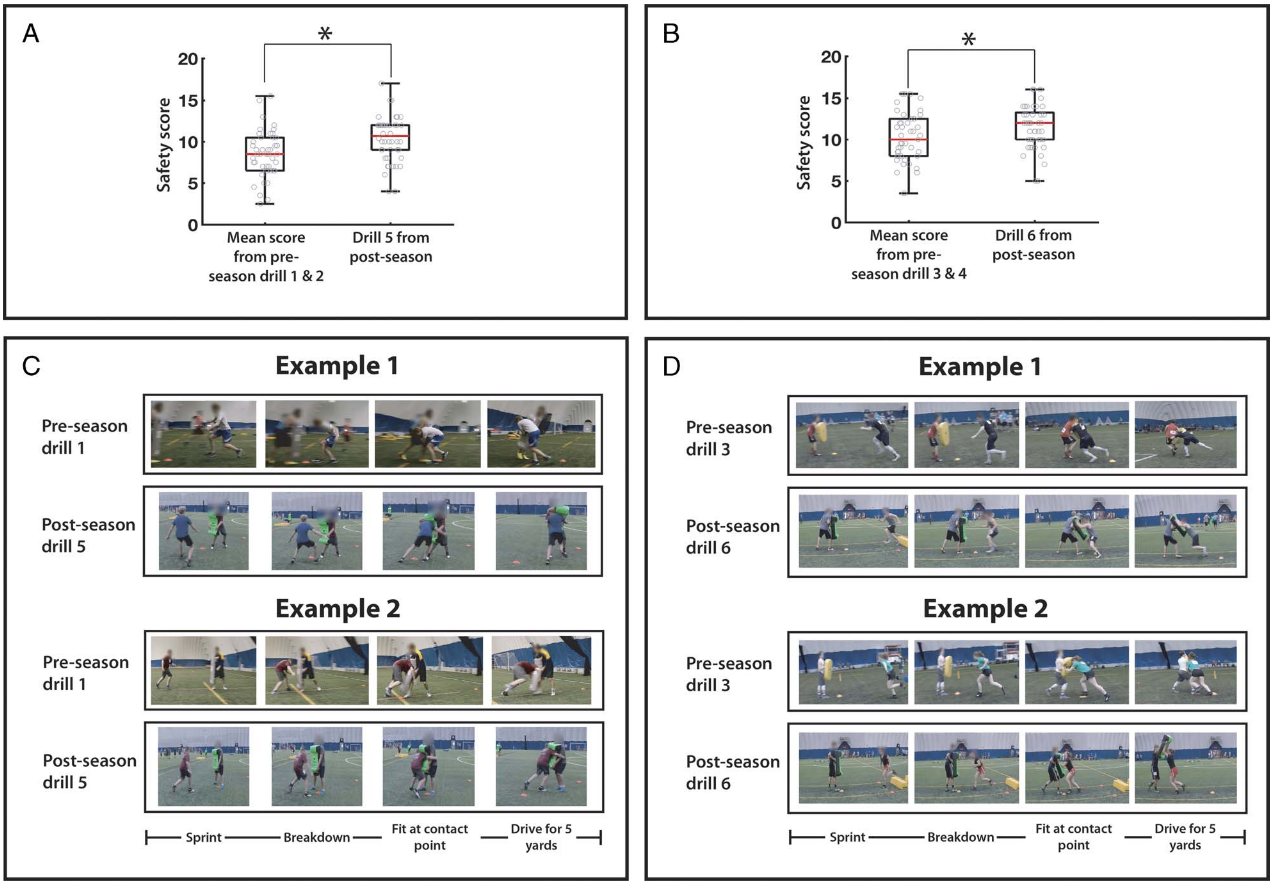

FIGURE 5—Results from tackling and blocking skill translation and generalizability assessments. (A, B) Statistical results from ANOVA between PRE season mean safety baseline scores and drill 5 (Fig. 1E) and 6 (Fig. 1F) postseason (*$P < 0.05$). (C, D) Case-studies from PRE and POST seasons assessment showing the improvement in the player's technique for tackling (C) and blocking (D).

Recently, Swartz et al. (22) showed that a prepractice helmet-less tackling training program in collegiate football can help reduce head impacts by up to 28%, which is similar to our results in high school players (~30% difference between preintervention and postintervention exposure). One difference between our approach and Swartz's program is that athletes in our study kept their helmets on during the prepractice intervention exercises. This was done to help the athletes practice delivering contact safely and not use their head as the primary impact point while simulating practice- or game-like conditions to the best of our ability. Wearing of helmets during the drills also allowed for coaches to emphasize the need to keep the helmet out of the contact. Such findings help to emphasize that the solution to changing behaviors for safer sport is a function of targeted interventions and daily practice (Fig. 5C–D). This positive learning process was demonstrated among the present athletes who showed in drills 5 and 6 that skills acquired throughout the intervention were generalizable to increasingly challenging game-like situations, and adaptable to a changing environment, effectively demonstrating retention and transfer of necessary skills (31,32). Together, both approaches show promise for the use of prepractice data-informed interventions as an effective tool for teaching athletes how to properly engage in contact, and improving safety in football.

One key additional component to the method proposed in our study is that the players, and the coaching staff, were informed and educated about the specific skills that required additional work, using film from the baseline assessment (PRE). This information was shared with players and coaches using individualized and team-specific results from the film analysis, which helped players and coaches understand the blocking and/or tackling skills that needed additional attention. The use of film analysis to catalyze performance improvement is not new to sport, as advances in video technology have enhanced the learning of sport skills through easier means of communication, and visual feedback (33–35). The use of the players' videos was introduced in our study after MID season testing to enhance teaching and help the athletes understand the reason behind the prepractice drills executed twice a week.

TABLE 1. Accelerometer data from the GForce trackers mounted in the football helmets.

	PRE **Intervention**	**1-Month *POST* Intervention**	***P***
No. practices	5 ± 1	4 ± 1	0.5225
Frequency of impact exposure per session	9 ± 4	6 ± 3	0.0022
Average cumulative linear acceleration per session (*g*)	272.19 ± 112.78	186.10 ± 80.98	0.0037
Average cumulative rotational velocity per session ($°\cdot s^{-1}$)	4047.46 ± 1838.71	3789.98 ± 2170.24	0.6378

Values are in mean ± standard deviation. Group differences were assessed using a paired *t* test.

This approach was designed to reinforce the importance of correct behaviors when making a safe tackle, or block, which inherently also likely helped make players accountable for their own individual weaknesses. Altogether, such a method may offer an appropriate compromise between maintaining competitive community sport programs and promoting sporting activities where fun and safety are integral to a team's success. Moreover, although physical practice through repetition may help athletes learn proper skill, combining such practices with video observation may enhance skill transfer for more long-term retention of the proper techniques (36). This, however, will require further research as the current design is limited in testing this hypothesis.

After the enactment of provincial legislation such as Rowan's law (37), in Ontario, Canada, initiatives like the one proposed in our study will become instrumental to making contact sports safer. Further, this program, among others, will effectively reduce the cumulative exposure to repetitive subconcussive head impacts and risk for injury, among football athletes and athletes in other contact sports, moving forward.

Limitations. There were limitations to our study that should be acknowledged. First, despite the success in integrating both video feedback and daily practice, this design cannot differentiate whether biweekly repetition of the prescribed intervention drills or the video feedback was most effective in helping players improve their technique (35). Future research will include different research groups to help answer this question. This will be a critical step moving forward as a better understanding of the tools that are more effective in changing behaviors may help to inform future and more efficient allocation of resources in efforts to assess, intervene and increase player safety. For the benefits of this study to be scaled up, and extended to the larger community, it is clear that leagues, football programs and coaches will need to invest efforts toward learning and implementing tools designed to assess technique by video, effectively. Although this may require additional resources from sport stakeholders, it is believed that such commitment to customized feedback, and training programs, will optimize athletic development, and refocus coaching practices toward a sport culture where safety of the athlete is the priority, as a way to reduce head injuries.

In the current analysis, the football experience of each player preseason was not accounted for. One may suspect that the level of experience in contact football may affect the players' learning curve in safer play and effectiveness of the proposed intervention (35). This is because athletes with previous experience with tackling and/or blocking may have limited potential in terms of improvement resulting from the intervention. Similarly, athletes with little exposure to contact football may show inflated improvements in their safety scores, given that these participants started with minimal experience. Though previous football experience was not controlled in our study, it was assumed that the distribution of experienced and inexperienced players was equally split. In future designs, a detailed demographic form will be assigned preseason to inquire about each participants' level of experience with football and other contact sports, and subsequently assess the degree of effectiveness of this intervention independently of experience. With the recent rise of popularity of alternative sports like flag football among youth athlete, future study designs may also consider exploring differences in baseline performance based on athletes' previous experience through different developmental trajectories, including both flag and contact football. The effect of position played were not explored in this study, due to the limited sample size. However, the ability to block and tackle may differ for offensive and defensive players given their varying previous experience in executing these skills. Thus, future research should also explore the effects of position played on both baseline performance, and the effectiveness of the intervention, by splitting groups based on offensive and defensive positions. Nonetheless, youth and high school players should be expected to know how to both tackle and block properly, since a large proportion of athletes play on both sides of the ball.

Lastly, the design used for this study did not account for possible improvements strictly due to season-long participation in football practices and games. Though different steps were taken to control for such effect (e.g., the internal control period between PRE and MID season testings and the introduction of drills 5 and 6 at postseason testing), future designs should include a control group that does not take part in any of the intervention drills, throughout the season. Though this might introduce logistical limitations with respect to compliance from coaches, parents and/or athletes (i.e., assigning players to intervention or control conditions), such a design would provide robust evidence that the intervention proposed here is central to inducing changes in the safety scores between the MID and POST season time points, and promoting safer play.

CONCLUSIONS

As concerns for youth and adolescent athletes playing contact sports continue to increase, our proposed novel, comprehensive and community-based intervention for making football participation safer shows great promise. It is imperative that we incorporate evidence from scientific innovation to change rules, develop better education tools, and enhance coaching practices to catalyze the processes by which participation in sport can contribute to physical and mental health. As we work to integrate data-informed interventions into our community sports, we are creating opportunities to improve public health outcomes by decreasing the economic burden associated with football-related head injuries, and the long-term neurological consequences related to repetitive exposure to subconcussive impacts. Moving forward, such practices will become key contributors in reducing exposure to head impacts among child and adolescent athletes while enhancing technique and behaviors on the field, thus allowing coaches to develop athletes who master their game while striving to promote safer play.

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Results from this study are presented clearly, honestly and without fabrication, falsification, or inappropriate data manipulation. Results of the present study do not constitute endorsement by the American College of Sports Medicine (ACSM).

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