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Concussions in Sports

Improper Fit in American Youth Football Helmets Across One Competitive Season

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Abstract—Improper helmet fit is related to sport-related concussion symptomology. The objective of this study was to determine the prevalence of improperly fit helmets in American youth tackle football players across one competitive season. Four recreation leagues including 147 players (45.2 ± 14.7 cm, 147.5 ± 9.0 kg), aged 7–12 years, participated in pre-season and post-season data collection timepoints. Participant and league demographics were collected at pre-season. Helmet fit was assessed at pre- and post-season using a 13-item checklist. A helmet was defined as improperly fit if failed to comply with or more of the checklist items. Most players (84%) rented helmets from the league. At preseason, 71.4% of helmets, and at post-season 79.6%, were improperly fit with no significant change over time ($p = 0.14$). Of the 105 improperly fit helmets at the start of the season, 61% were still considered improperly fit at post season. The 11–12 year old age group had significantly more improperly fit helmets than the 7–10 year old age group at post-season ($p = 0.033$), but not pre-season ($p = 0.655$). American youth football players depend on the league to fit their helmet. Most players did not meet at least one checklist criteria. Helmets improperly fit at preseason were still not fit at post.

Keywords—Athletic injuries, Head protective devices, Risk factors, Concussion, Pediatric, Tackle, Helmet, Football, Youth.

INTRODUCTION

In the United States (US), almost one million children aged 6–12 play American tackle football.[13] Over 10 years, there were over 3.4 million Emergency Department visits for sports-related traumatic brain injuries in the US, with 70% attributed to youth athletes.[13] Concussions compose approximately 9% of all injuries in youth football with injury rates ranging from 2.38 to 6.16 per 1000 athlete-exposures in games and 0.24–0.59 in practices.[15,22,31] Youth athletes are at high risk for concussion, more severe symptoms following head injury, and longer recoveries,[6,7,35] highlighting the importance of early and effective care in this population.

Risk factors for concussion in youth athletes should be addressed with education and prevention strategies. Proper tackling technique,[25,32] coach and player education,[32] rule or drill changes to limit head contact,[1,32] alternatives to tackle football,[32] and concussion management state laws,[24] are examples of effective intervention strategies. Quality protective equipment can also be considered a relatively easy prevention strategy to utilize.[23] Extensive research supports that football helmets reduce the risk of serious head and facial injuries,[4] and may reduce concussion rates as well.[2,11,34] Previous research has reported certain helmet brands may reduce concussion risk,[11] but recently football helmets that recorded lower impact severity in the lab were associated with lower concussion rates in football players.[2] Additionally, football helmets have been associated with concussion symptoms. A seminal

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study reported that high school football players who sustained concussions while wearing an improperly fit helmet had more, and longer lasting, symptoms.[17] This is concerning since 62% of youth lacrosse and ice hockey players were found to have at least one criteria indicating an improperly fit helmet.[38] Youth athletes (i.e. younger than high school level) are typically dependent upon stakeholder help with equipment fitting. Despite noteworthy concussion prevalence in the sport, research has not examined helmet fit in American youth tackle football.

Helmet fit could be influenced by several factors including type, size, and reconditioning status. National Operating Committee on Standards for Athletic Equipment (NOCSAE) certifies all football helmets. But headforms used during this process are limited in number and therefore may inadvertently constrain the sizes available to youth, parents, and leagues to purchase.[29] Helmets with a longer time frame since reconditioning become more prone to deterioration.[37] Improperly fit helmets are also associated with more concussion symptoms.[17] In high school football players, improper helmet fit and inadequate maintenance can be frequent.[16] It could be postulated that youth athletes are less responsible and knowledgeable, and therefore might be less compliant in maintenance of their helmets during a season. Yet time across one competitive season, and age of the player, has not been examined in football helmet literature. Therefore, the primary purpose of our study was to determine the prevalence of improperly fit helmets over the course of a single competitive season in youth American tackle football players. The secondary purpose was to determine if time and player's age were associated with improper helmet fit.

MATERIALS AND METHODS

A cross-sectional research design was utilized. Independent variables were time (pre- and post-season) and player age (7–10 years(y) [''Mites''] and 11–12 years [''Termites'']). Prevalence of improperly fit helmets was the dependent variable. Players from four youth tackle football leagues participated. Each of the four leagues were within the state of South Carolina but varied in location (urban, rural, *etc*). The leagues were from different community-based recreation departments within no national organization (i.e. Pop Warner), nor helmet fitting policies. None of the leagues had formal equipment managers. Coaches were responsible for fitting helmets. Players were assigned teams based on age and included both boys and girls. There were no other exclusion criteria. Parents/guardians of all football players were emailed an invitation to participate that included information about the study through their league director. Parents/guardians could respond to the email and indicate they did not want their child to participate, otherwise consent of the parent/guardian was assumed and verbal assent was obtained from the player before each data collection session. IRB approval was obtained from the University of South Carolina's IRB before teams were contacted.

League demographics were obtained through the recreation department's websites or conversation with league directors before the season started. Helmet rental fee, number of teams, players, and coaches were collected for descriptive purposes. Player demographics were collected directly from the child. Age was self-reported in whole years. Weight was obtained in kilograms to the tenth decimal using battery-powered digital scales (Tanita Digital Scare BWB-800A; Seca 869/874). Standing height was measured in centimeters using portable stadiometers (Shorr Productions, Maryland). Players were wearing full pads and cleats during measurements due to the time proximity of data collection to practice time. Head circumference was obtained with a measuring tape by starting 2.5cm above participants' eyebrows and following the perimeter of the head.[33] Concussion history was determined by a verbal yes or no to the question, ''Have you ever seen the doctor for being hit in the head from playing sports?''. Parents/guardians were permitted to answer the question on behalf of the player. Helmet demographics included brand, construction date, size, and helmet acquisition. Helmet acquisition was either rented from the league, newly purchased by the parent, or second hand from a family member or friend. Helmets provided by the leagues were fit by coaches before the first day of full contact. In addition to the actual size (i.e. the size listed inside the helmet), recommended size was determined by using the players head circumference and comparing it to the brand's manufacturer guidelines, with helmet type considered when needed.

A 13-item checklist was adopted from previous research examining helmet fit in youth lacrosse and hockey (Table 1).[38] The checklist was originally developed using basic helmet fit guidelines from national sport organization standards.[38] Each item in the checklist was considered equally weighted and was addressed one at a time by the research assistant with the player and their helmet. The research assistant circled ''yes'' on the checklist if the criteria was considered met or properly fit and would circle ''no'', if the criteria were not met. ''Improper fit'' was operationally defined as not meeting one or more of the checklist criteria; to be considered ''properly fit'' all 13 items on the checklist had to be met.[38]

TABLE 1. 13-criteria checklist used for helmet fit assessment.

The helmet appears in good condition
All padding is in place
All snaps and screws are in place
NOCSAE football and sticker/logo is visible
Helmet fits head snugly all sides
Helmet covers the base of the skull
Crown of helmet is 1–2 fingers above eyebrows
Helmet does not impinge neck movement
Helmet does not cover eyes when pressing down
Chin straps have equal tension
Facemask does not slip when pulled left to right
Facemask does not slip when pulled up and down
Skin on forehead moved with helmet front to back and left to right

Adapted from previous research[18].

Before data collection, all research assistants attended a helmet fit inspection training taught by a community helmet expert. The expert had 20 years of experience fitting youth football player's helmets. The training consisted of a lecture on helmet fit components, hands-on training, and practice. After the training, reliability was measured with the assessment of a variety of helmet types and sizes. The helmet expert and each research assistant evaluated individual helmet fit using the checklist. Inter-rater reliability findings (Fleiss Kappa = 0.70–0.98) suggest substantial agreement (0.61–0.80) to almost perfect agreement (≥0.81).

Player and helmet demographics were collected at the pre-season time point and player demographics again at post-season. The pre-season time point occurred within the first two weeks of the season, before the first full-contact practice. The post-season time point occurred within the last two weeks of the season before the final game. There was approximately 14 weeks between time points for each league. Multiple research stations were set up next to the football fields for efficient data collection. To assess helmet fit, players were asked to put on their helmets as they normally would for a practice or game. After each league's data collection, the head coach was notified of any helmet fit concerns so that they may address the issue as would be custom if the coach found the same error themselves.

To determine the required sample size, we set β (statistical power) at 0.80 and α at 0.05, with an anticipated attrition rate of 10%. Using previous helmet fit research,[38] we determined it was necessary to collect data on 174 participants. Descriptive statistics for continuous and categorical variables were calculated. Overall prevalence of improperly fit helmets and individual checklist criteria were determined. A McNemar test was used to determine change in overall helmet fit from pre-season to post-season. Improper helmet fit between age groups were compared with cross tabulation Chi-square analyses. Chi-square tests were also used to determine if there was an association between recommended and actual helmet size. Extra-small and extra-large helmet sizes were collapsed with small and large sizes, respectively, due to small cell sizes. Statistics were analyzed with SPSS Statistical Software (Version 26; SPSS Inc, Armonk, NY) with *a priori* alpha of 0.05 for statistical significance.

RESULTS

Most league's registration fee included an associated helmet rental. Each league had between 2 and 15 teams and at least one "Mite" (7–10 years) and one "Termite" (11–12 years) team. Coach staffing ranged from 8 to 52, per league. Data were collected on 267 participants at pre-season (age 10 ± 1 years, height 46.0 ± 14.6 cm, weight 147.9 ± 8.9 kg, BMI 20.8 ± 4.8 kg/m^2, head circumference 54.5 ±1.8 cm, positive self-reported concussion history 22/267, 8.2%) (Table 2), with 41.2% of participants in the 7–10 age group (n = 110) and 58.8% in the 11–12 age group (n = 157). Pre-season helmet demographics can be found in Table 3. The frequency of models by brand varied (Schutt: 6, Ridell: 3, Rawlings: 2, Xenith: 2).

Only 147 players had data for both pre- and post-season time points (Table 2). Four players (2.7%) reported sustaining a concussion during the season. Overall, 71.4% of helmets (n = 105) at preseason and 79.6% (n = 117) at postseason were improperly fit. There was not a statistically significant change in the proportion of improperly fit helmets from pre- to post-season. (X^2_{146} = 2.2, p = 0.14). Of the 105 improperly fit helmets at pre-season, 83 (79%) remained unfit. Whereas 34 helmets that were considered fit at pre-season, were not by the post-season time point. When asked, 35.2% (n = 51) of players indicated they had had a haircut within two weeks of the post-season data

TABLE 2. Player anthropometrics at pre- and post-season.

	Pre-season	Post-season	95% Confidence interval for mean difference
Weight (kg)[a]	45.2 ± 14.7 (n = 145)	45.5 ± 14.8 (n = 130)	(− 2.3, − 0.5)
Height (cm)[a]	147.5 ± 9.0 (n = 147)	148.4 ± 9.3 (n = 146)	(− 1.2, − 0.4)
Head circumference (cm)	54.3 ± 1.8 (n = 147)	54.3 ± 1.8 (n = 146)	(− 0.1, 0.2)

[a]Statistically significant difference from pre-season to post-season. 95% CI not including 1.0 were considered statistically significant.

TABLE 3. Helmet demographics at preseason.

Demographic variable	Frequency (%)
Helmet brand	
Schutt	226 (85.0)
Riddell	26 (9.8)
Rawlings	7 (2.6)
Xenith	6 (2.3)
Helmet construction date	
Not found	84 (31.6)
2005–2009	14 (7.7)
2010–2014	79 (43.4)
2015–2019	89 (48.9)
Helmet acquisition	
Rented	220 (82.7)
Newly Purchased	38 (14.3)
Secondhand	8 (3.0)

n = 266: one player's demographics could not be determined from the helmet.

collection. Most players (46.2%, $n = 68$) indicated no individual had adjusted their helmet during the season. For those who did, while allowing for multiple answers, 38.7% ($n = 57$) and 17.7% ($n = 26$) indicated a coach or a parent addressed helmet fit at some point during the season, respectively. Frequencies of helmet checklist criteria that were not met/improperly fit are depicted in Figure 1. Frequency of the number of criteria not met varied from 1–2 (pre-49.7%; post-42.2%), 3-5 (pre-40.7%; post-42.9%), to 6–10 factors (pre-9.6%; post-14.9%). For age groups, the termites (11–12 years) had significantly more improperly fit helmets than mites (7–10 years; $\Gamma_1^2 = 5.019$, $p = 0.025$). Actual helmet size was significantly associated with recommended helmet size ($X_{24}^2 = 147.047$, $p < 0.0001$) at pre-season. However, only 115 of the 267 (43%) helmets matched on actual and recommended size.

DISCUSSION

Our study is the first to examine helmet fit in youth American tackle football players. When considering all youth sports, the prevalence of head injury is the highest in football, ice hockey, and lacrosse.[27] Neck strengthening, education, rule changes, and protective equipment are interventions that have been proposed to limit the prevalence of head injury. Helmets are a prevention strategy that have effectively decreased the incidence and severity of head, skull and facial injuries in sports and bicycle studies.[14,18] Helmets are a relatively easy prevention strategy to implement and enforce, but only if their use includes proper fit to match helmet conditions during laboratory impact testing.[38]

Player demographics were like those reported in previous research on youth football teams.[10,20,22] Height and weight changed over the season, but head circumference did not. Youth grow significantly during the age ranges reported in our study.[3,26] Practically, since head circumference was unchanged, one could surmise that if the helmet size accurately fits at the beginning, it will be unlikely the child needs a different helmet size during the remainder of the season. The pre- and post-season prevalence of positive concussion history is similar to previous research in this age group,[15,21] and supports continued research regarding prevention strategies.

Most helmets were rented from the YFB leagues as part of their registration fees Therefore, the league staff were responsible for fitting the helmets. Three of the leagues used more than one helmet brand with varied models. This is understandable as different brands may fit different head shapes. However, coach helmet fitting education is not a mandatory requirement for recreation leagues, nor teams affiliated with national organizations. Previous research on the implementation of "Heads Up Football" training reported that nearly half of coaches did not attend the safety clinic before their season began.[19] During data collection, we noticed that the leagues stored and distributed their helmets in sheds near their football fields. Helmet fitting happened within the first week of the season, before practice started. All players on the team arrived within the time frame and waited in line, providing those who came late, less time for fitting. Allocating more time for helmet fitting before practice starts, or providing a time frame not associated with practice, may be beneficial to improving helmet fit. However, this will be a challenge because of parent schedules and coach volunteer hours. The development of helmet fit guideline posters and/or infographic flyers to be displayed where helmet fitting takes place may be more practical to help coaches with this massive endeavor.

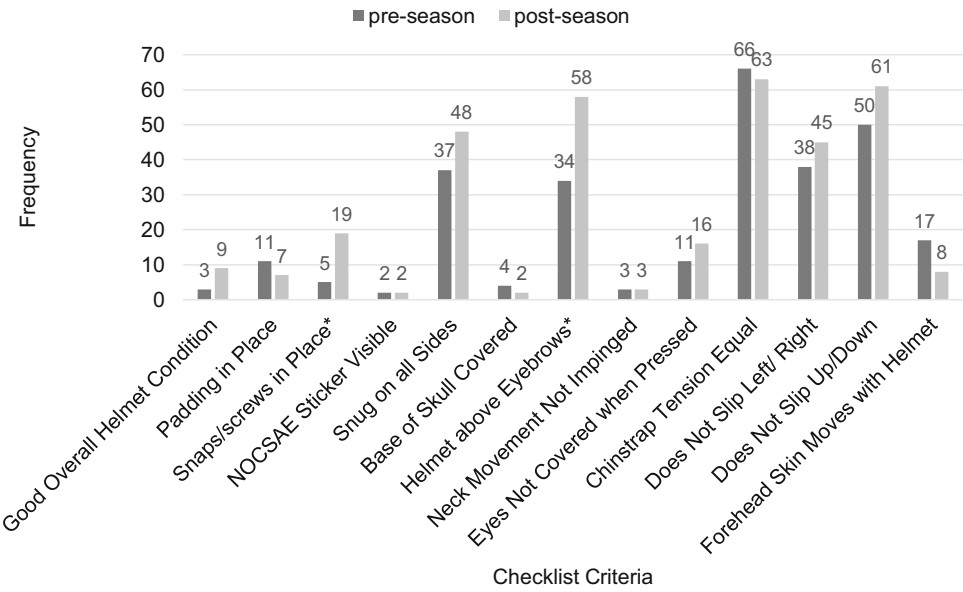

FIGURE 1. Frequency of checklist criteria not met at pre- and post-season.

The CDC does not recommend the use of a helmet older than 10 years.[9] There were 14 helmets that should have been retired. Additionally, nearly one-third of the helmets did not clearly indicate the construction date on the helmet. All of these helmets were provided by leagues. Although construction date was not a helmet fit criterion, these helmets could be considered not safe for play. A study on concussed high school football players reported those wearing an "old" helmet were less likely to have symptoms resolve in 1 day as those wearing new helmets.[12] Until more research is done on helmet age and their ability to maintain impact standards, youth football leagues should not use helmets older than 10 years. It's important to note, that of the brands recorded within the study, Rawlings is no longer making football helmets.

Over 70% of the helmets we evaluated had one or more checklist criteria not met and considered improperly fit based on the very conservative operational definition.[38] Research examining helmet fit in organized sport reported 46% of helmets were improperly fit in high school football players,[28] and 62% in boy's lacrosse and ice hockey players combined.[38] Our study found a higher prevalence of improperly fit helmets. The high percentage is concerning because even though helmets cannot prevent concussions,[4] they may reduce symptom severity.[17] In an epidemiology study, 32% of high school football players were documented as wearing an improperly fit helmet at the time of their concussion.[17] The players who suffered a concussion, and had improperly fit helmets, averaged more symptoms and experienced an additional week of symptoms compared to their counterparts. Besides concussion symptomology, approximately 7% of helmets worn by athletes who sustained catastrophic head injuries were incorrectly fit or defective at time of incident.[5] This is compelling information to support the need for youth to be wearing a properly fit helmet. We are the first to examine helmet fit across one competitive season. There was not a statistically significant change between time points. Most helmets (91/147) did not change classification; therefore, this may indicate if the helmet is properly fit at the beginning, it will likely remain fit throughout the season. Yet it is important to note 34 helmets did change helmet fit from pre to post-season warranting the recommendation that helmet fit checks should be integrated into the season.

Most improperly fit helmets had one or two checklist criteria not met. Equal chinstrap tension was the most common helmet criteria not met. This has been reported in other helmet fit research as the most common,[36] or second most common error.[30,38] Chin strap tension is a relatively quick and easy fix that could be addressed during practice or games. The next two most common checklist criteria not met were "snug all sides" and "does not slip when facemask is pulled up and down." Both criteria are related to how loose the helmet is and are impacted not only by helmet size, but also the padding inside of the helmet. This mimics previous research in which 49% of high school football players had significant movement of their helmets up-and-down or side-to-side and were not considered 'snug'.[16] The first step of fitting a helmet should be evaluating a player's head circumference to

determine the recommended helmet size.[39] Only 43% of helmets in our study matched on actual and recommended helmet size. Due to NOCSAE's headform limitations for lab testing, it could be manufacturers are unable to produce a variety of youth helmet sizes for the growing youth heads.[29] However, manufacturers are developing new systems to design helmets specifically for youth football players.[8] Future research should investigate how helmet size is determined by stakeholders (i.e. using head circumference or through estimation "eyeing up" a player's head). Then, appropriate head measuring materials or new measurement techniques should be developed and distributed to YFB leagues and parents.

The older age group had more improperly fit helmets than the younger age group at the post-season timepoint. The interaction of age and properly fit helmets was previously investigated in high school football athletes. The study reported underclassman had significantly more helmet fit errors than upperclassman; with freshman having the most errors.[28] Our results were in contrast with this previous research which was unexpected. It could be suspected that at preseason all helmets are fit by coaches but thereafter, during the season, the older age group is wrongfully given the responsibility of noticing if helmet does not fit correctly, whereas the younger group this assumption is not made. This particular research question should be explored again.

We found that over 80% of players rented their helmets from the YFB league and therefore were fit by league coaches. Many players (38%) indicated a coach had helped with helmet fit at some point during the season. Anecdotally, youth players generally do like wearing a properly fit helmet as it feels tight on their head and face. It could be coaches or parents altered helmet fit to make them more comfortable for the youth. We had very few helmets provided by the parent, but 14% of players indicated a parent had helped with helmet fit at some point during the season. Past research illustrates that parents are ineffective at properly fitting bicycle and skating helmets on their children.[30] Of the families, 90% of the parents and children felt that it was "easy" or "pretty easy" to fit a helmet but 96% of helmets were found to be in poor condition or improperly fit.[30] This illustrates a gap in actual helmet fit competence and over-confidence of parents and youth. Improved, or different, education strategies and materials on proper helmet fitting for parents and their children need to be developed.

A limitation of our study is we cannot determine accuracy for the youth player self-reporting variables such as their age, helmet acquisition, and concussion history. Although utilized in previous research in youth contact sports[38] and supported by sport organizations, the helmet fit checklist utilized in this study has not been validated. Although our subsample size (players in both pre and post time points) was lower than the power analysis, we found statistical significance. The results of this study may not be generalized to YFB leagues outside of the Southeast Region of the US. Lastly, in order to have efficient data collection, multiple research assistants assessed helmets, one at each data collection station. However, these research assistants were trained with substantial to nearly perfect inter-rater reliability.

In conclusion, most helmets were considered improperly fit by conservative standards. Chin strap tension was the most common checklist criteria not met, which can be easily addressed when recognized by stakeholders (i.e. coaches, parents). Players grew during the season, but head circumference did not. Yet, helmet size seems to be a crucial factor as almost half of helmets did not match with the manufacturer's recommended size; and lack of snugness and slippage in different directions were frequently documented during helmet fit assessments. The older age group had more improperly fit helmets than the younger age group. Future research needs to examine helmet size selection, fitting interventions during the season, and the interaction of age and fit.

Practical implications of the findings are indicated. (1) Manufacturer guidelines should be consulted, and ample time provided to try on different helmets, when size selection is determined for each youth football player. (2) If the youth football helmet is properly sized and fit at the beginning of the season, it will likely stay fit throughout the season. (3) Leagues and their coaches who are primarily responsible for helmet fitting should utilize current educational resources, and manufacturers or organizations develop on-site materials to guide them in proper fitting. (4) Checking chin straps before the first contact-practice should be a priority in youth American tackle leagues.

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