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Examining the influence of the Get aHEAD Safely in Soccer™ program on head impact kinematics and neck strength in female youth soccer players

Victoria E. Wahlquist[a], Joseph J. Glutting[b] and Thomas W. Kaminski[a]

[a]Athletic Training Research Laboratory, University of Delaware, Newark, DE, USA
[b]School of Education, University of Delaware, Newark, DE, USA

Contact:
Thomas W. Kaminski
kaminski@udel.edu
Human Performance Laboratory, University of Delaware,
Room 159 Fred Rust Ice Arena, 547 South College Avenue, Newark, DE 19716, USA

Abstract
The objective was to examine the efficacy of the Get aHEAD Safely in Soccer™ intervention on head impact kinematics and neck strength in female youth soccer players. The control group (CG) consisted of 13 players (age: 11.0 ± 0.4 yrs), while the experimental group (EG) consisted of 14 players (age: 10.6 ± 0.5 yrs). Head impact kinematics included peak linear acceleration (PLA), peak rotational acceleration (PRA), and peak rotational velocity (PRV). Pre- and post-season measures included strength measures of neck/torso flexion (NF/TF) and extension (NE/TE). Data were analysed using a multilevel linear model and ANOVA techniques. No differences in PLA, PRA, or PRV were observed between groups. The EG showed significant improvement in NF strength while the CG showed significant improvement in NE strength. Both groups significantly improved in TF pre- to post-season. The foundational strength components of the Get aHEAD Safely in Soccer program appear to show a benefit in youth soccer players beginning to learn the skill of purposeful heading.

Keywords
Football; muscle strength; concussion; wearable sensors; repetitive head impacts

Introduction

In the United States, soccer is one of the most popular youth sports with over 3 million participants (US Youth Soccer, 2020). In soccer, players are allowed to use their heads to advance the ball in play. There is concern about concussions in the youth population and how repetitive head impacts can affect players later in life; as such the United States Soccer Federation (US Soccer) announced the US Soccer Concussion Initiative, which provides guidelines on purposeful heading in the youth population (US Club Soccer, 2015). The guidelines state that heading be banned in players aged 10 years and younger, while allowing players aged 11–13 a range of 15–20 headers in practice per week and unlimited headers in games. Headers become unlimited in practices and games in players aged 14 years and older. Missing from these guidelines are directives for coaches and administrators as to how to properly teach soccer heading to this specific age group.

To fill in the gaps between heading guidelines and teaching header skills to youth players, the Get aHEAD Safely in Soccer™ program was created (United Soccer Coaches, n.d.). There are five principles to the Get aHEAD Safely in Soccer™ program: 1) teach proper heading technique, 2) develop strong neck and core musculature, 3) avoid dangerous play situations, 4) educate referees who enforce the rules and guidelines, and 5) use lightweight soccer balls to decrease the mass imparted on the head. The goal of the program is to equip youth soccer coaches with the tools to properly teach young soccer players the correct form and technique needed to head the ball. Coaches are also furnished with header drills that progress from beginner to more advanced, along with neck and torso strengthening exercises. Neck and torso strengthening exercises are included because current research suggests that stronger neck musculature is correlated to a decrease in head acceleration (Caccese, Buckley, Tierney, Arbogast et al., 2018b; Gutierrez et al., 2014; Peek et al., 2020).

Head impact kinematics can differ based on age and sex. Age is one factor in which head accelerations are higher in youth players compared to high school and collegiate players (Caccese, Buckley, Tierney, Rose et al., 2018a; Kalichová & Lukášek, 2019). This difference is thought to be due to youth players having weaker neck musculature as opposed to their mature counterparts (Caccese & Kaminski, 2016; Queen et al., 2003). Additionally, female soccer players have been observed to have higher head accelerations than male soccer players (Caccese, Buckley, Tierney, Rose et al., 2018a; Chrisman et al., 2019). Head acceleration is also affected by soccer playing scenarios, whereby goal and corner kicks result in higher head impact magnitudes while throw-ins and bounces have lower head impact magnitudes (Caccese et al., 2016; Harriss et al., 2019; Miller et al., 2020). In contrast to head impact kinematics, high school male soccer players head the ball 2.2 times more than their female counterparts (Huber et al., 2021). The higher head impact exposure in males is also seen in those aged 11 years through those playing soccer professionally (Sandmo et al., 2020).

The purpose of this study was to determine the efficacy of the Get aHEAD Safely in Soccer™ program intervention on head impact kinematics and neck and torso strength in female youth soccer players over the course of one soccer season. We hypothesized that the those who completed the program would have an increase in neck and torso strength and smaller head impact kinematics compared to the control group.

Methods

Twenty-seven female youth soccer players were recruited from two local youth soccer clubs. Each team was a competitive travel team in the Under-12 (U12) division. All participants signed the university institutional review board approved child assent forms, while parents signed the parental permission forms (UDIRB 1168008-7). Participants completed a general health questionnaire which included demographic data, player position, number of years playing soccer, and concussion history.

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One team served as the control group while the other team was assigned as the experimental group. The control group conducted soccer practices and games with their normal tactics, which did not include any neck strengthening or heading techniques. While adhering to their normal practice and game routines, the experimental group also participated in the Get aHEAD Safely in Soccer™ program, which included drills that taught appropriate purposeful heading along with neck/core strengthening exercises. Once each week during practice, the experimental group would complete a header drill(s) involving 15–20 purposeful headers. These drills were conducted by the coach and completed using lightweight, size 5 "Heading Trainer" (The Training Triangle, LLC, State College, PA) soccer balls. In addition, twice weekly, and before the start of practice, a member of the research team directed the experimental group in completing the neck/core strengthening exercises outlined in the Get aHEAD Safely in Soccer™ program (Wahlquist & Kaminski, 2021). Each team participated in one soccer season that lasted 3.5 months.

All participants wore the Triax SIM-G (Triax Technologies, Norwalk, CT) head impact sensor, secured to the back of the head using a custom, tight-fitting headband, during each practice and games. Each sensor has a triaxial accelerometer and gyroscope that measure peak linear acceleration (PLA) and peak rotational velocity (PRV), respectively. Peak rotational acceleration (PRA) was calculated using PRV. Our protocol was based on previous work with these same devices (Caccese et al., 2016; Lamond et al., 2018; Wahlquist & Kaminski, 2021). Additionally, these sensors have a high repeatability, outperform helmet impact devices, and are reliable for impacts under 80 g (Cummiskey, 2015; Tiernan et al., 2018). A member of the research team carefully monitored compliance so that the players wore the sensors during each practice and game.

Each participant completed pre- and post-season measures of neck girth and neck and torso strength. These measurements were all derived by the same tester (TWK) at both the pre and post season time points and were completed at their respective soccer practice facilities. A standard clinical plinth was used for stabilization when necessary. Neck girth was measured at just above the thyroid cartilage using a tape measure (Figure 1(a)). Neck flexion and extension strength were measured using a handheld dynamometer (microFET2, Hoggan Scientific, Salt Lake City, UT) placed on the forehead and back of the head, respectively (Figure 1(b)). Torso flexion and extension strength were also measured with a handheld dynamometer placed on the sternum and between the shoulder blades, respectively (Figure 1(c)). Participants completed 3 trials each of neck and torso flexion and extension while lying on a plinth starting in a neutral position. The three trials were then averaged and used in the statistical analysis. One player from each team was not present for the post-season strength testing resulting in 12 players in the control group and 13 players in the experimental group completing the strength testing both pre- and post-season.

Data variability for headers per game (HPG), total number of headers per player (HPP), and headers per player per game (HPPPG) were calculated using simple statistics. Neck and torso strength measures and neck girth were analysed using a repeated measures ANOVA with group as the independent variable. Data were analysed using a multilevel linear model. Multilevel models typically include both random-effects and fixed-effects. The dependent variables were PLA, PRA, and PRV and the one fixed-effects predictor was group. The fixed-effect predictor was on the nominal level of measurement and was dummy coded. All reported p-values were two-sided.

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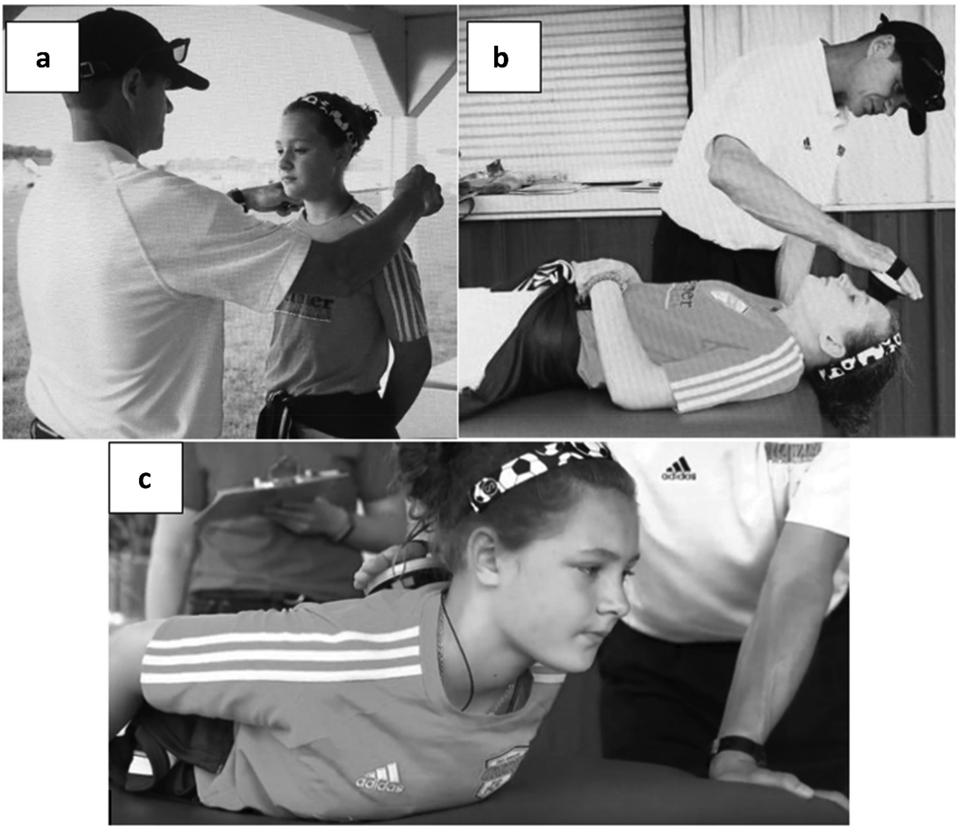

Figure 1. (a) Preparing for neck girth measurement, (b) Mid-range of neck flexion strength measurement, and (c) End-range of torso extension strength.

Results

Twenty-seven female youth soccer players in the U12 division participated in the study, 13 in the control group and 14 in the experimental group (Table 1). The control group had 41 headers over 10 games and 5 headers over 14 practices while the experimental group had 40 headers over 20 games and 1501 headers over 27

Table 1. Participant demographics and header counts.

Participants	Control (N = 13)	Experimental (N = 14)	Total (N = 27)
Age (years)	11.0 ± 0.4	10.6 ± 0.5	10.8 ± 0.5
Height (cm)	152.0 ± 11.3	146.3 ± 5.4	149.0 ± 9.0
Weight (kg)	44.0 ± 13.0	37.3 ± 5.9	40.5 ± 10.3
Games	10	20	30
Headers	41	40	81
Headers/Game	4.1 ± 2.8 (0–10)	2.0 ± 1.6 (0–5)	2.7 ± 2.3 (0–10)
Headers/Player	3.5 ± 5.2 (0–17)	3.1 ± 3.7 (0–11)	3.3 ± 4.4 (0–17)
Headers/Player/Game	0.3 ± 0.9 (0–6)	0.2 ± 0.4 (0–3)	0.2 ± 0.6 (0–6)
Practices	14	27	41
Headers	5	1501	1506
Headers/Game	0.4 ± 0.6 (0–2)	55.6 ± 84.2 (0–220)	36.7 ± 72.9 (0–220)
Headers/Player	0.4 ± 0.8 (0–2)	114.3 ± 17.3 (85–139)	59.6 ± 59.3 (0–139)
Headers/Player/Game	0.04 ± 0.2 (0–1)	5.1 ± 7.5 (0–20)	3.6 ± 6.7 (0–20)

Mean ± SD (Range).

Table 2. Pre- and post-season neck girth and strength measures.

	Control (N = 12)		Experimental (N = 13)		Total (N = 25)	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
Neck Girth (cm)	29.8 ± 2.8	29.9 ± 2.4	28.8 ± 1.4	28.2 ± 1.4	29.3 ± 2.2	29.0 ± 2.1
Neck Flexion (N)	57.9 ± 14.5	64.8 ± 14.1	53.0 ± 11.3	64.0 ± 11.4	55.4 ± 12.9	64.4 ± 12.5
Neck Extension (N)	84.6 ± 17.8	98.4 ± 20.0	87.9 ± 16.0	86.0 ± 11.7	86.3 ± 16.6	91.9 ± 17.1
Torso Flexion (N)	63.5 ± 12.7	76.9 ± 12.9	72.6 ± 14.5	84.2 ± 13.0	68.2 ± 14.2	80.7 ± 13.2
Torso Extension (N)	82.7 ± 17.1	83.1 ± 13.2	74.8 ± 8.2	84.4 ± 11.7	78.6 ± 13.5	83.8 ± 12.2

Mean ± SD.

Table 3. Head impact kinematics (Games).

	Control (N = 31)	Experimental (N = 33)	Total (N = 64)
PLA (g)	30.2 ± 16.0	28.5 ± 8.6	29.3 ± 12.7
PRA (krad/s^2)	3.6 ± 2.4	3.0 ± 1.6	3.3 ± 2.0
PRV (rad/s)	13.0 ± 5.4	12.7 ± 6.2	12.8 ± 5.8

Mean ± SD.

practices. This totalled 81 headers over 30 games and 1506 headers over 41 practices. The control group did not perform any header drills *during practice* while the experimental group performed 15–20 headers per week in practice in accordance with US Soccer Heading Guidelines. HPG, HPP, and HPPPG are summarized in Table 1.

Twelve players in the control group and 13 players in the experimental groups completed the pre- and post-season measures of neck girth and neck and torso strength (Table 2). There were no significant differences in neck girth between groups. There was a significant main effect for time (p = .001) for neck flexion whereby all players improved from pre- to post-season. Interestingly, there was a 20.75% increase in neck flexion strength in the experimental versus an 11.9% increase in the control group. Interestingly there was also a significant main effect for time (p = .039) and a group x time interaction (p = .008) where the control group showed significant improvement or increase in neck extension strength as compared to the experimental group. In stark contrast to the neck flexion strength gains, the experimental group actually showed a slight decline (−2.16%) in strength over the 3.5 month study period. There was a significant main effect for time in that both groups showed improvement in torso flexion strength pre- to post-testing (p = .001). Improvement included a 21% gain in the control group compared to a 15.98% gain in torso flexion strength in the experimental group. There were no statistically significant changes in torso extension strength for either group, even though there was a 12.83% (9.6 N) improvement pre to post-season in the experimental group vs a very small (0.48%) improvement in the control group.

Due to the difference in heading exposure between groups during practices and the use of different soccer balls, we only report the PLA, PRA, and PRV for head impacts during games (Table 3). Head impact kinematics were recorded for 31 headers in the control group and 33 headers in the experimental group for a total of 64 headers. There were no significant differences observed between the control and experimental groups in PLA (p = .692), PRA (p = .379), or PRV (p = .852).

Discussion

This is the first study to examine the effects of the Get aHEAD Safely in Soccer™ program on head impact kinematics and neck and torso strength from pre- to post-season. The number of purposeful headers performed in games by our players in the U12 age group were low. Following the Get aHEAD Safely in Soccer™ program, positive changes were seen in neck and torso strength, however there were no changes in head impact kinematics. The Get aHEAD Safely in Soccer™ program appears to be beneficial in augmenting neck and torso strength over the course of one competitive soccer season. Youth soccer coaches can easily incorporate activities targeting neck/core strengthening into their practice routines along with other soccer development activities that enhance muscle activation to resist forces that will ultimately occur during heading and/or aerial ball challenges.

Practice headers varied widely between the two groups; with the control group having performed only 5 headers while the experimental group had 1501 headers. It is important to note that the control group conducted practices with their normal tactics that *did not* include purposeful heading drills at the discretion of the coaching staff; while the experimental group was a part of the Get aHEAD Safely in Soccer™ intervention. This difference is responsible for the huge disparity in headers between the two groups. Most importantly is that the 1500+ headers performed by the experimental group in practice were done so using the lightweight soccer balls. Interestingly, the control group was observed to head the ball two times more per *game* than the experimental group. However, both groups had the same number of purposeful headers on average per player (3.5 vs. 3.1) and per player per game (0.3 vs. 0.2). This equates to one player heading the ball once every three or four games which is a low compared to the heading exposure experienced by older youth and adult soccer populations. Male and female soccer players in a large European study averaged 18 headers per game, 6 times more than what we observed in our study (Beaudouin et al., 2020). A difference that needs to be considered is that in Europe at the time of their study there were no restrictions or guidelines on purposeful heading in youth soccer players as compared to the United States where players are not allowed to head the ball if they are 10 years and younger. Most recently (February 2020) the English Football Association (FA) adopted "Heading Guidance" for 6–16 year old youth soccer players whereby there is no heading in training in those aged 11 and younger, and a graduated approach to heading for children in the developmental phase of soccer between the ages of 12 and 16 (The FA, 2021). Typically, the number of purposeful soccer headers experienced by soccer players increases with age, especially at the high school and collegiate levels. Kaminski et al. (2020) observed over a ten-year period that female high school soccer players average 1.7 headers per player per game and over a fifteen-year period, collegiate soccer players (both females and males) tend to average 2.4 and 3.6 headers per player per game, respectively. This appears to be a logical progression over the course of a playing career. For soccer players who continue past their youth career and participate at both the high school and collegiate level, the increase in the number of headers will likely follow. At the same time, their level of physical and mental maturity has improved, enabling them a skill set and strength level that is better equipped to handle aerial challenges and purposeful heading.

Head impact kinematics did not differ between the control and experimental groups in our study. One possible reason for this could be that the experimental group only practiced heading with the lightweight soccer balls and therefore were not exposed to head impacts that would have been imparted from a fully-inflated size 4 soccer ball. In turn, the players may not have been prepared for a heavier ball which then resulted in higher head accelerations occurring in soccer matches. It is also possible that the Triax Sim-G sensors used in this study may not be as sensitive at identifying low magnitude head impacts. PLA values in our youth soccer players were similar to those found in other studies (Caccese, Buckley, Tierney, Rose et al., 2018a; Chrisman et al., 2016, 2019; Harriss et al., 2019). Two previous studies reported smaller PLA values, approximately 20 g, during a season of play and a weekend tournament (Chrisman et al., 2016; Harriss et al., 2019). Harriss et al. (2019) utilized a similar head impact sensor and observed female soccer players in the U13–U15 divisions. Chrisman et al. (2016) observed male and female soccer players aged 12.5 years old and used a skin-mounted head impact sensor. In another study by Chrisman et al. (2019), male and female soccer players (U12 and U14) were observed for one month of play. Females in the U12 division did not head the ball during the observation period and the average PLA for the remainder of the groups was in the high 30 g range. In an acute heading protocol, Caccese et al. (2018b) reported PLA values in the mid-30 g range for the 12–14 year old soccer players. They also reported similar values for the high school and collegiate populations utilizing the same head impact sensors as the current study (Caccese, Buckley, Tierney, Rose et al., 2018a). It is also quite possible that the low number of total head impacts lead to a situation whereby we were not sufficiently powered statistically to even be able to identify meaningful differences had they existed.

Generally speaking, neck and torso strength increased overall in both the control and experimental groups. Except for a strange aberration that occurred with neck extension strength (2.16% decrease pre to post-season), there were marked improvements in neck flexion, along with torso flexion and extension strength in our experimental group soccer players. We contend that the deficit in neck extension strength is likely meaningless, and perhaps related to measurement error and the fact that there were simply no gains over the course of the 3.5 month soccer season. It is enlightening to see that in the brief 3.5 month period of time that the Get aHEAD Safely in Soccer™ neck/torso strength training tactics were employed that the improvements that occurred were favourable. We argue that with additional time and with enhancements in the execution of the exercise themselves that the program will prove useful and worthwhile for coaches to implement in the name of better player safety. Similar to the many other studies that have examined neck strength in youth soccer players, we too obtained neck girth measurements on our subjects, however there were not significant improvements in neck size for either group of players. It is likely that the 3.5 month period that lapsed between measurements was simply not enough time for significant improvements in neck girth size to have occurred. We would suggest that if that variable is to be included in future studies it should be examined over longer periods of time. For comparison a study that examined the effects of an 8-week neck specific resistance training versus general resistance training in youth athletes aged 13–16 years old, all participants had improved neck girth and strength (Eckner et al., 2018). Similar to our findings, those in the neck specific resistance training group had greater improvement compared to the control group. Another study also implemented a resistance training program over 14 weeks on soccer players aged 15–18 years old (Miller et al., 2020). Müller & Zentgraf (2020) observed an increase in neck strength and a decrease in peak linear acceleration of the head during soccer headers. In acute heading protocols, two studies examined the relationship between head mass, neck girth, and neck strength and head acceleration in soccer players ranging in age from 12–24 years old (Caccese, Buckley, Tierney, Arbogast et al., 2018b; Gutierrez et al., 2014). Both studies observed that less neck strength (weaker) corresponded to increased head acceleration or greater impact magnitudes. Caccese et al. (2018a) also reported that smaller head mass and neck girth correlated to an increased head acceleration. An increased risk of concussion has also been reported to be related to smaller neck girth and weaker neck strength (Collins et al., 2014). However, with every 1 pound increase in neck strength, the odds of concussion decreased by 5% (Collins et al., 2014). In contrast, a musculoskeletal model, using American football head impact data, suggested that neck strength contributions differ depending on the head impact severity, such that neck musculature can better stabilize the head at lower head impacts compared to higher head impacts (those that more commonly result in a concussion; Kuo et al., 2019). Mihalik et al. (2011) reported that there was no correlation between static neck strength and head impact kinematics in a youth ice hockey population. In a systematic review by Peek et al. (2020), they concluded that increased neck strength resulted in decreased head acceleration and that neck strengthening may be beneficial to concussion mitigation. Despite their recommendations, the most effective neck strengthening method is still unknown. The results of the current study suggest that neck and torso strength improve over the course of a season with neck and torso strengthening exercises being performed twice weekly. It is possible that greater changes in strength would likely be observed over a longer period of time, such as from the two-year period from age 11 to age 13, the age group in which US Soccer recommends limited heading in practice.

A unique part of the Get aHEAD Safely in Soccer™ program is the use of lightweight soccer balls during the header drills. Players, coaches, and parents of the experimental group were receptive to the idea of using the lightweight soccer balls and the players were excited to use them in header drills. Although we did not formally assess this, anecdotally, the research team and the coaches *observed* an improvement in header technique and form and an increased confidence in the players from the beginning to the end of the season. We argue that lightweight soccer balls should be utilized in header drills to help players focus on technique and form; drawing attention away from any fear that may be associated with heading a fully-inflated size 4 ball, especially in the 11–13 age groups who are still learning the skill of heading. Additionally, we suggest that because this age group of female soccer players head the ball so infrequently during competitive matches, that purposeful heading drills using lightweight balls be limited to no more than one practice session each week. This would allow coaches to focus more attention on other areas of skill development and soccer playing tactics.

We acknowledge certain limitations with the current study such as only having two teams, both small in number, from the mid-Atlantic region of the US; with one team serving as the control group and the other as the experimental group. Studies involving youth soccer teams are difficult from a recruiting standpoint and although our budget was limited we were able to incentivize both teams by providing a small monetary award to each club at the conclusion of the study. We were also limited to one soccer season of play, lasting 3.5 months. Implementing the intervention over the course of a year or more may elicit greater benefits from the neck and torso strengthening component of the Get aHEAD Safely in Soccer™ program. This contention is supported by a study by Kumahara et al. (2021) using male soccer players aged 9–13 years old, who completed a core strengthening program over one year, had an increase in core muscle strength and dynamic balance. We also acknowledge that our method of collecting strength data using a handheld dynamometer while convenient and efficient for data collection in the field, may contain some measurement variability in terms of our set-up and stabilization procedures. We felt that by using the same tester and setup for baseline and post-season measurements, along with averaging the measurements, helped to curtail any measurement errors that may have occurred. Future research should include both male and female soccer players in the U13 and U14 age groups as well as larger sample sizes.

In conclusion, it is evident that our cohort of female youth soccer players are not involved extensively in performing purposeful headers during practices and games. The use of lightweight soccer balls during practice drills became an accepted method of performing heading drills safely throughout the course of the season. The Get aHEAD Safely in Soccer™ program intervention resulted in improvements in neck/torso strength while head impact kinematics changed very little. Further study of the intervention over an extended period of time (>1 year) is warranted.

Disclosure statement

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ORCID

Thomas W. Kaminski http://orcid.org/0000-0003-0924-0978

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