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Models of Video Feedback for Youth Athletes Performing an American Football Tackle

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Context: Video feedback is an expeditious method for improving athlete safety when performing activities with an inherent risk of injury. Providing appropriate and validated feedback during tackling training in American football may be a mechanism for athletes to learn safe tackling performance.

Objective: To determine the effect of video feedback in the instruction of tackling form.

Design: Controlled laboratory study.

Setting: Laboratory.

Patients or Other Participants: A total of 32 youth football athletes (28 boys, 4 girls; age = 11.8 ± 0.8 years) participated in 1 day of training. Of those, 14 participants completed 2 additional days of training and a 48-hour retention and transfer test.

Intervention(s): Video feedback using self as model, expert as model, combined self and expert model, and oral feedback to promote safe tackling performance in a laboratory environment.

Main Outcome Measure(s): Shoulder extension, cervical extension, trunk angle, pelvis height, and step length by training block and over time.

Results: For the 1-day training group, main effects for time were observed for shoulder extension ($P < .01$), cervical extension ($P = .01$), pelvis height ($P < .01$), and step length ($P < .01$), with better performance for pelvis height and step length after combined feedback. For the 3-day training group, main effects of time were identified in pelvis height ($P < .01$) and step length ($P < .01$), with combined feedback showing better performance than other methods in shoulder extension and pelvis height. Combined feedback resulted in better performance compared with its component parts and oral feedback alone. In the combined model, participants viewed both their performance and the expert model, enabling them to see the difference between current and required performance.

Conclusions: Combined feedback may be superior to other forms of feedback in improving movement performance. This effect can be generalized across disciplines that provide instruction and feedback in movement.

Key Words: motor learning, injury prevention, concussion

Key Points

- Video feedback improved tackling performance in youth athletes.
- The effectiveness of each model may depend on the length of training provided.
- Combined self and expert feedback may produce better outcomes with a sufficiently long training duration.

In a 2015 position statement, the American Academy of Pediatrics recommended that officials and coaches enforce the rules of proper tackling, including zero tolerance for illegal, head-first hits.[1] In 2022, the National Athletic Trainers' Association updated its position statement on head-first contact behavior in American football players to include a recommendation on training proper tackling form to limit head-first contact.[2] Researchers have estimated that 1.6 million to 3.8 million cases of concussion occur in sport and recreation each year in the United States, with sport-related concussion rates estimated between 0.19 and 1.78 per 100 000 participants.[3,4] Head contact during blocking and tackling is the most prevalent mechanism of injury or activity associated with concussion.[5]

Researchers have indicated that providing coaches with a comprehensive education plan consisting of tackling training, equipment fitting, and practice guidelines may reduce the number of head impacts experienced by youth football players.[6–9] A major youth football regulatory body, USA Football, supplied guidelines to reduce contact involving the player's head.[10] The "Heads Up" program recommended by USA Football offers a framework for instruction in the tackling technique, although a standardized mechanism of giving feedback to learners has not been developed. The Qualitative Youth Tackling Scale (QYTS) provides a feedback framework comprising 6 components of a vertical tackling style[11] that has been suggested to decrease the number of head accelerations experienced in a laboratory setting[8] (Supplemental Figure 1, available online at https://dx.doi.org/10.4085/1062-6050-0602.22.S1). These 6 items focus the learner on portions of the tackle form that primarily remove the head from contact, with a secondary goal of successfully tackling the opponent, and can be used to identify errors when delivering feedback. The recommendations on tackling style have been altered since this protocol was developed, and USA Football now recommends a shoulder-leverage, rugby-style technique. This technique emphasizes contact with the shoulder at or below the nipple line with the head placed to the trailing side of the body rather than contact with the chest in an upright position as previously described.[12] The motor-learning and feedback techniques described herein are adaptable to new tackling techniques, as well.

Video modeling and feedback is a common motor-learning technique used in many training situations to alter movement patterns in order to prevent injuries and improve athletic performance.[13–15] In motor learning, the learner observes the actions and patterns of a performer and develops a pattern of motor behavior. This performer or model can come in many different forms, including a video representation, allowing learners to regulate their movements and helping to correct mistakes made during performance.[16] The model used during the feedback technique can affect the information the learner receives from feedback.[17] Feedback using a video model may provide an effective means to integrate feedback into youth performance training. Video modeling and feedback is used by coaches, trainers, and medical professionals to help alter the motions of athletes,[15] in the rehabilitation setting,[18] and in human performance.[19,20] When supplying feedback using video, the facilitator must be aware of the effect of the model used to exhibit proper execution of the skill. The model offers a visual blueprint for the learner to mimic as well as to draw inferences, either explicit or implicit, regarding the proper movement pattern.

Several investigations have been conducted using augmented video feedback to improve movement patterns in adolescents using various models.[17,21] Self-observation during video feedback uses the performer as the model, delivering a video playback of the learner's current performance of the skill.[17,22] This model provides no visual information on the desired pattern and thus requires any information on this pattern to be given through another mechanism, such as oral feedback. With expert-only modeling, learners only view video of an expert's performance. This video type allows learners to see the form they have been instructed to perform but supplies no information regarding current performance.[23] Self-observation plus expert, or combined, modeling provides learners with information on their current performance plus information on the correct performance of the skill.[21,24] This method allows learners to identify the differences between their current performance and the expert model, creating the potential for visual feedback rather than a model alone. Video feedback involving all of these models was shown to alter movement patterns.[17,21–24]

The purpose of our study was to explore the effect of video models during feedback on movement performance in youth football athletes. Previous researchers have indicated the model used during the feedback protocol can affect adaptation of the motor patterns that occur during motor learning.[17,21–24] However, the effect of model type on changes in performance of a specified tackling form has not been studied in youth athletes. We hypothesized that combined feedback would encourage performance that more closely mirrored the instructed form.

METHODS

Participants

A total of 32 participants (28 boys, 4 girls; age = 11.8 ± 0.8 years, tackling experience = 2.5 ± 2 years) were recruited for a 1-day training and evaluation, with a subset of 14 male participants performing an extended 3-day training with 48-hour retention and transfer testing. All participants and their parents gave informed assent and consent, respectively, and the study was approved by the Biomedical Sciences Institutional Review Board of Old Dominion University (No. 2015H0010).

Procedures

For the 1-day training, participants were equally divided among all conditions for a total of 7 boys and 1 girl per modeling group. For the 3-day training, participants were divided among conditions as follows: 4 boys in each of the self and the combined modeling groups and 3 boys in each of the expert and the oral modeling groups. Initially, participants were randomly assigned to 1 of the 4 modeling groups. However, given that not all initially randomized participants chose to engage in the 3-day training, we purposefully assigned participants to a treatment group after the initial recruitment timeframe to maintain a similar number of participants per group in the 3-day training program. The training consisted of baseline testing and 4 training blocks of 3 tackles in the motion-capture data-collection area. Data were analyzed for the 1-day group at baseline, after instruction, and after training. Analysis for the 3-day group included 2 additional training days and a 48-hour retention and transfer test.

Instrumentation

Movement was measured using a 10-camera motion-capture system (model Vantage; Vicon Motion Systems Ltd) recording at 120 Hz. We placed 43 retroreflective markers using a modified Helen Hayes marker set on the head, torso, arms, pelvis, shanks, and feet. The Vantage system had an absolute error of 0.203° in a controlled laboratory study.[25] Custom-designed headgear ensured stability of the head-marker clusters during contact. Two-dimensional video was collected with a tablet (model Surface Pro 4; Microsoft Corp) using Camstudio (version 1.4; Redersoft Software). This video was used to provide video feedback to participants.

Tackling Circuit

The tackling circuit consisted of tackles in which the learner started from a position 5 ft (1.5 m) away from and 1 ft (0.3 m) lateral to the target (Supplemental Figure 2). The target was a 90-lb (40.1-kg) stand-up tackling dummy with a center of mass near the contact area, which was specifically designed for this research. All participants started the task in a comfortable athletic 2-point stance, with feet toward the target, knees and hips slightly bent, and a small forward lean. At the baseline time, they were instructed to tackle the dummy 5 times as they typically would when playing football. Next, individuals were instructed on the 6 standard components of the QYTS as the tester (E.S.) read the subjective feedback column of the Table, after which they performed 3 tackles. Only the subjective column was

Table. Qualitative Youth Tackling Scale Provided as Verbal Feedback to Participants

Subjective Feedback	Objective Measure
1. Take short, choppy steps.	Step length <75% of standing pelvic height over last 250 cm to target
2. Reach your arms back and wrap up when you make contact.	Shoulder extension >45° during last 0.5 s before contact
3. Lower your body by bending your knees.	Average pelvic height <75% of standing pelvic height over last 0.25 s before contact
4. Keep the head across the front of the target.	Visual verification of head placement on opposite side of approach on contact
5. Contact the target with the front of the shoulder.	Trunk angle between 35° and 55° relative to ground on contact
6. Keep the neck extended; do not hit with your head down.	Cervical extension >45° on contact

visible to the participant. These tackles were then used to provide the first feedback intervention by group. The feedback groups were self, expert, combined self and expert (combined), and oral only. The self-feedback group received video modeling involving only the participant. Oral feedback was standardized based on errors during performance and used the same standardized format as for all other groups. The expert feedback group received video modeling using only video of an expert. Oral feedback was standardized based on errors during performance and used the same standardized format as for all other groups. The combination feedback group received video modeling that involved both the participant and an expert as the model. Oral feedback was standardized based on errors during performance and used the same standardized format as for all other groups. For the oral-only group, no video modeling was provided, but participants received oral feedback in the same standardized format as for all other groups. Video clips of collegiate passing plays were supplied during feedback.

Feedback Process

Feedback was given in 4 blocks of 3 tackling trials (Supplemental Figure 3) by a researcher (E.S.) with training in tackling performance and experience providing oral feedback during sport activities. Previous researchers indicated that evaluators with experience observing human movement, such as athletic trainers and physical therapists, displayed substantial to slight agreement with motion capture when evaluating the components of the QYTS.[11] After instruction, participants performed 3 tackles with no feedback and then were supplied with oral and video feedback per their group assignment. The feedback process was repeated 4 times, giving the participants 4 exposures to video and oral feedback. The researcher visually evaluated each tackle in real time and determined which components of the QYTS in the person's performance were furthest from the goal movement. Participants were told to use a dry-erase marker to circle the portions of the QYTS tackling movement that they believed they performed while looking at the list in the Table. The researcher then identified for the athlete the 2 errors he noted by reading those errors from the sheet and pointing to their location on the sheet. No individual had <2 errors in any trial block. If >2 errors were present, those that appear highest on the Table were selected. The QYTS system was valid and reliable when used by expert evaluators.[11] While the oral portion of the feedback was taking place, the video to be used as feedback for that block was edited to cut the pretackle and posttackle portions and time the combined video components so that contact with the target occurred at the same time in each video component. Participants were given access to a 17- × 10-in (43.18- × 25.4-cm) computer screen for the viewing of all videos. The video in which the athlete had the most critical errors was used for the model and feedback at the end of each block. Within 1 minute of completing the last tackle for the block and after oral feedback, the player was instructed to view the tackle performance video edited to provide the model for the treatment group 4 times, twice at full speed and twice at one-half speed. The combination modeling group was presented with a split-screen view of each portion of the feedback; all others were given a full-screen view. The video for the self- and combination feedback groups was updated after each block to reflect the videos of trials performed during the previous practice block. The number of repetitions of video modeling were the same for all individuals receiving video feedback. For those receiving oral feedback only, the feedback indicated which errors occurred and then the athlete watched an assembled video of football pass plays without tackles for the same length of time as for the treatment groups. The last block of 3 tackles was used as the final data point for this subgroup. Total time watching the videos in each block was 15 seconds and over the total protocol was 1 minute.

For the 3-day training, feedback was provided for an additional 2 sessions of instruction, 3 tackles, and 4 blocks of 3 tackling trials over the subsequent 2 days using the same format as during usual team practice. Players were individually removed from team practice and completed the training battery. They then waited for 48 hours to return to the laboratory for retention and transfer testing, during which time they did not engage in team practice or practice tackling. The 48-hour retention testing consisted of 3 additional tackles from the same location as during training and a transfer task of 3 tackles from a 5-yd (4.6-m) lateral offset from which tacklers were asked to shuffle laterally to the previous starting spot and then complete the tackle as trained. Transfer tasks are used to assess the level of learning that participants have achieved by changing the task slightly to evaluate the participant's ability to adapt to new task demands, which indicates motor learning.

Data Analysis

For the 1-day group (n = 32), the statistical analyses were separate 4 (feedback group)-by-3 (training time) analyses of variance (ANOVAs) of the kinematic measures of each QYTS biomechanical variable by 3 (time: baseline, instruction, and end of training). A secondary 4 × 5 ANOVA was conducted for the 14 individuals in the 48-hour retention training, adding retention and transfer times. Power analysis in an earlier study[24] demonstrated that combined feedback for knee-flexion displacement resulted in a Cohen *f* of 0.31; with a power of 0.8 and a predicted α of

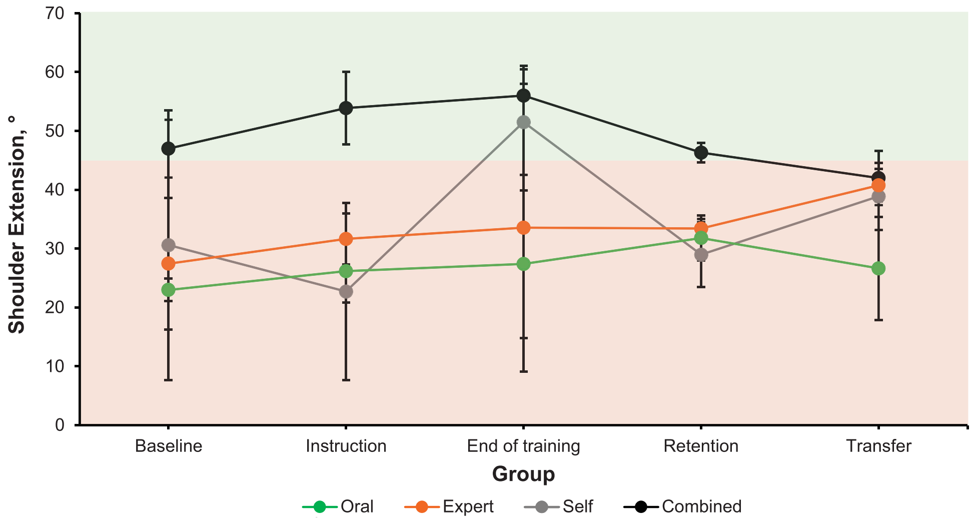

Figure 1. Effect of treatment from baseline to transfer for shoulder extension in 3-day treatment. Main effects of group were found ($F_{3,10}$ = 11.762, P < .01, η_p^2 = 0.8). Closer-to-goal performance for combined (49° ± 5°) than self (35° ± 11°; P < .01; d = 1.2), expert (33° ± 11°; P < .01; d = 1.7), and oral (27° ± 6°; P < .01; d = 3.2) models was evident. The green segment of the graph represents the desired performance; the red segment represents performance outside of the desired window of performance.

.05, the required sample size per group was 3 participants. Because of unequal group sizes in the 3-day group, we evaluated sphericity and, when a violation was identified, applied a Greenhouse-Giesser correction. The average range of motion for each time using motion capture supplied 1 data point for each participant over the 5 motions analyzed: shoulder extension, cervical extension, trunk angle, pelvis height, and step length. We adjusted values that were different using the Fisher least significant (LSD) correction for each multiple measure to maintain an overall a priori significance level of $P \leq .05$. Given that the data presented here did not include head impacts or measures of head acceleration, the changes in performance did not reflect improved safety. Previous researchers tracking head accelerations found a change in the number of head impacts recorded after training.[8]

RESULTS

For the 1-day training, effects of time were noted for shoulder extension, cervical extension, pelvis height, and step length over time, but no interactions were evident. Regarding the effect of treatment on shoulder extension (Supplemental Figure 4), progress occurred toward the goal movement over time ($F_{3,28} = 8.15$, $P < .01$, $\eta_p^2 = 0.2$), indicating better cocking of the arms to wrap the dummy but no differences between groups ($F_{3,28} = 2.25$, $P = .11$). For cervical extension (Supplemental Figure 5), we observed progress toward the goal movement, showing that participants kept their heads up between times ($F_{3,28} = 4.83$, $P = .01$, $\eta_p^2 = 0.3$) but no differences between groups ($F_{3,28} = 0.27$, $P = .85$). Progress toward the goal movement between times was present for pelvis height, suggesting that the athletes lowered their center of gravity (83% ± 5% of standing pelvis height to 77% ± 12%; $F_{3,28} = 25.71$, $P < .01$, $\eta_p^2 = 0.7$; Supplemental Figure 6), and demonstrated a difference within groups ($F_{3,28} = 3.87$, $P = .02$). Post hoc LSD analysis indicated progress toward the goal movement in the combined (67% ± 11%) over expert (83% ± 15%; $P < .01$; $d = 0.9$) and oral (81% ± 6%; $P = .01$; $d = 0.9$) groups. A shortened step length can improve players' ability to change directions and control their body before contact. We found progress toward the goal movement in step length (Supplemental Figure 7) due to time (101% ± 17% of standing pelvis height to 81% ± 26%, $F_{3,28} = 15.52$, $P < .01$, $\eta_p^2 = 0.4$) and group ($F_{3,28} = 4.06$, $P = .02$, $\eta_p^2 = 1.0$). Post hoc LSD testing showed progress toward the goal performance in self (82% ± 26%) compared with oral (102% ± 30%, $P = .02$; $d = 0.8$) and combined (63% ± 15%) feedback compared with oral feedback (102% ± 30%; $P < .01$; $d = 1.2$). We observed no effects of treatment for trunk angle, which allowed the participant's head to remain farther away from the point of contact with the target ($P = .85$ for group and $P = .31$ for time; Supplemental Figure 8).

A secondary 4 × 5 ANOVA (Figures 1–5) was performed with the 14 participants (self = 4, expert = 3, combined = 4, oral = 3) in the 3-day condition (14 boys; age = 11.5 ± 0.5 years, experience = 3.02 ± 1 years). No interactions were seen within the data. Main effects of time were identified in pelvis height ($F_{4,10} = 9.02$, $P < .01$, $\eta_p^2 = 0.474$; Figure 4) and step length ($F_{4,10} = 9.67$, $P < .01$, $\eta_p^2 = 0.49$; Figure 5). Post hoc LSD testing for pelvis height (Figure 4) indicated progress toward the goal movement in the percentage of standing pelvis height from baseline (83% ± 2%) to the end of training (79% ± 9%; $P = .03$; $d = 0.6$) and to retention (72% ± 4%; $P < .01$; $d = 2.4$). Retention performance in the percentage of standing pelvis height (72% ± 4%) was closer to the goal movement than transfer (85% ± 6%; $P < .01$; $d = 2.6$). Progress toward the goal movement was evident between times for step length (Figure 5) from baseline (95% ± 16%) to instruction (88% ± 19%; $P = .03$; $d = 0.6$), to the end of training (78% ± 20%; $P < .01$; $d = 0.8$), and to retention (71% ± 5%; $P < .01$; $d = 1.0$), as well as instruction (88% ± 19%) to retention (71% ± 5%; $P = .01$; $d = 0.7$). Retention performance in the percentage of standing pelvis height (71% ± 5%) established greater progression toward the goal movement than transfer (99% ± 7%; $P < .01$; $d = 3.7$).

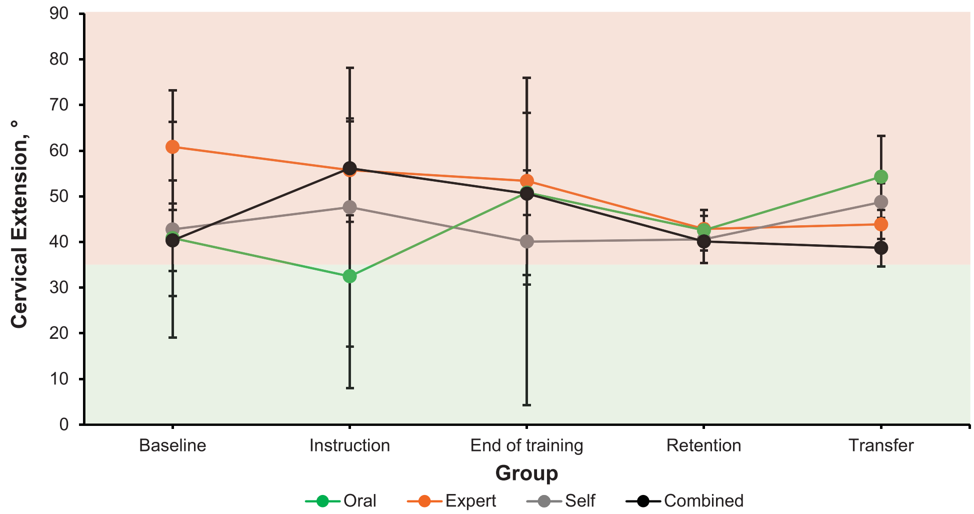

Figure 2. Effect of treatment from baseline to transfer for cervical extension in the 3-day treatment. The green segment of the graph represents the desired performance; the red segment represents performance outside of the desired window of performance.

Main effects of group were found for shoulder extension ($F_{3,10} = 11.762$, $P < .01$, $\eta_p^2 = 0.8$; Figure 1) and pelvis height ($F_{3,10} = 5.466$, $P < .05$, $\eta_p^2 = 0.9$; Figure 4). Post hoc LSD analysis for shoulder extension (Figure 1) indicated greater progress toward the goal for combined (49° ± 5°) than self (35° ± 11°; $P < .01$; $d = 1.2$), expert (33° ± 11°; $P < .01$; $d = 1.7$), and oral (27° ± 7°, $P = < .01$; $d = 3.2$) feedback. Group differences were also noted for pelvis height in the percentage of standing pelvis height (Figure 4) for combined (75% ± 6%) over self (81% ± 2%; $P = .02$; $d = 0.7$), over expert (80% ± 9%; $P = .02$; $d = 0.4$), and over oral (80% ± 4%; $P = .03$; $d = 0.5$) feedback. At baseline, step length ($F_{3,10} = 2.232$, $P = .15$, $\eta_p^2 = 0.41$) and shoulder extension ($F_{3,10} = 2.167$, $P = .16$, $\eta_p^2 = 0.39$) showed no differences.

DISCUSSION

Based on our outcomes, portions of the football tackle can be modified with the use of video modeling and feedback. In the 1-day training group, the effect of training was seen in all movements except for trunk position. We observed group differences for pelvis height and step length, with most of the differences involving the combined group. In the 3-day training group, the combined feedback group performed better in pelvis height and shoulder extension and at several individual times compared with other feedback groups. The lack of an interaction between time and group could be due to a lack of statistical power or to preexisting group differences. However, no group differences at baseline were identified. Future researchers should retest this result. Regression toward the initial pattern of movement is often seen in retention and transfer testing for skills without sufficient practice and integration time. For the 3-day training group, this time included an additional 2 training sessions. During this investigation, retention-time performance remained relatively stable compared with performance at the end of the 1-day training session. Retention time performance was better than transfer-time performance for many of the self, expert, and combined models. The lack of variability in the training task

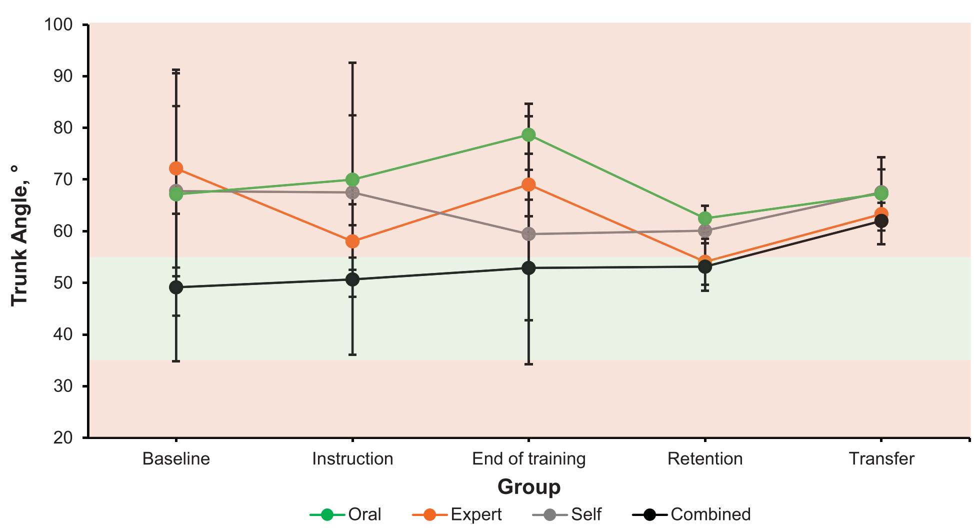

Figure 3. Effect of treatment from baseline to transfer for trunk angle in the 3-day treatment. The green segment of the graph represents the desired performance; the red segments represent performance outside of the desired window of performance.

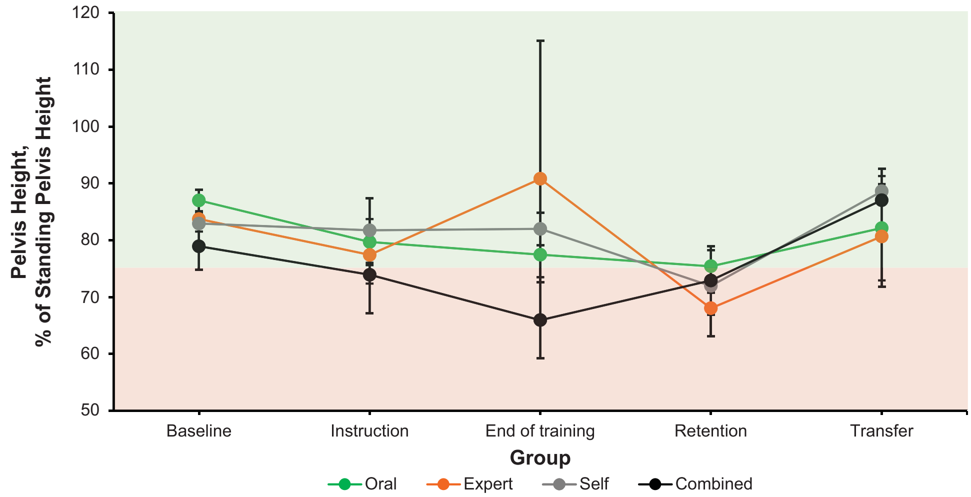

Figure 4. Effect of treatment from baseline to transfer for pelvis height for the 3-day treatment. Main effects of time were identified ($F_{4,10}$ = 9.02, P < .01, η_p^2 = 0.474). Progress to goal from baseline (83% ± 2%) to the end of training (79% ± 9%; P = .03; d = 0.6) and from baseline (83% ± 2%) to retention (72% ± 4%; P < .01; d = 2.4) was demonstrated. Retention performance (72% ± 4%) was closer to goal than transfer (85% ± 6%; P < .01; d = 2.6). Main effects of group were found ($F_{3,10}$ = 5.466, P < .05, η_p^2 = 0.9). Group differences were also present for combined (75% ± 6%) versus self (81% ± 2%; P = .02; d = 0.7), expert (80% ± 9%; P = .02; d = 0.4), and oral (80% ± 4%; P = .03; d = 0.5) models. Retention performance (72% ± 4%) was closer to goal movement than transfer (85% ± 6%; P < .01; d = 2.6). The green segment of the graph represents the desired performance; the red segment represents performance outside of the desired window of performance.

may have affected participants' ability to adapt to the new motor pattern required for the transfer task.[26–28]

For the 3-day training group, step length and pelvis height were better at the end of training, with the combined model being better for each variable. To correctly perform a movement, learners develop a cognitive representation of the desired movement that must then be implemented.[16,29] Different mechanisms of augmented feedback provide different information to this cognitive representation. When learning the tackle technique, participants in the self-modeling group were not shown images of the desired technique. Withholding information did not allow these athletes to extract meaningful information on the goal movement beyond the errors provided orally, which limited their ability to form a cognitive representation of the goal movement. The expert modeling group was unable to see their own performance, which limited the knowledge of performance that can be extracted from video, again with information being provided only via oral feedback. In the combined group, players were able to see both their performance and that of the expert. By viewing both images, participants could determine the difference between the 2 models, which offered richer information when creating a

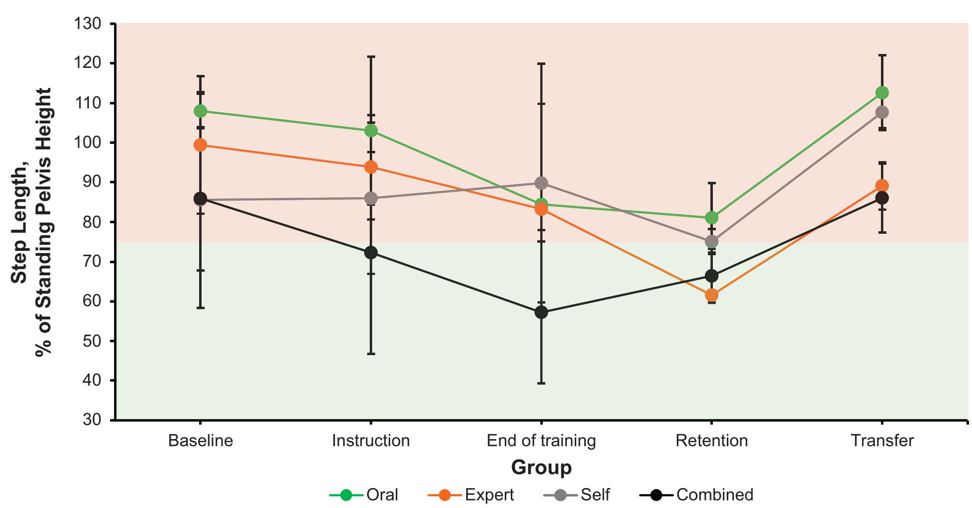

Figure 5. Effect of treatment from baseline to transfer for step length in the 3-day treatment. Main effects of time were identified ($F_{4,10}$ = 9.67, P < .01, η_p^2 = 0.49). Progress toward goal occurred between time points from baseline (95% ± 16%) to instruction (88% ± 19%; P = .03; d = 0.6), end of training (78% ± 20%; P < .01; d = 0.8), and retention (71% ± 5%; P < .01; d = 1.0) and from instruction (88% ± 19%) to retention (71% ± 5%; P = .01; d = 0.7). Retention performance (71% ± 5%) was closer to goal movement than transfer (99% ± 7%; P < .01; d = 3.7). The green segment of the graph represents the desired performance; the red segment represents performance outside of the desired window of performance.

cognitive representation of the movement. Combining an expert model with a self-model supplied knowledge of performance and was successful in improving performance in earlier research.[13,21,30]

Prior authors studied small sample sizes in different sports and often focused on behavioral outcomes. When performance was specifically targeted, skill acquisition using self-observation and expert comparisons reduced head impacts[8] and enhanced performance in rowing,[31] jump landing,[32] and weightlifting[33]; modeling overall was effective.[34] Whereas modeling itself is effective, adding feedback can improve results.[35]

We primarily used knowledge of performance over knowledge of results for the feedback regimen. An appropriate use for knowledge of performance is instructing and providing specific prescriptive feedback on performance.[36] The performance itself is the key outcome. Currently, the impetus is to characterize the correct form that increases safety and then implement that form. Moving forward, investigators may choose reduced head accelerations as the end goal and use knowledge of the results to allow tacklers to develop their own biomechanical form rather than specifying an ideal performance.

Improving tackle performance is critical to enhancing the safety of youth football participants and to movement training in general, and although debate persists as to which movements are components of a safe tackle, our findings help to establish mechanisms to instruct any technique. Our outcomes do not offer information on tackle safety, only a mechanism to provide athletes with feedback while developing tackling skill. Even though organizations have recommended a focus on tackle performance and have developed mechanisms aimed at increasing safety, methods to instruct players in tackle performance have not been readily available. In our research, we indicated that combined video and oral feedback was effective in altering tackle form. Additional examination is needed to address the individual differences in athletes that may affect the feedback given, including self-control of the feedback timing as well as the appropriate tackle mechanisms to reduce head impacts. These differences include both learning mechanisms and physical mechanisms that may alter the way a young athlete learns.

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SUPPLEMENTAL MATERIAL

Supplemental Figure 1. The Qualitative Youth Tackling Scale.

Supplemental Figure 2. Participant starting position relative to target.

Supplemental Figure 3. Feedback timing diagram. For training days in the 3-day group, the diagram begins with a 5-tackle block and continues to the end.

Supplemental Figure 4. Effect of treatment on shoulder extension at the baseline, instruction, and posttraining time points. An improvement over time was noted ($F_{3,28} = 8.15$, $P < .01$) but no difference by group ($F_{3,28} = 2.25$, $P = .11$). The green segment of the graph represents the desired performance; the red segment represents performance outside of the desired window of performance.

Supplemental Figure 5. Effect of treatment on cervical extension at the baseline, instruction, and posttraining time points. Improvement between time points was demonstrated ($F_{3,28} = 4.83$, $P = .01$), but no difference occurred between groups ($F_{3,28} = 0.27$, $P = .85$). The green segment of the graph represents the desired performance; the red segment represents performance outside of the desired window of performance.

Supplemental Figure 6. Effect of treatment on pelvis height at the baseline, instruction, and posttraining time points. An improvement between time points ($F_{3,28} = 3.87$, $P = .02$) and a difference between groups ($F_{3,28} = 3.87$, $P = .02$) were found. Progress toward the goal in the combined (67% ± 11%) over expert (83% ± 15%; $P < .01$, $d = 0.9$) and oral only (81% ± 6%; $P = .01$, $d = 0.9$) groups was noted. The green segment of the graph represents the desired performance; the red segment represents performance outside of the desired window of performance.

Supplemental Figure 7. Effect of treatment on step length at the baseline, instruction, and posttraining time points. An improvement was present ($F_{3,28} = 15.52$, $P < .01$) with an effect for group ($F_{3,28} = 4.06$, $P = .02$). Differences were seen between self (82% ± 26%) and oral (102% ± 30%; $P = .02$) and between combined (63% ± 15%) and oral (102% ± 30%; $P < .01$) groups. The green segment of the graph represents the desired performance; the red segment represents performance outside of the desired window of performance.

Supplemental Figure 8. Effect of treatment on trunk angle at the baseline, instruction, and posttraining time points. The green segment of the graph represents the desired performance; the red segments represent performance outside of the desired window of performance.

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