KINEMATIC ANALYSIS OF SOCCER HEADING TECHNIQUE

Kathy Ludwig
Barry University, Miami Shores, FL, USA

The purpose of this investigation was to determine if collegiate players who head the ball frequently (FH) use a different technique than collegiate players who head the ball infrequently (IH). Twenty-four women's collegiate soccer players with at least 9 years of soccer heading experience were separated into FH and IH groups. Ten maximal standing headers were videotaped. The FH group had significantly larger change in ball velocity, trunk ROM, and neck and trunk angular velocity at contact. It was concluded that women who headed the ball frequently used a different technique than women who head the ball infrequently. This difference in technique was best manifested in the change in ball velocity from pre-contact to post-contact.

KEY WORDS: soccer, heading technique

INTRODUCTION: In recent years, a controversy has developed over the role of repeated soccer headers in causing brain injury in soccer players. Several studies have examined the brain injury risks associated with soccer (Matser, et al., 1999, 1998; Sortland & Tysvaer, 1989; Tysvaer & Lochen, 1991) and found that soccer players are at a higher risk of brain injury than controls. One recent study of current soccer players (Jordan, et al., 1996) did not find evidence that soccer players were at a higher risk of brain injury than active controls. Although there is still controversy concerning the risks involved in soccer heading, it is logical to assume that there are more variables involved in causing brain injury than just the number of headers performed. In fact, Jordan et al. (1996) concluded that further study might reveal important differences that contribute to head injuries, including "heading style" (p. 210). Yet, there is a paucity of research describing heading technique. Of the few studies that have been described heading technique (Burslem and Lees, 1987; Mawdsley, 1978; Schneider & Zernicke, 1988), only Mawdsley gives a kinematic description of the heading technique. Maudsley's study, however, was published in 1978 and studied only 1 participant performing two types of jump headers. This study is designed to determine whether players who head the ball more frequently demonstrate a standing heading technique that differs from players who head the ball less frequently. It may be that these frequent headers have developed a technique that lessens the effects of the ball-head impact. If this is the case, this technique needs to be determined.

METHODS: Women's collegiate soccer players (N = 24) were videotaped heading a soccer ball in a laboratory setting. Participants were volunteers from women's collegiate soccer teams. All participants had experience heading a soccer ball, were injury free, and reported no previous serious head injuries. Participants were separated into Frequent Header (FH) and Infrequent Header (IH) groups based on self-reports, coach's reports, and teammate ratings. A Participant must have been rated a FH or IH by two of the above criteria to qualify as FH or IH.
Reflective markers were placed on the participants' left and right acromion processes, spinous process of C7, left and right greater trochanters, spinous process of L5, and left and right femoral epicondyles. A latex cap was used to secure reflective markers to the top of the head, and just above the left and right ears. A PEAK5 Motion Measurement system was used to determine the following dependent variables: (a) change in pre-contact to post-contact ball velocity, (b) range of motion of the trunk from initiation of trunk flexion to contact, (c) angular velocity of the neck (independent of trunk velocity) at contact, and (d) trunk angular velocity at contact.
Each participant was videotaped performing 10 trials after completing 3 warm-up trials. A specially designed ball catapult consistently served the soccer ball to participants at a height just above their eyebrows and a velocity of around 8 m/s. Participants were instructed to head the ball using the standing heading technique (keeping both feet in contact with the floor). They were instructed to head the ball as hard as possible back towards the ball launcher as in a shot

on goal. The third acceptable trial from each participant was chosen for analysis. The tapes from each of the four cameras were digitized automatically using the Peak5 automatic data capture mode. The soccer ball was manually digitized throughout the trial.

A Hotelling's T-test was performed to determine if differences existed between the FH and IH groups. Because significant differences were found in the multivariate T-test, individual univariate tests were be performed on each of the dependent variables.

RESULTS: Participants consisted of 24 female soccer players with at least 2 years of collegiate soccer playing experience who were divided into two groups (frequent and infrequent headers). All participants were currently injury free and reported no previous serious head injuries. Criteria for separation into the frequent or infrequent header groups included: (a) self-identifying as a frequent/infrequent header and (b) coach or teammates identifying participant as a frequent/infrequent header. Demographic data including age, height, seated height, weight, and frequency of heading per game were collected from each participant. Demographic data for each group are presented in Table 1.

Table 1 Demographic Data of the Participants

Variable	FH Group		IH Group	
	M	**SD**	**M**	**SD**
Age (years)	24.20	3.4	25.40	4.2
Height (m)	1.66	3.6	1.66	5.1
Seated Height (m)	.87	.03	.87	.02
Weight (kg)	61.10	4.7	64.50	6.0
Headers per game	**8.30***	**3.0**	**2.90***	**1.7**

* significantly different at $p<.05$

There was a significant difference between groups in the Hotelling's T-test ($\underline{F}(4,17) = 214.82$, $\underline{p} < .0001$), therefore univariate tests were performed on each of the dependent variables. The mean values for the dependent variables are presented in Table 2.

All participants used a split stance with their feet shoulder width apart. All participants stepped toward the ball and arched their back in preparation. The FH group used a larger step, greater back extension, and larger follow-through than the IH group.

The FH group added a significantly greater velocity to the ball post-contact ($\underline{F}(1,20) = 36.66$, $\underline{p} <.0001$) than the IH group. The FH group also used a significantly greater Trunk ROM ($\underline{F}(1,20) = 11.75$, $\underline{p} = .003$), angular velocity of the neck about the trunk at contact ($F(1,20) = 8.12$, $p = .01$), trunk angular velocity at contact ($\underline{F}(1,20) = 56.27$, $\underline{p} = .0001$).

Table 2 Summary Data for Dependent Variables

Variable	FH Group		IH Group	
	M	SD	M	SD
Velocity Diff. (m/s) (post vel. – pre vel.)	3.00	0.93	1.52	0.43
Trunk ROM (deg)	27.30	5.19	16.58	8.99
Neck Angular Vel. (deg/sec)	395.94	153.09	186.76	189.25
Trunk Angular Vel. (deg/sec)	281.84	27.53	146.74	269.52

* significantly different at $p<.05$

DISCUSSION: The frequent header group (FH) added significantly more velocity to the ball post-contact than the infrequent header group (IH). This specific variable has not been examined by previous studies. However, Mawdsley (1978) discussed the importance of transferring momentum to the ball in order to best absorb the force of ball - head contact. All but one participant in this investigation added velocity to the ball. The post-contact ball velocity was greater than the pre-contact ball velocity. This suggests that participants transferred velocity to the ball. Thus, the technique used by FH was better at transferring velocity to the ball than that chosen by IH. A post-hoc regression analysis on possible predictors of velocity difference revealed that trunk velocity at contact was the best and only significant predictor of velocity difference ($R^2 = .58$, $F\,(1, 19) = 25.99$, $p < .0001$).

This change in velocity of the ball, an outcome of several aspects of heading technique, could be a very good predictor of experienced heading technique. In fact, a discriminant function analysis of all five dependent variables measured in this study found that the difference in ball velocity was the best variable at predicting group membership.

The trunk ROM of the FH group (M = 27.30 deg) was significantly higher than trunk ROM of the IH group (M = 16.58 deg). Although previous analyses of soccer heading did not measure trunk ROM, a powerful flexion of the trunk from the hips was described (Mawdsley, 1978). The FH group's higher ROM of trunk flexion likely contributed to the greater change in velocity of the ball as compared to the IH group by allowing the trunk more time to accelerate.

The FH group also exhibited a significantly higher neck angular velocity at contact than the IF group (FH: M = 395.94 deg/s, SD = 153.09; IH: M = 186.76 deg/s, SD = 189.25). This difference in angular velocity of the neck at contact suggests that the FH group continued to powerfully flex the neck up to and through contact. In fact, the FH group reached maximum neck angular velocity within .008 s of contact, with many participants reaching maximum velocities after contact. The IH group had a greater variance in the timing of maximum neck angular velocity around contact. The IH group had a greater absolute difference from contact than the FH group. Thus, the FH group reached maximum velocity closer to contact. This indicates a better timing of transfer of velocity that was evident in the higher post-contact ball velocities of the FH group.

The mean angular neck velocities at contact of both FH and IH groups were higher than the 120 deg/s reported by Mawdsley (1978). This difference might be explained by the difference in heading techniques studied. Mawdsley studied jump headers, where the participant jumped in preparation for the header. This study investigated standing headers, where participants kept both feet on the ground. This contact with the ground provided a firm base for the participants to push from and may have allowed participants to gain greater velocities. Mawdsley (1978) also reported that the angular velocity of the neck, in relation to the trunk, slowed just prior to contact. Mawdsley concluded that this deceleration was due to a tightening of the neck muscles to stabilize the head for contact. No such deceleration of the neck was evident in the FH group in this investigation. In fact, many frequent headers continued to increase their neck angular velocity through contact with the ball. This difference in technique could also be explained by the difference in skill investigated – jumping versus standing header. The lack of a firm base in the jump header may have necessitated the stabilization of the head prior to contact. Another explanation for the higher neck angular velocities found in this study is the fact that only one participant was studied in Mawdsley's investigation. The heading technique used by the one participant might be a unique, individual technique, which differs from the heading technique of the population. However, one other heading study, Burslem and Lees (1987), reported similar deceleration of the head (neck) just prior to contact. This study (Burslem & Lees, 1987) also investigated jump headers, leading one to conclude that these differences in angular velocity around contact are due to a difference in the skill studied. Further investigation comparing standing and jump headers is needed. The frequent headers in this study used a short, powerful flexion of the neck just prior to contact with the ball. This flexion and the velocity of this flexion appear to be important parts of heading technique. Therefore, a quick, powerful flexion of the neck is recommended and should be emphasized when teaching heading technique.

The mean angular velocity of the trunk of the FH group was significantly higher than that of the IH group (FH: M = 281.84 deg/s, SD = 27.53; IH: M = 146.74 deg/s, SD = 53.01). The FH group was flexing at the hips and back at a greater rate than the IH group. This difference could be the result of the FH group having greater strength in the abdominal and hip flexors. The higher angular velocity of the trunk displayed by the FH group could also be a result of their greater trunk ROM. The increased trunk ROM allowed the trunk to accelerate to a higher velocity at contact. The angular trunk velocity of 168.3 deg/s reported by Mawdsley (1978) is better than 100 deg/s less than the mean trunk velocity at contact of the FH group in this investigation. This difference is probably best explained by the difference in the heading technique measured. Mawdsley studied the jump header where the feet were no longer in contact with the floor when the participant heads the ball. This lack of a firm base of support to push from may account for the slower trunk velocity.

Mawdsley's (1978) reported trunk velocity (168.3 deg/s) was, however, greater than the mean trunk velocity of the IH group (146.74 deg/s). Weaker abdominal and hip flexors, as well as, a lesser-developed timing of trunk and hip flexion may explain the slower trunk velocity of the IH group. Mawdsley's participant did not reach peak angular trunk velocity until just after impact, indicating that the participant was powering through the ball. The IH group in this study showed a wide variation in the timing of peak trunk velocity. Most IH participants reached peak velocity before contact and a few reached peak velocity as much as .16 s prior to contact. Thus, despite the lack of a base of support, the participant performing the jump header created greater velocity of the trunk at contact. This greater velocity was probably the result of better timing and stronger abdominal and hip flexor muscles.

CONCLUSION: Within the scope and limitations of this study, two conclusions can be made. First, women collegiate soccer players who head the ball frequently use a different technique than players who head the ball infrequently. Secondly, the difference in technique between FH and IH was manifested in a difference in ball velocity from pre-contact to post-contact. The variables responsible for this change in velocity are: (a) increased ROM and angular velocity of the trunk, and (b) a short, powerful flexion of the neck beginning just prior to contact and continuing through contact.

REFERENCES:

Burslem, I., & Lees, A. (1987). Quantification of impact accelerations of the head during the heading of a football. In Reilly, et al. (Eds.), *Science and Football: Proceedings of the First World Congress of Science and Football* (pp. 243-248). Liverpool: E. & F.N. Spon.

Jordan, S. E., Green, G. A., Galanty, H. L., Mandelbaum, B. R., & Jabour, B. A. (1996). Acute and chronic brain injury in United States national team soccer players. *American Journal of Sports Medicine*, **24** (2), 205-210.

Matser, E.J., Kessels, S.G., Lezak, M.D., Jordan, B.D., & Troost, J. (1999). Neuropsychological impairment in amateur soccer players. *JAMA*, 282 (10), 971-973.

Matser, E.J., Kessels, S.G., Lezak, M.D., Jordan, B.D., & Troost, J. (1998). Chronic traumatic brain injury in professional soccer players. *Neurology*, 51, 791-796.

Mawdsley, H. P. (1978). A biomechanical analysis of heading. *Momentum*, Edinburgh **3**:30 16-20.

Schneider, K., & Zernicke, R. (1988). Computer simulation of head impact: Estimation of head-injury risk during soccer heading. *International Journal of Sport Biomechanics*, **4**, 358-371.

Sortland, O., & Tysvaer, A. T. (1989). Brain damage in former association football players. *Neuroradiology,* **31**, 44-48.

Tysvaer, A. T., & Lochen, E. A. (1991). Soccer injuries to the brain: A neuropsychologic study of former soccer players. *The American Journal of Sports Medicine*, **19** (1), 56-60.