Preliminary Characterisation of Soccer Header Technique and Head Kinematics via High-Speed Motion Capture and Instrumented Mouthpiece

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I. INTRODUCTION

Soccer is a globally popular sport with a relatively high rate of concussion [1]. Although the most frequent concussion mechanism is player-to-player contact [1], headers are a fundamental feature of soccer and account for the majority of head impacts in the sport [2]. Head kinematics experienced during headers vary between sexes [3] and levels of play [4], and exposure to repetitive head impacts has been associated with deficits in memory, balance, and neuro-ophthalmologic function [5-6]. Improving technique has been suggested as a method for reducing the overall head impact burden of headers [7]; however, research investigating the relationship between header technique and head impact magnitude has been limited [8-9]. The aim of the present study was to characterise header technique with a high-speed motion capture system and to elucidate the associations between technique and head kinematics measured with an instrumented mouthpiece [10].

II. METHODS

Male and female soccer players between the ages of 11 and 22 were recruited to participate in this study which was approved by the Wake Forest School of Medicine Institutional Review Board, USA. Participants were instrumented with mouthpiece sensors which contained a tri-axial accelerometer and tri-axial angular rate sensor embedded in acrylic (Figure 1, Left). The accelerometer and angular rate sensor recorded at a sampling rate up to 6400 samples per second (Hz) whenever the accelerometer detected an acceleration of at least 3 g along any axis for at least 3 milliseconds (ms). Each recording was approximately 60 ms in duration.

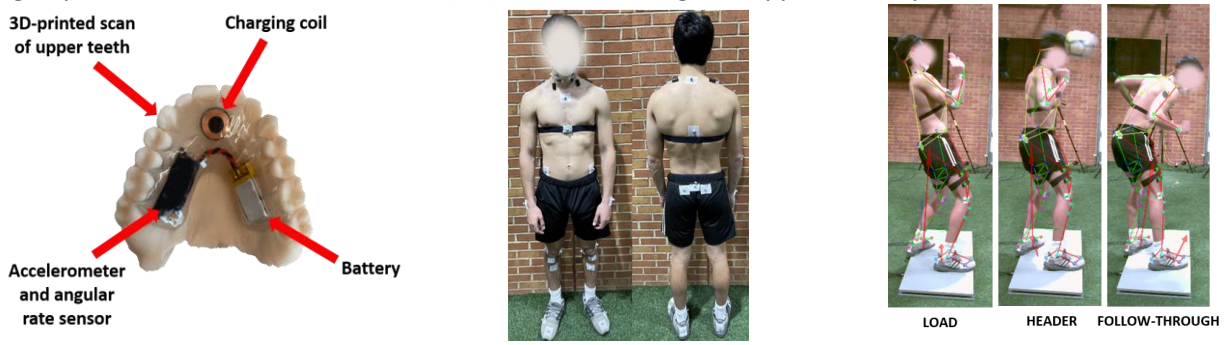

Fig. 1. (Left) Mouthpiece sensor used to measure head kinematics. (Middle) Reflective motion capture markers placed on a male participant. (Right) Snapshots of participant header technique at pre-header loading (200 ms before ball contact), ball contact, and follow-through (200 ms after ball contact).

A motion capture system (Qualisys Ab, Gothenburg, Sweden) was used to measure body kinematics using 44 markers per participant (Figure 1, Middle) [11]. Four wireless electromyography (EMG) surface electrodes (Cometa Systems, Milan, Italy) were placed on the left and right upper trapezius and sternocleidomastoid and measured muscle activity at 2000 Hz. Eight motion capture cameras recorded marker position at 200 Hz while two video cameras recorded at 85 Hz. A third video camera was time-synchronised to the mouthpieces and recorded continuously at 30 Hz. Participants completed testing while on force plates which measured ground reaction forces at 800 Hz (AMTI, Watertown, MA, USA). Participants attended two data collection sessions. A member of the research team stood approximately 5 metres in front of participants and tossed soccer balls underhand toward the participants at the centre of the motion capture cameras. Participants were instructed to head the ball back toward the thrower. A total of 10 headers were performed at each session. Motion

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capture data were post-processed with Qualisys Track Manager then exported to Visual3D (C-Motion, Inc., Germantown, MD, USA) for metric extraction [11]. Three events were defined for each header: pre-header loading (200 ms before ball contact), ball contact, and post-header follow-through (200 ms after ball contact) (Figure 1, Right). At each event, five metrics were calculated: neck flexion/extension angle relative to the thorax (NA), shoulder axial rotation angle relative to the hips (SA), back flexion/extension angle relative to the pelvis (BA), and left/right knee flexion/extension angle (LKA, RKA). Data recorded by the mouthpiece were post-processed in MATLAB (MathWorks, Natick, MA, USA). Rotational acceleration was derived, and linear acceleration was transformed to the head centre of gravity. All recorded events were film-verified. Descriptive statistics (median and interquartile range [IQR]) of head kinematics (peak resultant linear acceleration [PLA], rotational acceleration [PRA], and rotational velocity [PRV]) and technique metrics were calculated.

III. INITIAL FINDINGS

To date, 11 participants have enrolled (64% female; ages 13-21), and eight participants have completed at least one data collection session. A summary of technique metrics collected from two subjects (S1, 16-year-old male; S2, 16-year-old female) is provided in Table I. From a sample of 133 headers, PLA ranged from 7.22 g to 30.5 g with a median (IQR) of 12.1 (3.81) g; PRA from 328 rad/s^2 to 1750 rad/s^2 with a median of 707 (386) rad/s^2; PRV from 2.57 rad/s to 9.71 rad/s with a median of 5.05 (1.49) rad/s. Of the 20 headers described in Table I, median PLA, PRA, and PRV were 9.48 (2.17) g, 806 (217) rad/s^2, and 5.97 (2.24) rad/s for S1 and 12.1 (3.35) g, 611 (198) rad/s^2, and 4.78 (0.809) rad/s for S2, respectively.

TABLE I

COMPARISON OF TECHNIQUE METRICS BETWEEN ONE MALE (S1) AND ONE FEMALE (S2) PARTICIPANT (N=10 HEADERS/PARTICIPANT)

		NA (degrees)		SA (degrees)		BA (degrees)		LKA (degrees)		RKA (degrees)	
		Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
Load	*S1*	-4.64	9.44	-16.1	4.65	18.1	12.7	42.4	21.4	53.4	18.9
	S2	-12.5	5.39	-0.686	2.68	-11.7	10.4	28.0	9.55	24.4	5.82
Header	*S1*	15.0	9.38	-14.0	4.42	25.0	19.9	35.0	26.0	38.1	19.3
	S2	-2.32	11.5	3.30	3.20	-6.02	16.9	21.5	12.8	19.3	15.1
Follow-through	*S1*	2.97	10.5	-9.58	4.00	33.5	25.9	25.7	14.7	36.0	18.9
	S2	-0.563	8.07	3.14	4.39	2.99	16.3	5.80	8.40	5.38	5.63

NA = neck flexion/extension angle; SA = shoulder axial rotation angle relative to hips; BA = back flexion/extension angle relative to pelvis; LKA, RKA = Left/right knee flexion/extension angle. In all cases, flexion was defined as positive. Counterclockwise rotation of the shoulders relative to the hips when looking inferiorly from above the shoulders was defined as positive.

IV. DISCUSSION

This short communication presents preliminary results from an ongoing study aiming to characterise soccer header technique and to understand the associations between header technique and head kinematics. Inter-subject technique differences are captured by the motion capture system (Table I), and the ranges of PLA, PRA, and PRV captured suggest variability in head kinematics during headers. Information collected from force plates and EMG sensors may provide additional metrics for technique characterisation. The headers evaluated are not necessarily reflective of what players may experience in competition but may be analogous to headers experienced during training where the majority of headers occur [4]. Future work will enroll more participants and compare technique and head kinematics between sexes and level of play. Header technique is a coachable aspect of soccer participation; therefore, associations between technique and head impact magnitude may inform training interventions with potential to reduce head impact burden.

V. REFERENCES

[1] Zuckerman et al, Am J Sports Med, 2015
[2] Press et al, CJSM, 2017
[3] Saunders et al., Clin Biomech, 2020
[4] Filben et al., J Biomech, 2021
[5] Nowak et al, JAMA Ophthalmol, 2020
[6] Caccese et al, Med Sci Sports Exerc, 2019
[7] Quintero et al, J Appl Behav Anal, 2020
[8] Becker et al, J Hum Kinet, 2021
[9] Caccese et al, Sports Biomech, 2017
[10] Rich et al., Ann Biomed Eng, 2019
[11] Wren et al, Gait Posture, 2020