CONTRIBUTIONS OF THE AXIAL SPINE TO KICKING BIOMECHANICS IN THE DIPPING KICK AMONG ELITE SOCCER PLAYERS

Evan M. Miller, MD[1]; Garrett Bullock, PT, DPT, DPhil[2]; Brian R Waterman, MD[1]; Kristen F Nicholson, PhD[1]; Tadhg J. O'Gara, MD[1]

[1]Department of Orthopaedic Surgery, Atrium Health Wake Forest Baptist, Winston-Salem, North Carolina
[2]Department of Orthopaedic Surgery, Wake Forest School of Medicine; Centre for Sport, Exercise and Osteoarthritis Research Versus Arthritis, University of Oxford; Nuffield Department of Orthopaedics, Rheumatology, and Musculoskeletal Sciences, University of Oxford

The aim of this study was to develop normative data for thoracic, lumbar and pelvic range of motion (ROM) during a soccer dipping kick among five NCAA Division I and high-level youth soccer players, comparing successful and unsuccessful kicks. The "dipping" kick is a complex, skill whereby a player strikes the ball so that it initially rises, but due to its top spin subsequently "dips" toward the intended target. From a repeated measures, cross-sectional design, successful kicks had a lower thoracic rotation at ball contact and average maximum thoracic rotation at 31.1±26.5º compared to the average maximum value for unsuccessful kicks at 43.7±28.6º, although not statistically significant. This study suggests that twisting the thoracic spine away from the target in an effort to "whip" and dip the ball may be suboptimal. The thoracic spine is more in line with the pelvis in successful kicks.

KEYWORDS: Soccer, normative data, range of motion, spine, pelvis

INTRODUCTION: A direct free kick in soccer provides a unique scoring opportunity. The direct free kick taken within 25 yards of the goal has a conversion rate of only 6-13% (Ager, 2015; Link et al., 2016). Because the opposing team attempts to block the free kick by standing 10 yards in front of the ball, successful free kicks often incorporate the dipping technique to go over the wall of players and then dip beneath the crossbar. The dipping kick is executed by a distinct biomechanical action to impart these movement characteristics onto the soccer ball. Understanding the various components that influence the quality of the dipping kick can be utilized to develop tangible areas for improvement for players at all levels of training. While the instep kick approach has been extensively studied, few studies have been conducted to address the granular biomechanical movements needed to perform the dipping kick, especially regarding spinal movement (Lees et al., 2010; Shan et al., 2005; Kellis et al., 2004; Kawamoto et al., 2007; Bessenouci et al., 2020; Lopez et al., 2011). As a result, kicking has been treated as predominantly a lower-body motor skill, despite increasing evidence of the importance of trunk and spine motion in other high-level sports including track, gymnastics, and rugby (Kruse et al., 2009; Plais et al., 2019; Sinclair et al., 2013). With cross-sectional studies demonstrating upwards of 50% of professional and recreational soccer players having experienced a disabling low back pain episode, further study is warranted to analyze spine and pelvic biomechanics in soccer, especially for more complex kicking attempts during the game (Kruse et al., 2009; Plais et al., 2019; Ball et al., 2019). This current study sought to provide normative data for thoracic, lumbar and pelvic range of motion (ROM) during a soccer free kick among an elite NCAA division I soccer population, compare successful and unsuccessful kicks, and evaluate these findings in the context of existing biomechanical literature. Our hypothesis was that thoracic and lumbar flexion and extension would differ between both groups. This information can be utilized for training purposes and to further improve player performance by focusing on a neglected biomechanical component of a successful kick – the spine (Fullenjamp et al., 2014).

METHODS: A repeated measures, cross-sectional study was conducted in a sample of asymptomatic, NCAA Division I College and professional "best free kick specialists" soccer players at the Wake Forest McCreary Field House on a soccer pitch. Two NCAA Division I, one semi-professional, and two high level youth soccer players consented to participate. Data were excluded if a participant endorsed pain, had undergone surgery in the past 12 months, or was unable to participate in all aspects of soccer play. Kinematic three dimensional (3D) motion data were collected using 52 reflective markers with a 10 camera motion analysis system (Qualisys AB, Göteborg, Sweden). Motion data were collected at 200 Hz. Reflective markers were positioned over specific anatomical landmarks including the thoraco-lumbar spine and pelvis. The same operator(s) performed all marker placements to avoid inter-test variability. Joint kinematic and kinetic data were calculated using a previously described model (Wren et al, 2020). The pelvis was defined by markers overlying the two anterior superior iliac spines and the sacrum. Lumbar motion was defined relative to pelvis. From the posterior view, markers were placed on the upper (C7) and lower (T10) spine. Players wore their cleats that they commonly used in competitions. They were instructed to kick the ball with maximal effort, with the dipping technique, and to aim for the corner which was closest to them (the “near post”).

Figure 1: Schematic of Dipping Direct Free Kick Arrangement with Marker Placement

All participants did warm-up exercises prior to measurements taken and practiced kicking the ball three-five times beforehand. Following the warm-up period, players kicked twenty attempts. A Fédération Internationale de Football Association (FIFA) official standard match ball for professional soccer games was placed twenty yards in-line with the near post of a FIFA and NCAA standardized goal (Ager, 2015). The near post upper corner was labeled as the 0.9 by 0.9 m corner in-line with the player. Five 1.83 m Rogers Athletic Titan Pop Up Dummies were placed ten yards between the goal and the player, where the average height of an adult soccer player is reported to be 1.83 m. Each player made twenty attempts at scoring. A successful attempt was defined as when the ball cleared the defender barrier and passed into the designated upper corner. Kinematics were calculated from the entire kicking cycle and analyzed at key time points using Visual3D (C-Motion, Inc. Germantown, Maryland). Point of ball contact was correlated to peak velocity of the foot. Means (standard deviations (SD)) and medians (interquartile ranges (IQR)) were calculated for both descriptive statistics and biomechanical variables. Flexion in the sagittal plan was indicated by a positive value and extension a negative value. Kinematics at point of ball contact and at maximum values were compared by a series of t-tests to compare two successful and two unsuccessful attempts per participant for a total of ten successful and ten unsuccessful efforts. Analyses were completed in IBM SPSS, version 19.0 (IBM, Chicago, IL, USA).

RESULTS: Data from a total of 20 kicks with 2 successful and 2 unsuccessful kicks from each of the 5 participants were analyzed. The average age, height and mass of the participants were mean age: 20.2±2.5 years old, height: 1.76±0.1 m, mass: 72.1±5.7 kg respectively. At the point of ball contact for successful kicks, the average lumbar flexion, tilt, and rotation were 39.8±13.2º, 3.5±8.5 º, and 7.5±12.9º respectively. Thoracic flexion, tilt, and rotation was 7.3±6.0º, -2.4±7.3º, and 8.1±34.8º respectively. Pelvic anterior/posterior tilt was -32±9.5º and obliquity was 4.1±4.2º. There were no significant differences in comparison to unsuccessful measurements at point of ball contact (Table 1). For successful kicks, the average maximum lumbar flexion, tilt, and rotation were 59.5±14.6º, 22.3±5.2º, and 26.8±5.2º respectively over the thirty frames prior to ball contact and 130 frames following the kick. Thoracic flexion, tilt, and rotation were 40.7±16.3º, 13.7±8.7º, and 31.1±26.5º respectively. Pelvic anterior/posterior tilt was 13.5±9.2º and obliquity was 6.4±2.6º. While there were no significant differences in comparison to unsuccessful measures, successful kicks had a lower thoracic rotation at ball contact and average maximum thoracic rotation at 31.1±26.5º compared to the average maximum value for unsuccessful kicks at 43.7±28.6º, although not statistically significant. The range of average mean values per time frame comparing successful to unsuccessful kicks in regard to thoracic and lumbar flexion/extension and rotation are shown in Figure 2.

Table 1: Spine and Pelvis Free Kick Mechanics of Successful and Unsuccessful Free Kick

Point of Ball Contact				
	Unsuccessful (mean ± SD)	Successful (mean ± SD)	P Value	Cohen's d
Lumbar Flexion (º)	41.6±12.1	39.8±13.2	0.758	0.14
Lumbar Tilt (º)	2.9±7.8	3.5±8.5	0.860	0.08
Lumbar Rotation (º)	6.8±13.8	7.5±12.9	0.912	0.05
Thoracic Flexion (º)	7.5±5.2	7.3±6.0	0.939	0.25
Thoracic Tilt (º)	3.3±6.5	-2.4±7.3	0.800	0.11
Thoracic Rotation (º)	20.0±33.2	8.1±34.8	0.444	0.35
Pelvic Ant/Post (º)	-29.6±9.3	-32±9.5	0.511	0.30
Pelvis Tilt (º)	-2.6±5.8	-3.4±4.2	0.756	0.34
Maximum Value				
	Unsuccessful (mean ± SD)	Successful (mean ± SD)	P Value	Cohen's d
Lumbar Flexion (º)	59.3±15.3	59.5±14.6	0.971	0.09
Lumbar Tilt (º)	19.7±6.5	22.3±5.2	0.341	0.17
Lumbar Rotation (º)	25.3±6.9	26.8±5.2	0.589	0.12
Thoracic Flexion (º)	43.7±6.7	40.7±16.3	0.273	0.24
Thoracic Tilt (º)	13.5±7.3	13.7±8.7	0.554	0.07
Thoracic Rotation (º)	43.7±28.6	31.1±26.5	0.320	0.31
Pelvic Ant/Post (º)	14.8±9.7	13.5±9.2	0.763	0.22
Pelvis Tilt (º)	6.4±5.2	6.4±2.6	0.978	0.09

SD: Standard Deviation; Ant/Post: Anterior, Posterior

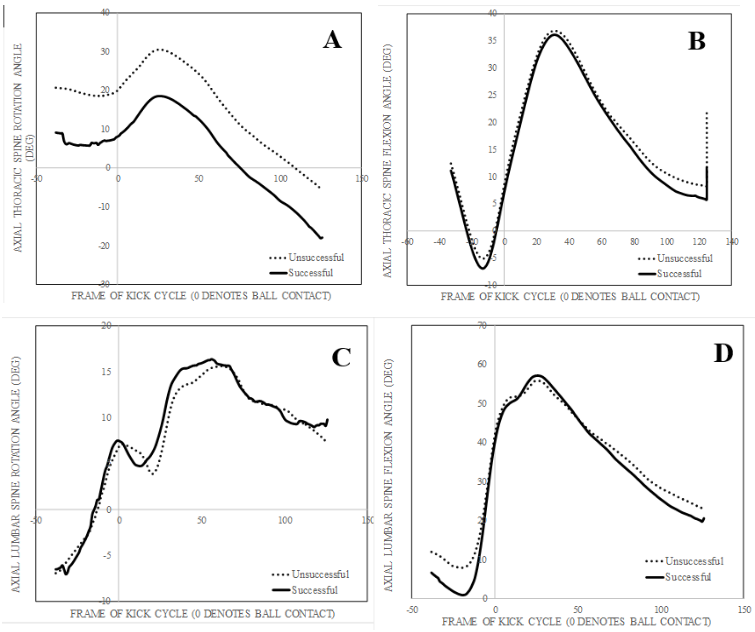

Figure 2: Group means for thoracic rotation (A) and flexion angle (B), lumbar rotation (C) and flexion angle (D) for successful and unsuccessful kicks (Positive values indicate rotation to right side or increased flexion)

DISCUSSION: To the extent of our knowledge, an examination of the thoracic and lumbar spine during the dipping soccer kick has not been previously reported. Previous studies regarding kicking biomechanics overall have examined the spine as a single functional segment, which provides limited information on how the thoracic and lumbar spine move in conjunction to each other. This study improves our knowledge of optimum biomechanics involved in its execution. In short, this study suggests that twisting the thoracic spine away from the target in an effort to “whip” and dip the ball may be suboptimal. It was initially hypothesized that the spine and pelvis ROM parameters for a successful dipping kick would differ from what had been reported for a regular soccer kick as reported by Langhout et al. This was not the case in the present study. One of the main findings of this study was that total spine flexion did not differ when comparing the results of the dipping kick to previous reports on the maximal instep kick, where total spine flexion was approximately 41 degrees at ball contact (Langhout et al., 2017). In Bessenouci et al.’s 2019 study focusing specifically on the direct free kick, the player’s approach time, approach distance, approach speed along with the leg and foot speed were demonstrated to have a significant correlation to success. The pelvis and spine were not analyzed. This study further expands on Bessenouci et al.’s reports to provide a more complete biomechanical picture specifically for the dipping direct free kick.

CONCLUSION: While there were no statistical differences between successful and unsuccessful attempts, successful kicks had a lower thoracic rotation at ball contact and average maximum thoracic rotation at 31.1±26.5º compared to the average maximum value for unsuccessful kicks at 43.7±28.6º. These values provide normative data for soccer players that can be further utilized for correct posture and alignment for players who attempt this often difficult yet important skill in the sport.

REFERENCES:

Ager D. The Soccer Referre’s Manual . 6th ed. Bloomsbury; 2015.

Ball JR, Harris CB, Lee J, Vives MJ. Lumbar Spine Injuries in Sports: Review of the Literature and Current Treatment Recommendations. Sports Medicine - Open. 2019;5(1). doi:10.1186/s40798-019-0199-7.

Bessenouci H, Haceini A. Analysis of some biomechanical variables influencing the accuracy of direct free kicks in soccer. Computer Methods in Biomechanics and Biomedical Engineering. 2019;22(sup1):S340-S342. doi:10.1080/10255842.2020.1714936

Dörge HC, Andersen TB, SØrensen H, Simonsen EB. Biomechanical differences in soccer kicking with the preferred and the non-preferred leg. Journal of Sports Sciences. 2002;20(4):293-299. doi:10.1080/026404102753576062

Fullenkamp AM, Campbell BM, Laurent CM, Lane AP. The contribution of trunk axial kinematics to poststrike ball velocity during maximal instep soccer kicking. Journal of Applied Biomechanics. 2015;31(5):370-376. doi:10.1123/jab.2014-0188

Grosdent S, Demoulin C, Rodriguez de La Cruz C, et al. Lumbopelvic motor control and low back pain in elite soccer players: a cross-sectional study. Journal of Sports Sciences. 2016;34(11):1021-1029. doi:10.1080/02640414.2015.1085077

Juárez D, López De Subijana C, Navarro E. Kinematic Analysis of Kicking in Young Top-Class Soccer Players.; 2011. https://www.researchgate.net/publication/51635913

Kawamoto R, Miyagi O, Ohashi J, Fukashiro S. Kinetic comparison of a side-foot soccer kick between experienced and inexperienced players. Sports Biomechanics. 2007;6(2):187-198. doi:10.1080/14763140701324966

Kellis E, Katis A, Gissis I. Knee biomechanics of the support leg in soccer kicks from three angles of approach. Medicine and Science in Sports and Exercise. 2004;36(6):1017-1028. doi:10.1249/01.MSS.0000128147.01979.31

Kruse D, Lemmen B. Spine Injuries in the Sport of Gymnastics. Vol 8; 2009. http://journals.lww.com/acsm-csmr

Plais N, Salzmann SN, Shue J, Diez Sanchez C, Urraza FJ, Girardi FP. Spine Injuries in Soccer.; 2019. http://journals.lww.com/acsm-csmr

Langhout R, Tak I, van der Westen R, Lenssen T. Range of motion of body segments is larger during the maximal instep kick than during the submaximal kick in experienced football players. Journal of Sports Medicine and Physical Fitness. 2017;57(4):388-395. doi:10.23736/S0022-4707.16.06107-7

Lees A, Asai T, Andersen TB, Nunome H, Sterzing T. The biomechanics of kicking in soccer: A review. Journal of Sports Sciences. 2010;28(8):805-817. doi:10.1080/02640414.2010.481305

Link D, Kolbinger O, Weber H, Stöckl M. A topography of free kicks in soccer. Journal of Sports Sciences. 2016;34(24):2312-2320. doi:10.1080/02640414.2016.1232487

Shan G, Westerhoff P. Soccer: Full-body kinematic characteristics of the maximal instep Soccer kick by male soccer players and parameters related to kick quality. Sports Biomechanics. 2005;4(1):59-72. doi:10.1080/14763140508522852

Sinclair J, Atkins PK, Hobbs SJ. Upper body kinematic predictors of ball velocity during out of hand kicking in international level rugby league kickers. International Journal of Sports Science and Engineering. 2013; 7.2:101-110

Wren TAL, O’Callahan B, Katzel MJ, et al. Movement variability in pre-teen and teenage athletes performing sports related tasks. Gait and Posture. 2020;80:228-233. doi:10.1016/j.gaitpost.2020.06.003