A BIOMECHANICAL ANALYSIS FOR PROFICIENT AND LESS-PROFICIENT SUBJECTS FOR SOCCER HEADING

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Soccer is one of the most popular sports and is played and watched by millions of people around the world. In heading the players intentionally strike the ball using his head; therefore it is essential to instruct them in a proper manner how to do it optimally. Our results showed that lower and upper body had a significant difference between the proficient and less-proficient subjects. For upper body kinematics, the proficient subjects exerted lesser elbow angles (47.6° (1.9) than the less-proficient (58.7°(3.5)). In the case of lower body kinetics, the proficient subjects exerted greater ankle moment (1.9(0.2) Nm/Kg) than les-proficient subjects (1.5(0.3)Nm/Kg). With the results obtained it became possible to create particular training programs on how to perform a skill better and therefore result in an improvement of their ability.

Key words: Skill, kinematics, kinetics, training programs.

INTRODUCTION: Soccer is the most global and accessible sport on the planet. Latest numbers estimate that approximate 265 million people are playing soccer globally on a regular basis. The global nature of the game is emphasized in the fact that the FIFA has 207 member associations around the world, which accounts for approximately 90% of the world countries[1]. Soccer is also interesting from a biomechanical perspective, as the fundamental skills inherent within the game encompass a wide range of kinematic functions, with particular emphasis on flexion and extension characteristics of anatomical lower extremity joints. There is also a great deal of scope to understand the kinetics involved, and how this varies depending on the skill being undertaken. Furthermore, the fact that soccer is played by such a diverse global population is indicative of the fact that no soccer athlete is the same, each athlete will differ in muscle activation process, kinematics and techniques, all of which are deemed by the process of coaching and learning from a young age. Soccer can be broken down into a number of defined actions, which enable a kinematic analysis to be undertaken with much greater ease. Lees et.al (2010) found that the development of motion capture technology and advances in biomechanical methods have made an impact on the understanding of the kicking skill. Furthermore, whereas previous reviews and overviews [1, 3] considered mainly the kinematic, kinetic and electromyographic characteristics of the kicking leg, there are a number of other aspects that have been the subject of recent exploration[2].Advancing from the traditional kicking skill, there are a number of remarkable studies which focus on other skills, such as the heading technique which will be studied in this project. Studies which involved analysis of the heading skill focus primarily on the injury and safety with the cranium. Shewchenko et al (2005) focused on the heading and head response, and discussed the controversy surrounding the long term effects of repeated impacts from heading, whilst Broglio et al [5] conducted a similar study which focused on potential protective headgear used in soccer. Little information is available regarding the heading biomechanics (kinematic and kinetic aspects). Heading as a skill is interesting as the action is unique to soccer. In heading, a player intentionally strikes the ball using his head, and the technique therefore involves significant impact to a delicate part of the body. It is therefore essential to apply a more in depth instruction to soccer players when coaching them how to header a soccer ball optimally. The main objective of this study was to provide a comparison between proficient and less-proficient subjects with regards of their kinematic, kinetic parameters. We hypothesized that proficient subjects will exhibit greater flexion and extension of lower extremity during the header.

METHODS: A total of 6 subjects were recruited, comprising of 3 recreational players (Less-proficient) (age 22±3, height 170± 8 cm; weight 74± 13 Kg, and 3 regular soccer players (Proficient), (age 23±3, height 175± 10 cm; weight 75± 15 Kg) with playing experience (for the regular soccer players) of at least 10±3 years. All the players gave informed consent before participation, in accordance with the local university's Institutional Review Board guideless. To eliminate the effect of shoe variations on the player's performance, all players wore the same shoe model (F50 Adidas, Germany), with sizes ranging from US9 to US11. The experiment was conducted at the gait analysis laboratory at the local university. Two embedded forces plates (AMTI, UK) on the floor were used to obtain GRF data at a sample rate of 1000Hz. A motion capture system (Vicon MX, Oxford Metrics, UK) consisting of eight infrared cameras, was employed to collect kinematics data at a sample rate of 100 Hz. The force-plates were synchronized to the motion capture system both were calibrated according to the manufacturer's recommendations before the heading trials were conducted. Thirty-five retro reflective markers (14 mm diameter) were attached to the player following the full body model based on the Plug-In-Gait Marker set in order to facilitate the capture of the players' soccer heading motion. There were six trials in total per subject. For the first two trials, the subject was instructed to head the ball in the regular way but the subject was given a particular target to try and aim at. For the final two trials, the subject was required to complete the heading technique without leaving the ground. The ball was thrown with a parabolic trajectory to a height pf 2.5 meters from a 45° angle to the frontal plane. Unpaired t- were conducted with the assumption that variance between proficient and less-proficient subjects was similar. These were used for statistical comparisons between the proficient and less-proficient groups, and the variables used were peak joint angles, peak joint angular velocity, peak joint moments, peak power and eccentric and concentric work at each joint (hip, knee, and ankle) in the sagittal plane. All significant difference were set at p=0.05.

RESULTS : For the dominant side, we observed a markedly lower average peak elbow flexion angles ($p < 0.05$) in proficient players (47.6±1.9)(Table 1).The angular velocity data showed considerably differences ($P<0.001$) in the right ankle joint between the means of proficient (2.0 ± 0.5) and non-proficient subjects (3.4 ± 0.9 °/s) (Table 2), as well as for maximum moment at the non-dominant ankle (1.9 ± 0.2 Nm/kg and 1.5 ± 0.3 Nm/Kg) (Table 3).The mean positive work data showed proficient subjects exhibit a significant larger energy variation ($P<0.05$) in the dominant knee joint (48.9 ± 17.4)J/ kg compared with less-proficient (28.6 ± 11.9 J/Kg as well a significant increase in the non-dominant ankle (57.1 ± 15.3 J/Kg and 41.9 ± 8.37 J/Kg) (Table 4). The mean anteroposterior (AP) GRF data showed significant greater magnitude ($P<0.03$) of AP GRF for the proficient subject in the right leg (17.9 ± 4.1 %BW) compared with the 12.7 ± 1.3 % BW) (Table 5).

Table 1
Peak Joint Angles (°)

	Dominant side			Non-dominant side		
Joint`	Proficient	Non-proficient	p-value	proficient	Non-proficient	p-Value
Elbow	47.6(1.9)	58.7(3.5)	0.04*	48.5(5.2)	59.8(6.2)	0.045*

Table 2
Joint Angular Velocities (°/s)

	Dominant side			Non-dominant side		
Joint	Proficient	Non-proficient	p-value	proficient	Non-proficient	p-Value
Ankle	2.0(0.5)	3.4(0.9)	<0.001*	2.63(0.7)	3.38(1.25)	0.18

Table 3
Joint Moments (Nm/Kg)

	Dominant side			Non-dominant side		
Parameter	Proficient	Non-proficient	p-value	proficient	Non-proficient	p-Value
Ankle	1.6(0.6)	1.6(0.4)	0.47	1.9(0.2)	1.5(0.3)	0.04*

Table 4
Joint positive work (J/Kg)

	Dominant side			Non-dominant side		
Parameter	Proficient	Non-proficient	p-value	proficient	Non-proficient	p-Value
Knee	48.9(17.4)	28.6(11.9)	0.03*	50.9(4.7)	53.5(8.9)	0.06
Ankle	40.8(12.4)	31.2(6.9)	0.08	57.1(15.3)	41.9(8.3)	0.04*

Table 5
Ground Reaction Force (%BW)

	Dominant side			Non-dominant side		
Parameter	Proficient	Non-proficient	p-value	proficient	Non-proficient	p-Value
AP	17.9(0.05)	12.7(0.01)	0.02*	3.3(0.01)	2.6(0.01)	0.32
ML	7.7(0.03)	7.2(0.01)	0.38	1.6(0.03)	1.2(0.01)	0.87
Vertical	92.9(0.17)	81.8(0.06)	0.18	101.1(0.07)	94.4(0.18)	0.29

DISCUSSION Prior reports suggest that the implementation of an elbow swing improves jump height by increasing the height and velocity of the body's center of gravity [6]. The increase of the height and the velocity of the body's center of gravity due to elbow swing contributes to the total vertical momentum, and has been seen to increase the magnitude of the vertical GRF [6]. This is important with regards to the hip and knee extensors as an arm swing may also improve jumping performance by creating an additional downward force on the body as the extensors will be a better position to exert vertical GRF[7, 8]. It was observed that within a propulsion skill, the influence of the elbow swing is underestimated within soccer. The downward force generated by the hip and knee extensors during a jump slows the contraction velocity of the muscles themselves, allowing for a greater muscle force development highlighted by the greater concentric contraction of a subject during a normal header in comparison to a standing header (10.5 and 1.37 W/kg for proficient subjects and 8.5 to 2.03 W/kg for less-proficient players on their right knee. The inclusion of an arm swing during a heading skill in soccer can now be quantified and its importance highlighted, therefore new methods of coaching can be implemented to target this particular aspect in a less-proficient subject to enable them to become more adept at such a skill.

CONCLUSION Proficient subjects generally exhibit more desirable characteristics during each trial such as better joint coordination, and higher ground impulse, representing an overall greater ability in implementing the skills. Trends become associated with particular skills, as for instance the ankle joint was the most prominent during the present study. Understanding the action of muscles at each joint is the key concept in determining differences between the two groups and building a basis on how less-proficient and beginner soccer players can transcend the barrier to proficiency. With the results obtained it became possible to create particular training programs to target specific kinematic parameters which will enable less-proficient subjects to increase their understanding on how to perform a skill better and therefore result in an improvement of their ability. This is one of the key applications of the study, and by using collected data it becomes possible to specify useful training programs.

REFERENCES

1. Glynn, J.A., et al. *KINEMATIC DIFFERENCES BETWEEN 'ONE-FOOTED'AND 'TWO-FOOTED'YOUNG SOCCER PLAYERS KICKING WITH THE NON-PREFERRED LEG.* in *ISBS-Conference Proceedings Archive*. 2013.
2. Lees, A., et al., *The biomechanics of kicking in soccer: A review.* Journal of sports sciences, 2010. **28**(8): p. 805-817.
3. Azidin, R.M.F.R., et al., *TREADMILL VERSUS OVERGROUND SOCCER-SPECIFIC FATIGUE: THE EFFECT ON HAMSTRING AND QUADRICEPS STRENGTH AND FRONTAL PLANE PEAK KNEE JOINT MOMENTS IN SIDE-CUTTING.*
4. Shewchenko, N., et al., *Heading in football. Part 2: biomechanics of ball heading and head response.* British journal of sports medicine, 2005. **39**(suppl 1): p. i26-i32.
5. Broglio, S.P., et al., *The efficacy of soccer headgear.* Journal of athletic training, 2003. **38**(3): p. 220.
6. Ashby, B.M. and J.H. Heegaard, *Role of arm motion in the standing long jump.* Journal of Biomechanics, 2002. **35**(12): p. 1631-1637.
7. Feltner, M.E., D.J. Fraschetti, and R.J. Crisp, *Upper extremity augmentation of lower extremity kinetics during countermovement vertical jumps.* Journal of sports sciences, 1999. **17**(6): p. 449-466.
8. Harman, E.A., et al., *The effects of arms and countermovement on vertical jumping.* Med Sci Sports Exerc, 1990. **22**(6): p. 825-33.