THE CHARACTERISTICS OF FEMALE SOCCER KICKING REVEALED BY 3D KINEMATICS AND ELECTROMYOGRAPHY

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Soccer is the most popular sport in the world and rapidly becoming one of the most popular sports in North America. Despite its popularity, little research has been done to facilitate the rapid demand of quantitative findings. Even less attention is being paid to the fact that females now make up almost half the players worldwide. This study initiates a research on female soccer kicking using state-of-the-art technology. The high-tech unit consists of a 3D motion capture system with 9 high-speed cameras (120 Hz) and wireless electromyography (EMG) collection. The results revealed that a) Elite subjects combined the flexion and extension of the hip, knee and ankle joint to perform the kick while novice subjects primarily used the knee to generate momentum; b) elite group showed a significant higher EMG intensity.

KEY WORDS: Joint angles, flexion/extension, range of motion, emg intensity

INTRODUCTION: Soccer, known as football outside of North America, is the most popular sport in the world. Played and watched in six continents, it is suggested that over 40 million people are registered soccer players worldwide, a statistic that is surely on the rise. In North America the game has experience significant growth. In the United States the number of individuals who play soccer has risen 90% since 1987, with over 19 million having played soccer at least once in the past year (SGMA, 2002). This sport looks to have even greater numbers in the future, as the majority of individuals participating are youth. When the age of registered participants is examined, nearly 80% of players are under the age of 18 in the United States, a fact that is likely true not only in North America but also throughout the world (SGMA, 2002). However, scientific researches on soccer are not proportional to its popularity. There are hardly quantitative descriptions on soccer, even on some basic skills like kicking and passing. The main reasons are: a) soccer is a team sport, unlike technique dominant gymnastics, individual skill is only one of many vital factors; b) it is very difficult to collect unconstrained data to illustrate soccer skills quantitatively. Therefore, the previous studies supply mainly a qualitative explanation on soccer skills (Barfield, 1998; Dorge et al, 2002) and the coaching procedure is still based on individual trainer's experience.

It's no doubt that trainer's experience plays a vital role in a successful team. Yet, individual basic skills like kicking and passing should not be neglected in soccer training, especially for the beginners. Knowing the characteristics of an optimized style will help coaches to launch an aim-oriented training and speed-up the learning process. As the soccer booming has started in Canada, especially for girls, a scientific-oriented (vs. experience-oriented) basic skill training should be supplied for coaches. It will save time and supply efficiency. One way for achieving such a goal is to quantitatively determine the characteristics of elite players (or the difference between elites and novices), so that coaches can design their training program based on such a quantitative depiction. Thus, the goals of this study are: to quantitatively describe soccer kicking in three-dimensional space and to disclose the characteristics of neural muscle control through a comparison between an elite group and novices.

METHODS: The method consists of the synchronization of four measuring systems – a high-speed nine-camera system (VICON v8i, 120 Hz with an accuracy of < 0.9 mm), normal video recorder, wireless EMG collection (1080 Hz), and sound capture – as well as biomechanical modelling. The 3D motion capture system was used to determine body kinematics, tracking 46 reflective markers (15 mm. in diameter) and supplied the spatial position, velocity, and acceleration of limbs and/or joints (Figure 1). EMG captured muscle activity, which was utilized to fractionate our response process in order to get intensity and timing of neural control as well as the coordination among muscle groups. Video and sound capture permitted a traditional outside view of motion analysis. Together, these systems supply information on how athletes interact with the environment and what information a person uses while preparing to produce an action. Such synchronized tests present a promising way to measure, analyze and understand any complex skill (normal/abnormal, or experienced/ inexperienced).

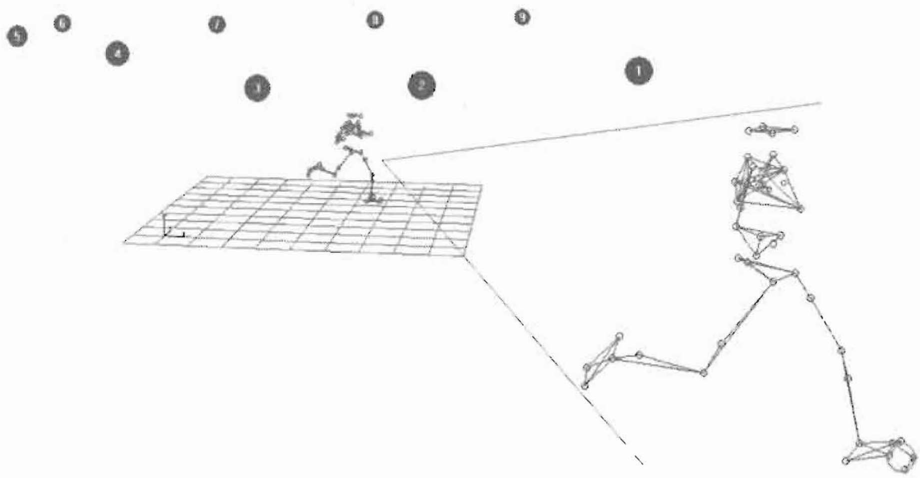

Figure 1 The set-up and a sample of 3D motion capture of female soccer kicking.

For our tests we used wireless EMG. In contrast to "wired" systems, a wireless telemetry system reduces movement constraints permitting greater flexibility in the kinds of tests that could be done. It also minimized unwanted compound influences (the interference of wires), allowing researchers to obtain data from an un-manipulated process. Analysis based on such measurements would more accurately reveal the true nature of a movement.

Ten elite soccer players from the varsity women's soccer team and 10 novices were recruited. The elite players had in average 12 years of soccer experience. All participants completed an informed consent form for human subjects' tests. Trials were conducted on a two-centimeter thick wrestling mat (mimic the grass playground) and completed with a standard size soccer ball (Federation Internationale de Football Association, FIFA, standard). An additional two-centimeter thick mat approximately ten meters wide and two meters in height was used to reduce rebound of the ball, preventing damage of the equipment. This mat was an easy target to contact, thus subjects were asked to kick the ball as hard as possible. All participants completed six kicks, three by each foot. Similar to a penalty-kick in soccer, the ball was placed in a central location in front of the participant. No restrictions as to the approach to the ball or the type of kick were given to the subject.

Before testing, subjects were hooked up to a four-channel wireless NORAXON EMG. The electrodes for EMG collection were placed on the right and left quadriceps and hamstrings. Subjects were then asked to perform a maximum voluntary contraction (MVC) against manual resistance for each of the four muscles. The EMG envelops obtained from raw EMG during kicking were then normalized by MVCs, such the changes of muscle power vs. time could be characterized on a scale of %MVC.

RESULTS AND DISCUSSION: The kinematics results revealed that Left kick had similar trends to right kick. For the purposes of contrasting the differences between novice and elites, only right kick data was analyzed in this paper as well as data from dominant and non-dominant kicks.

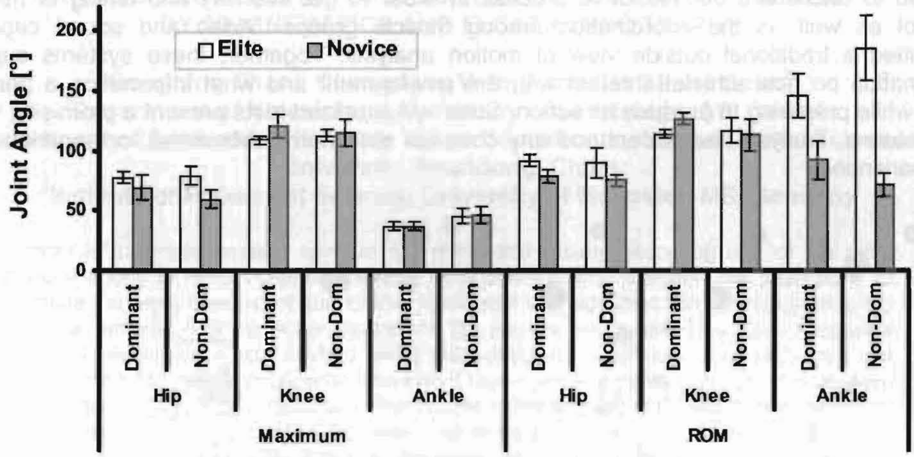

Figure 2 Maximum and ROMs of joint angles.

As shown in Figure 2, during a kick with their dominant foot, elite participants reached an average maximum hip angle of 81.6° of extension with a standard deviation (SD) of seven degrees, whereas, an average maximum hip angle of 68.5° with a SD of 6.9 degrees was found for the novice participants. Therefore, a significant difference of 13° was confirmed between the two groups ($p < 0.05$). This difference reaches 21° for the non-dominant Foot. Furthermore, the range of motion (ROM) was significantly higher ($p < 0.01$) in the elite subjects when performing a right kick (dominant or non-dominant) as the novice subjects reached in average 77° of flexion/extension during the movement while elite subjects had a range of motion of 96° of flexion/extension. The Knee analysis showed that novice participants had greater maximum knee angle than elite subjects (118°±SD of 10° and 108°±SD of 4° respectively) in dominant foot kick. The novice subjects also had greater ROM about the knee flexion/extension as elite players reached 112° while novice subjects had an average range of motion of 120°. The most significant difference was found in Ankle ROM. Elites did much more foot flexion/extension during a kick than novice for both dominant and non-dominant foot.

The EMG analysis of right quadriceps showed that there was a highly significant difference between the two groups in level of muscular activity (intensity) of the soccer kick ($p = 0.000$) The novice group kicked the soccer ball with an average of 60% of their MVC while the elite group licked with an average intensity of 160% of their MVC (Figure 3).

The above results suggested that elite subjects combined the flexion and extension of the hip, knee and ankle to perform the kick while novice subjects primarily used the knee to generate momentum. The coordination of multiple joints allows elite individuals to require less flexion or extension of one specific joint as a whip-like motion is created. As joint angles – time results confirmed, experienced player initiated the movement in the hips and followed a proximal to distal segmental sequence, ending with the foot accelerating through the ball during contact. The use of the knee joint as the primary source of momentum in novice subjects demonstrates that, when attempting to perform a task that an individual is unfamiliar with, novices are more simplistic than an experienced individual, i.e., the novice kick is comprised of movements that are noncomplex and easy to control. Combined with EMG intensity results, it could suggest that the elite players use multiple segments to perform a kick in a sequential timing of these segments, and these factors contribute to a more powerful as well as a coordinated kick than that of novices.

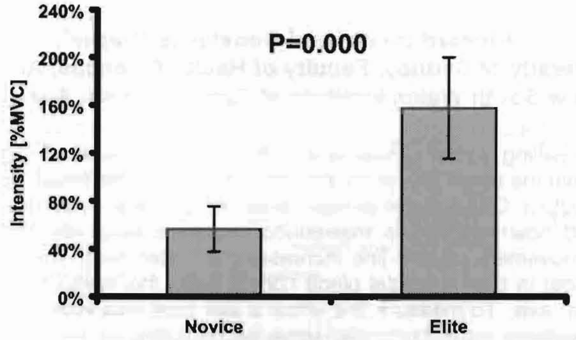

Figure 3 Mean Intensity shown as a percentage of subjects MVC for right kicks.

CONCLUSION: A sequential joint control causes the foot and lower leg to follow the hip and thigh is a key for a powerful kick. This causes an increased momentum as the foot approaches the ball more efficiently than just using knee-control strategy found in non-experienced players.

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Acknowledgement:

This work was supported by Alberta Learning Research Excellence Envelope (REE, Canada), Westgrid (Canada), and Sport Science Association Alberta (SSAA, Canada).