Influence Of Ground Reaction Forces And Joint Velocities On Kicking Velocity

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ABSTRACT

Kicking is a vital component in the game of soccer. One factor that goes into delivering a successful kick is the speed at which the ball travels, the ball velocity. Many factors play a role in increasing or decreasing the speed at which a player is able to kick the ball, and the variables of interest in this study include ground reaction force and joint velocities of the lower extremities. To date, no known studies have analyzed these factors. **Purpose:** The goal of this study was to analyze what factors play a role in increasing kicking velocity, which in turn increases ball velocity of a soccer kick. **Methods:** Four female collegiate soccer players, completed 6 instep soccer kicks to analyze the factors that play a role in kicking velocity. Their motion was captured using the Cortex 8.1 Motion Analysis Software. Measurements were taken for ball velocity, right and left ASIS, and right and left ankles. **Results:** Significant correlations were found between peak resultant ball velocity and GRF in the X direction (-0.907), GRF in the Y direction (0.867), R ASIS velocity (0.950), R ankle velocity (0.855), and L ankle velocity (0.977). No significant correlations were found between peak resultant ball velocity and GRF in the Z direction (0.788), or peak resultant ball velocity and peak joint velocity of the L ASIS (0.692). **Conclusion:** Braking force of the planting leg is shown to correlate significantly with kicking velocity. Although great braking force allows for a faster ball, this can have other implications to injury. Rotational velocity of the hip also allows for greater ball velocity. These are one of many factors that play a role in kicking velocity and further studies are needed to show the relationships between these variables.

INTRODUCTION

Kicking is a vital component in the game of soccer. One major factor that influences the success of a scoring attempt in soccer is ball velocity. Essentially, the faster the ball is traveling, the harder it is to block. Many factors have been looked at to try and determine what plays a role in a well-executed soccer kick. Some of these variables include flexibility, hamstring and quadricep strength, body composition, and ground reaction force. Previous studies have shown exercise programs used to strengthen the muscles used in kicking have been successful in increasing kicking velocity (Manolopoulos, et al., 2013). Another study showed a positive correlation between height and kicking velocity (Atack, et al., 2019). Although studies have been successful in determining single factors that help to increase kicking velocity, this is a complex movement with many different variables that contribute to it, and it's hard to determine one singular variable that will enhances kicking velocity.

In this study, ground reaction force (GRF) and joint velocities of the lower extremities are variables of interest for increasing kicking velocity. To date, no known studies have analyzed the specific relationship between GRF, joint velocity and kicking velocity. The purpose of this study was to analyze the influence of ground reaction forces and joint velocities on kicking velocity.

References

Manolopoulos, E. , Katis, A. , Manolopoulos, K. , Kalapotharakos, V. & Kellis, E. (2013). Effects of a 10-Week Resistance Exercise Program on Soccer Kick Biomechanics and Muscle Strength. *Journal of Strength and Conditioning Research, 27* (12), 3391-3401. doi: 10.1519/JSC.0b013e3182915f21.

Ball, K. (2012, December 11). *Loading and performance of the support leg in kicking*. Journal of Science and Medicine in Sport. Retrieved November 1, 2022, from https://www.sciencedirect.com/science/article/pii/S1440244012002101?ref=pdf_download&fr=RR-2&rr=75c351e1987e876c

Orloff, H., Sumida, B., Chow, J., Habibi, L., Fujino, A., & Kramer, B. (2008). Ground reaction forces and kinematics of plant leg position during instep kicking in male and female collegiate soccer players. *Sports Biomechanics*, *7*(2), 238–247. https://doi.org/10.1080/14763140701841704

Three-dimensional kinematics and ground reaction forces during the instep and outstep soccer kicks in pubertal players. Taylor & Francis. (2010, September 14). Retrieved November 1, 2022, from https://www.tandfonline.com/doi/full/10.1080/02640414.2010.504781

Jones, P. A., Herrington, L., & Graham-Smith, P. (2016, May 24). *Braking characteristics during cutting and pivoting in female soccer players*. Journal of Electromyography and Kinesiology. Retrieved November 1, 2022, from https://www.sciencedirect.com/science/article/pii/S1050641116300463?ref=pdf_download&fr=RR-2&rr=7636b105bc07e14b

Accuracy measurement of different marker based motion analysis systems for biomechanical applications: A round robin study. (2022). PloS One, 17(7), e0271349–. https://doi.org/10.1371/journal.pone.0271349

METHODS

For analysis of ball velocity, joint velocity and GRF during the instep soccer kick, the 3D motion camera Cortex 8.1 and corresponding force plate was used, using the Helen-Hayes marker locations. This system consists of 8 cameras, 37 markers on the body, and 1 force plate. Markers were placed on the front of the head, on the right and left sides of head, both shoulders (on the acromion process), the right offset (middle of scapula), the right upper lateral arm at the proximal end and the left upper lateral arm on the distal end, the right and left lateral and medial elbows (epicondyles), the right forearm on the proximal ulnar side, and the left forearm on the distal ulnar side, the right and left radial and ulnar wrists on the styloid processes, the right and left ASIS, the V. Sacral, the right and left thighs (right higher than the left), the lateral and medial knees on both sides, the right and left shank (anterior, right higher than left), the lateral and medial ankles on both sides (malleolus), the right and left heels, and the right and left toes (proximal 2nd metatarsal). A 38th marker was attached to the ball using tape.

Before any captures were taken, participants warmed up for 5 minutes on a stationary bike, followed by a series of lower body stretches. Each participant was given 3 practice instep kicks on each leg. 3 captures on each leg were recorded for each participant. During each kick, the participant was guided to land their planting leg on the force plate to capture force data. The data from the cameras and force plate delivered data to the software Cortex 8.1 for analysis.

RESULTS

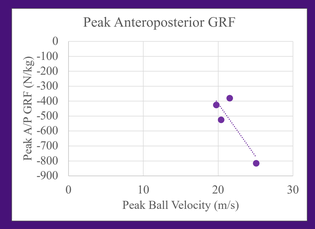
Table 1 shows the values for peak resultant ball velocity alongside absolute peak GRF values in the antero-posterior, medio-lateral, and vertical directions. Table 2 shows values for peak resultant ball velocity and peak resultant joint velocities. Table 3 represents all correlation values along with 95% confidence intervals (C.I.) for each variable.

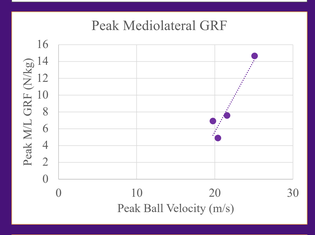
Significant correlations were found between peak resultant ball velocity and GRF in the antero-posterior direction (-0.907), GRF in the mediolateral direction (0.867), R ASIS velocity (0.950), R ankle velocity (0.855), and L ankle velocity (0.977). No significant correlations were found between peak resultant ball velocity and GRF in the vertical direction (0.788), or peak resultant ball velocity and peak joint velocity of the L ASIS (0.692).

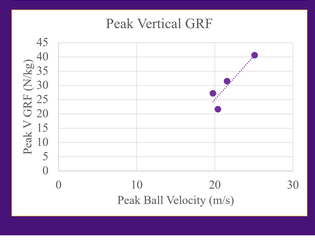
Table 3. Correlations of Variable with Right Foot Peak Resultant Ball Velocity

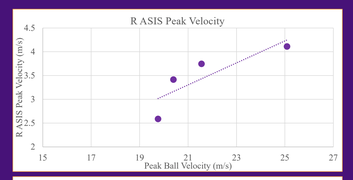
	Correlation	Lower C.I.	Upper C.I.
Peak Anteroposterior GRF	-0.907*	-0.998	0.422
Peak Mediolateral GRF	0.867*	-0.565	0.997
Peak Vertical GRF	0.788	-0.714	0.995
Right ASIS Peak Velocity	0.950*	-0.129	0.999
Left ASIS Peak Velocity	0.692	-0.803	0.993
Right Ankle Peak Velocity	0.855*	-0.596	0.997
Left Ankle Peak Velocity	0.977*	0.236	1.000

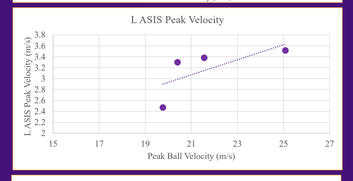
Table 3. *Indicates strong correlation. A correlation of >(-)0.800 is considered strong. GRF= ground reaction force, ASIS= anterior superior iliac spine, C.I.= confidence interval.

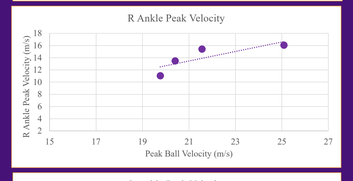


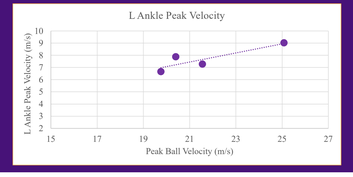












CONCLUSION

Right ASIS velocity correlated significantly with peak ball velocity. This was expected to occur, because the faster motion up the kinetic chain would translate to a higher ball velocity down the chain. This also explains why right ankle velocity would positively correlate with peak ball velocity, because the faster the ankle and foot are traveling to kick the ball, the faster the ball will travel after contact.

Left ankle velocity reached its peak prior to the right ankle reaching its peak velocity. This significant correlation could be due to the player stepping with a higher velocity, which in turn resulted in a higher ball velocity. The whole motion is connected, so if the player begins the kick faster, the result will be a higher overall ball velocity.

Significant correlations in this study included peak GRF in the anteroposterior direction and peak ball velocity, peak GRF in the mediolateral direction and peak ball velocity, right ASIS peak velocity, right ankle peak velocity and left ankle peak velocity. GRF in the anteroposterior direction correlated negatively with peak ball velocity, so the lower (more negative) GRF, the higher values of ball velocity were recorded. This is important to note because of the high braking force that is applied to the player's leg. In sports and other activities, high braking forces are known to increase the likelihood of injury in the lower extremities. However, in this study we see that the higher the braking force, the higher the ball velocity that is reached. Female soccer players may be at an increased risk for knee injuries due to this high braking force. Further studies are needed to study the effects of braking forces on soccer athletes during an instep soccer kick.

Table 1. Absolute Peak GRF values & Peak Resultant Ball Velocity

Peak Ball Velocity (m/s)	A/P GRF (N/kg)	M/L GRF (N/kg)	V GRF (N/kg)
25.09	(-)815.12	14.68	40.60
19.76	(-)425.11	6.92	27.26
21.56	(-)379.64	7.59	31.49
20.04	(-)524.90	4.90	21.66

Table 1. Peak ball velocities from a right foot in-step soccer kick along with peak absolute GRF. A/P = anteroposterior, M/L = mediolateral, V = vertical, GRF= ground reaction force, m/s= meters per second, N/kg= Newtons per kilogram of body weight

Table 2. Peak Resultant Joint Velocities & Peak Resultant Ball Velocity

Peak Ball Velocity (m/s)	Right ASIS (m/s)	Left ASIS (m/s)	Right Ankle (m/s)	Left Ankle (m/s)
25.09	4.11	3.52	16.09	9.02
19.76	2.59	2.47	11.05	6.66
21.56	3.75	3.38	13.88	7.65
20.04	3.42	3.29	13.50	7.88

Table 2. Peak ball velocities from a right foot in-step soccer kick along with peak joint velocities. ASIS= anterior superior iliac spine, m/s= meters per second