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# Relationship between Ball Kick Velocity and Leg Strength: A Comparison between Soccer Players and Other Athletes

Takanori Noguchi[1*], Shinichi Demura[2], Yoshinori Nagasawa[3]
[1]Fukui University of Technology, Fukui, Japan
[2]Graduate School of Natural Science & Technology, Kanazawa University, Kanazawa, Japan
[3]Kyoto Pharmaceutical University, Kyoto, Japan
Email: [*]t-noguchi@fukui-ut.ac.jp

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This study compared soccer players with non-soccer players, with respect to the relationship between ball velocity due to an instep kick and various leg strengths. Ten young university soccer players and ten other athletes (non-soccer players) had their instep kick ball velocity (BV) measured with respect to isokinetic leg strength. The BVs from the soccer players were significantly greater than those from the non-soccer group. However, this group also had significantly inferior dorsiflexion strength of the ankle joint (low: low angular velocity), extension of the knee joint (low, middle, and the total value of the evaluation parameters of all angular velocities), and flexion of the hip joint (middle). Positive and significant correlations between BV and flexion and dorsiflexion strengths of the ankle joint (low), extension (low, middle, high, and total), and flexion of knee joint (low and total), extension (low, high, and total), and flexion (high) of the hip joint were found in the soccer group, but a significant negative correlation was found only between BV and hip joint flexion strength (middle) in the non-soccer group. In conclusion, soccer players have similar or inferior isokinetic leg strength in comparison to other athletes, but their BV is faster.

*Keywords*: Soccer; Ball Kick Velocity; Leg Strength

## Introduction

Recently, a device for training and evaluating the isokinetic strength of the lower limbs, i.e., the isokinetic strength measurement device, has been used not only by top players but also, more broadly, by non-professional players. This device can evaluate and increase the muscle strength of various body sites (Tsuyama, Kobayashi, Saito, Kiyota, & Nakajima, 2007; Chan, Chan, Fong, Wong, Lam, & Lo, 2011). In addition, it has the additional advantage that players and coaches can select body sites and specific motions of interest, and examine competitive characteristics in order to improve the strength of specific muscle groups. To best understand conditioning and muscle strength, it is important for athletes to be motivated to improve their competition performances and to participate in a vigorous training regime. In soccer games, players need to make quick, precise movements. In particular, the instep kick is frequently used when the ball needs to be kicked very hard.

In order to obtain a high leg swing velocity, the exertion of knee extension and hip flexion strength is important (Levanon & Depena, 1998). Hence, many studies have been performed using the above-stated isokinetic strength measurement device. Tsuyama et al. (2008) reported that the extension and flexion strength of the knee joint and flexion strength of the hip joint in soccer players were significantly greater than those of archery athletes. In addition, they also reported that senior soccer players have greater isokinetic leg strength than junior soccer players (Rochcongar, Morvan, Jan, Dassonville, & Beillot, 1988; Gür, Akova, Pündük, & Küçükoğlu, 1999; Hoshikawa, Iida, Muramatsu & Nakajima, 2007). However, the above previous studies mainly examined the magnitude of leg strength or morphological characteristics of their legs as soccer players. In short, the relationship between ball kick velocity and leg strength has not been examined in detail. In the case of isokinetic muscle contraction, contraction characteristics differ for each person and with respect to angular velocity (Tsuyama, Kobayashi, Saito, Kiyota, & Nakajima, 2007). In addition, the type and amount of necessary leg strength differs among competitive sports. Because soccer players need to make quick instep kicks, the ability to exert a large amount of force over a very short time is necessary.

The peak velocity and right angle of the foot at the time when the ball is kicked determines the resultant ball velocity (Kellis & Katis, 2007). With regard to an instep kick in soccer, it is important that the hip, knee and ankle joints all work together in a chain reaction, transferring the base energy to the end area with an accelerating flail-like action. In this case, the hip joint—which fulfills the base role—must move large muscle groups and exert a large amount of power to begin the swing action (Sports Medicine Committee of Japan Football Association, 2005). Because muscles have the physiological characteristic that their contraction speed decreases when putting forth a large amount of power (Sports Medicine Committee of Japan Football Association, 2005), it is considered that muscle power exertion with not only high angular velocity but also with low angular velocity at the early stage of the kicking is important. In addition, the ankle joints must be maintained in a fixed position in order for the power conveyed at the moment of kicking the ball to not be dispersed. Therefore, training for increasing swing speed, and the technical practice for keeping the ankle joint in a fixed state (right angle) when the ball is being kicked is indispensible for soccer players.

[*]Corresponding author.

 

It is expected that existing products will be improved and measuring devices will be developed in the future, and the isokinetic strength measurements will be used in the teaching fields of various types of sports. Taking this into account, it is important for soccer players to isolate the characteristics of isokinetic strength as well as its relationship with ball velocity in order to adequately use the measuring device for training and strength evaluation purposes.

This study compared soccer players with other athletes with respect to the relationship between ball velocity and various leg strengths.

## Methods

### Subjects

Subjects in this study included ten healthy young male soccer players (age 20.0 ± 0.8 years, height 172.3 ± 5.0 cm, weight 64.4 ± 5.3 kg) and ten male athletes (age 21.1 ± 0.57 years, height 173.2 ± 5.1 cm, weight 68.8 ± 5.9 kg) who were not soccer players (the non-soccer group). All subjects have trained for at least five years in their respective sports. The non-soccer group consisted of four baseball players, two kendo competitors, one softball player, one basketball player, one American football player, and one track and field athlete, all of whom did not receive special training in soccer. Before the measurements were taken, the purpose and procedure were explained in detail and informed consent was obtained from all participants. This experimental protocol was approved by the ethics committee at Kanazawa University.

### Measurement Procedure

Matsuda et al. (2010) divided the legs into a kicking leg and a supporting leg, defining the former leg as the dominant leg. All measurements were performed on the dominant leg.

Ball kick velocity was measured by using the formula No. 5 ball officially recognized by FIFA with moderate air pressure (Pelada, molten), using an ultrasound speed meter (2ZM-1300, Mizuno). The distance from the ball to the speed meter was set at 10 m, and a net (height 2.0 m × width 2.0 m) was placed a distance of 1.0 m in front of the speed meter (height 1.5 m) (**Figure 1**). The subjects were free to choose an approach distance and performed an instep kick at maximum effort twice. Kilometers per hour (unit: km/h) was used for the evaluation variable.

Isokinetic leg strength was measured using a CYBEX-NORM (CN77, SIMIZU MEDICAL). This device is capable of measuring isokinetic strength values by adjusting an attachment while matching the range of motion in each joint. The measurement data obtained from this device was taken into a note-PC via a USB cable and analyzed with specialty software (HUMAC2009, SIMIZU MEDICAL). Isokinetic strengths of hip and knee joint flexion/extension and ankle joint flexion/dorsiflexion were measured. Extension and flexion of hip and knee joints were measured for three specific angular velocities; low (30 deg/sec), middle (120 deg/sec), and high (240 deg/sec).

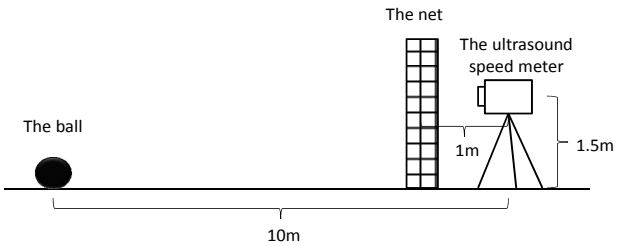


**Figure 1.**
Measurement of ball kick velocity

In a preliminary experiment, it was confirmed that the subjects' flexion and dorsiflexion strength of their ankle joints at middle and high angular velocities could not be measured. Hence, their strengths were measured only at low angular velocities. After one practice run, the test was performed twice in between one-minute intervals to eliminate the effects of fatigue. Isokinetic strength was evaluated with maximum torque (unit: Nm) and the larger value was interpreted to have the larger isometric leg strength (Kannus, 1994).

Of the two trials, the highest values of the ball kick velocity and leg strength were used. In addition, flexion and extension strengths of the knee and hip joints were used as the respective values of low, middle, and high angular velocities and their total value as evaluation parameters.

### Statistical

Mean differences of physical characteristics (height and weight), ball kick velocity, and isokinetic leg strengths between the soccer group and the non-soccer group were examined by an unpaired t-test. The mean difference was assessed by effect size (ES). The relationships between ball kick velocity and isokinetic leg strengths were examined using Pearson's correlation coefficient. Statistical significance (α) was set at $p < .05$.

### Results

Height and weight (height: t = 0.37, weight: t = 1.61, $p > 0.05$) showed no significant differences between the soccer group and the non-soccer group. **Table 1** shows the means and standard deviations of ball velocity and isokinetic strength of each leg part, correlations between ball kick velocity and each strength value, test results of the mean differences between both groups, and effect size (ES). Significant correlations were found between ball kick velocity and ankle joint flexion and dorsiflexion strengths (low angular velocity), knee joint extension (low, middle, and high angular velocities and total) and flexion (low angular velocity and total), and hip joint extension (low and high angular velocities, and total) and flexion (high angular velocity) (r = 0.70 over) in the soccer group, but only between ball kick velocity and hip joint flexion strength (middle angular velocity) and (r = –0.65) in the non-soccer group

Ball kick velocity of the soccer group was significantly greater than that of the non-soccer group (t = 9.71, $p < 0.05$. Ankle joint dorsiflexion strength (low angular velocity), knee joint extension strength (low and middle angular velocities, and total) and hip joint flexion strength (middle angular velocity and total) were significantly larger in the non-soccer group. Insignificant differences were found in knee joint flexion and hip joint extension strengths. Effect sizes of the mean difference in ball kick velocity and ankle joint dorsiflexion strength (low angular velocity) between both groups were 0.92 and 0.82, respectively. Effect sizes of the mean differences in ball kick velocity and in knee joint extension (middle angular velocity, total) and hip joint flection strengths (middle angular velocity) were 0.53 - 0.60.

**Table 1.**
The relationship between ball kick velocity and each isokinetic strength.

| | | The soccer group (n = 10) | | | The non-soccer group (n = 10) | | | t-test | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | r | Mean | SD | r | t-value | *p* | ES |
| Ball kick velocity | | 103.40 | 4.08 | | 84.40 | 4.22 | | 9.71 | 0.00* | 0.92 |
| Ankle | Flexion (low) | 77.70 | 9.77 | 0.74* | 79.20 | 10.26 | 0.31 | 0.32 | 0.75 | 0.08 |
| | Dorsiflexion (low) | 40.40 | 5.08 | 0.70* | 59.50 | 8.09 | 0.30 | 6.00 | 0.00* | 0.82 |
| Knee | Extention (low) | 251.10 | 43.44 | 0.82* | 299.40 | 43.80 | 0.44 | 2.35 | 0.03* | 0.48 |
| | Extension (middle) | 149.00 | 26.81 | 0.79* | 191.90 | 30.29 | 0.21 | 3.18 | 0.01* | 0.60 |
| | Extension (high) | 105.40 | 20.28 | 0.83* | 117.40 | 18.47 | –0.12 | 1.31 | 0.21 | 0.30 |
| | Extension (total) | 505.50 | 83.56 | 0.88* | 608.70 | 83.11 | 0.28 | 2.63 | 0.02* | 0.53 |
| | Flexion (low) | 138.30 | 14.83 | 0.88* | 151.20 | 24.31 | 0.38 | 1.36 | 0.19 | 0.31 |
| | Flexion (middle) | 105.40 | 14.28 | 0.62 | 115.50 | 13.70 | –0.14 | 1.53 | 0.14 | 0.34 |
| | Flexion (high) | 82.00 | 12.02 | 0.54 | 86.60 | 16.66 | –0.06 | 0.67 | 0.51 | 0.16 |
| | Flexion (total) | 325.70 | 32.45 | 0.88* | 353.30 | 47.74 | 0.13 | 1.43 | 0.17 | 0.32 |
| Hip | Extention (low) | 274.50 | 54.25 | 0.93* | 318.10 | 51.61 | 0.15 | 1.75 | 0.10 | 0.38 |
| | Extension (middle) | 196.30 | 51.13 | 0.56 | 239.40 | 58.25 | 0.14 | 1.67 | 0.11 | 0.37 |
| | Extension (high) | 133.90 | 57.49 | 0.75* | 146.80 | 33.50 | 0.09 | 0.58 | 0.57 | 0.14 |
| | Extension (total) | 604.70 | 145.42 | 0.84* | 704.30 | 135.34 | 0.14 | 1.50 | 0.15 | 0.33 |
| | Flexion (low) | 177.30 | 44.74 | 0.47 | 206.50 | 21.22 | –0.14 | 1.77 | 0.09 | 0.39 |
| | Flexion (middle) | 137.00 | 26.59 | 0.42 | 165.80 | 16.64 | –0.65* | 2.75 | 0.01* | 0.54 |
| | Flexion (high) | 100.00 | 21.19 | 0.78* | 105.40 | 13.47 | 0.22 | 0.65 | 0.53 | 0.15 |
| | Flexion (total) | 414.30 | 82.71 | 0.59 | 477.70 | 36.74 | –0.29 | 2.10 | 0.05* | 0.44 |

*$p < 0.05$. Isokinetic strength: low = 30 deg/sec, middle = 120 deg/sec, high = 240 deg/sec; Unit: ball kick velocity (km/h), isokinetic strength (Nm) ES: effect size.

## Discussion

Height and weight showed insignificant differences between the soccer and the non-soccer groups. However, the soccer group had inferior knee joint extension (low and middle angular velocities) and hip joint flexion strengths (middle angular velocity) as compared to the non-soccer group. The non-soccer group in this study was composed of general competitive athletes (see 2 Subjects in the method). Because sports such as baseball, basketball, track and field frequently involve running and jumping, leg strength plays an important role. In Kendo (the Japanese art of fencing) and American football, athletes need to withstand rough physical contact. Therefore, it is estimated that leg strength develops as a result.

Because kicking and running are skills that are frequently used in soccer, it may be generally assumed that soccer players have superior leg strength. Tuyama et al. (2007) reported that their isokinetic knee joint extension strength was significantly greater than that of archery athletes at low angular velocities (30 deg/sec). However, because the movements required in archery are static and do not significantly displace the center of gravity, archery athletes are not considered to have a great amount of dynamic leg strength. Hence, from the above report based on comparison with archery athletes, it cannot be judged that soccer players have greater leg strength.

It was reported that the mean value of isokinetic knee extension strength of the Canadian Olympic soccer players was 249.7 Nm (Rhodes, Mosher, McKenzie, Franks, Potts, & Wenger, 1986), isokinetic knee extension and flexion strengths of Greek elite soccer players were 247.0 ± 29.0 Nm, 146.0 ± 12.0 Nm, respectively (Poulmedis, 1985), and Japanese university soccer players were 246.7 ± 36.8 Nm, 139.3 ± 15.3 Nm (Tsuyama, Kobayashi, Saito, Kiyota & Nakajima, 2007). These were measured under the same conditions as those used in this study (30 deg/sec). Any mean is almost the same as those of the present soccer group, and less than that of the present non-soccer group.

From the present results, soccer players may display inferior leg strength exertion at low velocities to that of general sports athletes. Furthermore, isokinetic strength of ankle joint dorsiflexion at low angular velocities is inferior in soccer players as compared to non-soccer players (ES = 0.82). This is attributed to the manner in which the ankle joint is moved. In short, it is necessary for soccer players to kick the ball while keeping the ankle joint in a fixed state, so that the force transmitted from the ankle joint is not dispersed at the moment of impact. For that, they may have had difficulty exerting the isokinetic leg strength required to move their ankle joint smoothly toward dorsiflexion. On the other hand, strength exertion at low and middle angular velocities differed, and isokinetic strengths of knee joint extension and hip joint flexion at high angular velocities between the soccer and the non-soccer groups were different, albeit in insignificant ways. These results differed from those of strength exertions at low and middle angular velocities, and may be attributed to the fact that, because shooting a soccer ball is a swinging action at high velocities, players frequently use this action during practice and games. From the above, it is inferred that soccer players possess inferior isokinetic leg strength at low and medium angular velocities, but have superior or similar leg strength at high angular velocities as compared to athletes in other sports.

Furthermore, the soccer group was found to possess inferior isokinetic leg strength at low and middle velocities in comparison to the non-soccer group, but had faster ball kick velocities (ES = 0.92). In addition, ball kick velocity showed positive and significant correlations with the following strengths: ankle joint flexion and dorsiflexion strength (low angular velocity), knee joint extension strength (low, middle, and high angular velocities, and total), hip joint extension strength (low and high angular velocities, and total), and flexion strength (high angular velocity). Significant correlations between the isokinetic strengths

 

and the ball velocity were found in the soccer group. Hence, it is inferred that they have excellent technique to give a strong impact to a ball and players with larger isokinetic strength could make it reflect the ball velocity. On the other hand, a significant positive correlation was not found in the non-soccer group. Even if non-soccer players had large isokinetic strength, they cannot apply well it to kick velocity due to a lack of appropriate kicking skills. In short, it is considered that the larger isokinetic strength does not become an important factor determining ball velocity. Therefore, it is judged that players need to have adequate kicking techniques in order to possess the isokinetic strength contribute to the ball velocity.

Players can gain the unique motor fitness required for a particular sport by repetitive practice of special movements in addition to fundamental strength training (Demura, 2011). In the case of soccer players who mastered appropriate kicking techniques and shooting movements, the following is considered: players with superior leg strength generally have a higher kick velocity. In addition, they may be able to further increase the ball kick velocity by increasing leg strength. In short, even if players have superior leg strength, the ball kick velocity will not improve unless the shooting technique is mastered.

## Conclusion

Soccer players have similar or inferior isokinetic leg strength to non-soccer players, but their instep kick is faster. In the case of soccer players with superior shooting technique, those with superior isokinetic leg strength have faster ball kick velocity.

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