Short Communication

The relationship between isometric mid-thigh pull variables, jump variables and sprint performance in collegiate soccer players

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Objectives: The purpose of this study was to examine the relationship among isometric mid-thigh pull (IMTP) variables, jump variables and sprint times in collegiate soccer players. Additionally, this study was conducted to demonstrate that strength characteristics influence the relationship between jump variables and sprint times.

Design and Methods: Twenty-five collegiate soccer players performed IMTP, jump and sprint assessments. For IMTP, the force output at 100ms (F100ms) and peak force (PF) were analyzed. Countermovement jump (CMJ) and drop jump (DJ) index were measured. A 30m sprint was performed, and the times at 10m, 20m and 30m were recorded. Pearson's product-moment correlation and a one-way analysis of variance (ANOVA) were used at $p = 0.05$. A cluster analysis was performed to divide all the subjects.

Results: The F100ms significantly correlated with DJ-index ($r = 0.433$) and sprint times at 20-30m ($r = -0.444$). All the subjects were separated into high (HG: N = 9), medium (MG: N = 7) and low (LG: N = 9) groups based on the F100ms, because the coefficient of variation for F100ms was high (34.3%). There was a strong significant relationship between CMJ and sprint time at 10-20m in HG ($r = -0.915$), however there were no significant relationship in MG and LG.

Conclusions: The F100ms can be used as an indicator for identifying athletes who have a statistically significant relationship between CMJ and flying sprint times. The results of the present study suggested that coaches should realize F100ms might provide the foundation to improve the sprint performance.

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Key words: short sprint performance ■ acceleration ■ explosive strength ■ isometric strength

INTRODUCTION

The total distance covered by soccer players during a match is over 10km.[1] The number of sprints and average distance per sprint are approximately 23 times[2] and 5-15m[1] respectively, whereas the sprint distance of a match is between 130m and 280m which is dependent upon playing positions[2]. The sprint speed is an important factor and necessary for superior performance for soccer players, as a study showed that professional soccer players are better sprinters compared to amateur players.[3,4]

A number of studies examined the relationships between sprint performance and strength characteristics including back squat and countermovement jump (CMJ) in soccer players.[5,6] One study showed 1 repetition maximum (1RM) back squat is strongly correlated with 10m sprint time ($r = -0.94$).[6] Indeed, several studies showed improvement of 20m sprint time for soccer players with increased maximum strength.[7,8] These studies indicate that improving maximum strength plays an important role for sprint performance for soccer players.

Assessing 1RM can be fatiguing and time consuming, whereas an isometric mid-thigh pull (IMTP) may provide a more effective method to assess the force production. The IMTP described by Haff et al.[9] is widely used to evaluate the force production in detail. The IMTP is used to measure vertical ground reaction force (GRF) to derive maximum as well as explosive strength such as force at 100ms (F100ms) and rate of force development (RFD).[10] Relationships between IMTP variables and jump performances such as CMJ,[11] static jump (SJ)[12] and drop jump (DJ)[13], and peak power from CMJ were shown to be highly correlated with RFD ($r = 0.81$) and peak force ($r = 0.75$) with from IMTP[14]. For the relationships between IMTP variables and sprint performance, West et al.[15] showed a moderate correlation ($r = -0.54$) between the F100ms from IMTP and 10m sprint time in rugby players. Although it was clear that the F100ms was moderately correlated with the sprint time from static positon, this study did not examine the split times to evaluate the top speed in flying sprints. Soccer players typically do not sprint from static posture so the flying sprint performance seems more applicable and should be examined. At the same time, the foot contact time during sprinting is approximately 100ms to 200ms.[16-18] Therefore, the ability to produce force during short foot contact times may be important factors. The purpose of this study was to examine the relationship among IMTP variables, jump variables, and

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sprint times in collegiate soccer players. Additionally, this study was conducted to analyze the utilization of IMTP variables for training analysis.

METHODS

Subjects

Twenty-five male college volunteers were recruited from an intercollegiate soccer team with all playing positions, with the exception of goalkeeper, represented (age: 20.20 ± 0.87 years, height: 1.72 ± 0.06 m, weight: 67.12 ± 6.14 kg). All the subjects who were free from injury were permitted to participate in this study by the team trainer. The testing protocol was described to each participant in the paper before obtaining informed consent from each subject and in accordance with the guidelines of the University's Institutional Review Board.

Isometric mid-thigh pull testing

The IMTP was performed with a custom designed power rack that allows fixation of the bar height. The subjects performed IMTP standing on 60 × 120cm force plate (Ex-Jumper, DKH, Tokyo, Japan), sampled at 1000Hz.[19] Lifting straps and athletic tape were used to remove the influence of grip strength. The body position was determined with knee angle between 125 and 135 degrees, which was assessed using a hand held goniometer. The trunk was in an upright position.[9,13] Familiarizing the IMTP, each subject performed two practice attempts during the previous day. Two practice attempts at 50% and 75% of the subject's perceived maximum effort were performed as warm up before the IMTP testing.[20] The subjects performed 3 trials with 2 minutes rest between each trial. They were instructed to pull the bar as hard and fast as possible for 6 seconds. They received verbal encouragement during the IMTP.

The vertical GRF during the IMTP was measured. The peak force and the F100ms from the initial point of force increase were determined from the force–time curve. The peak force was defined as peak GRF minus participant's body weight, and the F100ms was defined as the absolute value of GRF from 100ms after initial point of the pull minus participant's body weight.[15] The initiation point of the pull was determined when a GRF exceeding 105% of the participant's body weight was achieved.[21] The highest value of both variables in the 3 trials was analyzed. Test-retest reliability for F100ms and PF were shown in Table 1, and it met the standard for reliability which is ICC > 0.70.[22]

Jump Testing

After IMTP testing, CMJ and DJ were performed as jump testing. The CMJ was performed on a 60 × 120cm force plate, data sampled at 1000 Hz (Ex-Jumper, DKH, Tokyo, Japan). The subjects performed 2 trials with hands on hips to minimize the influence of arm swing, and they were instructed to jump as high as possible. The subjects descended from the standing position to a self-selected depth, and jumped with maximal effort. The best of 2 trials was used for analysis. The calculation of the jump height was based on flight time and gravitational acceleration ($9.81 m \cdot sec^{-2}$).

The DJ was performed from an upright standing position on a box of 30cm height with hands on hips. The subjects stepped off a box and rebounded with the shortest foot contact time and jumped at maximal effort. The foot contact time and the jump height were measured by the switch mat (Multi-Jump Tester, DKH, Tokyo, Japan). The best jump index (DJ-index) of 2 trials was analyzed. The DJ-index was calculated by following equation.[23] The participants were instructed to minimize alternations in their knee angle at the moment of landing to remove the effect of landing strategy during CMJ and DJ.

$$\text{DJ-index (m/sec)} = \text{Jump height (m)} \cdot \text{Contact time}^{-1} \text{ (sec)}.$$

Sprint Testing

Forty-eight hours after the first testing day, the 30m sprint testing and 10m split times were collected. The warm up took about 15min including dynamic stretching and 2 attempts of 30m sprints as practice. The light gates (TC Timing System, Brower Timing Systems, Utah, USA) were set up at 0 (start), 10, 20 and 30m (goal). All the participants performed 3 trials with approximately 3 minutes rest between each trial. The subjects started in 2 point standing position from 0.5m behind the first gate to prevent early triggering and were instructed to run as fast as possible. The fastest 30m sprint time of the 3 trials was analyzed[15].

Statistical Analysis

Descriptive statistics were presented as mean and standard deviation (SD). Intraclass correlation coefficients (ICC) and coefficient of variation (CV) were used to assess the reliability of testing. The relationship between IMTP variables, jump variables and sprint times were analyzed using Pearson's product-moment correlation. In order to assess relative strength of the correlation, the scale modified by Hopkins et al.[24] was used: small = 0.1 to 0.29, moderate = 0.30 to 0.49, large = 0.50 to 0.69, very large = 0.70 to 0.89, nearly perfect = 0.90 to 0.99 and perfect = 1. A cluster analysis with Ward's method was performed to separate all subjects into three groups based on F100ms. This analysis calculated Euclidian distance based on the F100ms, and separated individuals to high, medium and low group respectively. One-way analysis of variance (ANOVA) was used to determine the difference among three groups. When significant F values were found ($p \leq 0.05$), post hoc testing were done. The Cohen's d value was calculated based on mean and SD to show practical significance. The statistical analysis for the Pearson's correlation, the cluster analysis, and the ANOVA were performed using SPSS v22 software (IBM, New York, USA). The criterion for statistical significance was considered as $p \leq 0.05$.

RESULTS

The descriptive data included mean, SD, CV and ICC for all variables are shown in Table 1. The F100ms was moderately correlated with DJ-index ($r = 0.433$, $p < 0.05$). The F100ms was also correlated with sprint times at 10m ($r = -0.521$, $p < 0.01$), 30m ($r = -0.417$, $p < 0.05$) and 20-30m ($r = -0.444$, $p < 0.05$) respectively.

Table 1 Performance characteristics and reliability.*

Test	Variable	Mean ± SD	CV(%)	ICC
Isometric mid-thigh pull	F100ms (N)	736.68 ± 269.17	36.5	0.71
	Peak Force (N)	2067.16 ± 325.07	15.7	0.83
Jump	CMJ (cm)	39.97 ± 5.00	12.5	0.93
	DJ-index (m/sec)	1.77 ± 0.37	20.7	0.87
	DJ-height (cm)	31.28 ± 5.22	16.7	0.89
	DJ-contact time (sec)	0.19 ± 0.07	12.5	0.84
Sprint	Sprint 0-10 m (sec)	1.66 ± 0.06	3.8	0.75
	Sprint 0-20 m (sec)	2.92 ± 0.11	3.7	0.87
	Sprint 0-30 m (sec)	4.11 ± 0.16	4.0	0.94
	Sprint 10-20 m (sec)	1.26 ± 0.06	4.7	0.75
	Sprint 20-30 m (sec)	1.19 ± 0.06	5.2	0.81

* CV = coefficient of variation; ICC = intraclass correlation coefficient;
F100ms = the force output at 100ms from initial point of the pull;
CMJ = countermovement jump; DJ = drop jump.

Although there were statistically significant relationships between the F100ms for IMTP and sprint times, the CV for the F100ms were much higher than criteria for acceptable reliability[22] as shown in Table 1. These data suggest that the ability to produce force at 100ms was highly dependent on the individual athlete. Therefore, a cluster analysis was conducted to separate those subjects to three 100ms force groups; high group (HG: N = 9), medium group (MG: N = 7), and low group (LG: N = 9). As the result, CVs for F100ms were within criteria for acceptable reliability as follows: 15% in the LG, 8% in MG, 13% in HG respectively. The descriptive data for each group and the comparison among three groups in all variables were shown in Table 2. There were statistical differences observed in F100ms ($F[2,22] = 89.839$, $p < 0.01$), PF ($F[2,22] = 4.552$, $p < 0.05$), DJ-index ($F[2,22] = 4.233$, $p < 0.05$) and sprint time at 0-10m ($F[2,22] = 3.547$, $p < 0.05$). For the F100ms, HG was

Table 2 Performance characteristics in each group.*

Test	Variable	HG (n = 9)	MG (n = 7)	LG (n = 9)	One-way ANOVA	
		Mean ± SD	Mean ± SD	Mean ± SD	Multiple comparison	Cohen's *d*
Ant	Height (m)	171.14 ± 4.64	172.14 ± 8.57	173.39 ± 6.85	n.s.	-
	Body weight (kg)	64.86 ± 5.47	70.09 ± 6.46	67.05 ± 6.19	n.s.	-
Isometric mid-thigh pull	F100ms (N)	1042.80 ± 130.43	700.82 ± 55.26	458.45 ± 66.36	HG > MG HG > LG MG > LG	3.26‡ 5.65‡ 3.92‡
	Peak Force (N)	2265.02 ± 369.30	2080.00 ± 153.89	1859.30 ± 264.73	HG > LG	1.26†
Jump	CMJ (cm)	42.90 ± 5.22	39.60 ± 4.39	37.32 ± 3.97	n.s.	-
	DJ-index (m/sec)	2.02 ± 0.44	1.58 ± 0.22	1.68 ± 0.26	HG > MG	1.21†
	DJ-height (cm)	34.20 ± 6.17	28.04 ± 3.37	30.88 ± 4.00	n.s.	-
	DJ-contact time (sec)	0.17 ± 0.02	0.18 ± 0.02	0.19 ± 0.02	n.s.	-
Sprint	Sprint 0-10 m (sec)	1.63 ± 0.06	1.66 ± 0.03	1.70 ± 0.07	LG > HG	1.07†
	Sprint 0-20 m (sec)	2.87 ± 0.10	2.95 ± 0.09	2.96 ± 0.12	n.s.	-
	Sprint 0-30 m (sec)	4.01 ± 0.15	4.16 ± 0.13	4.17 ± 0.17	n.s.	-
	Sprint 10-20 m (sec)	1.24 ± 0.05	1.29 ± 0.07	1.26 ± 0.06	n.s.	-
	Sprint 20-30 m (sec)	1.15 ± 0.05	1.21 ± 0.05	1.21 ± 0.06	n.s.	-

* HG = high group in the force output at 100ms of IMTP; MG = medium group in the force output at 100ms of IMTP; LG = low group in the force output at 100ms of IMTP; F100ms = the force output at 100ms from initiation point of the pull; CMJ = countermovement jump; DJ = drop jump.
† = significantly difference ($p < 0.05$). ‡ = significantly difference ($p < 0.01$).

statistically higher than MG (d = 3.26, $p < 0.01$) and LG (d = 5.65, $p < 0.01$), MG was also statistically higher than LG (d = 3.92, $p < 0.01$). In the peak force, HG was significantly higher than LG (d = 1.26, $p < 0.05$). HG was also statistically higher than MG in DJ-index (d = 1.21, $p < 0.05$) and faster than LG in sprint time at 0-10m (d = 1.07, $p < 0.05$). The relationship among the IMTP variables, jump variables, and sprint times for each group were analyzed. There were no statistically significant relationships between the F100ms and sprint times in each group, but there were strong statistically significant relationships between CMJ and sprint times: 10-20m (r = -0.915, $p < 0.01$) and 20-30m (r = -0.764, $p < 0.05$) in HG and 20-30m (r = -0.775, $p < 0.05$) in MG.

DISCUSSION

The purpose of this study was to examine the relationship among IMTP variables, jump variables and sprint times in soccer players, and to propose how to utilize IMTP variables for analyzing/modifying training to enhance sprint performance. Some of the results from the current study corresponded with previous study that indicated a significant relationship between F100ms and sprint time for 10m.[15] The ability to produce high force momentarily is quite important, because it allows for maximal force production with relatively short foot contact times (i.e. 100ms), ultimately resulting high acceleration. The primary finding of the current study was that F100ms was significantly correlated with sprint times. Based on the current study, the F100ms could be an indicator for identifying athletes who have a significant relationship between CMJ and flying sprint performance Correlation analysis indicated that relationships between CMJ and flying sprint times in HG were much higher than MG and LG. Particularly for HG, the correlation between CMJ and flying sprint time at 10-20m was very high (r = -0.915), indicating that the F100ms is the most useful variable identified to aid in ascertaining the relationship of vertical jump performance and flying sprint performance. Thus, the F100ms would be considered as prerequisite for identifying the strong relationship between CMJ and flying sprint times. Although some previous studies also demonstrated the significant relationship between CMJ and sprint time in soccer players,[5,6] the influence of individual strength on this relationship has yet to reported. The current study has provided additional evidence that sprint ability is dependent upon a variety of physical qualities.

Jump training is usually incorporated to enhance sprint performance. However, poor strength may increase the chance of poor performance development or injury from jump training,[25] so that strength could be considered as a fundamental for jump training. Strength development for the prevention of injuries from jump training has been recommended[25,26]. Moreover, athletes with high relative strength could effectively improve jump performance through power training, such as jump squats, as compared with athletes with low relative strength.[27] Establishment of the solid foundation of strength prior to power training would be recommended.[27] The current study showed that the relationships between CMJ and sprint times were weak in LG. Therefore, there is a possibility that the F100ms plays a role to potentially identify the minimum requirement to enhance sprint performance effectively by vertical jump training. Strength training, including back squats with 75%-90% 1RM for 10 weeks, significantly improves relative strength for relatively weak participants.[28] Therefore the athletes with low F100ms should focus on strength training prior to starting jump training even during relatively short training periods.

There are some limitations for this study. Firstly, the CV of the F100ms was much higher than other testing variables (Table 1). The previous studies that examined the F100ms also demonstrated the high CV, which it was ranged 25-43%.[10,19] A lack of familiarization to perform IMTP may be the reason of this high value of CV, although a previous study demonstrated that the familiarization of the IMTP was enough at two practices with submaximal effort as warm-up.[29] Secondly, the jump heights for CMJ and DJ were calculated by flight times, whereas calculations based on GRF may provide more accurate calculations.

CONCLUSION

The primary finding of this study was the significant relationship between F100ms and flying sprint time at 20-30m. Furthermore, all the subjects were separated to three groups by F100ms, and the relationship between CMJ and sprint time was examined. In HG, there was strong significant relationship between CMJ and flying sprint time at 10-20m, although there were no significant relationships in MG and LG. Therefore the F100ms can be used as an indicator for identifying athletes who have a statistically significant relationship between CMJ and flying sprint times. These results represent options for coaches to evaluate athletes and create individualized training programs using IMTP testing.

COMPLIANCE

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