Paper

Factors affecting the 180-degree change-of-direction speed in youth male soccer players

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Received June 12, 2018 ; Accepted February 12, 2019

The purpose of this study was to clarify the factors that primarily affect the change-of-direction speed (CODS) in youth soccer players. Subjects were 70 youth soccer players. CODS were measured with a laser velocity doppler device. First, based on the 0m point, each subject was asked to start from the -10m position and change direction at a cutting line (5m from the 0m point) and returned to the 0m point as fast as possible. The section from the 0m to 4m points was defined as the approaching section, and the time within the section was defined as the approaching time (Tapp). The 1m section from the 4m point to the cutting line, where COD was made, was then defined as the cutting section, and the time within the section was defined as the cutting time (Tc). The section from the 4m point after the COD to the 0m point was defined as the accelerating section, and the time within the section was defined as the acceleration time (Tacc). Finally, the total of the times was defined as CODS. Subjects were classified into a fast group (FG) and a slow group (SG). CODS ($p = 0.001$) and Tc ($p = 0.001$) in FG was significantly faster than SG; however, no significant difference was observed in Tapp and Tacc. SG speed ($p = 0.002$) at the 4m point was significantly faster than FG ($p = 0.015$); however, FG deceleration and acceleration were larger than those of SG ($p < 0.001$). Meanwhile, peak points of deceleration (Pdec) and acceleration (Pacc) for SG were closer to the cutting line than those for FG ($p \leqq 0.001$). The results of this study suggest that Tc was affected by deceleration before COD. Therefore, it is suggested that soccer players are required to be good at deceleration as well as acceleration over short distances to improve their CODS.

Key words : Soccer players, Change of direction speed, Acceleration/deceleration, 505 agility test

Human Performance Measurement Vol. 16, 1-10 (2019)

1. Introduction

Ball sports such as soccer and basketball require rapid approaches to the player with the ball, rapid switches between offense and defense, and rapid reactions to opponent movements; namely, change of direction (COD) associated with rapid acceleration and deceleration rather than straight-line sprinting (Little and Williams, 2005; Stolen et al., 2005). Bloomfield et al. (2007) reported in an analysis of the British premium league where soccer players changed direction approximately 600 to 800 times within a game depending on player position. This clarified the importance of COD in soccer.

COD is a rapid whole-body movement associated with change of velocity or direction in response to a stimulus. This is defined as agility in ball sports (Sheppard and Young, 2006). Agility is largely classified into “perceptual information and decision-making factors” and “change-of-direction speed (CODS) (Young et al., 2002). Agility during games is seen in response to stimuli such as ball situations and opponent movements, and it is affected by cognitive and decision-making skills

(Sheppard and Young, 2006). In addition, agility tests, which include reactive time, examine the ability to predict action following reactive time (Young and Farrow, 2006). For instance, Gabbett et al. (2008) conducted an agility test to evaluate the reaction of first team and farm level rugby players in response to instructions provided by light. According to the results, first team players were significantly faster than farm level players were. This suggested that the higher the game skills become, the greater the ability to predict movements is. Meanwhile, CODS is the ability to change direction and speed in predetermined movements within predetermined sections, and this has been used by many researchers as an indicator of agility excluding perceptual information and decision-making factors (Jones et al., 2009; Parsons and Jones, 1998; Young and Farrow, 2006). In addition, CODS in soccer players has also been used as one standard to examine physical fitness in individuals and teams, and to select elite players (Little and Williams, 2005; Sasaki et al., 2011a; Sporis et al, 2010; Tsukoshi and Asai, 2010).

Deceleration and acceleration before and after COD were reported as important factors in CODS (Draper and Lancaster, 1985; Young et al, 2001). Observation of 180-degree COD on a sagittal plane revealed changes in speeds in the phases of acceleration, deceleration, pauses and acceleration. The 505 agility test developed by Draper and Lancaster (1985) was classified into four phases: (1) acceleration phase from start line to maximum speed, (2) deceleration phase from maximum speed to cutting line (touched by a foot at the time of COD), (3) COD phase, and (4) acceleration phase from COD to goal. In regard to (1) and (2) above, players exhibit high acceleration in straight-line sprinting; however, they also require the ability to decelerate rapidly as they approach the cutting line (Stolen et al., 2005). In regard to (2), (3), and (4), from a rapid deceleration to the cutting line to COD and acceleration after COD, it is predicted that players are required to be on the ground for an extended period of time due to rapid deceleration from a high approaching speed. As a result, COD is predicted to be difficult. The firing frequency of motor neurons during the shift from eccentric contraction (deceleration) to concentric contraction (acceleration), which is the muscular contraction of motor units, may have influenced acceleration from COD to goal in (3) and (4) above (Jones et al., 2009). The acceleration, deceleration, pause, and acceleration phases are each mutually related. Therefore, a comprehensive understanding of the temporal changes in speed in all phases would clarify the relationship between phases, and a comparison of the temporal changes in speed would clarify the level of CODS control. In addition, clarifying the relationship between the phases and the most effective factors for CODS, including variables, would be of value in establishing training designed to improve CODS in soccer players.

Therefore, this study was conducted to clarify the CODS and acceleration in both the deceleration and acceleration phases targeting youth soccer players and to clarify the most effective factors for CODS.

2. Methods

2.1. Subjects

Subjects were 70 youth soccer layers (age: 16.6±0.8 years old; height: 170.7±5.8 cm; weight: 59.0±6.8 kg). They were all field players. Subjects received written explanations of the purpose of the experiment, methods and risks, the method of data management, and other elements in advance. We obtained informed consent in writing from all the subjects. This study was conducted after obtaining approval from the Nippon Sport Science University Ethics Review Committee (Approval No. 010-H27).

2.2. Experimental design

Measurement of CODS (Fig. 1) was performed according to the procedures used in a previous study (Kaneko et al., 2015), which applied a revised 505 agility test developed by Draper and Lancaster (1985). We set the start line (-10 m) at 10m before the 0m position, and the cutting line at 5 m beyond the 0m position. Each subject was asked to run 15 meters from the start line and cutting line as fast as possible, quickly perform a 180-degree COD, and return to the 0 m position as fast as possible. The section from the 0 m to 4 m positions was defined as the approaching section, and the time within the section was defined as the approaching time (Tapp). The 1m section from the 4 m position to the cutting line was defined as the cutting section, and the time within the section was defined as the cutting time (Tc). The section from the 4m

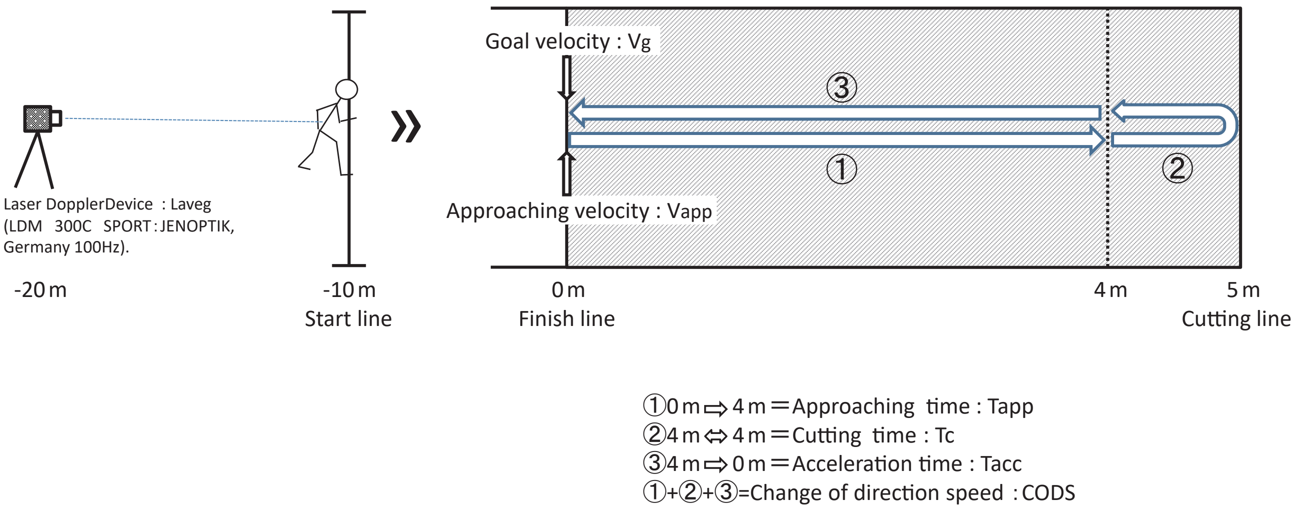

Fig 1. Change of direction speed test.

position after the COD to the 0 m position was defined as the accelerating section, and the time within the section was defined as the acceleration time (Tacc). The total of the times was defined as CODS (Fig. 1).

CODS was measured by a LAVEG (LDM 300C SPORT laser velocity doppler device manufactured by JENOPTIK, 100Hz), which was also used in previous studies (Hader et al., 2015; Kaneko et al., 2015). The LAVEG was placed 10 meters behind the start line. The height of lens focus was fixed at 100 cm with a tripod. The examiner adjusted the focus of the LAVEG lens to the trunk of each subject while measuring the movement from the start line to the goal, including COD. Subjects were asked to place their dominant foot on the cutting line without taking a roundabout path and to perform COD quickly. An examiner was positioned on the side of the cutting line to confirm that each subject's shoe touched the cutting line. When visual confirmation was difficult, video images were examined. Each subject made two attempts and the faster time was recorded. In this study, the dominant foot was designated as the main foot used to handle the ball.

CODS is mainly affected by straight-line sprinting speed, lower limb muscular strength and power (Young et al., 2002). In this study, therefore, we measured 30m sprints to evaluate straight-line sprinting speed, isokinetic concentric extensor and flexor peak torques, and leg extension power (leg power) in reference to the study by Jones et al. (2009) to evaluate the lower limb muscular strength and power. The 30 m sprint was measured by LAVEG in the same manner as for CODS. The position where an examiner placed LAVEG and the starting position of the subject were the same as those for CODS measurement. LAVEG was focused on each subject to measure from the start line to the goal 30 meters away. Each subject was asked to start in the standing position and sprint twice for 30 meters as fast as possible. A starting pistol was used, and the faster time was recorded for analysis. Isokinetic concentric extensor and flexor peak torques used to evaluate the lower limb muscular strength and power were measured by a muscular strength evaluation device (Cybex600 manufactured by Cybex). Subjects were asked to sit in a chair with a Cybex, fix their trunk, hips, and femurs with belts, adjust the lateral epicondyle of femur to the rotation axis, and fix the knee joints with bands. After warmup and exercise for muscle exertion, each subject attempted the test. Setting the angular velocity at 60 deg/sec, each subject was asked to perform a single attempt of three consecutive reciprocating motions from 90-degree knee flexion to 0-degree knee extension. Leg extension power was measured by a hydraulic isokinetic leg press machine (T.K.K.1865 LEGPOWER manufactured by Takei Scientific Instruments). Subjects were asked to place a non-stretchable belt around their hips and perform the maximum extension movement with the hip, knee, and leg joints from the 90-degree knee joint position. Velocity was set at 1.0 m/s. The attempts were performed twice, and the higher value was used for analysis. We ensured a sufficient break to prevent fatigue from influencing the results of CODS, 30 m sprint, lower limb muscular strength and power.

2.3. Data analysis

We analyzed CODS using body trunk data measured by LAVEG. Distance data was obtained by LAVEG based on the body trunk data and time-distance data was installed into Microsoft Excel to calculate the sprinting distance and time. The data was smoothened in reference to the method developed by Kintaka (1999) with a 1Hz fourth-order low pass filter (Butterworth filter) and smoothened time-distance data was time-differentiated (△t: 1/100 sec) to calculate velocity data. Furthermore, velocity data was time-differentiated to calculate acceleration data. Mean values of velocity and acceleration at each position between -10 to 5 m positions were calculated. Speed at the 0m position was defined as approaching velocity (Vapp) (Fig. 1), speed at the 0m position after COD was defined as goal velocity (Vg) (Fig. 1). In addition, maximum value of acceleration in deceleration phase was defined as deceleration peak (Dec), maximum value of acceleration after COD was defined as acceleration peak (Acc), and the position at which the highest acceleration was measured was defined as position of deceleration peak (Pdec) and position of acceleration peak (Pacc) (Fig. 2), respectively. We calculated 30 m sprint time and speed based on the record of the body trunk position of subjects measured by LAVEG in the same manner employed for CODS analysis. Velocity at 5 and 10 m positions (V5 m, V10 m) and maximum velocity during 30 m sprint (Vmax) were calculated in reference to a previous study that compared velocity between CODS and straight-line sprinting using LAVEG (Hader, et al., 2015). Isokinetic concentric extensor and flexor peak torques were measured by asking subjects to perform three consecutive reciprocating knee extensions and flexions at full effort to record peak torque value for each motion. We converted analog data obtained from the leg press machine using an A/D converter (Power Lab 1kHz manufactured by ADInstrument) and recorded it as leg power. We visually confirmed the velocity data on computer for the section to be analyzed and calculated the mean power in the section in which the velocity data stabilized.

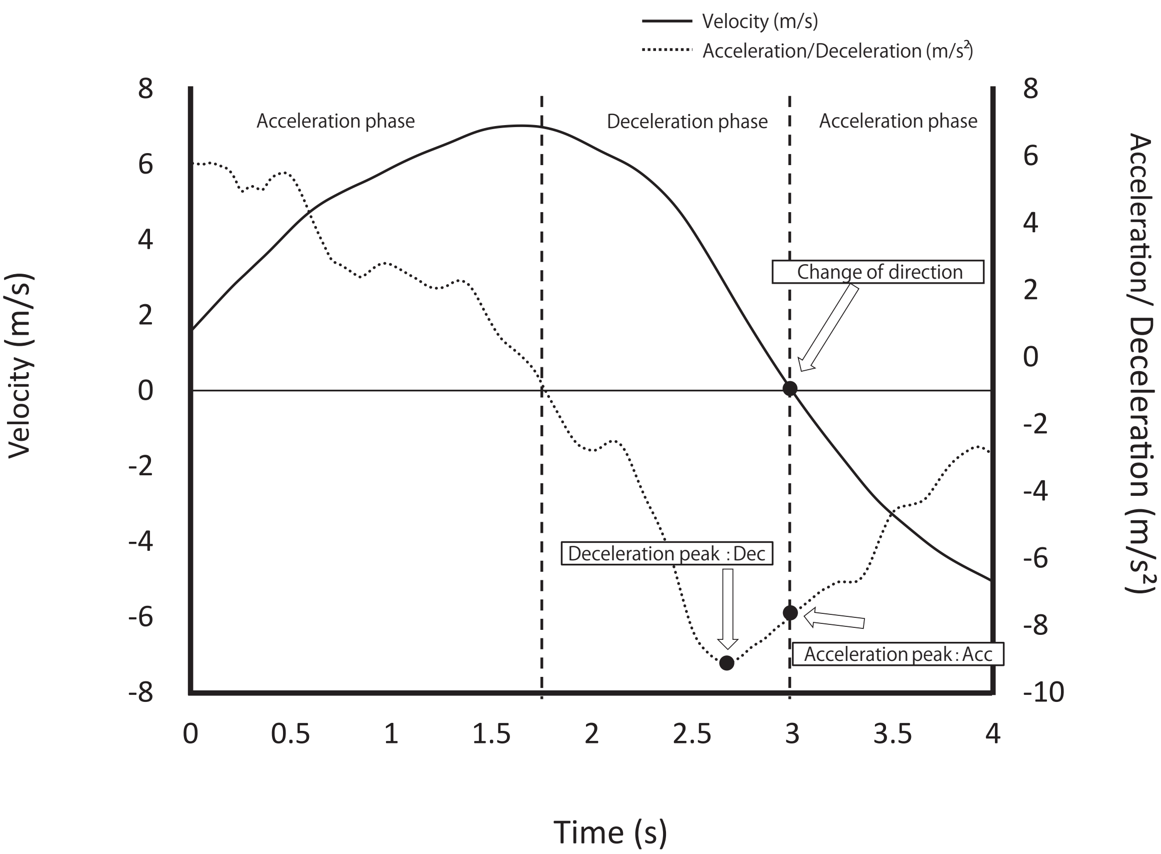

Fig 2. The velocity curve calculated from Laveg (n=1)

2.4. Statistical analysis

To clarify changes in velocity regarding CODS before and after COD, subjects were classified into a Fast Group (FG) and a Slow Group (SG) according to total time between the -10 and 0m positions. Based on the mean time of 70 subjects (4.57±0.5 SD), 24 subjects with -0.5 and lower SD were classified into FG and 19 subjects with +0.5 or higher SD were classified into SG to compare variables. All variables were indicated in mean value±standard deviation. Variables in FG and SG were compared by independent t-test. Two-way analysis of variance was applied to the comparison of velocity and acceleration at the 4m position using FG and SG as two factors, and at the 4m positions before and after COD as two factors. To examine the correlation between each variable with CODS, we conducted multiple regression analysis using CODS as a dependent variable and other variables as independent variables (stepwise method). During analysis, we checked collinearity to confirm that there was no multicollinearity with the selected independent variables. As a result, tolerance of this study was 0.75-0.89 and variance inflation factor (VIF) was 1.12-1.34, which showed that tolerance was greater than 0.25 and VIF was less than 2.0. SPSS Statistics ver.22.0 (manufactured by IBM) was used for analysis. We set less than 5% as the level of significance for each test.

3. Results

This study was conducted to clarify the temporal changes in CODS depending on deceleration and acceleration using LAVEG. In regard to the reproducibility of the values calculated by LAVEG, the interclass correlation coefficient (ICC) of CODS between the 1st and 2nd times was 0.81.

Tables 1 and 2 show the physical characteristics between FG and SG, and comparison of CODS variables. Comparison of CODS variables (Table 2) showed CODS and Tc in FG to be significantly faster than those in SG although there was no significant difference between Tapp and Tacc. In addition, Vapp and Vg in FG showed significantly higher velocities than those in SG. Dec and Acc in FG showed significantly higher acceleration than those in SG. Pdec and Pacc in SG were recorded in significantly closer positions to the cutting line than those in FG.

Fig. 3 showed the mean values of velocity and acceleration at each position of CODS in FG and SG. Table 3 showed the mean values of velocity and acceleration at the 4m position before and after COD in FG and SG. Velocity at 4m position in SG showed significantly higher than that in FG both before and after COD. Acceleration at 4m position in FG showed significantly higher than that in FG before and after COD. Table 4 showed the mean values of 30 m sprint, lower limb muscular strength, and leg power in FG and SG.

Table 5 showed the results of multiple regression analysis by stepwise method using CODS of all subjects as dependent variables and other variables as independent variables. As a result, Tc, Vapp, Vg and Dec showed correlation with CODS, and standardized partial regression coefficient was confirmed to be statistically significant.

Table 1. Physical characteristics in FG and SG.

		FG (n = 24)		SG (n = 19)		
Variable	Unit	Mean	SD	Mean	SD	p value
Age	yrs	16.8	0.8	16.3	0.7	0.067
BH	cm	170.1	6.0	169.5	5.9	0.739
BW	kg	60.2	6.6	55.4	6.4	0.019*

FG : Fast group; SG : Slow group.

*: $P < 0.05$

Table 2. Comparison of CODS variables in FG and SG.

		FG (n = 24)		SG (n = 19)		
Variable	Unit	Mean	SD	Mean	SD	p value
CODS	sec	2.45	0.04	2.70	0.06	0.001*
Tapp	sec	0.74	0.04	0.74	0.04	0.701
Tc	sec	0.80	0.08	1.05	0.11	0.001*
Tacc	sec	0.90	0.04	0.91	0.04	0.644
Vapp	m/s	6.72	0.19	6.48	0.22	0.001*
Vg	m/s	-5.48	0.26	-5.27	0.30	0.014*
Dec	m/s^2	-11.02	1.72	-9.60	1.06	0.002*
Acc	m/s^2	-9.20	1.63	-7.46	1.47	0.001*
Pdec	m	4.53	0.19	4.78	0.24	< 0.001*
Pacc	m	4.66	0.13	4.91	0.28	< 0.001*

CODS: Change of direction speed ; Tapp : Approaching time; Tc : Cutting time; Tacc : Acceleration time; Vapp : Approaching velocity; Vg : Goal velocity; Dec : Deceleration peak; Acc : Acceleration peak; Pdec : Position of deceleration peak; Pacc : Position of acceleration peak.

*: P < 0.05

Table 3. Comparison of 4m position deceleration/acceleration of the CODS in FG and SG.

			FG (n = 24)		SG (n = 19)		
	Variable	Unit	Mean	SD	Mean	SD	p value
4 m position	Velocity	m/s	3.53	0.41	3.86	0.39	0.002*
		m/s	-2.82	0.25	-3.07	0.25	0.015*
	Deceleration	m/s^2	-7.71	1.01	-6.14	1.03	< 0.001*
	Acceleration	m/s^2	-4.96	0.75	-3.77	0.91	< 0.001*

FG : Fast group; SG : Slow group.

*: P < 0.05

4. Discussion

The purpose of this study was to clarify the changes in velocity and acceleration in both deceleration and acceleration phases in CODS targeting youth soccer players and to clarify the most effective factors for CODS.

The existing 505 agility test developed by Draper and Lancaster (1985) applies an optimum approaching speed from the start line to the cutting line, which may reduce the burden of deceleration before COD. Therefore, the 505 agility test focuses on the acceleration phase after COD. In this study, we modified the 505 agility test by asking subjects to sprint from the start line, which required subjects to exhibit higher adjustability from acceleration to deceleration before COD than the standard 505 agility test.

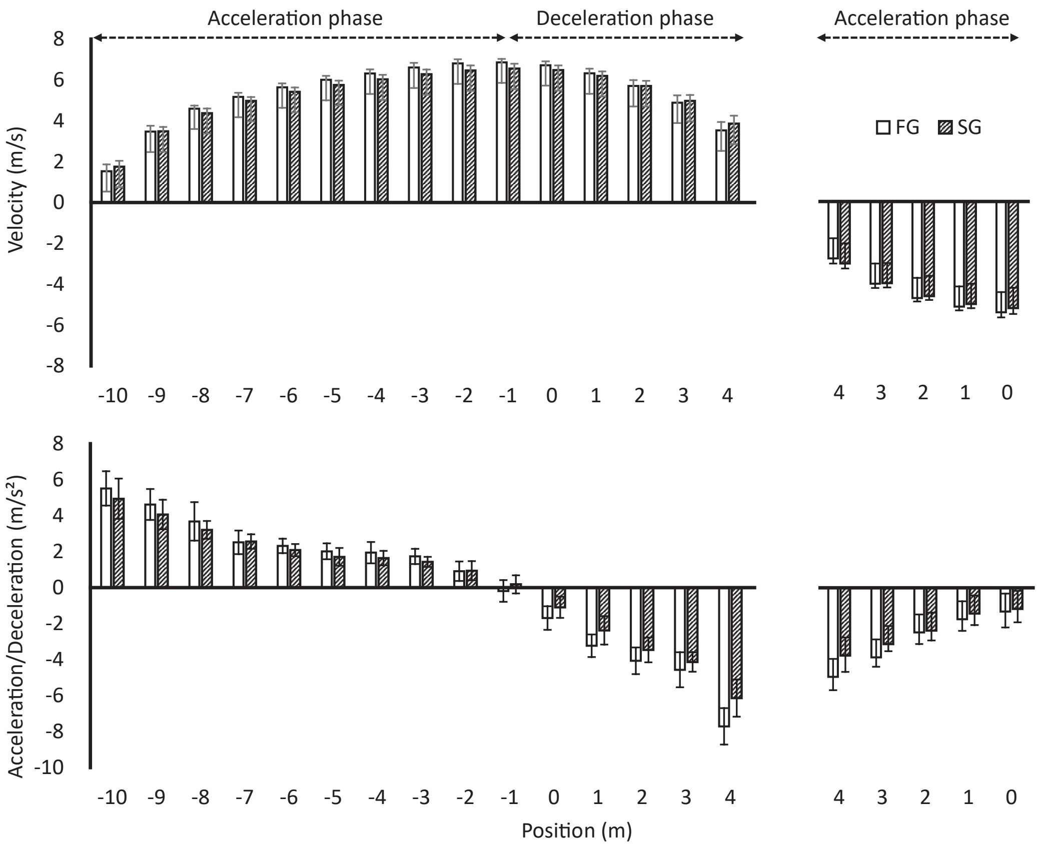

Fig 3. Comparison of each position velocity and deceleration/acceleration of the CODS in FG and SG.

Table 4. Comparison of 30m-sprint, Isokinetic concentric extensor/flexor and Legpower variables in FG and SG.

		FG (n = 24)		SG (n = 19)		
Variable	Unit	Mean	SD	Mean	SD	p value
30 m-sprint	Sec	4.68	0.19	4.99	0.23	0.001*
V5 m	m/s	5.95	0.16	5.63	0.22	0.001*
V10 m	m/s	7.15	0.25	6.80	0.25	0.001*
Vmax	m/s	8.29	0.31	7.80	0.37	0.001*
Isokinetic Con Ext	Nm	183.8	28.0	158.7	15.8	0.001*
Normalised Isokinetic Con Ext	Nm/BW	3.05	0.30	2.88	0.29	0.135
Isokinetic Con Flex	Nm	108.4	20.2	96.9	12.6	0.037*
Normalised Isokinetic Con Flex	Nm/BW	1.80	0.25	1.75	0.15	0.613
Leg Power	W/BW	12.3	1.5	10.9	1.3	0.005*

30 m-sprint : 30 m-sprint time; V5 m: Velocity of 5 m position; V10 m: Velocity of 10 m position; Vmax: 30 m-sprint of maximum velocity; Con Ext : concentric extensor peak torque; Con Flex : concentric flexor peak torque; Leg Power : Leg Power.

*: $P < 0.05$

Table 5. Multiple regression analysis with CODS as dependent variable. (n = 70)

Dependent variable : CODS (R^2 = 0.916)			
Independent variable	partial regression coefficient	standardized partial regression coefficient	
	B	β	p value
constant	3.312		
Tc	0.683	0.828	< 0.001*
Vapp	-0.151	-0.303	< 0.001*
Vg	0.059	0.155	< 0.001*
Dec	0.006	0.082	0.041*

Tc : Cutting time; Vapp : Approaching velocity; Vg : Goal velocity; Dec : Deceleration peak.

*: P < 0.05

A comparison of variables in FG and SG showed FG to have significantly higher weight than SG. In addition, with the exception of Tapp and Tacc, all variables (30 m sprint, isokinetic concentric extensor and flexor peak torques, and leg power) in FG were significantly higher than those in SG (Table 1, 2 and 4). FG also revealed a higher velocity in each position in the acceleration phase, excluding the -10 m and -9 m positions, than SG (Fig. 3). In addition, FG revealed a significantly higher velocity at the 5 and 10m positions in 30 m sprint. These suggested a greater acceleration ability over short distances in FG than in SG (Table 4). Although FG revealed higher velocity than SG did at the -1 m position (Fig. 3), deceleration started at the -1 m position (0.25 m/s^2). This suggested higher acceleration until the 0m position in FG; however, the shift to deceleration began before the 0 m position.

After the 0m position, the velocity in FG and SG was reversed at the 3m and 4m positions before COD. Given that the velocity in SG at the 4m position was significantly faster than that in FG (Table 3) and Pdec in SG was closer to the cutting line than that in FG (Table 2), it was thought that SG touched the cutting line from the position in which deceleration began, which extended the time and distance to the position at which the velocity of the body trunk reversed from positive to negative. In the acceleration phase after COD, velocity in SG at the 4 m position was -3.07±0.25 m/s while that in FG was -2.82±0.25 m/s, which showed a significantly higher velocity in SG (Table 3). As described above, it was thought that the time and distance between positions during deceleration before COD were closely related. Because of the extension of the time and distance between the positions from the point at which SG touched the cutting line during deceleration to the point at which the velocity of the body trunk reversed from positive to negative, the distance from the position at which the body trunk paused to the 4 m position during re-acceleration became greater in SG than in FG. In other words, SG had a greater distance to use for acceleration to the 4m position than FG did, which, in the end, may result in a significantly higher velocity in SG than in FG. However, FG showed higher acceleration at the 4m and 3m positions after COD (Fig. 3). This suggested that velocity after the 3m position was higher in FG and reversed in Vg.

Immediately after the legs absorb the burden of knee extension, the trunk rotates on a horizontal plane to perform COD (Brown and Vescovi, 2003; Jones et al., 2009). Comparison of lower limb muscular strength in FG and SG in this study using the normalized value with weight showed a significant difference in leg power only (Table 4). Jones et al. (2009) reported that legs absorb the burden of extension during deceleration in COD, making eccentric contraction power an important factor for 180-degree COD. Although we did not examine eccentric contraction power in this study, isokinetic concentric extensor and flexor peak torques as well as leg power in FG were higher than those in SG, which was thought to affect Dec and Pdec in the deceleration phase. In addition, COD was reported to be affected not only by lower limb muscular strength and power, but also by posture and arm movement (Brown and Vescovi, 2003; Sasaki et al., 2011b). Therefore, Young and Farrow (2006) stated that lower limb muscular strength and power should be considered as part of the functions of the kinetic chain in COD. In addition, Young et al. (2002) reported the importance of lowering the center of gravity position and generating ground reaction force during re-acceleration from COD. Furthermore, Hirose and Mineta (2015) reported that ground reaction force is generated by the vertical and horizontal directional forces against the running direction, making it important to maintain the balance between the two forces to acquire the maximum ground reaction force.

This study was conducted to compare the temporal changes in CODS using LAVEG in order to clarify the level of CODS control in youth soccer players and to identify the most effective factors in CODS. According to the results of multiple regression analysis on all variables regarding CODS using the stepwise method, standard partial regression coefficients in Tc, Vapp, Vg and Dec revealed statistical significance. No correlation was observed with straight-line speed, lower limb muscular strength and power. Tc showed the strongest correlation with CODS. Tc includes three phases: deceleration, pause, and acceleration. It is thought that without the smooth shift of these three phases in COD, change of speed could not be performed promptly, which would result in preventing ideal COD performance. Harder at al. (2015) conducted a comparison of velocity in the deceleration phase of 45-degree and 90-degree CODS in elite soccer players aged 16 using LAVEG, and reported that extreme deceleration may delay COD and acceleration after COD. Hewit at al. (2013) stated that length, frequency of strides and adjustment of posture in the deceleration phase of 180-degree COD could minimize the loss of time caused by COD (from deceleration to pause). This suggested that the velocity reverse between FG and SG at the 3 m and 4 m positions, and the high deceleration in FG (Fig. 3, Table 3) may express the level of CODS control, which may also function dominantly in acceleration after COD. In other words, velocity adjustment in the deceleration phase may have significantly affected Tc in FG to make it significantly faster than in SG. Therefore, it is important that soccer players have the ability to promptly shift from acceleration to deceleration in the deceleration phase. However, in this study, we measured CODS using LAVEG and obtained 0.81 of the interclass correlation coefficient through two measurements. There was a considerable difference between individuals regarding the measurement accuracy for COD (measured points of the subjects' body trunk were reversed), which is an issue to be addressed in a future study.

5. Conclusion

The purpose of this study was to clarify the changes in CODS and acceleration in the deceleration and acceleration phases targeting youth soccer players, and to clarify the most effective factors for CODS. As a result, CODS and Tc in FG were faster than those in SG, and significant difference was observed between them. Tapp and Tacc revealed no significant difference. Velocity at the 4m position before COD in SG was significantly higher than that in FG while the acceleration in FG was higher than that in SG. These suggested that SG required more time for deceleration before COD than FG did.

Tc, Vapp, Vg, and Dec showed correlation with CODS. In particular, Tc showed the strongest correlation with CODS. However, it was suggested that Tc was strongly affected by deceleration before COD. Therefore, it was thought that the ability to promptly shift from acceleration to deceleration in the deceleration phase is important for soccer players in regard to CODS.

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