PRINCIPAL COMPONENTS OF THE 180°-TURN WITH THE BALL KINEMATICS IN YOUTH SOCCER PLAYERS

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The interpretation of parameters extracted from sophisticated sport-specific techniques is not always straightforward. This is the case of the 180° change of direction with the ball in soccer. The 180°-turn performance of ten Under-13, sub-elite soccer players was recorded by means of a motion capture system. Principal Component Analysis (PCA) was applied to a set of 21 anthropometrics and kinematic variables including center of mass related quantities and joints range of motion. The first three principal components, explaining 61% of the overall variance, were retained and discussed. PCA unveiled the relevant structure of the dataset, describing both movement speed and amplitude issues, and the relationship between body size and the change of direction ability.

KEY WORDS: change of direction, dribbling, sport kinematics, principal component analysis.

INTRODUCTION: One of the aims of sport biomechanics is to quantitatively characterize techniques and identify movement determinants. A common challenge in this domain is simplifying the high-dimensional information available from 3D motion capture systems (Lamb & Stöckl, 2014). The main soccer technical skills have received a wide coverage in literature. Commonly, the key performance outcomes could be easily determined in terms of accuracy or speed. However, the choice of clear performance parameters is not straightforward when considering complex techniques like the 180° change of direction with the ball (180°-turn).
The 180°-turn is useful in one vs. one situations and offers a strong tactical advantage. Sophisticated and sport-specific agility and balance skills are required to change direction rapidly while keeping the possession of the ball and deceiving the opponents intervention (Chaouachi et al., 2012). To the authors' knowledge, little is known about the biomechanics of this skill. Our primary goal was to extrapolate the main 180°-turn performance determinants, besides execution speed. At this scope, Principal Component Analysis (PCA) was applied to reduce the dimensionality of a set of biomechanical and anthropometrical parameters extracted from 3D data recordings. The secondary and concurrent objective was to investigate through PCA the underlying data structure in a complex sport skill, as already done in clinical gait analysis (Carriero, Zavatsky, Stebbins, Theologis, & Shefelbine, 2009; Deluzio, Wyss, Costigan, Sorbie, & Zee, 1999).

METHODS: Ten Under-13 sub-elite right-footed male soccer players participated to the study. After a standardized warm-up, players were instructed to dribble the ball as fast as possible over a 5-m straight course, change direction after crossing a line defined by two cones and dribble the ball back to the starting point. Each participant completed five trials; only correct executions were retained. An optoelectronic motion capture system (BTS Spa, Italy) recorded the instantaneous 3D positions of 21 reflective markers positioned on players' skin and clothes (Zago et al., 2014). Customized MATLAB® software was used for data processing and statistical analysis. Body Center of Mass (CoM) coordinates was estimated through the segmental centroid method, as detailed by Mapelli et al. (2014). Hip, pelvis and shoulder joints angles were computed considering the relative anatomical frames rotation (ZY'Z'' Euler convention); knees were modeled as 1-degree-of-freedom joints. To equalize recordings, only the frames comprising 90% of the whole pelvis rotation excursion were analyzed (Figure 1). A set of four anthropometric and 17 kinematic parameters was considered: participants' age, height, weight and BMI; CoM track length; CoM peak velocity, acceleration and deceleration; normalized CoM height vertical range of motion (RoM); pelvis peak rotation angular velocity; 11 joint angular RoMs.

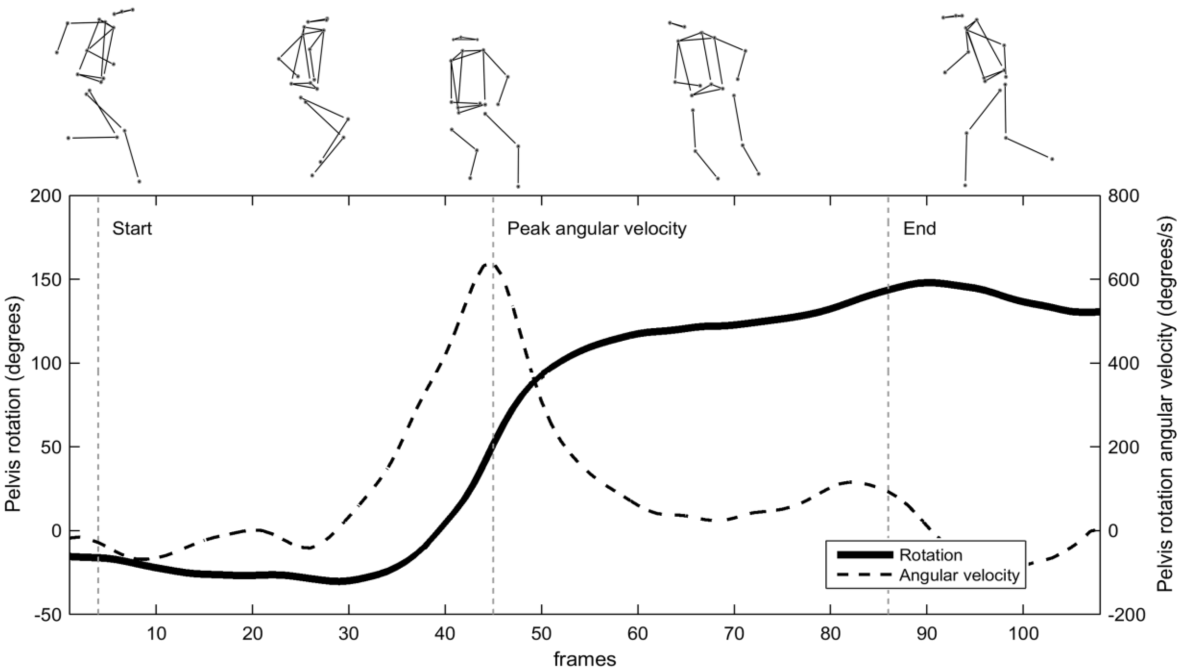

Figure 1. Explanatory illustration of events location: 90% of the pelvis rotation (thick line) range of motion was considered. Pelvis rotation velocity is also shown (dashed line).

Descriptive and multivariate statistics were used to characterize the trials sample. PCA was performed on the correlation matrix of the normalized dataset in order to reduce its dimensionality and evaluate its variability. Principal component (PC) loadings were computed and, based on Jollife's criterion, only the first three were retained (Dunteman, 1989). Interpretation of PCs was done by considering only the variables with larger absolute loading.

RESULTS: Mean execution time of the 29 correct retained trials was 0.68±0.53 s. Due to the asymmetrical nature of movements, we registered kinematic differences between sides, especially in the average hip and knee flexion and in the arm abd/adduction. Table 1 shows the loadings of each variable along the first three PCs. High loadings were highlighted to easily locate the relevant coefficients. The proportion of explained variance was also reported (Dunteman, 1989). The first three PCs explained 61% of the overall dataset variance. The proportion of variance accounted for by the first three PCs is very low only for pelvic RoM (14%). In fact, this variable was explained by PC4 and PC6 (loadings: 0.51 and 0.66, respectively). However, since small components reflect redundancies among the variables with high weighting, these variables could be considered substantially unimportant. While this could result in discarding some important details, our objective was to explain the majority of variation in the data, and capture the primary modes of variation.

DISCUSSION: In the present study, we inspected 21 biomechanical parameters extracted from the 180°-turn in youth soccer players. According to a classical definition, skill is the ability to bring out pre-determined results with the minimum outlay of energy or time (Knapp, 1963). Since technique precision was artificially constrained by the laboratory settings, our main performance reference becomes execution time. Our analysis aimed at unveiling the most relevant variables beneath this performance outcome.

The first PC could be read as a 'motion magnitude' factor. It is positively related with CoM track length, CoM vertical RoM and peak velocity as well as upper and lower limbs joints RoMs. Thus, high PC1 scorers possessed larger range of movement and peak linear velocity. The main negative relevant loading is about height (and partly weight), which seems to be opposed to ample and fast movements. This is reasonable, since for a smaller player is easier to quickly change his body momentum. Moreover, a large CoM vertical lowering could

bring the body CoM closer to the ground, which helps in managing dynamic balance in change of direction tasks (Chaouachi et al., 2012).
PC2 describes the 'speed' of movement with respect to body size. Weight and BMI showed high positive loadings, together with pelvis rotation velocity, while CoM peak acceleration/deceleration had negative coefficients. This suggests the evidence that heavier players are at disadvantage in producing explosive accelerations. The third PC has negative relevant loadings and describes a sort of 'age effect'. Besides an obvious connection between age and height, a less obvious influence on peak CoM acceleration and speed capabilities is addressed. This might be the evidence of a second order, subtle relationship between these parameters, that could be interpreted as the increased sprint ability caused by the increment with age of muscular fibers size and quantity (Bangsbo & Iaia, 2013).
Figure 2 provides a graphical representation of each trial in the plane of the first two principal components. Trials were arbitrarily grouped based on execution time: below the 25th percentile (0.33 s, 'Fast turners'), above the 75th percentile (0.91 s, 'Slow turners'), and included in the inter-quartile range ('Average turners'). We observe that Fast turners tend to score high on PC1, while scoring either negative or positive on PC2. The plot unveils interesting relationship between parameters: for instance, the two fast trials in the fourth quadrant might suggest that good performance in the 180°-turn can be achieved even with relatively small peak accelerations, as long as body weight and BMI are low.

CONCLUSION: The results of this study should be considered as a first exploratory insight about the biomechanics of the 180° change of direction with the ball. A bigger sample of trials need to be collected to draw conclusions able to enhance the training process. Nevertheless, the current analysis highlighted some performance features of the 180°-turn. PCA, as hypothesized, was helpful in identifying the structure of data variability. In particular, movement degrees of freedom, expressed by joints RoMs (Bernstein, 1967), appeared to be beneficial to optimize execution time, which ultimately represents a competitive advantage in game situations. Body size turned out to affect braking, accelerating and rotation capabilities.

Table 1. Principal component loadings and explained variance for the considered parameters.

Variable name	Mean (SD)	Explained variance (%)	PC1	PC2	PC3
			36.8	14.5	9.5
Age (years)	12.6 (0.4)	44	0.06	0.02	**-0.66**
Height (m)	1.54 (0.07)	59	**-0.54**	0.27	**-0.48**
Weight (kg)	42.9 (6.2)	85	-0.40	**0.76**	-0.34
BMI (kg/m^2)	18.1 (1.5)	84	-0.07	**0.91**	-0.10
CoM track length (m)	2.0 (1.4)	88	0.91	0.18	-0.11
CoM vertical RoM (% body height)	12.1 (4.3)	52	**0.55**	-0.45	0.14
CoM peak velocity (m/s)	3.1 (0.4)	50	**0.53**	0.03	**-0.46**
CoM peak deceleration (m/s^2)	13.5 (2.0)	55	0.34	-0.44	**-0.48**
CoM peak acceleration (m/s^2)	10.5 (2.8)	64	0.25	**-0.62**	**-0.44**
Pelvis rot. peak angular vel. (°/s)	414 (90)	48	-0.13	**0.63**	0.27
Right hip flexion RoM (°)	57.9 (30.2)	82	**0.85**	0.27	-0.10
Left hip flexion RoM (°)	47.7 (17.9)	68	**0.79**	0.11	-0.20
Pelvis rotation RoM (°)	162.5 (30.0)	14	0.34	0.16	-0.06
Right hip rotation RoM (°)	29.3 (12.2)	67	**0.79**	0.08	0.20
Left hip rotation RoM (°)	35.4 (10.2)	68	**0.81**	0.01	0.16
Right hip adduction RoM (°)	40.3 (14.5)	54	**0.66**	0.05	0.33
Left hip adduction RoM (°)	43.4 (17.9)	54	**0.64**	-0.10	0.36
Right knee flexion RoM (°)	76.7 (30.6)	76	**0.84**	0.22	-0.09
Left knee flexion RoM (°)	55.6 (15.8)	59	**0.70**	0.25	-0.19
Right arm adduction RoM (°)	44.5 (19.3)	52	**0.69**	-0.06	-0.19
Left arm adduction RoM (°)	54.6 (22.6)	55	**0.63**	0.35	0.16
		Latent root	7.7	3.0	2.0

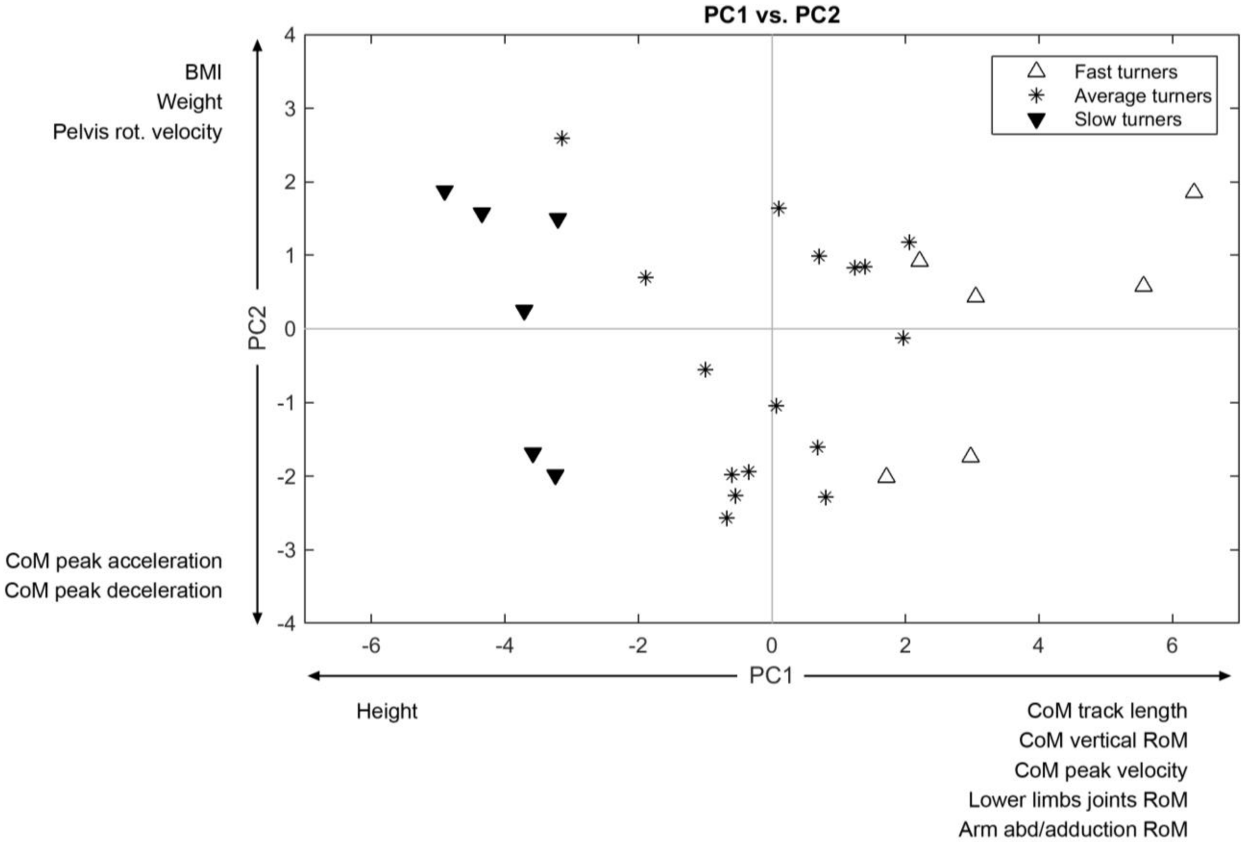

Figure 2. Position of each trial on the PC1-PC2 plane, grouped by execution time. Relevant loading variables are reported in the proper direction for each component.

These results might help in increasing knowledge about this specific technique and could provide a basis for future recommendations for training exercises.

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