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Change of Direction Ability

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The Relationship among Acceleration, Deceleration and Changes of Direction in Repeated Small Sided Games

by

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The change of direction (COD) ability is perhaps the most significant fitness component in team sport games. One of the best ways to develop COD as well as other components of the game in soccer is the regular inclusion of small sided games (SSGs) in the training process. Therefore, the aim of this research was to determine changes in physiological and kinematic variables in repeated SSGs in youth soccer players. Additionally, we investigated the relationship between selected IMA variables such as acceleration, deceleration and changes of direction. Participants included sixteen U17 soccer players from a 2nd league professional team with a high aerobic capacity. The study design involved six 3-min 4 × 4 SSGs with goalkeepers and with a 3-min rest interval between games, during two training sessions played on a field of 25 x 35 m. The results showed that the intervention protocol consisting of repeated SSGs generated an intensity below the anaerobic threshold. This allowed for the maintenance of all variables (Heart Rate, Total Distance Covered, Velocity, Acceleration, Deceleration, Change of Direction) at a similar level throughout the subsequent six SSGs. The analysis revealed that in the six SSGs, players performed the most Acc and Dec, then COD Right and the least COD Left. From the third game on, a decrease in the number of COD Right was noticed. We hypothesized that progressive neuromuscular fatigue on the dominant side caused a more symmetrical trend in COD.

***Key words**: soccer, external loads, heart rate, anaerobic threshold, IMA variables, GPS technology.*

Introduction

Game analysis studies have demonstrated that soccer requires participants to repeatedly produce maximal or near maximal actions of short duration with brief recovery periods. Players have to perform numerous accelerations (Acc) and decelerations (Dec) during the game that affect the physical and physiological state of players and their performance, especially in the last minutes of the game (Beato and Drust, 2021; Russell et al., 2016). The importance of Acc and Dec during a match has been emphasized due to the high mechanical and metabolic demand for these activities (Martín-García et al., 2018; Riboli et al., 2021). Acc and Dec are classified as external training loads and are typically monitored using Global Positioning System (GPS) technology (Aughey, 2011; Beato et al., 2018; Beato and de Keijzer, 2019; Cummins et al., 2013). Change of direction (COD) actions (e.g., side-steps, swerves, turns, crossover steps, and by-pass maneuvers) are essential types of movements on the soccer pitch giving a player the chance to effectively evade or mark an opponent, to create space for his or her teammates, and to score a goal (Konefał et al., 2021; Rouissi et al., 2015; Trecroci, et al., 2018a). During one season of English Premier League match play, between 1000 and 1500 discrete movement changes were observed per game, with changes in activity occurring, on average, every 3.5 s (Trecroci et al., 2020). Performing an effective COD requires a high level of lower limb strength to manage rapid decelerations (producing eccentric force) and

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subsequent accelerations (producing concentric force) within a short time and in multiple directions (Trecroci et al., 2018b). In youth, the development of change of direction (COD) and sprint speed is a key component of successful competing in soccer across age. Therefore, it is recommended to train and monitor COD ability throughout the season for improving soccer players performance (Dos'Santos et al., 2019; Trecroci et al., 2016).

In high performance sports, maximum adaptive benefits are achieved when training stimuli are similar to those of competitive demands (Hauer et al., 2021). Small-sided games (SSGs) are game formats where coaches adjust task constraints to match players' responses to specific training goals (Clemente et al., 2022). These drill-based games have become popular in everyday soccer practice as they allow the delivery of physiological and motor stimuli, while players engage in tactical and technical challenges that simulate some of the dynamics of a formal match (Clemente and Sarmento, 2020). Hammami et al. (2018) revealed that conducting 2–3 SSG training sessions per week induced significant improvements in specific skills and moderate to large improvements in team sport-related physical fitness, such as VO_{2max}, speed, agility, jumping, and repeated sprint performance. Many previous studies analyzed different game formats and bout duration along with players' physiological, mechanical and endocrine responses (Chmura et al., 2019; Köklü et al., 2017). These improvements appear to be independent of the playing level and can occur either in the pre- or in-season period. Therefore, repeated small sided games are considered a significant and time-effective form of training.

For this form of training to be even more effective, it should be combined with the analysis of basic physiological variables such as the Heart Rate, VO_{2max} or the load at the anaerobic threshold. Additional information about training can also be obtained from the analysis of kinematic variables, such as the Total Distance Covered, Velocity, Acceleration, Deceleration, and Change of Direction. It should be noted that the variables described above are key components of modern soccer and deserve an in-depth analysis (Casamichana et al., 2018; Owen et al., 2020). Only such a comprehensive analysis based on the monitoring of subsequent repeated training loads can constitute the basis for the optimization and individualization of training loads. Therefore, the aim of the present research was to determine changes in physiological and kinematic variables in six repeated 3-min small sided games in youth soccer players. In addition, the aim was to investigate the relationship between selected IMA (Inertial Movement Analysis) variables such as acceleration, deceleration and changes of direction.

Methods

Participants

The research material consisted of sixteen U-17 soccer players (29 observations) from a professional sports club competing at the second Polish league level. The physical activity of all players, excluding goalkeepers was analyzed. Players' mean body height was 176.61 ± 5.71 cm, body mass 70.14 ± 7.06 kg and age 17.55 ± 1.00 years. Table 1 shows the mean values of physiological variables attained during an incremental treadmill test, seven days before the start of the study.

All participants were briefed with a detailed explanation of the proposed study and its requirements. They were informed of potential risks and provided with written consent forms. Participants were free to withdraw at any time, without any repercussions. This study maintains the anonymity of players following the data protection law. Participants were encouraged to maintain hydration and habitual nutrition in the 24 h prior to testing. The study was conducted according to the guidelines approved by the Wroclaw University of Health and Sports Sciences Ethical Review Board (14/2021). Additionally, the study conformed to the requirements stipulated by the Declaration of Helsinki, and all health and safety procedures were complied with.

Procedures

The study design involved carrying out six 3-min 4 × 4 games with goalkeepers with a 3-min rest interval between games, during two training sessions. The games were performed on a field with dimensions of 25 m x 35 m. Before starting the tests, players performed a standard 20-min warm-up of progressive intensity, including running, stretching, exercises with the ball, and repeated starts and stops. During the games, when the ball went out of bounds, the coach introduced another ball to intensify the effort of players. In addition, the coaching staff verbally motivated the players. The study was carried out at the beginning of the pre-season

period. External loads were determined using GPS sampling at 10 Hz, which included tri-axial accelerometer sampling at 100 Hz (Vector S7; Catapult Sports, Melbourne, Australia) (Beenham et al., 2017). Devices were secured between the upper scapulae, at approximately the T3–4 junction (Clavel et al., 2022). The devices were activated 15 min before use, in accordance with the manufacturer's instructions, to allow satellites to download the required almanac data. The data were downloaded after each session using manufacturers' proprietary software (Open Field, Catapult Sports). Using the software, data on the players' physical activity from successive small sided games were obtained, and then exported to a secure database for further analysis. Passive recovery periods between repeated SSGs were excluded from the analysis (Crang et al., 2022).

The metrics derived from each of the devices were: average Heart Rate (HR_{avg}) [bpm], maximal Heart Rate (HR_{max}) [bpm], Total Distance Covered (TDC) [m], mean Velocity (V_{mean}) [km·h^{-1}], maximal Velocity (V_{max}) [km·h^{-1}], maximal acceleration (Max_{acc}) [m·s^{-2}], maximal Deceleration (Max_{dec}) [m·s^{-2}]. Additionally, Inertial Movement Analysis (IMA) variables were recorded, such as: Acceleration (Acc) [number], Deceleration (Dec) [number], Change of Direction Right (COD Right) [number], Change of Direction Left (COD Left) [number] (Figure 1).

Statistical analysis

All the variables were checked to verify their conformity with a normal distribution. Arithmetic means and standard deviations were calculated. Repeated-measures ANOVA was used to compare mean values for the examined variables. Bonferroni post-hoc tests were performed to assess differences between means. The level of statistical significance was set at $p \leq 0.05$. All statistical analyses were performed using the Statistica ver. 13.3 software package (Dell Inc., Tulsa, OK, USA).

Results

Statistical analysis of physiological and kinematic variables in relation to six repeated small sided games revealed effects in relation to HR_{max} ($F = 3{,}520(5)$; $p = 0.005$), TDC ($F = 4{,}318(5)$; $p = 0.001$), V_{mean} ($F = 5{,}900(5)$; $p = 0.001$), and Max_{acc} ($F = 2{,}471(5)$; $p = 0.035$). There was no significant effect of HR_{avg} ($F = 1{,}980(5)$; $p = 0.086$), V_{max} ($F = 1{,}125(5)$; $p = 0.350$), and Max_{dec} ($F = 0{,}423(5)$; $p = 0.832$) (Table 2).

Figure 2 shows an analysis of the variance model for IMA variables (Acc, Dec, COD Right, COD Left) depending on six repeated small sided games. Analysis of the main results and their interactions is presented. The analysis revealed no significant interactions between IMA variables and six repeated small sided games ($F = 0.526$ (15); $p = 0.927$). Moreover, the main effects of analysis showed statistically significant differences for the six repeated small sided games ($F = 5.269$ (5); $p = 0.001$) and selected IMA variables ($F = 14.237$ (5); $p = 0.001$). Considering changes of the examined IMA variables in the six repeated small sided games, it was found that a significant difference occurred only in COD Right between the second and the third game ($p \leq 0.05$). Moreover, significant differences ($p \leq 0.001$) were found between IMA variables in each of the six games. In the first, second and sixth games, the number of Acc and the number of Dec were significantly greater than the number of COD Right and the number of COD Left, and the number of COD Right was significantly greater than the number of COD Left. In games three, four and five, the situation was similar, but no significant difference was found between COD Right and COD Left (Figure 2).

Discussion

One of the aims of the research was to determine changes in physiological and kinematic variables in six repeated 3-min small sided games in youth soccer players. Six 3-min games in a 4 x 4 format with goalkeepers were used in the research. As is well known, such games are similar to the specifics of a regular game, because they contain numerous technical activities that are necessary in training of youth soccer players (Beenham et al., 2017). Ideally, such games should also significantly improve physiological, motor and kinematic variables (Clemente et al., 2022). However, the novel findings of our experiment were that despite the coach's verbal incentives to trigger high pace, the intensity of the effort in the game format used ranged from 177 to 181 bpm HR_{max}, and the average intensity in subsequent games ranged from 166 to 169 bpm. This is a very interesting observation in the context of the progressive test conducted before the experiment, in which players achieved a HR_{max} of 200 and their HR at the anaerobic threshold was 181 bpm. As can be seen, the intensity of the games used was clearly below the anaerobic threshold (Clemente et al., 2022). We can conclude from these data that such responses significantly

influenced the recorded values of kinematic variables. All tested variables remained relatively constant in the six repeated SSGs. However, a deeper analysis showed that TDC and V_{mean}, which determined the average activity of players in the entire 3-min game, were the most sensitive to such an effort. Players achieved the highest level of these variables in the second game, and then, in the next four repetitions, they remained relatively constant. However, a different course of changes was recorded in explosive variables, which remained relatively constant from the first to the last game. Based on these observations, it can be assumed that in the first load, it is very difficult to achieve an optimal stimulation at the level of the central and peripheral nervous system (Chmura and Nazar, 2010). In addition, only training with an intensity above the AT can clearly affect changes in the level of kinematic variables in subsequent games (Chmura et al., 2019). This can be achieved by modifying the size of the playing area, the number of players, and the duration of work and rest (Clemente et al., 2022; Riboli et al., 2021).

Table 1. *Physiological variables measured during an incremental treadmill test.*

VO_{2max} (ml·kg·min^{-1})	VO_2 at AT (ml·kg·min^{-1})	HR_{max} (bpm)	HR at AT (bpm)
mean ± SD			
57.01 ± 5.73	46.24 ± 4.16	200.00 ± 9.09	181.13 ± 11.57

AT – anaerobic threshold

Figure 1. *The clock represents 360 degrees in which each quarter is 90 degrees and represents one of the four micro movements: Acc, Dec, COD Right and COD Left (source: www.support.catapultsports.com; accessed on 10.11.2022).*

Table 2. *Differences in physiological and kinematic variables in six repeated 3–min small sided games (mean ± SD).*

Variables	Games						F (Sig.)	SSD ($p \leq 0.05$)
	1	2	3	4	5	6		
HR_{avg} [bpm]	169.72 ± 7.32	168.75 ± 9.21	167.74 ± 10.51	166.64 ± 9.30	167.50 ± 10.22	166.04 ± 11.77	1.980 (0.086)	-
HR_{max} [bpm]	181.59 ± 7.65	183.10 ± 8.72	180.59 ± 9.45	180.28 ± 10.00	180.38 ± 10.88	177.45 ± 13.30	3.520 (0.005)	2>6
TDC [m]	371.13 ± 34.08	387.00 ± 41.67	364.79 ± 40.07	366.08 ± 36.64	364.79 ± 42.11	365.15 ± 37.32	4.318 (0.001)	2>3,4,5,6
V_{mean} [km·h^{-1}]	7.32 ± 0.66	7.39 ± 0.74	7.08 ± 0.76	7.03 ± 0.70	7.00 ± 0.57	6.89 ± 0.81	5.900 (0.001)	2>4,5,6 1>6
V_{max} [km·h^{-1}]	19.72 ± 2.01	20.50 ± 2.00	19.89 ± 1.95	19.89 ± 1.91	19.70 ± 1.69	20.32 ± 1.73	1.125 (0.350)	-
Max_{Acc} [m·s^{-2}]	3.27 ± 0.30	3.37 ± 0.37	3.22 ± 0.48	3.12 ± 0.38	3.12 ± 0.48	3.09 ± 0.44	2.471 (0.035)	2>6
Max_{Dec} [m·s^{-2}]	-3.53 ± 0.50	-3.45 ± 0.55	-3.44 ± 0.56	-3.36 ± 0.46	-3.48 ± 0.70	-3.39 ± 0.44	0.423 (0.832)	-

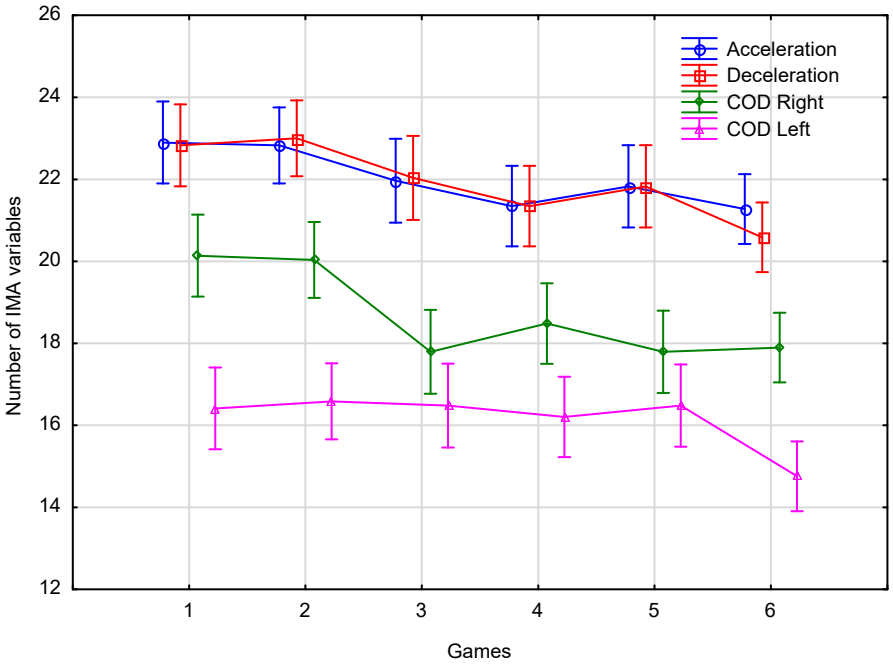

Figure 2. *IMA variables depending on six repeated 3 minute small sided games (mean ± SD).*

The Catapult Sports system used in the research enabled detailed IMA variables to be recorded. Therefore, we attempted to investigate the relationship between selected IMA variables such as acceleration, deceleration and changes of directions in the context of six repeated SSGs. Acc and Dec are frequently analyzed in the available literature (Russell et al., 2016). However, for many reasons, including health, tactical and technical ones, it is also worth considering Changes of Direction (COD) (Granero-Gil et al., 2020; Rouissi et al., 2015). Direction changes in soccer can be made to the right, left, and at different degrees (Figure 1). Carey et al. (2009) showed a strong

propensity for players to use the dominant foot during all football activities. This behavior was most common during set pieces, dribbling, and passing (85%). Furthermore, Granero-Gil et al. (2020) found significant differences in centripetal force between players with dominant right and left feet. Players only used the non-dominant foot under heavy pressure from the opponent. In our study, 75% of players had a dominant right leg. In this context, information related to the number of IMA variables is interesting. As in the official match, in our research, players performed the most Acc and Dec, followed by COD (Faude et al., 2012). Additionally, in our experiment, it was observed that players performed COD Right more often than COD Left. It is surprising that in the first two games, the difference between COD Right and COD Left was significant, while in the next three games, it lost its relevance as the number of COD Right decreased. Why did players start to play more symmetrically from the third game on? Could this be the effect of rapidly increasing neuromuscular fatigue in the more active COD Right (Trecroci et al., 2020)? It is extremely difficult to explain. The observation itself is very inspiring, but more research should be carried out to better understand these relationships.

In this context, the limitations of our research should be mentioned. It would be ideal to combine kinematic data with the analysis of technical and tactical activities using a drone or a camera system. Additionally, COD could be analyzed in the context of different intensities, e.g., low, medium and high. Furthermore, more attention could be paid to the laterality of the players surveyed and different game formats could be used.

Conclusions

The effort in repeated small sided 4 x 4 games with a goalkeeper on a 25 m x 35 m pitch generates an intensity below the anaerobic threshold. This translates into the maintenance of all variables (Heart Rate, Total Distance Covered, Velocity, Acceleration, Deceleration, Change of Direction) at a similar level for subsequent six small sided games.

In the small sided games analyzed, players performed the most Acc and Dec, then COD Right and the least COD Left. From the third game on, a decrease in the number of COD Right was noticed. Thus, perhaps under the influence of the more rapidly increasing neuromuscular fatigue in the dominant side, COD became more symmetrical.

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