Application of artificial intelligence in physical education and future prospects

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Abstract

The application of artificial intelligence in physical education is a widely debated topic and has an immense potential for the future. This article discusses the benefits of applying AI to physical education and its possible applications. It is argued that AI can be applied in a number of ways, and it can integrate different types of sensors to collect data. This data can then be used to train an autonomous system which will help the users to make intelligent decisions. Tactical behavior was assessed in subgroups based on team lines (goalkeeper – defenders, defenders – midfielders and midfielders – forward) before and after the intervention in an 8-a-side game. The results suggest that short-term differentiated practice seems insufficient to change linear outcomes, but useful to boost tactical-pattern regularity at subgroup level during the team-possession game phase. Youth-sport academy coaches should employ modified games introducing artificial rules to encourage young players to learn and strengthen the acquisition of regular tactical-patterns .

Keywords: artificial intelligence; physical education; learning; pedagogy; team sport; time-motion analysis; training

1. Introduction

Sports have become a discipline that everyone may pursue at any stage or age of life. Sports activities are open to all, including elders, children, and adults. Most people consider sports to be merely extra-curricular or co-curricular activities in institutions. Physical Education is a subject often forgotten in schools where kids do not have enough time to learn about it, or where such classes are either non-existent or take up very little class time in the curriculum. This article will highlight what artificial intelligence can be used for in this field, how it can help people learn, and some ways that it might be applied in future research.

Artificial intelligence may be used in physical education classrooms to help students learn and perform better (1). They may accomplish this using a number of technologies, including virtual reality, augmented reality, gaming, and so on. This is both to provide instructors new methods to structure classes and because technology has a lot of promise for application in the classroom. Teachers, for example, could be able to create virtual worlds in the classroom that students can travel and explore right away.

"The art or science of improving health via physical exercise," according to the definition of Physical Education. This may be used in a variety of situations, including sports and exercise. Artificial intelligence in physical education is a relatively new concept (a few of decades), but it has made remarkable development since its application. One of the early applications of AI was the creation of a soccer-playing robot. Soccer is one of the most popular sports in the world, thus starting AI development with soccer as the primary emphasis seemed a solid decision. In other words, this robot had to learn how to play soccer by observing humans play and then copying their movements. Researchers were able to boost its performance by 92 percent utilising this method.

Artificial intelligence has been applied in more complicated ways in recent decades. Researchers are always attempting to enhance the AI they develop in order to increase its performance. With daily breakthroughs and inventions produced by researchers, the effects of such growth are becoming more visible.

One of the ways this is being applied is in the field of physical education. A study was done to test the effectiveness of using an AI tool on a virtual soccer game. There are quite a few factors that had to be taken into account when designing such a test (Boni, 2022). This included making sure that it was a challenging game for the AI, ensuring that it didn't become bored, and ensuring that it kept competing with other teams throughout its game.Since the beginning of the modern and standardized sport in the late nineteenth century, there is a question bothering youth sport academy coaches: how to train young athletes on learning how to play. Educative methods and sport pedagogy are closely united and have evolved together from the traditional highly structured technique-based models in innovative approaches such as Nonlinear Pedagogy (Araújo & Davids, 2016; Araújo, Davids, & Hristovski, 2006; Bakeman, Quera, & Gnisci, 2009). This learner–environment-centered approach recognizes the emergent, self-organizing nature of learning and underpins the utilization of modified versions of games that manipulate a rich range of different constraints such as changes to space, equipment, and the introduction of artificial rules (Bastida-Castillo, Gómez-Carmona, De La Cruz Sánchez, & Pino-Ortega, 2019; Bizzini, Junge, & Dvorak, 2013). Introducing artificial rules, coach-made conditions not inherent to the laws of the game that constraint how players behave and modulate game affordances (e.g. touch limitation or floaters' inclusion, provides emergent learning environments that conduct players and teams to desired tactical behavior (Casamichana & Castellano, 2010).

Tactical behavior, interpersonal coordination according to the environment and opponent changes, can be assessed thanks to the advanced positional data that measure movement patterns and inter-player coordination to reveal the dynamics of soccer teams as complex social systems at the individual, dyadic, subgroup and team level (Duarte, Araújo, Correia, & Davids, 2012; Fleiss, Levin, & Paik, 2013). From an ecological approach, soccer teams are functional super-organisms that have been studied at team level (Gonçalves, Figueira, Maçãs, & Sampaio, 2014). Nevertheless, these super-organisms integrate interdependent interacting subsystems that organize themselves into networks either super-imposed upon or emerged inside the system to reach certain behavior regularity that enables them to handle the uncertainty of the social interaction with the opponent and the environment

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(Gonzalez-Artetxe, Pino-Ortega, Rico-González, & Los Arcos, 2020). Hence, the assessment of tactical behavior at dyadic and subgroup levels has been suggested (Jayaraman, Nathan, & Ng, 2021; Merlin et al., 2020).

Team-lines structures are distinct subsystems among the various subgroups because team location and distribution on the playing field restrict posterior tactical conduct (Grehaigne, Bouthier, & David, 1997). To our knowledge, no research has looked at the training impact of these modified games on tactical conduct in young soccer players based on team lines. Similarly, the influence of establishing artificial rules as important task restrictions on tactical behaviour based on team lines should be addressed while developing alternative training programmes. Differentiation between game phases should be explored due to behavioural differences between team-possession and no-possession game phases. In addition, since the goalkeeper's (Gk) involvement in the team-possession game phase has risen in recent years, he should be included in the measures (Low et al., 2020).

As a result, the goal of this research was to see how modified games with fake rules affected tactical behaviour based on team lines throughout the team-possession game phase in two different young soccer categories..

Methods

Participants

Participants were thirty-two Spanish youth-soccer players from under-14s (U-14: n = 16; age: 13.0 ± 0.4 years; playing experience: 6 ± 1 years; height: 1.56 ± 0.07 m; body mass: 46.7 ± 5.9 kg) and under-16s (U-16: n = 16; age: 15.9 ± 0.4 years; playing experience: 8 ± 1 years; height: 1.70 ± 0.07 m; body mass: 57.9 ± 8.3 kg) teams (natural groups not modified for the study) of the same club affiliated to a Spanish First Division Club (*LaLiga*). Each team was divided into two groups according to the coaches' perception of their technical – tactical level and their playing position to equally balance the quality of the teams: control and experimental groups (i.e. U-14s-control and U-14s-experimental; U-16s-control and U-16s-experimental). Parents, coaches and players, as well as the club, were informed about the research procedures and written consent for the children's participation was provided. All procedures had been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki, 2013) and the standards of the Bioethics Commission of the University of the Basque Country (Reg. Code 132 / 2018).

Study Design

The intervention took place in the final part of the season and consisted of four identical training sessions of ~ sixty minutes and two testing sessions, before (pre-test) and after (post-test), carried out twice a week on the same field and at the same time (18:00). Both testing sessions started with a standardized eight-minute warm-up based on the FIFA 11+ protocol and a thirty-meter sprint. Then, tactical behavior was assessed based on team lines during an 8-a-side soccer game (Gk + 7 vs. 7 + Gk), in which the control and experimental groups of each competition category faced each other. The match was played on a sixty by forty-meter field using formal 7-a-side goals and the offside rule set on the halfway line as well as applying all the other official game rules. Both control and experimental groups used the same 1-3-3-1 team formation with one goalkeeper (Gk), one central defender (CD), two lateral defenders (LD), one central midfielder (CM), two lateral midfielders (LM) and one forward (F). The players played in their usual playing position during both the pre-test and the post-test. Several balls were provided by two coaches to ensure gameplay was as fast as possible and avoided losing time. No coach feedback was allowed during the testing sessions (Parlebas, 2020).

Before the differentiated practice, all the players performed an eight-minute warm-up based on the FIFA 11+ protocol and five series of a minute of tag (Coutinho et al., 2018). Then, control and experimental groups of each competition category faced each other (U-14s-control vs. U-14s-experimental and U-16s-control vs. U-16s-experimental) during three seven-minute 8-a-side games (Gk + 7 vs. 7 + Gk) in the four training sessions in the same order (Figure 1). The control group played freely without restrictions and not knowing the playing conditions of the experimental group, which played conditioned by artificial rules as key task constraints (Figure 1). The team formation (i.e. 1-3-3-1) and the playing position of each player were the same as the pre-test during throughout training intervention. Along the same lines, the official offside rule was applied during the game, the replacement of the ball was ensured and coach feedback was forbidden as in the testing session (Coutinho et al., 2022; Pinder, Davids, Renshaw, & Araújo, 2011).

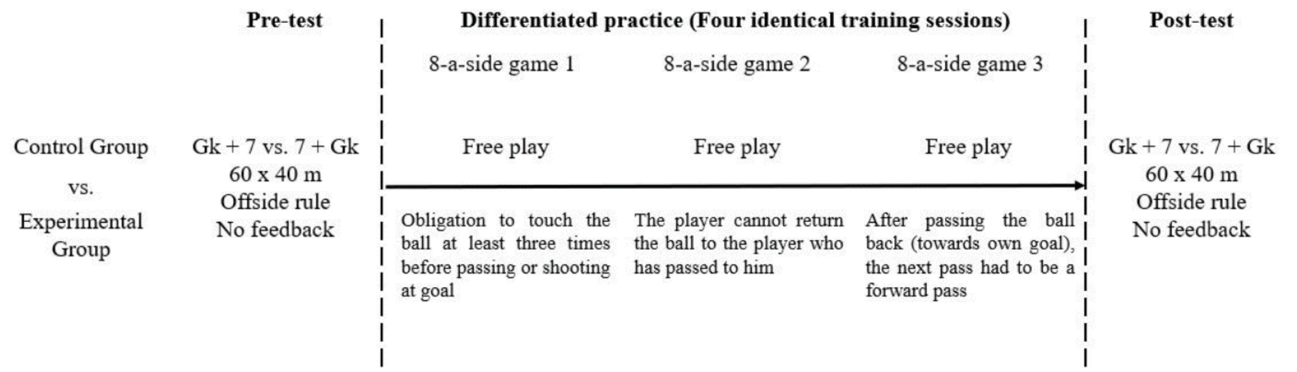

Figure 1. Study design.

Data Collection

A time-motion tracking system employing a local positioning system (LPS) (IMU; WIMU PROTM, RealTrack Systems, Almeria, Spain) based on ultra-wideband (UWB) technology was used to collect positional data in order to analyse tactical behaviour. This gear, which includes a reference system and tracking devices worn by all players in a specific vest, has been verified for tactical behaviour in a continuous test (Praça, Moreira, Rochael, Barbosa, & Travassos, 2022). To discriminate between playing phases, raw data was captured at 18 Hz and testing of 8-a-side games was recorded at 240 frames per second (fps) at FullHD resolution (1920 x 1080 pixels) using two iPhone 7 Plus (Apple Inc, Cupertino, Ca, USA) (i.e. team-possession game phase and no-possession game phase). After each session, the positional data was downloaded, synced with the movies, and analysed using S PROTM software (RealTrack Systems, Almeria, Spain). To measure tactical behaviour with high precision, the reference system was projected in the programme using a geographic information system (GIS) tool (Quera, Bakeman, & Gnisci, 2007).

Subgroups based on team lines were used to arrange positional data. Two lines of a single player (Gk and F) and two lines of three players make up the 1-3-3-1 team shape (i.e. central and lateral players of the backline and midfield). To analyse the short-term impact of modified games incorporating artificial rules on tactical conduct during the team-possession game phase, three subgroups based on these lines were considered: goalkeepers – defenders (Gk–DEF), defenders – midfielders (DEF–MID), and midfielders – forward (MID–F) (Figure 2).

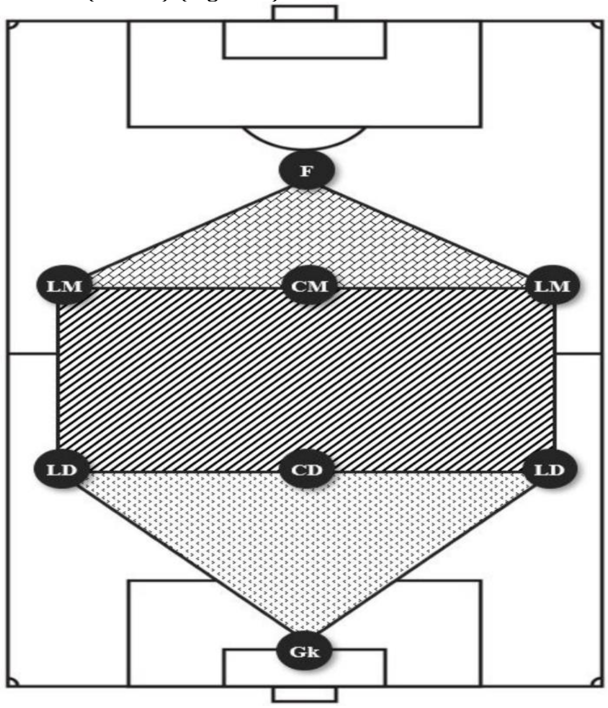

Figure 2. Graphical representation of subgroups based on team lines: goalkeeper – defenders [Gk–DEF] (represented by dots), defenders – midfielders [DEF–MID] (represented by lines) and midfielders – forward [MID–F] (represented by bricks). Gk = goalkeeper; CD = central defender; LD = lateral defenders; CM = central midfielder; LM = lateral midfielders; F = forward.

Tactical Variables

The three types of field-positioning-derived variables (i.e. *point* or centroid, *distance* variables and *area* variables; were selected to assess the effects of the training intervention on tactical behavior of each subgroup during the team-possession game phase: the change in the centroid position (CCP), the mean distance between teammates (dyads), and the surface area (SA). Apart from central tendency measures (i.e. means ± standard deviations [*SD*]), sample entropy measures of the time series of the tactical variables analyzed were calculated by the S PRO™ software (RealTrack Systems, Almeria, Spain) to assess the predictability of social interactions by nonlinear and noisy dynamic positional data (Renshaw et al., 2016). Measuring predictability involves examining time signals for periodicity or patterns of repeatability, assessing the level of order or complexity or the regularity of the tactical behavior: higher values of entropy reflect more unpredictability, while lower ones manifest more regularity and predictability (Castejon et al., 2021; Renshaw, Chow, Davids, & Hammond, 2010; Travassos, Davids, Araújo, & Esteves, 2013).

All the measurements were carried out for the team-possession game phase. To differentiate ball-possession for each team and exclude stoppages in play, the criteria established by Castellano were applied. To ensure the reliability of data quality, intra- and inter-observer agreements were evaluated by LINCE PLUS Research Software for Behavior Video Analysis using Cohen's kappa statistic, obtaining satisfactory intra- and inter-observer agreements (Coito, Davids, Folgado, Bento, & Travassos, 2022; Jacob, 1988).

Statistical Analysis

Descriptive outcomes are presented as means ± *SD*. Statistical analysis was carried out regarding the total team-possession game phase. Since the total team-possession game phase and, consequently, the amount of data differed between tests (i.e. the pre-test and the post-test), inferential statistics to assess intra-group changes could not be used. Thus, Cohen's *d* effect size (1988) was calculated to assess intra-group practical differences within each training-group (i.e. U-14s-control, U-14s-experimental, U-16s-control and U-16s-experimental) and for each subgroup (i.e. Gk–DEF, DEF–MID and MID–F). Thresholds for effect size (*d*) interpretation were: < 0.25, trivial; 0.50, small; 1.0, moderate; and > 1.0, large (Rhea, 2004). Furthermore, percentage change was calculated on all tactical variables from the pre-test to the post-test. Regarding SampEn measure (Richman & Moorman, 2000), since a single value of entropy can be obtained for the total team-possession game phase of each team, the comparison of the entropy values between the pre-test and the post-test was performed by the percentage change for all tactical behavior variables.

Results

Gk–DEF

Apart from U-14s-control Gk–DEF in dyads and SA variables, linear tactical behavior barely changed in the remaining three subgroups (Table 1). Non-linear outcomes showed different trends between the control and experimental subgroups. While U-14s- and U-16s-control Gk–DEF SampEn change (%) was positive for CCP and negative for dyads and SA, experimental subgroups trended to regularity, except for the SA in U-16s-experimental (Figure 3).

DEF–MID

Linear tactical behavior barely changed after the training intervention in both control and experimental subgroups and competition categories (Table 1). SampEn trends differed between control and experimental subgroups. While U-14s- and U-16s-control DEF–MID SampEn change (%) was positive for SA and negative for CCP and dyads, experimental subgroups trended to regularity, apart from CCP in U-16s-experimental (Figure 3).

MID–F

In general, linear tactical behavior barely changed after the training intervention in both control and experimental subgroups and competition categories, except for dyads in U-16s-experimental (Table 1). The trend of the changes was not clear for SampEn (Figure 3).

Table 1. Linear outcomes for tactical behavior based on team lines. Descriptive (mean ± *SD*) and intra-group comparison (% change and Cohen's *d*) for the subgroups (i.e., Gk–DEF, DEF–MID and MID–F) of both control and experimental groups and competition categories (i.e., U-14s and U-16s).

	Control					Experimental				
Tactical variables	Pre-test (mean ± *SD)*	Post-test (mean ± *SD)*	Change (%)	Cohen's *d* *d*	Int.	Pre-test (mean ± *SD)*	Post-test (mean ± *SD)*	Change (%)	Cohen's *d* *d*	Int.
U-14s										
Gk–DEF										
CCP (m)	0.49 ± 0.39	0.51 ± 0.32	3.15	0.04	Trivial	0.57 ± 0.32	0.66 ± 0.37	15.74	0.26	Small
Dyads (m)	14.76 ± 3.87	17.52 ± 4.94	18.69	0.62	Mod.	14.25 ± 3.63	14.06 ± 3.71	-1.37	0.05	Trivial
SA (m²)	132 ± 56	180 ± 66	36.31	0.78	Mod.	118 ± 47	110 ± 60	-7.15	0.16	Trivial
DEF–MID										
CCP (m)	0.59 ± 0.38	0.68 ± 0.44	16.15	0.23	Trivial	0.61 ± 0.36	0.77 ± 0.48	25.98	0.37	Small
Dyads (m)	15.53 ± 6.06	15.82 ± 4.70	1.89	0.05	Trivial	16.70 ± 5.88	16.82 ± 4.61	0.74	0.02	Trivial
SA (m²)	253 ± 116	252 ± 84	-0.51	0.01	Trivial	300 ± 115	280 ± 131	-6.63	0.16	Trivial
MID–F										
CCP (m)	0.70 ± 0.48	0.82 ± 0.51	17.84	0.25	Small	0.69 ± 0.49	0.79 ± 0.53	14.21	0.19	Trivial
Dyads (m)	14.91 ± 4.61	14.05 ± 3.35	-5.77	0.21	Trivial	15.36 ± 5.26	16.61 ± 5.48	8.14	0.23	Trivial
SA (m²)	116 ± 60	104 ± 58	-10.73	0.21	Trivial	117 ± 67	113 ± 53	-3.50	0.07	Trivial
U-16s										
Gk–DEF										
CCP (m)	0.60 ± 0.35	0.60 ± 0.39	1.12	0.02	Trivial	0.66 ± 0.39	0.67 ± 0.65	1.47	0.02	Trivial
Dyads (m)	17.04 ± 5.29	17.91 ± 5.10	5.05	0.17	Trivial	18.81 ± 4.82	19.79 ± 5.32	5.25	0.19	Trivial
SA (m²)	182 ± 103	194 ± 74	6.80	0.14	Trivial	221 ± 96	254 ± 101	14.76	0.33	Small
DEF–MID										
CCP (m)	0.70 ± 0.42	0.67 ± 0.56	-4.30	0.06	Trivial	0.69 ± 0.47	0.67 ± 0.39	-2.80	0.04	Trivial
Dyads (m)	18.92 ± 5.50	17.39 ± 5.94	-8.06	0.27	Small	14.19 ± 3.12	14.03 ± 3.26	-1.15	0.05	Trivial
SA (m²)	369 ± 163	338 ± 121	-8.31	0.21	Trivial	215 ± 83	210 ± 72	-2.27	0.06	Trivial
MID–F										
CCP (m)	0.92 ± 0.54	0.79 ± 0.58	-14.41	0.24	Trivial	0.84 ± 0.62	0.74 ± 0.44	-11.29	0.18	Trivial
Dyads (m)	15.12 ± 5.61	14.24 ± 5.17	-5.86	0.16	Trivial	10.74 ± 1.89	11.90 ± 2.62	10.89	0.51	Mod.
SA (m²)	106 ± 63	99 ± 46	-6.44	0.12	Trivial	70 ± 39	82 ± 47	18.33	0.29	Small

CCP = change in the centroid position; Dyads = the mean distance between players; SA = surface area; Gk–DEF = goalkeeper – defenders; DEF–MID = defenders – midfielders; MID–F = midfielders – forward; *SD* = standard deviation; Change = percentage change; *d* = Cohen effect size; U-14s = under-14s; U-16s = under-16s; Int. = effect size' qualitative interpretation; Mod. = moderate effect size.

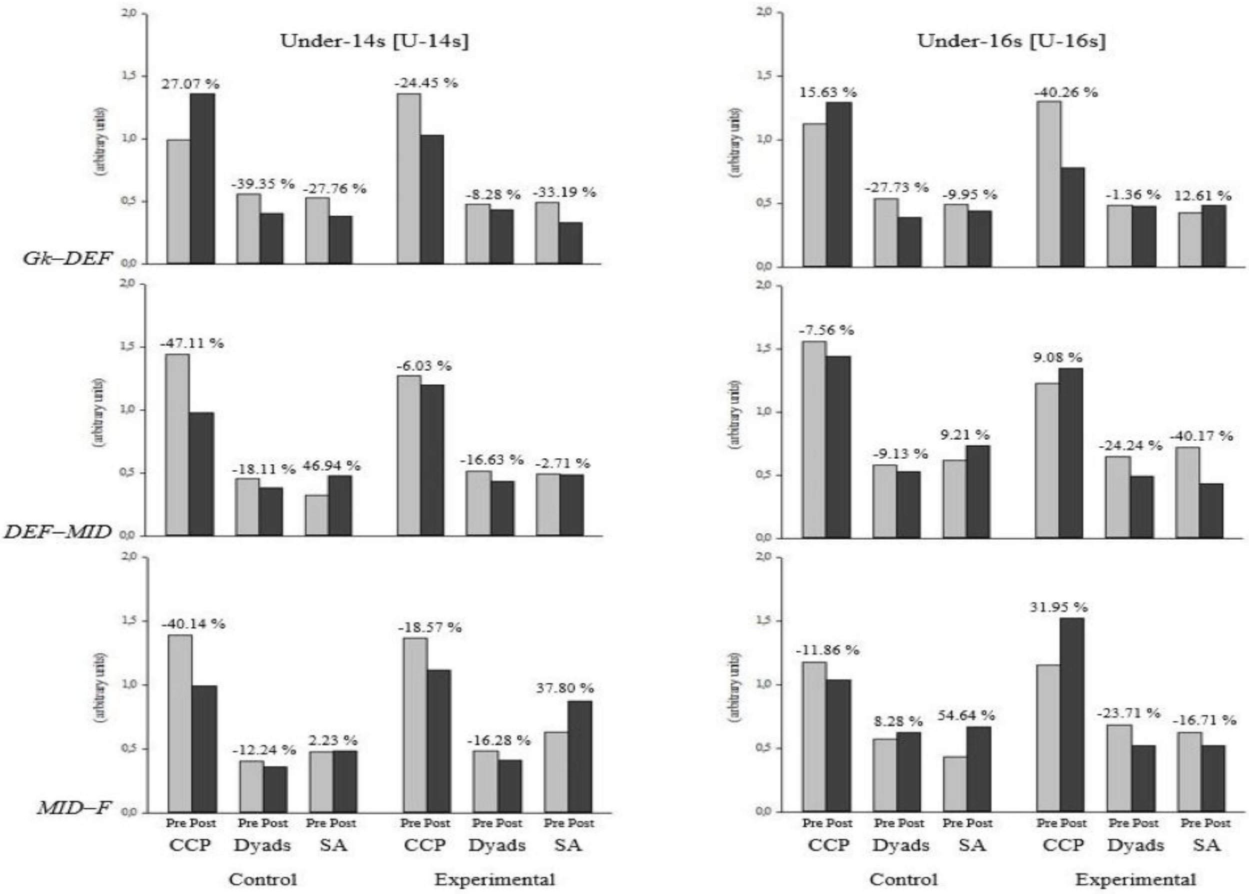

Figure 3. Non-linear outcomes for tactical behavior based on team lines (change in the centroid position [CCP], the mean distance between players [Dyads] and surface area [SA]). Sample entropy (SampEn) percentage change from the pre-test to the post-test for the subgroups (i.e. goalkeeper – defenders [Gk–DEF], defenders – midfielders [DEF–MID] and midfielders – forward [MID–F]) of both control and experimental groups and competition categories (i.e. U-14s and U-16s).

Discussion

The goal of this research was to see how modified games with fake rules affected tactical behaviour based on team lines during the team-possession game phase in two different young soccer categories. The main findings were that after a short period of free play without restrictions and modified games introducing artificial rules training programmes, linear tactical behaviour based on team lines barely changed, whereas tactical behaviour based on team lines trended toward greater regularity after introducing artificial rules. The findings show that modified games with fake rules played across four training sessions may be beneficial in building tactical-pattern regularity in young soccer players during the team-possession game phase.

In comparison to other studies in which Gk participated but was excluded from the analysis (Castellano, 2008; Chow, 2013), the current study has included the Gk due to the increasing participation of this player during the team-possession game phase and to guarantee one of the key pedagogical principles of NLP: representativeness (Rhea, 2004; Richman & Moorman, 2000). The goal and the keeper are relevant structural traits that determine the tactical structure in soccer game and constrain the team and the team-lines tactical behavior. While Gk–DEF linear outcomes barely changed from the pre-test to the post-test (Table 1), tactical behavior trended to regularity in Gk–DEF when play was conditioned by artificial rules (Figure 3). It seems that the artificial rules introduced as key task constraints led to Gk–DEF self-adjustment that resulted in greater regularity compared with those that played freely without restrictions. Specific and suitable modified games bearing in mind the Gk in the whole team-practice environment, thus it would be interesting to integrate the Gk in the team-possession game phase and to learn specific build-up play patterns (Rico-González, Pino-Ortega, Nakamura, Moura, & Los Arcos, 2020; Soto, Camerino, Iglesias, Anguera, & Castañer, 2019; Sreeraj & Arya, 2021).

Just like the Gk–DEF, DEF–MID linear tactical behavior barely changed after the training intervention (Table 1). This may be related to the shortness of the intervention consisting in a total volume of 84 minutes of differentiated practice distributed in four training sessions. Chow suggested time management as one of the principal challenges in implementing these sorts of NLP approaches because exploratory learning could be time-consuming. So, teachers and coaches should be patient on noticing an effect on linear tactical behavior by manipulating task constraints. However, it seems that short-term modified games intervention could be enough to influence non-linear tactical behavior. As Gk–DEF, experimental DEF–MID trended toward greater regularity (Figure 3), highlighting the need to design representative scenarios that exploit self-organizing processes to encourage youth players' learning (Chow et al., 2007; Cohen, 1960; Rico-González, Pino-Ortega, Nakamura, Arruda-Moura, & Los Arcos, 2020).

As well as Gk–DEF and DEF–MID, MID–F linear tactical behavior barely changed from the pre-test to the post-test

(Table 1), recommending the long-term development of modified games to prompt linear changes (Rico-González, Pino-Ortega, Nakamura, Moura, et al., 2020). In contrast to the other two subgroups based on team lines, there was no clear SampEn trend for MID–F after the training intervention (Figure 3). This could be associated with the unpredictability typical of forwards and the variety of the player profile of this position (Sampaio & Maçãs, 2012). Gonçalves et al. recommended forwards create more irregular movement-patterns and Coutinho et al. developed a ten-week enrichment training program only for young forwards. Similarly to the current study (Table 1), linear outcomes barely changed and *distance* variables (i.e. lateral and longitudinal movement regularity) trended to regularity after the enrichment training program (Sarmento, Anguera, Pereira, & Araújo, 2018). Despite the overall SampEn trends for *point* and *area* were not clear in our study, as Coutinho et al., the mean distance between attacking players trended to regularity after different training programs proper to the NLP framework (Figure 3). This suggests that different training programs that use NLP key pedagogical principles could be implemented to consolidate desired distances between teammates during the team-possession game phase.

Youth-sport academy coaches should introduce artificial rules on their training games to boost the regularity of tactical behavior on youth soccer-team lines during the team-possession game phase. A short period could be enough to encourage young players to learn and strengthen the acquisition of regular tactical-patterns. However, changes in linear outcomes should not be expected.

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Conclusion

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