Heart rate responses and technical-tactical aspects of official 5-a-side youth soccer matches played on soil and artificial turf.

UNIVERSITÀ DEGLI STUDI DI TORINO

Abstract

Using a randomized crossover design, this study aimed to compare the heart rate (HR) responses and match analysis parameters (i.e., type of action; the number of players involved in an action; the number of passes performed in a collective action; precision of the shots; lost balls; ball interceptions; dribblings; and tackles) of official 5-a-side youth male soccer matches played over 2 pitch surface (i.e., clay vs. artificial turf) conditions. Twenty-two young male soccer players (age 8.3 ± 0.4 years) engaged in 2 consecutive 15-minute periods in each experimental condition. During the match, 53% of HR responses exceeded 85% of the individual HR_{peak}. No difference emerged between both pitch surfaces and match periods for HR and match analysis indicators. The two 15-minute periods resulted in being appropriate for 8-year-old players, in resembling the intensity of play and the intermittent nature of adult soccer. The similar HR responses and technical-tactical patterns observed on the 2 surfaces indicate that youth match play is not affected by differences in pitch surface. To support the development of individual and team skills of young soccer players, coaches are advised to prioritize game knowledge based on divergent thinking and experience, rather than traditional teaching based on instructions.

Introduction

Many thousands of young athletes participate in soccer academy worldwide, and only a select few will achieve elite level because of both innate talent and deliberate practice (28). Reporting a limited influence of body size and maturity status on soccer-specific skills of 11- to 14-year-old players, Figueiredo et al. (19,20) claimed that there is a need for further research on potential determinants of performance in young soccer players. To plan effective youth programs for soccer academy, a multidisciplinary approach should be used, including technical-tactical, perceptual, psychological, and physiological contributions to the youth performance (19,20,23,24,29,31,34). Thus, youth soccer trainings should prioritize the development of basic motor abilities, improvement of soccer skills, and increase of the fitness level of young players (8,11,19,40). Accordingly, youth competitions should also be based on a progression, where the demands of the matches are sequentially linked to meet the physiological characteristics of the young players and to facilitate the development of their technical-tactical skills (5,9,10,39).

Considering that competitions pose a higher load on players than training, the main principle adhered to in most football nations is to preserve children from an excessive physiological strain. For this reason, the Italian Soccer Federation has differentiated the rules of youth matches in relation to the age of the children (i.e., 8–12 years) by reducing the number of players (range: 5–9), the pitch (range: 45 ×25–65 × 70 m), and goal (range: 3 × 2–6 × 2 m) dimensions, the ball size (number 4), and the match duration (range: 45–60 minutes, organized in 3 periods) (18). In particular, the first official Italian youth tournament (i.e., “Pulcini”) is organized for 8-year-old players, who engage in 5-a-side matches (i.e., 4 outfield players and 1 goalkeeper) played on a 45 × 25-m pitch (18). Each player has to play at least one of the three 15-minute periods of the match so that some players might engage in two 15-minute periods (18).

Despite the activity patterns and physiological demands of elite soccer players having been studied extensively, the few studies that have investigated prepubescent players during real match play mainly focused on 11- to 12-year-old children playing 11-a-side competitions on a regular pitch (9,10,39). Comparing the cardiovascular responses and the technical-tactical aspects of 11-year-old children during official 11-a-side and 7-a-side competitions, Capranica et

al. (9) claimed that the latter code was more suitable for children, favoring the occurrence for individual players to maintain possession of the ball and to cooperate with teammates performing more passes. Unfortunately, scientific information on younger players at the beginning of the soccer academy is practically nonexistent. This lack of important data may impact upon our understanding of the requirements of different youth soccer codes and hence our ability to develop strategies aimed to promote the potential of children (15).

Traditionally, in Italy, youth soccer matches and training sessions are organized on clay pitches. Because it resists heavy use, requires no trimming, is little influenced by adverse weather conditions, and has reduced maintenance costs (36), artificial turf is more and more used nowadays for official youth competitions. Because the nature and properties of the playing surface are fundamental to the playing characteristics of soccer (i.e., the player-surface and the ball-surface interactions); thus, it could be possible to hypothesize certain playing skill adaptations when teams compete on clay or on artificial turf (36). Considering that the years spent in the soccer academy are crucial for the technical-tactical development of young players, it could be relevant for coaches to know whether HR responses and technical-tactical demands of youth competitions vary in relation to the pitch surface. Recently, the ball skills and movement patterns of elite Swedish players during official matches on artificial turf and on natural grass have been analyzed (1). Despite there being no influence of the type of surface in terms of the total distance covered, high intensity running, and number of sprints, fewer sliding tackles and more short passes were observed when playing on artificial turf with respect to natural grass (1). Furthermore, the players reported that they perceived harder to play on artificial turf, and the authors claimed that there is a need for further research on the HR responses during match play on different pitch surfaces (1). However, it is important to consider that data collection during official matches is severely limited by the strict rules of the sport and by the scarce availability of athletes, who might be reluctant to participate in experimental settings perceiving them as a source of distraction from their athletic performance.

Fortunately, we had the opportunity to have access to physiological and match analysis measurements on young soccer players during official competitive matches. Thus, the aims of this study were as follows: (a) to analyze the 50-a-side match performed by 8-year-old children and (b) to determine whether the HR responses of young players and the technical-tactical aspects of their official matches differ in relation to pitch surface (i.e., artificial turf vs. clay). It was hypothesized that the pitch surface does not affect physiological and technical-tactical aspects of 5-a-side youth competitions.

Methods

Experimental Approach to the Problem

To determine whether the pitch surface affects HR responses of 8-year-old players and the technical-tactical aspects of their team during 5-a-side matches, experimental trials were conducted in a randomized, counterbalanced order so that all the players performed one match on artificial turf and one match on clay pitch surfaces.

When real match play is observed, a high variability emerges in the variables studied, mainly because of soccer performance based on the player's involvement in attacking and defensive movements related to those of the opposing players (22). Furthermore, different skill levels of individual players or of opposing teams and variations in training load or competitive periods

may render difficult data interpretation. Thus, to control for confounding factors, the following criteria were observed: (a) the players had to have at least 2 years of previous soccer training consisting of four 90-minute sessions per week; (b) the experimental sessions included matches played between the same opposing teams over 2 conditions (i.e., clay and artificial turf); (c) the coaches agreed to replicate the same training during the week preceding the matches under investigation, keeping the external training load constant (i.e., frequency and duration of training sessions, which included the same type and duration of drills); (d) matches were organized with a weekly cadence during the midseason (i.e., beginning of March), randomly alternating the 2 pitch surfaces.

For each experimental condition, 6 official 5-a-side matches of the Italian "Pulcini" (i.e., 8-year-old players) Soccer Championship were organized in the afternoon (between 16:00 and 17:00), on dry pitches, with average ambient temperature of 11.7 ± 2.4°C and air humidity of 63.1 ± 4.7%. Because during the three 15-minute periods of the youth 5-a-side match coaches have to observe a turnover of players for at least 1 period (18), the data were collected only on the players who were involved in 2 consecutive periods (total playing time: 30 minutes). During the rest period between match play, the children were provided with water, and coaches encouraged them to drink ad libitum to avoid dehydration.

In team sports, percentages of individual maximal heart rate (HR_{max}) have been used as markers of exercise effort (23,27). In children, several caveats limit the determination of HR_{max}. First, some parents are reluctant to allow their children to participate in laboratory maximal exercise tests when invasive methods are used or some attendant risks might be present. Furthermore, it is not clear whether a child actually reaches a true maximal performance during a progressive exercise test so that the term "peak" should be preferred (21). Second, formulas such as 220 - age or 210 - (0.65 × age) used in adults are not applicable for children, because peak HR is unchanged with age at least until before puberty (35). In this study, individual HR_{peak} was determined as the peak value reached in any of the 5-second periods observed during matches (23). The HR_{peak} values were considered only when yielded values similar to those reported in the literature for coaged children during exhaustive treadmill tests (8,35). Five categories were used to indicate the physical load imposed on athletes during their actual competitions (23,27): (a) >95% HR_{peak}; (b) 86–95% HR_{peak}; (c) 76–85% HR_{peak}; (d) 66–75% HR_{peak}; and (e) <=65% HR_{peak}.

A thorough analysis of match demands couples HR and the analysis of the activity patterns of the players (15), which varies in relation to the age (10), positional role (14,22), the level (30) of the players, the possession of the ball (22), the stages of the competitive season (30,32), and the success of the team (14). At the elite level, movements are classified from 0 km·h-1 (standing) to 30 km·h-1 (sprinting), and time-motion analysis data are collected by means of close-up video recordings of individual players, multicamera video recordings connected to electronic tracking devices, and global positioning satellite system (GPS) portable devices (33). Unfortunately, 2 aspects severely limit sound time-motion analysis in children. First, sophisticated equipments are associated with significant costs that may prohibit these techniques being employed at the soccer academy level. Second, the categories of movements adopted for elite players are not realistic in children because their movement speed is considerably slower. Furthermore, with respect to the high variability observed in the homogeneous population of elite players (22), an even higher interindividual variability is expected in the heterogeneous population of children (30). In fact, a given speed might be moderate for some young players and high for others. Thus, in this study, only a notational analysis was used to evaluate the teams for each period in the 2 experimental

conditions. An offensive action is defined as originating from the moment that a player gains possession for his team until the time that team loses possession of the ball to the opponent (7). The occurrence of the following indicators were considered: (a) type of action (leading or not leading to a shot); (b) number of players involved in an action; (c) number of passes performed in a collective action; (d) precision of the shots (i.e., inside or outside the goal area); (e) lost balls; (f) ball interceptions (i.e., a pass being caught or deviated by an opponent); (g) dribblings (i.e., the maneuvering of the ball around an opponent); and (h) tackles.

Subjects

The Institutional Review Board approved the study performed in accordance with the ethical standards in sport and exercise science research. Before the study, written informed consent was obtained from the children and their parents. Furthermore, 6 coaches, who held the Italian Soccer Federation qualification to coach youth soccer (i.e., Union of European Football Association "B" Licence Diploma, which includes the level 1 Youth Certificate) and had a minimum of 5 years of coaching experience within soccer academies, gave their full support to the study.

Twenty-two young (age 8.3 ± 0.4 years) male outfield (goalkeepers were excluded) soccer players participated in this study. They began their soccer practice at the age of 6 years and belonged to 6 prestigious youth clubs (Lazio Committee of the Italian Soccer Federation), which have developed talent identification projects to select players in this geographic area.

Procedures

Heart Rate Responses during the 5-a-Side Match

The athlete's HR was recorded as average values over 5-second intervals by means of an HR transmitter belt (Team System, Polar, Kempele, Finland) placed on the player's chest. Data stored in the belt were subsequently downloaded onto a portable computer using the specific software (Polar Precision software version 4, Kempele, Finland). Then, the time (seconds) spent in each HR category was calculated.

Match Analysis

The six 5-a-side matches were recorded by means of a video camera (JVC DL 107, Yokohama, Japan) positioned at a side of the pitch, at the level of the division line, at a height of 6 m and at a distance of 10 m from the sideline. The videotape was later replayed (VHS "JVC BR 8600", Yokohama, Japan), and the match analysis parameters were scored. To eliminate any interobserver variation in the measures, the same experienced observer, who has previously analyzed >200 matches, performed the notational analysis. To assess the test-retest reliability, before the study the observer scored a single match twice, each observation separated by 7 days, showing no difference between observations.

Statistical Analyses

Data are presented as means and SDs. The level of significance was set at 0.05. Because data did not meet the requirements for a normal distribution, differences between match period (first vs. second) and pitch surface (clay vs. artificial turf) for the HR responses and technical-tactical indicators were ascertained by means of the Mann-Whitney U test. Cohen's effect sizes (ESs) were also calculated (12), considering ES <=

0.2 trivial, from 0.3 to 0.6 small, <1.2 moderate, and >1.2 large (25).

Results

During the official matches, HR_{peak} values were 210 ± 3 b·min^{-1} (range: 206–214 b·min^{-1}), whereas the mean HR was 174 ± 24 b·min^{-1}. No difference for pitch surfaces and match periods emerged for HR responses and match analysis parameters, which showed low ESs (HR range: 0.04–0.53; match analysis indicators range: 0.08–0.42). Frequency of occurrence of HR responses within the <=65% HR_{peak} and 66–75% HR_{peak} categories was low, whereas higher occurrences emerged for the 76–85% HR_{peak}, 86–95% HR_{peak}, and >95% HR_{peak} intensity of efforts categories (Figures 1 and 2).

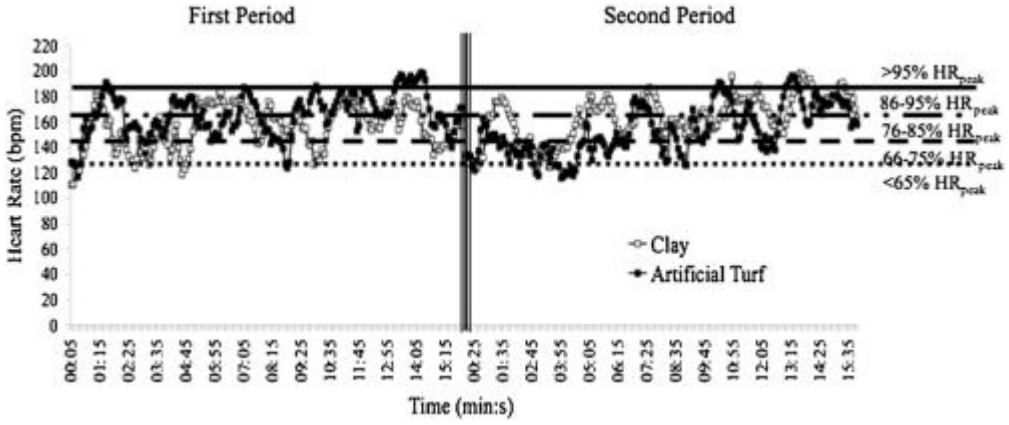

Figure 1. Heart rate responses of an 8-year-old player during the two 15-minute periods of a 5-a-side match played on clay and artificial turf. Horizontal lines indicate the limits of >95% HR_{peak}, 86–95% HR_{peak}, 76–85% HR_{peak}, 66–75% HR_{peak}, and <65% HR_{peak} categories.

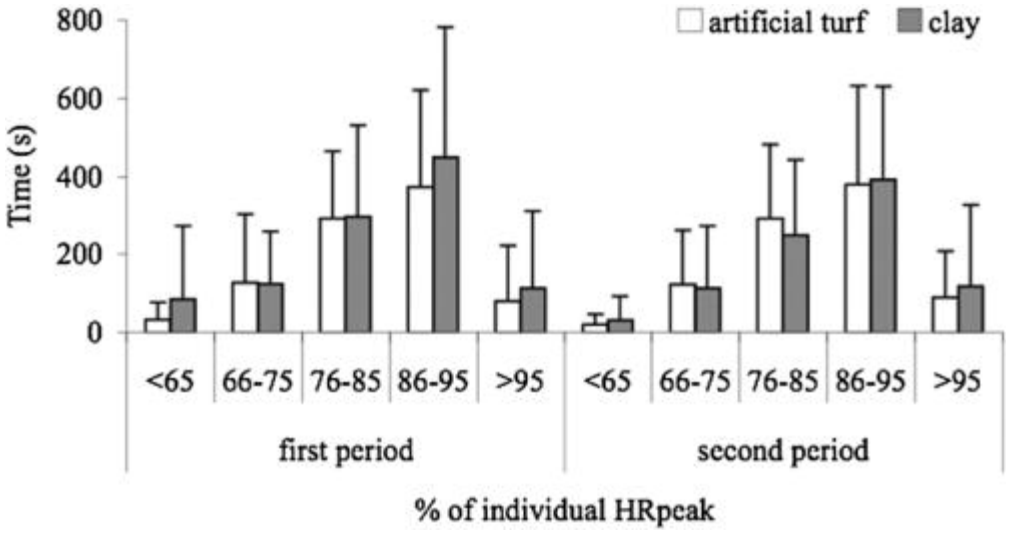

Figure 2. Means and SDs of time spent at intensity of efforts >95, 86–95, 76–85, 66–75, and <65% of individual HR_{peak} during the 5-a-side matches played on artificial turf and clay pitch surfaces.

Regarding the match analysis indicators (Table 1), offensive actions not leading to a shot (68%) showed a higher occurrence with respect to those ending with a shot (32%). In particular, the shots performed inside the goal area (62%) outnumbered the shots outside the goal area (38%). Individual actions occurred less frequently (12%) with respect to collective ones (2–3 players: 84%; >=4 players: 4%), with players performing a limited number of passes (1 pass: 60%; 2 passes: 37%). Compared with interceptions, a higher occurrence of lost balls was observed (ratio 0.84). During the whole match, players performed few

dribblings (range: 0–14), whereas tackles ranged from 5 to 28.

Indicators (*n*)	Pitch surface	
	Artificial turf	Clay
Offensive actions		
Not leading to a shot	18 ± 5	16 ± 4
Leading to a shot	8 ± 3	7 ± 3
Players involved in an action		
1 Player	4 ± 2	2 ± 1
2–3 Players	21 ± 4	20 ± 5
≥4 Players	1 ± 1	1 ± 1
Passes per action		
1 Pass	13 ± 4	12 ± 3
2–3 Passes	8 ± 4	8 ± 4
≥4 Passes	1 ± 1	1 ± 1
Shots		
Inside the goal area	5 ± 2	5 ± 3
Outside the goal area	4 ± 2	2 ± 2
Dribblings	3 ± 2	4 ± 3
Lost balls	39 ± 8	31 ± 9
Tackles	8 ± 5	10 ± 4
Interceptions	28 ± 6	27 ± 6

Table 1. Means and SDs of match analysis indicators recorded during the 15-minute periods of 5-a-side soccer matches played by 8-year-old children on artificial turf and clay pitches

Discussion

To facilitate the development of the technical-tactical skills of very young soccer players and to preserve them from an excessive physiological strain, in Italy, the size of the pitch, the number of players, and the duration of youth soccer codes increase according to the age of the children. This study represents the first attempt to the understanding of the HR responses and technical-tactical aspects of 8-year-old players during their official 5-a-side soccer competitions played under different circumstances (i.e., clay and artificial turf pitch surfaces). The main findings were as follows: (a) 5-a-side matches impose a high cardiovascular load on 8-year-old players; (b) pitch surface does not induce significant differences in the studied HR responses and technical-tactical parameters.

Although the interpretation of the present results might benefit from information on the fitness and skill levels of the children, the parental consent was limited to data collection during the official matches only. However, the sample was drawn from the best soccer academies of the Italian soccer federation and the

inclusion criteria guaranteed that the players had a similar soccer experience (i.e., 2 years of previous soccer training) and training status (i.e., four 90-minute sessions per week). Furthermore, individual peak HR values recorded during match play were similar to those reported in the literature from exhaustive laboratory tests (6,35). Actually, under laboratory conditions, a high interindividual variability in HR_{peak} has been observed, mainly attributed to profound influences of the subject motivation (35). With respect to the general children population, HR_{peak} values of the young soccer players showed a lower variability (35), which might indicate that the young players had a similar fitness level and were highly motivated to play at their best. Thus, these findings support the validity of the present research design, which estimated intensity of efforts from HR_{peak} values recorded during official competitions.

Because exercise during match play is noncontinuous, the diverse yet sustained physical activities determined erratic individual HR profiles (Figure 1). Despite the fact that the studied HR categories help to condense the intensity of efforts, the high SDs observed are likely to be a consequence of relatively large within-players, between-players, and match-to-match variability of the children's performance. Surely, to detect real systematic changes in performance characteristics, large sample sizes and multiple longitudinal observations over an extended period of time are required (15,22). Thus, the present data have only limited use for comparative purposes and are intended mainly to describe HR during youth soccer matches.

In agreement with the literature on youth soccer competitions (5,6,9,10,39), the 5-a-side match posed a high load on the 8-year-old players, who maintained for half of the playing time intensity of efforts >85% of individual HRpeak. In elite players, HR responses <85% and >85% of individual HRmax have been used to estimate the duration of aerobic and anaerobic work carried out, respectively (3). However, such an estimate could be questioned in children who have a relatively higher metabolic contribution from oxidative energy pathways than do adults exercising at the same relative submaximal intensity (35).

Variations in HR responses toward the end of 90-minute elite soccer matches have been reported, attributing increases to thermal stress and decreases to fatigue (2). Considering that even under most environmental conditions of elite match play fluid loss is minimal, metabolite accumulation remains fairly constant, and core temperature does not reach levels considered critical (17), it could be unfeasible to attribute to thermal stress the high HR values recorded in children during the two 15-minute match periods, which were organized under mild environmental conditions (ambient temperature around 12°C; humidity around 63%). In line with the findings of previous studies (5,9,16), the HR showed no difference between the 2 periods, indicating that a 15-minute match play has a duration that does not induce a variation in HR responses during the subsequent 15-minute period, despite the high intensity demands of the 5-a-side competition.

Actually, the intensity of soccer matches should be expressed as a percentage of individual HRmax and by describing the type and the duration of activity patterns of the players (37). Although in this study HR responses could indicate that overall exercise intensity was similar during the whole match, there is a need for further time-motion analysis data to support this speculation. In fact, a limitation of this study was that the single-camera recording frequently did not capture players not directly involved in the action, rendering inconsistent data collection of single player's movement patterns and allowing only sound evaluation of the notational indicators. In the future, the use of GPS may be a viable alternative at the soccer academy level. However, at present, these devices have a low sensitivity over distances <20 m (4), which might be a critical issue when considering that 5-a-side youth matches are played on 45 × 25 m and older children (i.e., 12 years) tend to run <15–25 m when playing on a 100 × 65-m pitch (10). Hopefully, future improvements in time resolution of GPS technology will foster further studies in youth soccer.

The literature (9,10,21) shows that playing 11-a-side matches might not be indicated in the developmental stages of youth soccer and that young and inexperienced players tend to play individual actions or to involve a limited number of teammates (9,38). In this study, the majority of actions involved 2–3 players of the 4 outfield teammates, whereas actions performed by a single player were 12% only. Considering that coaches have to develop the cooperation between young players (38), these findings indicate that 5-a-side matches are suitable for 8-year-old children who tend to play with teammates rather than individually. Furthermore, at this age, no role specialization is present so that collective actions tend to involve different players willing to support teammates. Conversely, the number of players involved in an action leading to a shot remains low (i.e., from 1 to 2). This indicates that young players still have to develop cooperative strategies to assist a teammate to be in the most favorable position to shoot. Furthermore, the lower occurrence of tackles, the higher occurrence of lost possessions with respect to interceptions, and the low involvement in dribbling highlight the fact that 8-year-old players still need to develop individual soccer skills. The present findings show that two 15-minute periods resulted in being appropriate for resembling the intensity of play and the intermittent nature of adult soccer. Furthermore, the reduced pitch dimension and number of players support the development of individual and team skills of young soccer players (9,10).

Under controlled conditions, the player-surface and the ball-surface interactions in soccer have been studied to verify biomechanical and physiological differences (13,26). However, soccer is an open-skill sport, and there is a need of an ecological approach to the study of the competition to determine whether the pitch surface actually affects the player's performance. Recently, Andersson et al. (1) reported that elite soccer players perceived as physically harder playing on the artificial turf with respect to the natural grass, although they maintained constant their movement patterns and technical-tactical parameters of their play. We observed similar HR responses and technical-tactical patterns when children played on the artificial turf with respect to those recorded on clay pitches, coherent with the findings of technical-tactical capabilities of players. These findings might substantiate the development of artificial turf on reproducing the playing characteristics of natural turf (36) and might also justify the continuing growth of artificial surfaces in soccer academies to provide a playing surface being less influenced by adverse weather conditions and regular intensive sport use. Because of the limited sample size of this study, the inherent variability observed in the studied parameters does not allow relying on a single observation of the 2 conditions and further research based on large sample sizes has to substantiate these findings (22). However, comparisons between clay and artificial turf suffer also the difficulty to control for maintenance status, temperature, humidity, moisture content, and frequency of the use of pitch surfaces (36).

Although the group of young soccer players was homogeneous and the official competition was controlled for potential confounding factors, the sample size was limited to 22 players, and the situational nature of soccer cast some doubts on the generalizability of the findings. Thus, future research in this area is strongly recommended even though in studies that investigate real-play situations, it might be difficult to replicate the experimental conditions with large samples. Despite these limitations, the present findings not only provide valuable information on physiological and technical-tactical parameters on youth soccer during real competitions but also suggest that longitudinal studies on different youth soccer codes are strongly recommended to provide researchers and coaches with a better understanding of the development of skills of this sport.

Practical Applications

To provide a competitive environment that could enhance the learning process of 8-year-old soccer players and preserve them from an excessive physiological strain, soccer federations are strongly advised to consider youth codes different from that adopted for adult players. Despite the fact that the studied physiological and technical aspects substantiated a certain suitability of the 5-a-side youth code, findings highlighted the need to develop individual defensive (i.e., tackles) and offensive (i.e., ball possessions and dribbling) technical skills of children and to improve more effective cooperative strategies between teammates. To assist young players to find appropriate solutions to game situations, coaches are advised to prioritize game knowledge based on divergent thinking and experience, rather than traditional teaching based on instructions. The achievement of technical-tactical goals should follow an exercise progression from ball passes between 2 (or more) players with no opposition, to a semiactive and active opposition. Then, to improve ball possessions, quick turnovers, and passes to a well-positioned teammate, the use of 3 vs. 1, 2 vs. 1, 3 vs. 2, and 4 vs. 3 technical-tactical games with simplified rules (i.e., a team with only offensive or defensive duties) should be preferred.

Acknowledgments

The first and second authors equally share the main responsibility for conducting this research work.

References

1. Andersson, H, Ekblom, B, and Krustrup, P. Elite football on artificial turf versus natural grass: Movement patterns, technical standards, and player impressions. J Sports Sci 26: 3–22, 2008.

2. Bangsbo, J. The physiology of soccer-with special reference to intense intermittent exercise. Acta Physiol Scand Suppl 619: 1–155, 1994.

3. Bangsbo, J. Physiology of training. In: Science and Soccer. T. Reilly, ed. London, United Kingdom: E. & F.N. Spon, 2002. pp. 51–64. .

4. Barbero-Alvarez, JC, Coutts, A, Granda, J, Barbero-Alvarez, V, and Castagna, C. The validity and reliability of a global positioning satellite system device to assess speed and repeated sprint ability (RSA) in athletes. J Sci Med Sport 13: 232–235, 2010.

5. Barbero-Alvarez, JC, Gomez Lopezet, M, Barbero-Alvarez, V, Granda, J, and Castagna, C. Heart rate and activity profile for young female soccer players. J Hum Sport Exerc 3: 1–11, 2008.

6. Barker, AR, Williams, CA, Jones, AM, and Armstrong, N. Establishing maximal oxygen uptake in young people during a ramp cycle test to exhaustion. Br J Sports Med. Epub ahead of print, 2009.

7. Bate, R. Football chance: Tactics and strategy. In: Science and Football. T. Reilly, A. Lees, K. Davids, and W.J. Murphy, eds. London, United Kingdom: E. & F.N. Spon, 1988. pp. 293–301.

8. Bunc, V and Psotta, R. Physiological profile of very young soccer players. Int J Sports Med Phys Fitness 41: 337–341, 2001.

9. Capranica, L, Tessitore, A, Guidetti, L, and Figura, F. Heart rate and match analysis in pre-pubescent soccer games. J Sports Sci 19: 379–384, 2001.

10. Castagna, C, D'Ottavio, S, and Abt, G. Activity profile of young soccer players during actual match play. J Strength Cond Res 17: 775–780, 2003.

11. Clumpner, RA. Sport Progressions. Champaign, IL: Human Kinetics, 2003.

12. Cohen, J. Statistical Power Analysis for the Behavioral Sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.

13. Di Michele, R, Di Renzo, AM, Ammazzalorso, S, and Merni, F. Comparison of physiological responses to an incremental running test on treadmill, natural grass, and synthetic turf in young soccer players. J Strength Cond Res 23: 939–945, 2009.

14. Di Salvo, V, Gregson, W, Atkinson, G, Tordoff, P, and Drust, B. Analysis of high intensity activity in Premier League soccer. Int J Sports Med 30: 205–212, 2009.

15. Drust, B, Atkinson, G, and Reilly, T. Future perspectives in the evaluation of the physiological demands of soccer. Sports Med 37: 783–805, 2007.

16. Drust, B and Reilly, T. Heart rate responses of children during soccer play. In: Science and Football III. T. Reilly, J. Bangsbo, and M. Hughes, eds. London, United Kingdom: E. & F.N. Spon, 1996. pp. 196–200.

17. Edwards, AM and Noakes, TD. Dehydration: Cause of fatigue or sign of pacing in elite soccer? Sports Med 39: 1–13, 2009.

18. Federazione Italiana Giuoco Calcio. Circolare n.1 Attività di Base-Stagione Sportiva 2008/2009. Available at: http://www.settoregiovanile.figc.it/evento_attivita.asp?id=22166. Retrieved December 10, 2009.

19. Figueiredo, AJ, Coelho, E, Silva, MJ, and Malina, RM. Predictors of functional capacity and skill in youth soccer players. Scand J Med Sci Sports. Epub ahead of print, 2010.

20. Figueiredo, AJ, Gonçalves, CE, Coelho, E, Silva, MJ, and Malina, RM. Youth soccer players, 11–14 years: Maturity, size, function, skill and goal orientation. Ann Hum Biol 36: 60–73, 2009.

21. Grant, A, Williams, M, Dodd, R, and Johnson, S. Physiological and technical analysis of 11 v 11 and 8 v 8 youth football matches. Insight 3:29–31, 1999.

22. Gregson, W, Drust, B, Atkinson, G, and Di Salvo, V. Match-to-match variability of high-speed activities in premier league soccer. Int J Sports Med. Epub ahead of print, 2010.

23. Helsen, WF and Bultynck, JB. Physical and perceptual-cognitive demands of top-class refereeing in association football. J Sports Sci 22: 179–189, 2004.

24. Helsen, WF, Hodges, NJ, Van Winckel, J, and Starkes, JL. The roles of talent, physical precocity and practice in the development of soccer expertise. J Sports Sci 18: 727–736, 2000.

25. Hopkins, WG. A scale of magnitude for effect statistics. Available at: www.sportsci.org/resource/stats/effectmag.html. Retrieved April 3, 2010.

26. Lees, A and Lake, M. The biomechanics of soccer surfaces and equipment. In: Science and Soccer (2nd ed.). Reilly, T and Williams, AM, eds. London, United Kingdom: Routledge, 2003. pp. 120–135.

27. Lupo, C, Tessitore, A, Cortis, C, Ammendolia, A, Figura, F, and Capranica, L. A physiological, time-motion, and technical comparison of youth water polo and Acquagoal. J Sports Sci 27: 823–831, 2009.

28. Malina, RM. Organized youth sports-background, trends, benefits and risks. In: Youth Sports: Participation, Trainability and Readiness. Coelho, M, Silva, A, J. Figuereido, Elferink-Gemser, MT and Malina, RM, eds. Coimbra, Portugal: Univerity of Coimbra Press, 2009. pp. 2–27.

29. Malina, RM, Eisenmann, JC, Cumming, SP, Ribeiro, B, and Aroso, J. Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13–15 years. Eur J Appl Physiol 91: 555–562, 2004.

30. Mohr, M, Krustrup, P, and Bangsbo, J. Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci 21: 519–528, 2003.

31. Morris, T. Psychological characteristics and talent identification in soccer. J Sports Sci 18: 715–726, 2000.

32. Rampinini, E, Coutts, AJ, Castagna, C, Sassi, R, and Impellizzeri, FM. Variation in top level soccer match performance. Int J Sports Med 28: 1018–1024, 2007.

33. Randers, MB, Mujika, I, Inigo, M, Hewitt, A, Santisteban, J, Bischoff, R, Solano, R, Zubillaga, A, Peltola, E, Krustrup, P, and Mohr, M. Application of four different football match analysis systems: A comparative study. J Sport Sci 28: 171–182, 2010.

34. Reilly, T, Williams, AM, Nevill, A, and Franks, A. A multidisciplinary approach to talent identification in soccer. J Sports Sci 18: 695–702, 2000.

35. Rowland, TW. Developmental Exercise Physiology. Champaign, IL: Human Kinetics, 1996.

36. Stiles, VH, James, IT, Dixon, SJ, and Guisasola, IN. Natural turf surfaces: The case for continued research. Sports Med 39: 65–84, 2009.

37. Stølen, T, Chamari, K, Castagna, C, and Wisløff, U. Physiology of Soccer: An update. Sports Med 35: 501–536, 2005.

38. Stratton, G, Reilly, T, Williams, AM, and Richardson, D. Youth Soccer: From Science to Performance. London, United Kingdom: Routledge, 2004.

39. Strøyer, J, Hansen, L, and Klausen, K. Physiological profile and activity pattern of young soccer players during match play. Med Sci Sports Exerc 36: 168–174, 2004.

40. Wein, H. Developing Youth Soccer Players. Champaign, IL: Human Kinetics, 2007.