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Special Populations: Issues and Considerations in Youth Soccer Match Analysis

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Abstract With advanced technological approaches like Prozone, Amisco and global positioning systems (GPS) becoming available in recent decades, match analysis has become the primary tool to examine physical and physiological demands during match play. Among youth team sports, male soccer players have received most attention by exercise practitioners and researchers. Yet, match analysis in youth soccer has not been as extensively studied as adult match play and there are a number of limitations in the research that has been conducted. Young players are not miniature adults, they possess lower aerobic and anaerobic capacity; limited glycogen stores; less well-developed thermoregulatory responses as well as a greater variation in maturation status. Furthermore, even at an elite level, most youth soccer match play is conducted on training grounds without suitable automated systems integral to professional stadia, thus reducing the ability to collect match data for this population. Therefore, special consideration needs to be taken when conducting a research study with youth players. The purpose of this paper is to review some of the issues and challenges in youth soccer while highlighting areas that would benefit from further exploration and to establish recommendations for coaches and/or researchers when undertaking match analysis. Furthermore, we also aim to highlight some of the key differences between youth and adult soccer players, and elite vs. non-elite youth players.

Keywords Football, Adolescents, Physiology, Global positioning system, Puberty

1. Introduction

Match analysis is recognised as a useful method to examine physiological demands and activity patterns of players by making observations during match-play [1]. In recent years, research into match analysis has increased in line with the development of advanced automated analysis systems such as Prozone® [2–4], Amisco® [5, 6] as well as Global Positioning Systems (GPS) [7–9].

Since Reilly and Thomas's seminal study [1] soccer match demands or work rate have typically been expressed by total distance covered across various match activity categories like walking, jogging, running and sprinting [1, 10]. Modern systems [2–9] allow match performance to be broken into frequencies, durations and percentage spent on each exercise pattern thus enabling the examination of work rate in greater detail. Furthermore subcategories can also be explored, such as fluctuations in exercise intensity [2, 3], physical capacities respective to playing position [5, 6], differences between the two halves of a game, and indications of fatigue through deterioration of work rate, especially towards the end of the game [7]. Analysis of these activities can help to identify players' strengths and/or weaknesses and can help prioritize areas where impro-vement is needed most [11]. As a result, the preparation of the team and individual players can be optimized so as to enhance performance levels.

Soccer continues to be an extremely popular sport around the world. As of 2006, twenty-two million players were identified as youth players with 18.7 million and 2.9 million male and female players, respectively [12]. The overwhelming popularity of youth soccer has generated more detailed attention towards young male soccer players and has subsequently resulted in more match analysis in this group compared with other youth team sports [8–10, 13–21]. The fundamental aim of this analysis is to improve com-petitive performance, and to improve training methods, especially in developmental programs, to enhance pro-gression into the professional game [9, 22, 23]. However, it should be noted that young male athletes face unique challenges in terms of the inconsistency of the velocity of physical growth [24, 25]. Some may have similar maturational status but different chronological ages [26]. This is particularly apparent between 13 to 16 years of age [26]. The transition stages are from childhood to pre-puberty (the period of life immediately before puberty), to adolescents (denoted by physiological changes in the musculoskeletal systems, development of cardiorespiratory

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and reproductive systems of the body) and towards adulthood [24]. It has also been widely reported that adolescents are not, nor should be treated as, mini adults [8, 27–29]. For that reason, we may expect to see different physical performances between young players of different maturational status as well as between young vs. adult players. Clearly, to extrapolate data from adult match analysis (such as speed thresholds) and apply them to youth players is not ideal. To date, to the best of the authors' knowledge, there have been no attempts to discuss the issues and challenges associated with conducting match analysis in youth players. As a result, much uncertainty exists. The purpose of this review is to highlight some of the issues and challenges in youth soccer and explore areas that would benefit coaches or researchers when undertaking match analysis. We also aim to highlight the differences between youth and adult player and elite vs. non elite youth players for further understanding of young players soccer performances.

2. Match Analysis Techniques in Youth Soccer

Match analysis within the sporting domain has progressed since its emergence in 1966 [30]. Nevertheless, the first analysis on soccer only occurred in 1976. The earliest system established in soccer match analysis was the notational system, along with the use of an audio tape recorder [31]. Subsequently, researchers incorporated this method with video recording [30]. Since then, a myriad of techniques have been employed for collecting match data, from traditional hand notation to video recording and sophisticated computer-aided techniques like Prozone and Amisco Pro to Global Positioning System (GPS) [1, 13, 32].

Most of the research studies in youth soccer have used the video recording method (Table 1). There are several possible reasons for this including easily accessible equipment and easy set up. The cameras are usually positioned at the pitch sidelines and close to the corner flags [8, 33]. During match play, the operator moves the cameras so as to focus on the targeted subject(s) [8] and later replays the recording for coding of activity patterns. However, only one to two players can be assessed at a time [8, 16] which is highly inefficient for team analysis and also very time consuming. Additionally, video analysis is unable to provide accurate information on the transition between speed thresholds, especially during high-intensity running [13]. As a result, some activities may be misinterpreted due to human error in data entry and may underestimate total distance covered in a match [13]. Clearly, these drawbacks suggest that this method is not ideal for observing variations in playing positions during match play; the lack of detailed analysis therefore has a knock-on effect on assessing overall team performance. To avoid any inter-observer disagree-ment, a single observer was typically used to quantify each player's match activities [16]. Consequently, the amount of time spent analyzing the match activities of different players is longer because the measurements cannot be performed simultaneously [8].

Modern and advanced technologies like Prozone and Amisco Pro have emerged and are often utilised by professional soccer clubs [3, 32, 34–37]. Such systems pro-vide very detailed analysis and have been validated to analyze the physical demands as well as the technical actions during match play. For instance, they have the capacity to break down each player's total distance covered at different intensities according to playing position, tracking multi-directional movements and the player's movement on or off the ball [3, 32, 34–36]. Additionally, real-time measurements [38] allow coaches or trainers to monitor athletes' performance immediately which helps in making decisions during match play (for example in tactical use of space). Although these systems are capable of providing valid and reliable data, these methods have some limitations for youth soccer. The most prominent drawback is the expense, therefore making it only viable for professional or elite soccer clubs. Moreover, the fixed installation of cameras means that data can only be recorded within the first team's home stadium whereas youth soccer is usually played on training grounds.

GPS units have more recently found applications in youth soccer match analysis (Table 1). This technology has overcome logistical issues and limitations with other fixed equipment, particularly as young players usually compete on a training ground in both elite and non-elite settings [13]. Athletes don the easy-to-use GPS units between their shoulder blades in a custom-made tight-fitting vest [13] prior to match play which draws on signals sent from at least three satellites to locate a signal from a GPS unit's position [39, 40]. Using this information a receiver is able to calculate and record data on position, time and velocity [40]. Similar to Prozone and Amisco Pro this systems tracks automatically, avoids the need to have one track for each player [40] and allows real-time measurements [41, 42]. Even without the real-time measurements, with the ad-vantages of GPS together with the GPS software, analysis can be undertaken in a much shorter time frame and provide a valuable pool of data for understanding players' performance. Indeed, data for each player's total distance covered, amount of time spent [13] and changes in velocity [39] at different intensities can be obtained, suggesting that GPS is a very practical tool in analysing youth match performance. The other advantage of this system is its capacity to monitor and record heart rate (HR) simultaneously according to the movement pattern [37]. Therefore, this allows a variety of functions, including (but not limited to) grading of exercise intensities, indicating the differences in physiological responses either between halves or playing position, preventing overtraining, estimating maximal oxygen uptake ($\dot{V}O_{2max}$) and energy expenditure [16, 43–45].

Nevertheless, although GPS appears to be the most useful method for match analysis, it does suffer from a number of limitations. Firstly, the accuracy of GPS is highly dependent on the sampling frequency [42, 46]. To the best of the author's knowledge, most studies have used 1 Hz and 5 Hz GPS units for young player match analysis (Table 1). In agreement with ealier findings [46, 47], lower sampling rate GPS may provide inaccurate distance travelled in short and high speed running, and also in movements that involve changes of direction. This was further supported by a recent study, suggesting that rapid directional changes degrades validity of the GPS [48]. Using a protocol that simulates running activities in soccer (Loughborough Intermittent Shuttle Test), the authors tested 5 Hz GPS (with interpolated 15 Hz output) on shuttle and curvilinear (running track) movement patterns. It is interesting to note that both trials showed inaccurate estimations of the distance covered (12,780 ± 325.61 m and 13,549 ± 105.45 m to actual distance 13,200 m respectively). It was concluded that as soccer is a multiple-sprint sport and involves multidirectional movement, GPS units with lower sampling frequency (≤5 Hz) are insufficient to accurately measure the distance during match-play. In addition, lower sampling rates produce less data and less detailed analysis. Thus, for the most precise results the use of higher sampling frequency GPS units (>5Hz) is suggested as more sensitivity is provided to the constant changing of direction, as well as improved validity and reliability for measuring total distance covered at changing speeds [48, 49].

Secondly, the GPS method is unable to distinguish between forwards, sideways and/or backward running. In this respect, using GPS together with video analysis could be considered for more accurate and meaningful analysis. Even though video recording has various technological limitations, using the methods in unison may be useful to quantify the frequency of soccer skills undertaken such as passing, dribbling, heading and ball possession as the recordings can be replayed as many times required per analysis.

Previous studies have proven that traditional methods such as notational and video analysis are inaccurate, labor intensive and very time consuming, thus highly inefficient for team analysis. Although automated systems like Prozone and Amisco Pro are superior methods, it appears that GPS technology allows the assessment of young players' movement patterns in an efficient (i.e. time, financial, practicalities) manner whilst also allowing monitoring of internal load (i.e. HR). These factors should therefore be taken into account when analyzing movement patterns in youth soccer. Collectively, GPS demonstrated the most appropriate approach for youth soccer analysis.

3. Unique Challenges for Young Players

The role of match analysis is just as important in young players as it is for adult players. The information can be used for several purposes including talent identification [9], examination of the athlete's readiness to compete, developing training programs that are based on the young players' needs and long-term training interventions [10]. Furthermore, there is a strong relationship between training status and physical performance during match play for young players aged 13 to 18 years [10]. In comparison with adults, youth soccer has not been extensively studied [8–10, 13–19]. So far, only a few studies have examined performance across a range of age groups [9, 13, 15] (Table 1). Understanding the physical demands according to age is essential for developing soccer-specific training and the individual needs that mimic the demands imposed within the game [15]. Additionally, there remains a lack of con-sensus in youth soccer match analysis. Many studies have based their work on adult research. However, young soccer players are not miniature adults and have different physical and physiological processes attributed to soccer performance [50]. These differences are due to lower aerobic and anaerobic capacity, lower glycogen stores, less well-developed thermoregulatory processes and differing maturation levels [29, 51, 52]. Therefore, young players' performances are expected to be different from their adult counterparts.

The intermittent nature of soccer requires a high aerobic capacity to sustain activity over a prolonged period of game time [33]. The available literature suggests that young soccer players cover between 5 to 8 km per match, which is 3 to 4 km less than adults [7, 9, 16, 20–23]. It appears the discriminating factors between young and adults players are disparities in aerobic capacity values as well as limited glycogen stores. In adults, the higher aerobic capacity reflects the higher level of cardiorespiratory fitness the individual has [53] and provides evidence of their ability to maintain performance throughout the duration of soccer games [54]. This may explain the relatively good correlations between aerobic power and distance covered, competitive ranking and quality of play during adult match-play [55, 56]. Furthermore, improvements in aerobic performance has been found to have a positive relationship with time spent in high intensity activity, number of sprints, touches of the ball and an improved recovery during high-intensity activity [57]. The younger population is known to have lower aerobic capacity, which is limited by body size (for example, smaller heart size), and therefore they have lower maximal cardiac output than adults [58]. So far, there is no evidence to support a relationship between aerobic capacity and total distance covered with young players and little is known about the 'trainability' of this population [24]. Malina et al. [26] suggested that sexual maturity was the primary contributor to the variance in intermittent shuttle run peformance. Using the 'stage of pubic hair' (PH) method developed by Tanner [59], they showed that a group of adolescents in PH 5 (adult in type and quantity) covered more distance (2,597 m) than PH 3 (darker, coarser and more curled hair; 2,492 m) and PH 1 (prepubertal; 1,513 m). This finding confirms that aerobic capacity will increase progressively during the maturational process. Nevertheless, after maturation, improvements in aerobic capacity may be more dependent on training [24].

A decrement in distance covered of between 5-18% was observed in the second half relative to the first half [20, 22, 34] regardless of playing position and age group in youth soccer [21, 34]. It has been proposed that fatigue was strongly associated with glycogen depletion and decreased distances covered towards the end of the game for adult soccer players [7]. Young athletes have limited glycogen stores – only 50-60% of adults [29] – and consequently their depletion rate is much faster than in adults [60]. This may also result in smaller distances covered in match play. However, there is no available research regarding this issue for young players during match play. Major limitations in research addressing glycogen depletion for young players include the ethical issues of invasive procedures such as blood sampling and muscle biopsies [24]. Therefore, child-adult differences in energy metabolism during exercise are still not fully known. Moreover, anaerobic power in young players is 50% less than their adult counterparts [61]. Inferior anaerobic capacity results in limited ATP supply during high intensity exercise, lower phosphofructokinase (PFK) activity causing reduced glycolysis [62] as well as lower maturation in muscle fibre distribution [24]. Therefore, we may expect to see less sprinting, slower speed and/or less distance covered in high-intensity activities for young players due to an immature anaerobic capacity [29]. Even so, anaerobic capacity will progressively improve as age increases, primarily by the gains in body size, muscle mass and increased enzymatic activity [24]. Despite this, it has been consistently reported that young players have an ability to maintain high-intensity running performance in both halves [20, 21, 34].

Another concern is that adolescents have anatomical and physiological characteristics which have been reported to impair thermoregulatory responses. These include di-minished sweating capacity, high ratio of body surface area to mass and lower cardiac output [52]. During prolonged soccer match play, young players may have disadvantages compared to adults due to thermoregulatory responses. Particular care must be taken in the preparation for and conduct of sporting activities for adolescents. Therefore, it is recommended that young players hydrate themselves when they have opportunities to do so during soccer matches [29].

As mentioned earlier, differences in soccer perfor-mances may occur due to greater maturity [51]. It was found that elite players were more mature than non-elite youth players when physical and physiological characteristics were compared [51]. Elite players were consistently reported as taller, leaner, more powerful and as having greater aerobic capacity than non-elite players [51]. This is because of maturity related advantages in body size, strength, speed and endurance [63]. This is in agreement with Strøyer et al. [19] (Table 1) who reported significant differences in terms of anthropometric data and $\dot{V}O_{2max}$ values between elite players at the end of puberty (Eep; 172.2 ± 6.1cm, 54.1± 8.2 kg, 63.7 ± 8.5 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$) and players at the beginning of puberty (EbP; 154.1±8.2 cm, 42.5 ± 7.2 kg and 58.6 ± 5.0 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$). Therefore, it can be expected that at the elite level, young players are physically and physiologically more advanced. They are also likely to have better match-running performances.

At this point, it is possible to conclude that young players cover reduced distances, produce a smaller number and frequency of high-intensity activities during match play than adults due to the physiological differences, maturity status as well as shorter duration of playing time during a game. Until recently, the existing research inadequately covered the differences between chronological vs. relative age, elite vs. non-elite youth players and children vs. adults in match analysis. Further information is required to establish more understanding of match-play demands in young soccer players. An alternative approach to assess match performances due to variations in playing time is by correcting the absolute value (total distance) to relative value (distance covered per playing min) thus allowing minute-by-minute analysis of distance run to be compared. As a result, comparisons are fair and equitable and allow more research on these topics to be undertaken. Moreover, recognising the limitation when investigating adolescent exercise metabolism, it is recommended that future research use non-invasive procedures like respiratory exchange ratio (RER) [60] to provide information on substrate utilization while exercising in steady state, or phosphorus nuclear magnetic resonance spectroscopy (^{31}PMRS) to clarify specific metabolism responses during exercise [24,60].

4. Categories of Movements and Speed Thresholds

At present there is no agreement on what movement categories should be coded during match analysis for soccer (Table 2). It is important to understand that there are observed movements which occur for a shorter period of time but still have an important outcome to the game (Table 3). For instance, high-intensity running and sprinting are often crucial for the match outcome such as winning possession of the ball, scoring goals and goal prevention [22]. In addition, although less time is spent engaged in sideways and backward running, jumping, tackling, heading and ball possession (accounting for 1-4% of total match activity time) [16], these activities are still associated with elevations in physiological demands [64] (Table 3). To date, the available literature has not discussed the criteria on selecting the match activities pattern for youth player analysis. In future, researchers may wish to focus on standardizing the movements that are typically observed in youth soccer, therefore acknowledging the standard movements in youth soccer.

Table 1. Distance covered and match analysis techniques in youth soccer match play

Study	Level / Country	Age	n	Number of games	Soccer pitch size	Game Duration	Game Format	Distance Covered [m]	Distance Covered [m] 1st half	Distance Covered [m] 2nd half	Method of measurement
Bucheit et al. [10]	Elite soccer academy (Qatar)	13 14 15 16 17	7 17 10 12 17	42	100 x 70 m	70 min 70 min 80 min 80 min 80 min	11 a side	6549 ± 597 7383 ± 640 8129 ± 879 8312 ± 1054 8707 ± 1101	N/A	N/A	1 Hz GPS
Capranica et al. [16]	Italian Youth Soccer Championship	11	6	2	100 x 65 m 60 x 40 m	N/A	11 / 7 a side	N/A	N/A	N/A	Video
Castagna et al. [8]	Non-elite (Italy)	11	11		100 x 65 m	60 min	11 a side	6175 ± 318	3155 ± 191	2990 ± 246	Video
Castagna et al. [21]	Elite soccer academy (Italy)	14	21	N/A	100 x 65 m	60 min	11 a side	6087 ± 582	N/A	N/A	1 Hz GPS
Goto et al. [9]	English Premier League Academy	9 10	22 11		44.8 x 26	60 min 70 min	6 a side	4356 ± 478 4056 ± 541	N/A	N/A	1 Hz GPS
Harley et al. [13]	English Clubs	U12 U13 U14 U15 U16	22 20 25 21 24		77 x 60 m 99 x 65 m	75 min 80 min	11 a side	5967 ± 1277 5813 ± 1160 5715 ± 2060 6016 7672 ± 2578	N/A	N/A	5 Hz GPS
Mendez-Villanueva et al. [15]	Elite soccer academy (Qatar)	13 14 15 16 17	16 20 17 18 15	42	100 x 70 m	70 min 70 min 80 min 80 min 80 min	11 a side	N/A	N/A	N/A	1 Hz GPS
Nakazawa et al. [14]	High school players (Japan)	16	27	N/A	N/A	60 min	N/A	5140.7± 476.6 5105.6± 459.8	2648.1 ± 292.7 2612 ± 328.3	2492.6 ± 236.8 2493.5 ± 198.1	Mobile GPS Video
Rebelo et al. [20]	Regional Level Portuguese Football League	14 - 17	30	2	N/A	80 min	N/A	6311± 948	N/A	N/A	Video
Stroyer et al. [19]	Elite and non-elite (Denmark)	12Nbp 12Ebp 14Eep	10 9 7	N/A	N/A	60 min 60 min 70 min	N/A	N/A	N/A	N/A	Video

Mean [± SD] values for total distance covered
N/A No data available
Nbp: beginning of puberty, Ebp: end of puberty, Eep: elite players at the end of puberty

The other issue with match analysis in young players is determining their speed zone thresholds (sometimes referred to as speed zones). Similar to match activity patterns, there is no agreement on what speed threshold should be used for this cohort (Table 2). The majority of studies adopted speed thresholds from other studies or from match analysis involving adults (Table 2). Two studies have suggested methods to determine the speed thresholds [9, 13].

Table 2. Match activities and speed thresholds in youth soccer match play

Ref	Match Activity	Speed Threshold
Bucheit [10]	Low intensity running High intensity running Very high intensity running Sprinting	< 13.0 km·h^{-1} 13.1 - 16 km·h^{-1} 16.1 - 19 km·h^{-1} >19 km·h^{-1}
Capranica [16]	Running forwards, backwards and with the ball Walking forwards, backwards and sideways Inactivity (no locomotion) Jumping Ball contact	N/A
Castagna [8]	Standing Walking forward Low intensity running Medium intensity running High intensity running Maximal speed running Walking backward Running backward Running sideways High intensity activity	< 8 km·h^{-1} < 8 km·h^{-1} < 8 km·h^{-1} 8.1 - 13 km·h^{-1} 13.1 – 18 km·h^{-1} ≥ 18 km·h^{-1} ≥ 13 km·h^{-1} ≥ 13 km·h^{-1} ≥ 13 km·h^{-1} ≥ 13 km·h^{-1}
Castagna [11]	Standing Walking Jogging Medium intensity running High intensity running Sprinting	0 - 0.4 km·h^{-1} 0.4 - 3.0 km·h^{-1} 3.0 - 8.0 km·h^{-1} 8.0 - 13.0 km·h^{-1} 13.0 - 18 km·h^{-1} > 18 km·h^{-1}
Mendez-Villanueva [15]	Speed zone 1 Speed zone 2 Speed zone 3 Speed zone 4 Speed zone 5	Below 60% of maximal aerobic speed From 61 – 80% of maximal aerobic speed From 81 – 100% of maximal aerobic speed From 101% of maximal aerobic speed to 30% of anaerobic speed reserve Above 31% of anaerobic speed reserve
Nakazawa [14]	Walking Jogging Running Sprinting Back-walking Back-running	N/A
Rebelo [21]	Standing Walking Jogging Medium intensity running High intensity running Sprinting Backwards running	0 – 0.4 km·h^{-1} 0.4 – 3.0 km·h^{-1} 3.0 – 8.0 km·h^{-1} 8.0 – 13.0 km·h^{-1} 13.0 – 18.0 km·h^{-1} ≥ 18.0 km·h^{-1} 5.0 – 15.0 km·h^{-1}
Stroyer [19]	Standing Walking Jogging Cruising Sprinting	N/A

N/A No data available

Table 3. Time spent (%) in each match activity

			Match Activity							
					Running					
Study	Age	Standing	Walking	Jogging	Low Intenisty	Medium Intensity	High Intensity	Very High intensity	Sprinting	Others
Capranica [16]	11 (7) (11)	4 % 3%	38% 39%			55% 55%		3% 3%		
Harley [13]	12-16						30.4%	11.9%	3.6%	
Goto [9]	9 -10 RT RL	44.2 ± 3.6% 47.0 ± 5.3%		34.5 ± 1.9% 34.3 ± 3.7%		15.4 ± 2.8% 13.3 ± 2.4%	4.5 ± 1.0% 4.3 ± 1.2%	1.2 ± 0.4% 1.2 ± 0.4%		
Stroyer [19]	12 Nbp 12 Ebp 14 Eep	9.6% 3.6% 3.1%	63.9% 57.1% 53. %	-	19.6% 31.3% 34.0%	-	6.8% 7.9% 9.0%	-	-	
Rebelo [21]	15	14.4 ± 5.0%	53.3 ± 8.3%	19.8 ± 4.5%		6.5 ± 2.0%	2.3 ± 1.2%		0.8 ± 0.4%	3.0 ± 1.8% (BWR)
Nakazawa [14]	16		37.8%	16.1%		32.3%			6.8%	3.1% (BWR) 3.9% (BWW)

Mean (± SD) values for time (%) spent in each match activity
7: 7 a side, 11: 11 a side
Nbp: beginning of puberty; Ebp: end of puberty; Eep: elite players in the end of puberty; RT: Retained player; RL: Released player; BWR: Backward running; BWW: Backward walking

The first study by Harley et al [13] used peak velocity (V_{peak}) from a ‘flying’ 10-m sprint which was then compared to relative V_{peak} of senior players (Table 4). Individual V_{peak} values were used to calculate mean V_{peak} for different age groups. This ratio was then applied to the commonly used thresholds (Th-S) for elite senior players:

$$(V_{peak} \div V_{peak} \text{ Group x Th-S})$$

Table 4. Speed Zone Thresholds [m·s^{-1}] by age group calculated from 10 m flying time [13]

	10 m Flying Sprint	<1	<2	<3	<4	<5	≥6
Senior	1.20	0.50	2.00	4.00	5.50	7.00	7.00
U16	1.31±0.06	0.46	1.83	3.66	5.04	6.41	6.41
U15	1.35±0.09	0.44	1.78	3.56	4.89	6.22	6.22
U14	1.51±0.08	0.40	1.59	3.18	4.37	5.56	5.56
U13	1.52±0.07	0.39	1.58	3.16	4.43	5.53	5.53
U12	1.58±0.10	0.38	1.52	3.04	4.18	5.32	5.32
1= Standing, 2 =Walking, 3 = Jogging, 4 = Running, 5= High speed running, 6 = Sprinting							

However, this method makes no attempt to differentiate between different levels of play in youth soccer (elite and non-elite) [13]. Elite youth players are known to have better physiological characteristics than their non-elite counterparts [51]. This is supported by Malina et al [25] and Bangsbo et al [53] who showed that elite players performed significantly better in explosive performance and sprinting ability due to greater maturity [26, 51]. Due to differences in performance capabilities, it would be inappropriate to apply the speed thresholds commonly used with elite adult players to non-elite young players.

Another approach, suggested by Goto et al [9], is where the flying 5-m sprint time was averaged and five speed zones were calculated based on mean average flying sprint speed to produce age-specific speed zones (Table 5). This value was then used to estimate the five speed zones using Team AMS Software (version 1.2, GpSport, Australia). However, the reasoning behind this methodology is vague and the authors [9] do not explain why the calculations were made in that particular order.

There have been no other attempts to determine the speed thresholds for use with young players while other researchers fail to fully acknowledge the significance of categorizing speed thresholds in youth player match analysis. The determination of speed thresholds is an important process for distinguishing exercise at different intensities. Consequently, coding speed thresholds properly may help to reflect the true distances and time spent in each match activity. This is particularly true when analyzing different age groups as sprint performance has been shown to significantly correlate with the age of young players and maturation [65]. Hence, one might expect different speed zones between youth and adult populations, different age groups as well as level of play. A potential benefit of discovering common match activities and speed thresholds is that it becomes possible to make a comparison between studies. Therefore, researchers or coaches can determine the optimal performance levels of youth soccer players across various age groups. However, due to variations in performance characteristics to different level of playing, the speed thresholds should be derived from the speed capabilities of the players.

Table 5. The speed zones for U9 and U10 players presented in [9]

Match activity	Age groups	
	U9	U10
Standing and walking	0.0 – 1.0 m·s^{-1}	0.0 – 1.0 m·s^{-1}
Jogging	- 2.0 m·s^{-1}	1.1 – 2.1 m·s^{-1}
Low speed running	2.1 – 3.1 m·s^{-1}	2.2 – 3.1 m·s^{-1}
Moderate speed running	3.2 – 4.1 m·s^{-1}	3.2 – 4.2 m·s^{-1}
High speed running	> 4.1 m·s^{-1}	> 4.2 m·s^{-1}

5. Positional Demands in Youth Soccer

The use of GPS makes it possible to determine the positional demands in youth soccer [10,15]. As with adults [3, 32, 35] similar trends have been reported for youth players including observations that midfielders covered greater distances than defenders and strikers [21], and centre-backs covered the lowest total distance and underwent the least high-intensity activities in comparison to wingers and strikers [10]. The significant performance variations in positional role may be related to the tasks of that specific position. For instance, midfielders covered more distance probably because of their linking role during match play [21], while wingers and strikers performed more sprints in order to generate space or to create goal-scoring opportunities [10]. However, the positional roles in youth soccer are not well enough understood to be conclusive due to limited match analysis studies in youth.

It was observed that the role of specialization is more apparent in either elite or highly trained players, or players in the late puberty stage [9, 26]. This may be due to physical capacity [10] and indicative of a mature tactical under-standing of position-specific tasks [19]. Meanwhile, role specialization appears to be less important for non-elite or moderate-level players and not applicable for younger age groups (pre-puberty) because younger players tend to use constant effort throughout the match [18]. Several authors have addressed the problem associated with early specialization – the so-called ‘relative-age effect’ [9, 20, 25, 26]. Firstly, selecting players into specific positions may discriminate between players who have greater physical attributes due to higher relative age [25]. It has been consistently reported that players who were born in the early part of the selection years are more likely to be identified as talented players [66]. Currently, physical attributes are considered one of the main influencing factors toward the selection of playing position rather than sports-skills *per se*. It is strongly suggested that players who have insufficient physical capacity because of late maturity, but possess potential for development, should be allowed to play at the highest level to avoid a later drop out [19]. In addition, match play exposure during adolescence is recognised as an important stimulus for the maximal attainable aerobic capacity [67].

Secondly, putting young players into positional play too early is likely to cause loss of physical ability and tactical skills after years of playing in the same position [25]. Moreover, this will restrict players to get more involved in the game. For this reason, young players should be encouraged to play in different positions to promote more versatile playing ability [20], greater involvement with the ball and team-mates and consequently develop a better understanding of the game.

It can be concluded that positional roles are more relevant for older players or at elite level competition. It is recommended that coaches play all of the players in all positions in different games for developmental purposes. With regards match analysis, this will lead to more generalized set of data that best represents the movement characteristics in youth soccer. This should clearly define the physical and physiological demands of the particular age group and diminish the effects of chronological vs. relative age.

6. Rules and Regulations for Youth Soccer

The rules governing soccer are different between adults and children. For youth soccer, the rules are designed to ensure safety, make matches more fun, more evenly matched [29] and to place emphasis on player development. One of the major differences in youth soccer is that rolling substitution [13] is allowed as long as each side has the allocated number of players on the field at once. This helps to maintain the pace of the game and allows children to maintain an optimal performance, unhindered by physiological limitations such as limited glycogen stores [50].

Furthermore, the size of the pitch is smaller, there are fewer players (this is most prominent for the younger age groups, but can also differ between age groups as well), and less playing time in comparison to adult soccer. In addition, the game format usually follows the national guidelines. For instance, the players in the study of Harley et al. [13] followed the rules and regulations outlined by the English Football Association. The U12 and U13 age-groups played on a three-quarter-size (77 x 60 m) pitch and U14, U15 and U16 played on a full-size pitch (99 x 65 m). Moreover, the U12, U13, U14 and U15 played in 3 x 25-min periods whereas the U16 played in 2 x 40-min periods. Meanwhile, in the study of Bucchiet et al [10] the players used Italian Soccer Federation guidelines where youth players were analysed on 100 x 70 m standard outdoor natural grass fields with 11 players per side. Playing time was 2 x 35 min for U13 and U14, 2 x 40 min for U15, U16 and U17, and 2 x 45 min for U18. Consequently, the differences in game format prevented a direct comparison between studies and the different levels of expertise (refer Table 1).

Most of the studies have reported results in terms of absolute values (refer Table 1). However, due to variations in playing time at different age groups as well as use of rolling substitutions, the absolute values alone may provide inaccurate comparisons. Indeed, players that have greater playing time will likely cover more distance than players that play for shorter amounts of time. To rectify this some authors have suggested that distance travelled should be adjusted according to individual match exposure time [10, 13].

A number of studies have reported match analysis data for younger players (≤12 years old) using a regular-sized soccer pitch with 11 players per team [8,11,16]. Only one study observed used appropriate soccer pitch dimensions for younger players [9]. Recently, the Fédération Internationale de Football Association (FIFA) showed that 87% of the voters (FIFA Football Committee) wanted to make pitches smaller and reduce the number of players, particularly in younger age groups (5 x 5 format for U7 and U8; 9 x 9 format for U11 and U12) [68]. It is extremely beneficial to promote appropriate-sized pitches for young players for several reasons. Firstly, it promotes greater involvement in the game, allows more touches of the ball and enables more passes and fewer tackles [16, 20, 38, 39]. This allows children to develop technical skills at an early age as they receive the ball on a regular basis, creates greater opportunity to score goals and encourages active participation for the goalkeepers [69]. Furthermore, it teaches decision making and ensures active concentration and awareness in the game as the ball is never far away. This is because younger age groups have reduced capabilities in terms of 'game understanding' which can be defined as, "the mastering of the rules that govern play and enabling the players to give the best possible response in the match context" [40]. Younger players usually do not know what they are supposed to do in match play; for example, instead of looking for the ball they tend to wait for the ball to come to them [20]. Thirdly, younger players spend a lot of time running and are physically worn out by half time when observed playing on a regular pitch [69]. This may explain the decrease in running distance in the second half compared to the first half [8] and may be associated with glycogen depletion [60]. Finally, young players tend to remain in a small area of the football pitch and it was suggested that this might be due to unsuitable pitch size [too large] or fitness levels of the players [8]. This suggests that different game conditions may show different responses. Playing in a game format which is not age appropriate may have resulted in a substantial loss of specific match analysis information regarding young players. It is essential to gain accurate knowledge regarding the demands of performance, so it can be used to manage physical and physiological demands of the players [70]. Therefore, it is important to investigate young players on an appropriate pitch size so that a true representation of the physical and physiological demands of young players can be determined. In addition, rolling substitution and duration of play are age-dependent factors which may account for discrepancies between studies [13].

7. Conclusions

The limited amount of research regarding young soccer athletes is surprising due to the large numbers of young athletes that train and compete from an early age. The increasing number of soccer clubs developing young players within their academies makes this even more surprising. Even though match analysis data within adults and young soccer players appear similar to a certain extent, the latter experience different physical and physiological demands, match conditions and are subject to differing maturational status. With the advantages of GPS units, the introduction of an age-specific analysis assessment may result in more appropriate and focused training and could help contribute to the optimization of players' performance. Furthermore, future research may also investigate the role of maturation and playing standard to establish a greater understanding on youth soccer performance.

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