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Research article

Development of body composition, hormone profile, physical fitness, general perceptual motor skills, soccer skills and on-the-ball performance in soccer-specific laboratory test among adolescent soccer players

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Abstract
The aim of the present study was to examine the development of on-the-ball skills in soccer-specific laboratory test and to examine how traditional measures of body composition, hormone profile, physical fitness, general perceptual motor skills and soccer skills were related to performance measured in open skill environment among 10, 12, and 14-year-old regional male soccer players (n = 12/group). The measured variables were height, weight, fat, muscle mass, testosterone, 10m sprint, agility, counter movement jump, peripheral awareness, Eye-Hand-Foot coordination, passing skill, dribbling skill and on-the-ball skills (performance time and passing accuracy) in soccer-specific laboratory test. A significant main effect by age was found in all measured variables except in fat, in peripheral awareness and in passing accuracy. In discriminant analysis 63.9% ($\lambda = 0.603$, $F = 4.600$, $p < 0.01$) of the players were classified correctly based on physical fitness and general perceptual motor skills into three ability groups originally classified with performance time in soccer-specific laboratory test. Correlation co-efficient analysis with-in age groups revealed that variables associated with performance time in soccer-specific laboratory test were peripheral awareness ($r = 0.72$, $p < 0.01$) in 10-year-olds; testosterone ($r = -0.70$, $p < 0.05$), dribbling skill ($r = 0.73$, $p < 0.01$) and passing skill ($r = 0.73$, $p < 0.01$) in 12-year-olds; agility ($r = 0.79$, $p < 0.01$), counter movement jump ($r = -0.62$, $p < 0.01$), dribbling skill ($r = 0.80$, $p < 0.01$) and passing skill ($r = 0.58$, $p < 0.05$) in 14-year olds. Corresponding relationships with passing accuracy were weight ($r = 0.59$, $p < 0.05$), fat ($r = 0.66$, $p < 0.05$), 10m sprint ($r = 0.71$, $p < 0.01$) and countermovement jump ($r = -0.64$, $p < 0.05$) in 10-year-olds; Eye-Hand-Foot coordination ($r = 0.63$, $p < 0.05$) in 14-year-olds. The relationship between soccer-specific anticipation time and performance time in soccer-specific laboratory test was significant only in the 14-year-old age group ($r = 0.76$, $p < 0.01$). To conclude, on-the-ball skill performance in soccer-specific laboratory test improved with age and it seemed that soccer-specific perceptual skills became more and general perceptual motor skills less important with age in soccer-specific laboratory test.

Key words: Football, youth, perception, growth, puberty.

Introduction

The most important variables for measuring performance in soccer are physical condition, technical skills and tactical performance (Rosch et al., 2000). General development of physical performance capacity during puberty is well documented in paediatric exercise literature. In research literature, adolescent growth spurt or, more precisely, peak height velocity is used as a milestone for timing the peak development of various physical performance abilities. In western societies, adolescent growth spurt in males occurs at approximately the age of 14. Studies of adolescent males in the general population suggest that speed tasks (e.g. running speed and agility) attain maximal gain before peak height velocity is reached, aerobic power at peak height velocity and power and strength afterwards (Beunen and Malina, 1988; Malina et al., 2004; Tanner et al., 1966). Similar findings, with only minor differences in timing of power and strength gains, have also been reported for both adolescent athletes and soccer players (Mero et al., 1989; Philippaerts et al., 2006).

Perceptual and decision-making factors are essential parts of motor performance in soccer and shouldn`t be ignored when players development is examined (Vaeyens et al., 2007; Ward and Williams, 2003). In general, the ability to process information becomes more efficient with increasing age (Kail, 1991). The actual visual system develops throughout childhood to reach the adult functional level at the age of 10-15 years (Crognale, 2002; Fukushima et al., 2000; Ishigaki and Miyao, 1994). At the same age, children are able to select the relevant information from various sources in the environment (Ross, 1976). On the other hand, expert-novice comparisons have indicated that perceptual motor skills are task-specific and the level of expertise attained by extensive task-specific practice is considered to be more important than the age itself in the development of task-specific skills. (Helsen and Starkes, 1999; Thomas, 1999). Research evidence about task-specificity is also available from youth soccer as Ward and Williams (2003) found elite soccer players to be better than sub-elite counterparts as early as age 9 in soccer-specific but not in general perceptual motor skills.

As a player's physical fitness capacity during puberty is mainly related to that player`s maturity, it has been suggested that the focus in youth soccer should be placed on ball-handling and game skills (Lindquist and Bangsbo, 1991). This suggestion receives support from skill research which has shown that the effect of age and maturation is less obvious in skill tests than in physical fitness tests (Eisenmann and Malina, 2003; Malina et al., 2005; Rosch et al., 2000; Vaeyens et al., 2006). Unfortunately, the measurements of skill development are also more problematic than those of physical fitness since performance in skill tests also depends on physical fitness abilities. Thus, it is difficult to separate the development of actual ball-handling skills from the development of physical performance. This is the case especially in many

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dribbling and passing tests which include a substantial proportion of running. Therefore, it is not surprising that the predictors of successful performance in various skill tests have been shown to depend on measured tasks (Malina et al., 2005).

Previous research has shown that physiological, technical and cognitive skills improve with age when these factors are measured with specific tests that do not include uncertainty. However, it is not clear how young soccer players open skills develop or how traditional tests are related to soccer-specific skills measured in open skill environment. The aim of the present study was to examine the development of on-the-ball skills in soccer-specific laboratory test and to examine how traditional measures of body composition, hormone profile, physical fitness, general perceptual motor skills and soccer skills were related to on-the-ball skills measured in soccer-specific laboratory test. Secondary purpose of the present study was to monitor young soccer players development in body composition, hormone profile, physical fitness, general perceptual motor skills and soccer skills during early puberty.

Methods

The participants of this study were 10-, 12- and 14-year-old male field soccer players (n = 12/group) representing a local club in a city of 160.000 inhabitants. The players' soccer abilities ranged from recreational to international level which means that the players in each age group were more heterogeneous in soccer abilities compared to youth teams in professional clubs. Participants' height was measured by wall-mounted stadiometer. Weight, body fat and muscle mass were analyzed with the body composition analyzer (Inbody 720, Biospace Co., Korea). Serum testosterone concentration was analyzed from venous blood samples (sensitivity 0.5 nmol/l) taken between 7.30 and 8.30 a.m. after 12 hours of fasting (Immulite 1000, DPC Diagnostics Corporation, USA).

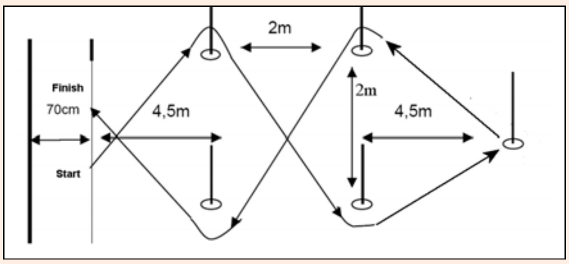

Figure 1. Illustration showing agility test.

Speed (10 m), agility (a figure 8 run) and explosive leg strength (counter movement jump = CMJ) were measured in order to examine players' physical fitness characteristics. A 10m all-out run from a stationary start and agility test were measured with photo cells (Newtest Oy, Finland). A test track recommended by the football association of Finland, in which the participant run forwards a 8-figure, was used as a agility test (Figure 1). Explosive leg strength was measured with CMJ on a jump mat (Newtest Oy, Finland). The best out of three trials was selected for further analysis in all physical fitness tests.

Participants' general perceptual motor skills were measured with peripheral awareness (PAT) and Eye-Hand-Foot coordination (EHF) tests (Coffey and Reichow, 1995; Erickson, 2007). PAT was measured using the Wayne Peripheral Awareness Trainer (Wayne engineering, USA) in which participants stood 60 cm away from the central cylinder, with eight peripheral lights mounted on 50 cm long rods in the cardinal and ordinal directions (Figure 2). Participants were asked to concentrate on the central light in the middle of the cylinder and, using a joystick, respond as quickly as possible to eight peripheral lights that were illuminated in random order. An average time of the eight directions was calculated, with the best out of three trials being selected. In the EHF test (Figure 2), the participants extinguished, in 30 seconds, and in a predetermined manner using their hands (29 lights) and feet (four lights), as many as possible of the randomly illuminated lights in the Wayne Saccadic Fixator (Wayne engineering, USA). Hand positions were pressed with the right or left index finger and foot positions by pressing pedals on the ground (North=forward, East=right, South=back, West=left). The number of extinguished lights was counted and the best out of three trials was selected.

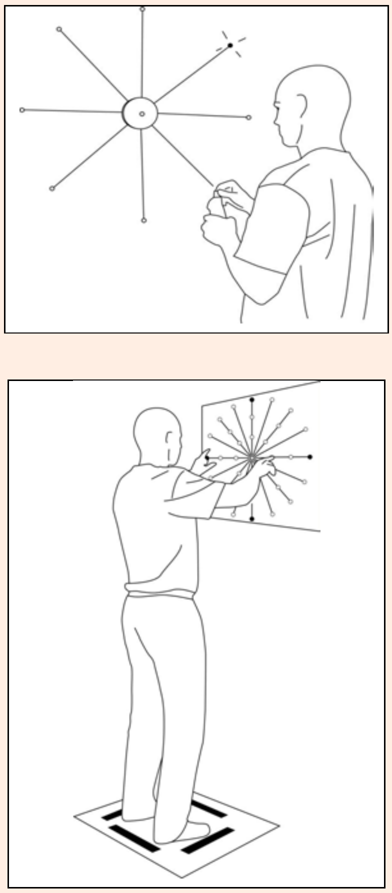

Figure 2. Illustration (top) showing peripheral awareness (PAT) test. Illustration (bottom)showing Eye-Hand-Foot coordination (EHF) test.

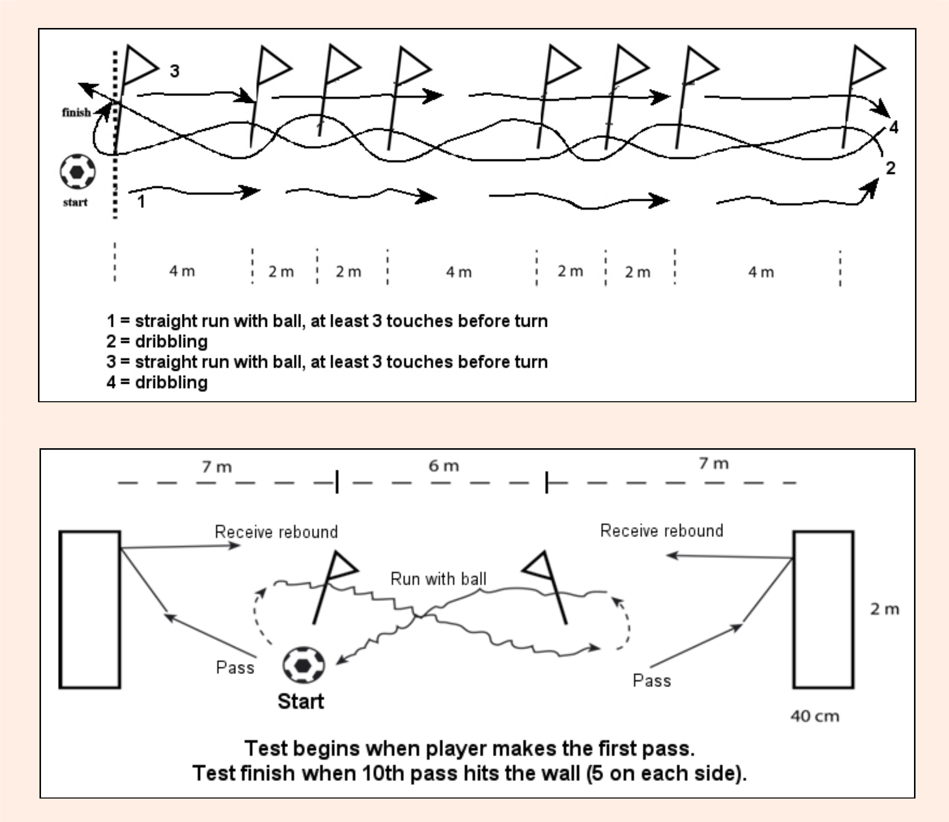

Figure 3. **Illustration (top) showing dribbling test. Illustration (bottom) showing passing test.**

Soccer skills were measured with the dribbling (Figure 3) and passing (Figure 3) tests used in the youth skill competitions in Finland. In traditional soccer skill tests, the participants were also instructed to perform three trials but at least one successful trial was required from each player. Trail was stopped immediately if the ball was lost. More than three trials was needed in 8 cases out of 72 (dribbling + passing) and every player succeeded in five trails. The results of the dribbling and passing test were also combined to variable ∑skill (=passing + dribbling) which was used in part of the statistical analysis and is shown in Table 1.

A laboratory test track (Figure 4) was constructed in order to measure soccer-specific perceptual motor skills in simulated \`on-the-ball\` performance. The test included a chain of typical soccer actions: anticipation, receiving, dribbling, feinting and passing. Firstly, the participant watched a near life-size video sequence (1) of a soccer player receiving the ball, running a short distance towards the participant, and passing to the right or left.

Table 1. **Mean (± SD) for anthropometrical, hormone profile, physical fitness, general perceptual motor skill, soccer skill and soccer-specific labora tory test variables.**

		10y	12y	14y
Anthropometrics	**Height (m)**	1.44 (.06)	1.57 (.11)	1.68 (.08)
	Weight (kg)	33.2 (4.0)	42.3 (8.4)	54.0 (7.8)
	Fat (%)	9.4 (3.5)	9.7 (3.8)	7.8 (3.5)
	Muscle Mass (kg)	15.9 (1.9)	20.8 (4.8)	28.0 (4.1)
Hormone Profile	**Testosterone (nmol/l)**	.15 (.52)	9.78 (7.05)	17.18 (5.72)
Physical Fitness	**10m (s)**	2.08 (.07)	2.02 (.05)	1.90 (.09)
	Agility (s)	7.57 (.22)	7.38 (.17)	7.17 (.16)
	CMJ (cm)	27.8 (4.2)	29.5 (3.4)	35.8 (4.2)
General Perceptual Motor Skills	**PAT (s)**	.36 (.07)	.33 (.06)	.32 (.07)
	EHF (times/30s)	28.8 (3.0)	34.2 (2.5)	36.5 ± 3.3
Soccer Skills	**Dribbling (s)**	29.4 (1.7)	29.0 (1.8)	26.5 (1.3)
	Passing (s)	42.2 (2.8)	39.4 (2.9)	36.6 (2.4)
	∑ Skill (s)	71.6 (4.1)	68.4 (4.5)	63.1 (3.5)
Soccer-Specific Laboratory Test	**Time (s)**	5.62 (.30)	5.54 (.30)	5.28 (.39)
	Anticipation (s)	.17 (.04)	.15 (.04)	.09 (.04)
	Dribbling (s)	2.84 (.25)	2.84 (.20)	2.66 (.19)
	Reaction (s)	.36 (.07)	.33 (.06)	.29 (.07)
	Aiming (s)	1.43 (.26)	1.53 (.16)	1.61 (.33)
	Passing (s)	.82 (.10)	.69 (.09)	.62 (.10)
	Accuracy (penalty pts.)	1.75 (.58)	1.47 (.32)	1.32 (.50)

CMJ = counter movement jump, PAT = peripheral awareness, EHF = Eye-Hand-Foot Coordination

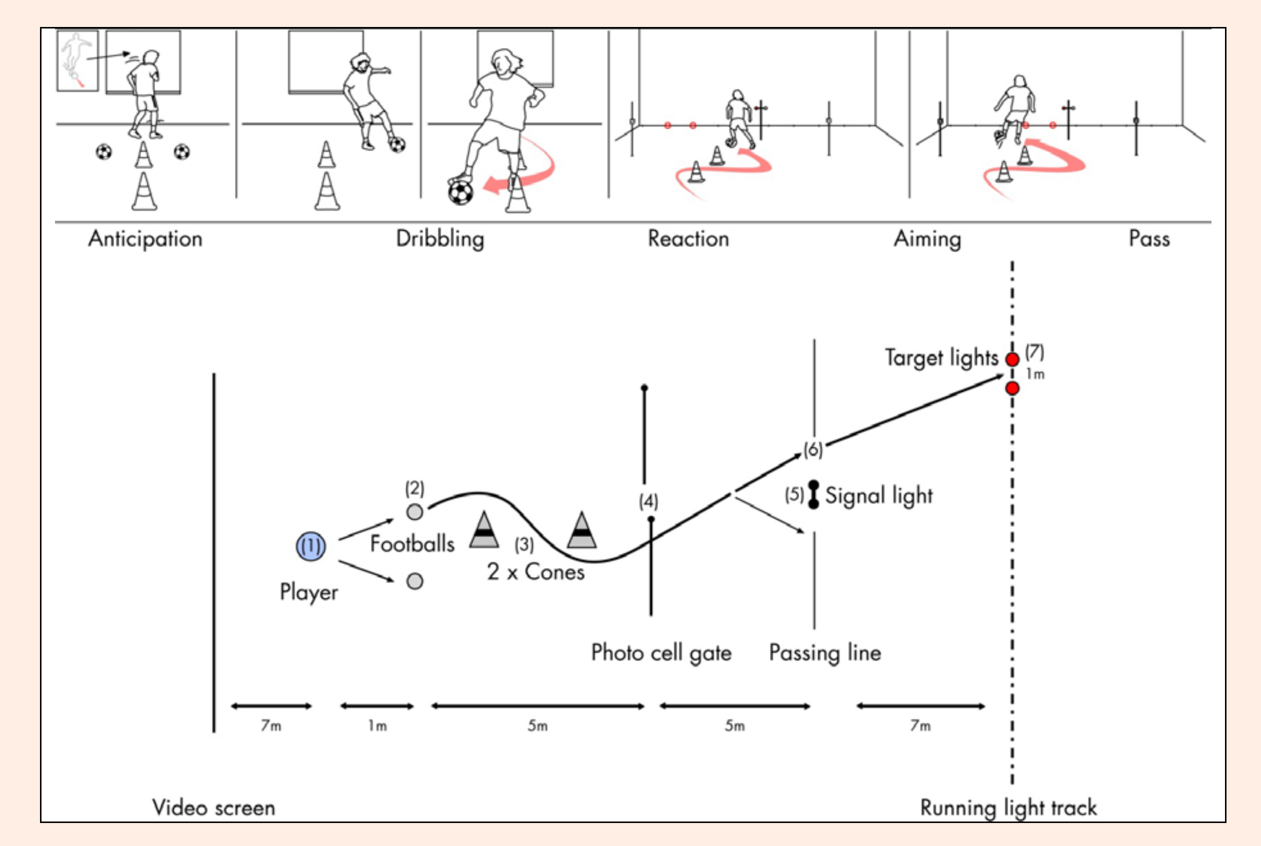

Figure 4. Illustration showing soccer-specific laboratory test.

The player correspondingly anticipated the pass and took the ball (2) located on his left or right hand side. Secondly, the participant dribbled the ball between two cones (3) and through the photocell-gate (4) which triggered a light (5) on the left or right hand side of a pole placed 5m in front of the photo-cell gate. The signal light determined which side of the pole the pass (6) should be given. Thirdly, the participant was instructed to direct a pass between two switched lights in a running light track (7) proceeding at the speed of 4.17 $m \cdot s^{-1}$. The participants were instructed to complete the entire performance as quickly and accurately as possible. In the soccer-specific laboratory test, the participants had 4 familiarization and 16 actual test trials (8 on each side in a random order) with a resting period of 45 seconds between each trial. The trials were recorded with three 50 Hz camcorders and analyzed with the APAS motion analysis software (Ariel Dynamics Inc., USA).

The analyzed variables were:

Anticipation time = the moment from the pass on the video sequence to the first movement towards the ball (video 1; Available from URL http:// http://www.jssm.org/ vol9/n4/video/1).

Dribbling time = time from the first ball touch to the moment of entering the photocell-gate (video 2; Available from URL http:// http://www.jssm.org/vol9/n4/video/2).

Reaction time = time from illumination of the direction stimulus (triggered by photocell-gate) to the moment when the gaze moved away from the stimulus light (video 3; Available from URL http:// http://www.jssm.org/ vol9/n4/video/3).

Aiming time = the moment of removing the gaze from the stimulus light to the moment of passing impact (video 4)

Passing time = the moment from passing impact to the moment when the ball entered the running light track (video 4; Available from URL http:// http://www.jssm. org/ vol9/n4/video/4).

Passing accuracy = "penalty points" according to the distance between the ball and switched light-pair when the ball entered the line of the running light track (0 points = hit, 1 point = one light-pair in front or behind, 2 points = two light-pairs in front or behind , etc.; video 4; Available from URL http:// http://www.jssm.org/ vol9/n4/video/4).

The validity of the test track was examined by comparing adult players of the highest national level (n = 9, 19.7 ± 3.8y) to regional level players (n = 9, 18.8 ± 3.5y) and comparing adolescent players selected (n = 12; 12.5 ± 1.5y) for regional talent camp organized by the national football association with age-matched players not selected (n = 12, 12.6 ± 1.7y). Selection for talent camp was done by youth national team coaches. According to independent samples t-test elite adult players (4.10 ± 0.20s) performed significantly better than sub-elite players (4.73 ± 0.29s) in the soccer-specific laboratory test (t = 6.106, $p < 0.001$, 95%CI 0.41-0.86) and according to discriminant analysis 87.5% ($\lambda = 0.503$, $\chi^2 = 14.758$, $p < 0.001$) of the adolescent players were classified correctly into the appropriate soccer expertise group based on performance time in the soccer-specific laboratory test. Reliability of the soccer-specific laboratory test was examined by analyzing twice the trials from 10 adolescent soccer players (12.6 ± 1.6y). The Pearson coefficient

Table 2. Effects of age for anthropometrical, hormone profile, physical fitness, general perceptual motor skill, soccer skill and soccer-specific laboratory test variables.

		Main Effect			Between age groups (p<)		
		$F_{(2,33)}$	p<	η^2	10y-12y	12y-14y	10y-14y
Anthropometrics	**Height (m)**	22.604	.001	.57	.01	.01	.001
	Weight (kg)	27.937	.001	.63	.01	.01	.001
	Fat (%)	1.203	ns.	.07	-	-	-
	Muscle Mass (kg)	30.866	.001	.65	.01	.001	.001
Hormone Profile	**Testosterone (nmol/l)**	31.778	.001	.66	.001	.01	.001
Physical Fitness	**10m (s)**	21.639	.001	.57	ns.	.001	.001
	Agility (s)	14.023	.001	.46	.05	.05	.001
	CMJ (cm)	13.903	.001	.46	ns.	.01	.001
General Perceptual Motor Skills	**PAT (s)**	1.555	ns.	.09	-	-	-
	EHF (times/30s)	21.371	.001	.56	.001	ns.	.001
Soccer Skills	**Dribbling (s)**	12.102	.001	.42	ns.	.01	.001
	Passing (s)	12.623	.001	.43	.05	.05	.001
	∑ Skill (s)	13.407	.001	.45	ns.	.01	.001
Soccer-Specific Laboratory Test	**Time (s)**	3.378	.05	.17	ns.	ns.	.05
	Anticipation (s)	15.012	.001	.48	ns.	.01	.001
	Dribbling (s)	1.087	ns.	.06	-	-	-
	Reaction (s)	2.895	ns.	.15	-	-	-
	Aiming (s)	1.581	ns.	.09	-	-	-
	Passing (s)	11.402	.001	.41	.05	ns.	.001
	Accuracy (penalty pts.)	2.504	ns.	.15	-	-	-

CMJ = counter movement jump, PAT = peripheral awareness, EHF = Eye-Hand-Foot Coordination

correlation for intra-observer (5.48 ± 0.62s vs. 5.49 ± 0.62s), inter-observer (5.48 ± 0.62s vs. 5.46 ± 0.60s) and test-retest (5.48 ± 0.60s vs. 5.42 ± 0.52s) reliability for the performance time in the soccer-specific laboratory test were 0.93 ($p < 0.001$), 0.86 ($p < 0.001$) and 0.81 ($p < 0.01$), respectively.

Tests were carried out in three separate days during preparation season. First testing day included anthropometrical, hormone profile and physical fitness tests. Second testing day included traditional soccer skill tests and third day general perceptual motor skill tests and soccer-specific laboratory test. Testing days were scheduled to teams training program so that no training took place in the day preceding the tests.

One-way ANOVA with Tukey's post hoc test was applied to detect differences between the age groups. Effect sizes determined with eta-squared (η^2) are reported for interpretative purposes with 0.01 regarded as a small effect, 0.06 a moderate effect and 0.14 a large effect. A stepwise discriminatory analysis (with probability of F: entry = 0.05, remove = 0.10) was applied to determine if combined variables could predict group membership of performance time or passing accuracy in the soccer-specific laboratory test when all players were treated as one group. A grouping variable for discriminant analysis was constructed by categorizing the players in each age group into three groups based on their performance time or passing accuracy in the soccer-specific laboratory test: good (best 25%, n = 9), average (50%, n = 18) and poor (last 25%, n = 9). Combined variables were used as independent variables. These variables were constructed by ranking players in each age group in each of the measured variables (from 1 = best result to 12 = worst result) and combining variables by averaging ranked values to describe muscle-hormone profile (muscle mass, testosterone), physical fitness (10m, agility, counter movement jump), general perceptual motor skills (peripheral awareness, Eye-Hand-Foot coordination) and soccer skills (dribbling, passing). With-in each age group Pearson's correlation coefficient was applied to examine the relationships between single variables and performance time in the soccer-specific laboratory test and between single variables and passing accuracy in the soccer-specific laboratory test. In addition, a linear regression was applied to examine the relationship between anticipation time and performance time in the soccer-specific laboratory test in order to estimate the role of soccer-specific perceptual skills in different age groups.

Approval from the ethical committee of the University of Jyvaskyla and written permission from parents were received before under-age participants were allowed to participate in the tests.

Results

Results of the measured variables are presented in Table 1. A significant main effect by age was found in other measured variables except in percentage of body fat and in peripheral awareness (Table 2). More detailed analysis between consecutive age groups revealed that all other measured anthropometrical, hormone profile, physical fitness, general perceptual motor skill and soccer skill variables improved with age but the differences in 10m, CMJ and dribbling skill in the 10 to 12-year age group, and in EHF in the 12 to 14-year age group failed to attain statistical significance (Table 2).

In the soccer-specific laboratory test, a significant main effect by age was found in performance time, anticipation time and passing time (Table 2). In reaction time, the differences just failed to attain a level of significance ($p = 0.069$). More detailed analysis between age groups revealed that in performance time ($p < 0.05$) and in passing time ($p < 0.001$), the 14-year age group was faster than the 10-year age group and, in anticipation time, was faster than the 10-year age group ($p < 0.001$) and the 12-year age group ($p < 0.01$). Only significant

Table 3. Correlation coefficients between soccer-specific tests variables (time and accuracy) and anthropometrical, hormone profile, physical fitness, general perceptual motor skill and soccer skill variables in different age groups.

		Performance time			Passing accuracy		
		10y	12y	14y	10y	12y	14y
Anthropometrics	**Height**	-.53	-.36	.10	.30	.06	.38
	Weight	-.31	-.24	.18	.59*	-.10	-.28
	Fat	.21	.02	-.02	.66*	-.47	-.24
	Muscle Mass	-.41	-.25	.17	.39	-.00	-.18
Hormone Profile	**Testosterone**	-.22	-.70 *	-.10	.07	-.17	-.11
Physical Fitness	**10m**	.57	-.05	.52	.71 **	-.26	.07
	Agility	.34	.03	.79 **	.35	-.02	-.21
	CMJ	-.35	.21	-.62 *	-.64 *	-.21	.03
General Perceptual Motor Skills	**PAT**	.72 **	.48	.33	-.13	.25	.08
	EHF	.17	-.35	-.44	-.43	-.10	.63 *
Soccer Skills	**Dribbling**	.13	.73 **	.80 **	-.01	-.27	-.26
	Passing	-.04	.73 **	.58 *	-.06	-.21	-.24
	∑ Skill	.02	.75 **	.70 *	-.04	-.24	-.26

CMJ = counter movement jump, PAT = peripheral awareness, EHF = Eye-Hand-Foot Coordination, * $p < 0.05$, ** $p < 0.01$.

difference between 10 and 12-year groups was found in passing time ($p < 0.05$). An example of 10-year-old and 14-year-old players' performance in the soccer-specific laboratory test is presented in video 5, in which overlay video technique is used to demonstrate typical differences between these two age groups (Video 5; Available from URL http://http://www.jssm.org/vol9/n4/video/5). In overlay video, players' performances were time synchronized to the moment when the passing impact on the video screen coincided with the original videos.

Based on discriminant analysis 63.9% ($\lambda = 0.603$, $F = 4.600$, $p < 0.01$) of the players were classified correctly based on physical fitness and general perceptual motor skills into three ability groups originally classified with performance time in the soccer-specific laboratory test. Combined variables were not able to classify group membership of passing accuracy. With-in each age group the relationships between single variables and performance time in the soccer-specific laboratory test as well as the relationships between single variables and passing accuracy in the soccer-specific laboratory test are presented in Table 3. The relationship between anticipation time and performance time was significant only in the oldest, 14-year age group ($r = 0.764$, $p < 0.01$) as presented in Figure 5.

Discussion

Hormonal changes during growth, especially increased testosterone secretion at the age of around 12 years (Winter, 1978), leads to peak height and weight velocity in boys at the age of around 14 years (Tanner et al., 1966). Increased testosterone secretion also promotes nerve conduction velocity by neural growth and myelination (Tan, 1996). As adult-like vision and the brain structure also develop well through adolescence (Crognale, 2002; Fukushima et al., 2000; Ishigaki and Miyao, 1994; McGivern et al., 2002), it is clear that every part of the simplified information-processing chain (stimulus detection - information processing - motor response; Schmidt and Lee, 2005) undergoes marked changes during growth. Changes in body composition and hormone profile among regional soccer players in the present study followed a well-known pattern. Serum testosterone concentration increased from practically zero to approximately 75 % of that found in adults and the muscle mass was almost doubled between 10 and 14 years. At the same time, physical fitness, general perceptual motor skills and soccer skills improved but differences were observed concerning the timing and magnitude of this improvement in different measured variables.

A significant difference between 12 and 14 year groups was found in all measured physical fitness variables (speed, agility and explosive leg strength) but only in the agility between 10 and 12 year groups. Acceleration in the development of speed and explosive leg strength between 12 to 14 years was likely to be related to changes in body composition, especially growth of the muscle mass, which increased almost 35% from 12 to 14 years. More constant development pattern in agility can be explained with coordination skills which were required more in the agility test than in the speed or in the explosive leg strength test. If nothing else, a significant difference found in agility between younger age groups was in line with the results of Eye-Hand-Foot coordination test in which a significant difference was found only between younger age groups. Nevertheless, results of the physical fitness tests suggested that the improvement was faster between 12 and 14 years compared to 10 to 12 years which are in agreement with the previous research data suggesting an adolescent acceleration after 13 years of age in physical fitness (Malina et al., 2004).

Contrary to the tendency found in physical fitness, the results in the 12 and 14 year groups were close to each other and better than the 10 year group in general perceptual motor skills. Development of general perceptual motor skills was likely related to the development of the nervous system which is known to attain more than 95% of its total size before 12 years of age (Malina et al., 2004). It was also worth noting that no significant differences between age groups were found in peripheral awareness requiring mostly stimulus detection, but the difference existed in the more demanding Eye-Hand-Foot coordination task in which information processing and motor responses were pressured. This indicated that the two older groups were more efficient than the 10-year group in processing information (brains) and/or producing faster motor responses (nervous system + muscles).

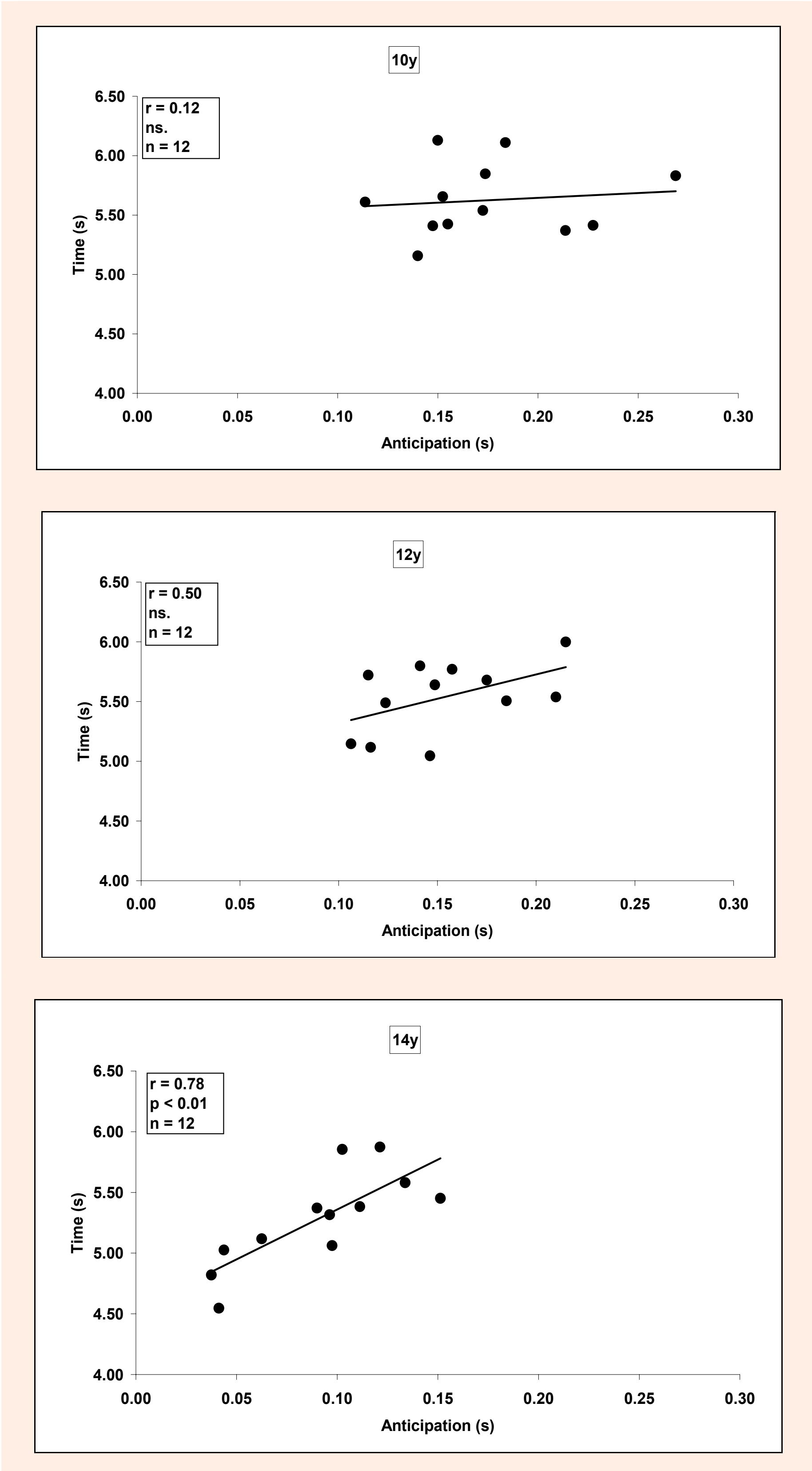

Figure 5. Relationship between soccer-specific perceptual skill (anticipation time) and performance time in soccer-specific laboratory test in different age groups.

Performance in soccer skill tests is influenced by many physiological, biomechanical and psychological factors as well as chronological age, playing experience, maturity status and tests used (Malina et al., 2005; Rosch et al., 2000). Because both traditional soccer skill tests used in the present study involved at least a moderate amount of running, it is likely that a substantial proportion of improvement was growth related development in physical fitness rather than improvement in ball-handling skills. However, individual differences in ball-handling skills were also observed. The most skilful player in the 10-year and 12-year group was also among the top three performers in the upper age group. This indicated that these players possessed more than a two-year advance in actual ball-handling skills since a similar advance was not present in the physical fitness capacity. In the process of identifying talent, the importance of measuring basic ball-handling skills at early puberty needs to be emphasized, because previous research has shown that time spent in individual practice reaches its maximum approximately at the age of 12 years (Ward et al., 2007). After that, training will be orientated more on game skills and the tactical aspects of the game, which means that the basic ball-handling skills required in elite-level soccer will be difficult to attain.

In the soccer-specific laboratory test, a significant difference between age groups was found in total performance time, in anticipation time and in passing time. Anticipation time to soccer-specific stimuli was almost twice as long in the 10-year age group as it was in the 14-year age group. Similar improvement during growth in the ability to anticipate intentions based on postural cues, have also been reported in racket sports (Abernethy, 1988; Tenenbaum et al., 2000). Reaction time to stimuli evoked during dribbling was approximately the same as that found in the general peripheral awareness test, which suggests that simultaneous ball-handling did not weaken the ability of the 10 to 14-year-old soccer players to perceive information from the environment. Aiming time was the only phase in the soccer test in which the performance time increased with age which was probably one reason why passing accuracy also improved slightly, although not significantly, with age. Thus it seemed that older players were able to make a better strategic decision in balancing their performance between speed and accuracy, which is consistent with previous findings suggesting that experienced athletes are better in monitoring performance and using regulatory strategies than novices (McPherson and Vickers, 2004). Passing time decreased with age, i.e. older players gave faster passes than younger ones. However, the difference in passing time between 12 and 14 year group was not significant which was contrary to be expected based on results in physical fitness and traditional soccer skill tests. It might be that the 14 year players used better regulatory strategy also in this phase of the soccer-specific laboratory test and deliberately reduced passing speed in order to achieve better outcome.

Passing into a constant speed target like in the soccer-specific laboratory test used in the present study is something that is not actually done very much in real soccer which was likely one reason why differences between age groups in passing accuracy were not significant. In real game successful passing event requires co-operation between two players - one giving the pass and one receiving the ball. This means that the player receiving the ball can also adjust his/her speed with the game flow and the player who is passing must predict teammates` speed with relation to game flow. However, even though current soccer-specific laboratory test failed to demonstrate differences between age groups, it is obvious that passing the ball to moving player is important skill in soccer and should be considered when skill tests are developed.

When all players were treated as one group, it was found that physical fitness and general perceptual motor skills were the best variables to predict performance time in the soccer-specific laboratory test. Physical fitness characteristics is widely acknowledged to be important factor in soccer (Reilly et al., 2000; Rosch et al., 2000) but divergent conclusions about the role of general perceptual motor skills are found in the research literature. According to cognitive sport psychology research, the motor abilities are task-specific and therefore experts do not possess superior general perceptual motor skills (Ericsson and Lehmann, 1996; Helsen and Starkes, 1999; Henry, 1958; Starkes and Deakin, 1984; Ward and Williams, 2003) but sport optometric research suggests otherwise (Loran and Griffiths, 1998; Sillero Quintana et al., 2007; Stephenson, 2007; Stine et al., 1982; West and Bressan, 1996). The results of the present study suggested that deficits in general motor abilities may partly explain why certain players do not progress as fast as others in regional-level soccer team but the rationality to test these skills on full-scale is doubtful because their importance seemed to diminish with age as will be discussed later.

Correlation coefficient analysis with-in age groups revealed that in the 10 year group the peripheral awareness was only variable to be associated with performance time in the soccer-specific laboratory test. This suggest that the development of basic information processing still underpins the effects of soccer-specific training, especially, if the players training background is rather similar. Passing accuracy in the 10 year group was found to be associated with tasks requiring speed, i.e. 10m sprint and counter movement jump. As younger players strategy tended to be more into "full speed than correct timing", it might be that only the quickest players were able to create enough time for themselves to attain balanced passing posture which then led to better passing accuracy. In the 12 year group, the players who were skilful and demonstrated more matured hormone profile performed better in the soccer-specific laboratory test. Similar results have been found in previous research which has shown that parameters associated with physical maturity are also associated with players` performance profile (Gil et al., 2007). In the 14 year group, physical fitness tests and traditional soccer skill tests were associated with performance time in the soccer-specific laboratory test which suggests that the 14 year players were able to transfer their existing potentiality into real-like action performed in open skill environment.

The results of the present study also suggested that soccer-specific perceptual skills became more important with age and general perceptual motor skills less so. In the 10-year-old group, general peripheral awareness explained 50 %, but soccer-specific anticipation time only 1 %, of the variance in performance time in the soccer-specific laboratory test. By the age of 14 years, these relationships had reversed. Soccer-specific anticipation time explained 61 %, and general peripheral awareness only 11%, of the variance in corresponding performance time. In practice, this means that the 10-year-old players were able to compensate weaker game-reading skills with better motor skills, but this was no longer the case with the 14-year-old age group. In addition, in the 14 year group better Eye-Hand-Foot coordination was actually associated with worse passing accuracy. These results confirms earlier suggestion that specific types of activities in sport training lead to the acquisition and development of sport-specific perceptual motor skills which are not directly related to general perceptual motor skills (Ward et al., 2007; Ward and Williams, 2003).

Conclusion

To conclude, a well-known, age-dependent development pattern in physical fitness and in soccer skills among adolescent soccer players was found in the present study. Although general and soccer-specific perceptual motor skills also developed with age, it seemed that soccer-specific perceptual skills became more important with age and general perceptual motor skills less important. Nevertheless, more research is warranted in order to understand the development of general and soccer-specific perceptual motor skills during growth. In addition, research lay-out in the soccer-specific laboratory test used in the present study was very simple compared to those situations that players have to face in the real game. Soccer-specific laboratory test involved some uncertainty compared to traditional soccer skill tests but was still a test from pre-determined start to pre-determined finish. In real game each player possess unique starting situation which is then followed by decisions and motor actions affected by the actions of teammates and opponents. Decisions and actions in the game are also influenced by the team`s playing style and tactics selected. Therefore, more research is also needed in order to develop tests that measures essential soccer skills in more game-like simulation or even in the game itself.

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Key points

- Physical fitness characteristics and general perceptual motor skills predicted performance time of the open skill soccer-specific laboratory test in the group of 10-14 year-old regional soccer players.
- Before puberty the players were able to compensate weaker soccer-specific skills with better general physical performance abilities.
- Soccer-specific skills became more important with age and at the age of 14 the players were not able to compensate soccer-specific skills with general physical performance abilities.
- Beside basic ball-handling skills it also important to recognize the importance of soccer-specific perceptual skills (anticipation and reaction) as a part of successful soccer performance.

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