THE RELATIONSHIP BETWEEN ENDURANCE CAPACITY, GAME PERFORMANCE AND ESTIMATED ACCUMULATION OF FATIGUE IN YOUNG FOOTBALL PLAYERS

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ABSTRACT

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Aerobic fitness is an important factor in football. However, there is still a lack of knowledge considering the relationships between endurance capacity, game performance and game intensity in young football players. Thus, the purpose of this study was to examine these relationships and to gather more detailed information about the game actions, intensity and accumulation of fatigue in youth football.

The subjects of the study were 11- (B-11, N = 12, height 1.46 ± 0.06 m, weight 35.1 ± 4.2 kg), 13- (B-13, N = 11, 1.59 ± 0.09 m, 46.5 ± 6.0 kg) and 15-year-old (B-15, N = 8, 1.71 ± 0.06 m, 60.4 ± 9.1 kg) young football players playing in a Finnish club team. The subjects' aerobic capacity (VO_{2max}) was tested on a treadmill test and estimated from the Yo-Yo Endurance Test Level 1-result. The players played an 11-a-side test match in their own age group, during which their heart rate was measured. The number and outcome of players' game actions were analysed using notational analysis system and players' average oxygen consumption during the match was estimated based on the heart rate data.

It was found that VO_{2max} of the players did not have a significant effect on the number or outcome of young players' game actions. However, in the players with lower VO_{2max} a statistically significant decrease in average heart rate ($p < 0.05$) and in relative average heart rate ($p < 0.01$) was observed between the halves. In the players with higher VO_{2max} only a borderline ($p = 0.054$) decrease was observed in relative average heart rate between the halves, indicating that the young players with higher VO_{2max} were better able to maintain their game intensity. In the players with higher VO_{2max} the average physical load of the game was also lower. Furthermore, it was found that the game intensity decreased significantly between the two halves due to accumulation of fatigue and that game intensity measured as relative heart rate gradually increased with increasing age.

Based on the current findings the endurance capacity of the young players seems to have an effect on the game intensity and that the average physical load during the game is lower in the players with higher endurance capacity. Thus, it may be suggested that some type of endurance training could be carried out in young football players. However, the emphasis in training should still be on developing skills and game understanding as the endurance capacity of the players did not seem to affect on the number and outcome of game actions. Small-sided games and football-specific interval training should be preferred, as those have been documented to improve endurance capacity, but also similarly skills and game understanding.

Keywords: football, young players, game intensity, game actions, endurance capacity, fatigue

CONTENTS

1 INTRODUCTION

Aerobic fitness is an important factor in a football match and it has been documented that high aerobic power (VO_{2max}) correlates with work rate during a match (Reilly 1997). Higher Vo_{2max} allows the players to run longer and faster and to be more involved in various actions of the game (Stølen et al. 2005). It has also been documented that aerobic capacity influences the match performance of the young players (Helgerud et al. 2001). High aerobic capacity also helps the players to recover better from high-intensity actions and intermittent exercise, typically observed in a football match (Reilly 1997).

However, in the Finnish training system the coaches have somewhat been afraid of including endurance training to young players training program even though research evidence evidently support it. There is also still a lack of knowledge about the game performance, intensity and match actions of the young football players as most of the research has been carried out in adult male players.

Moreover, so far most of the studies examining the effect of endurance capacity on game performance in football have concentrated on investigating the correlations between the movements profiles and maximal oxygen uptake of players. Less information is available about the relationship between the endurance capacity and on-the-ball actions in football, especially in young players.

The purpose of this study was to investigate if endurance capacity of Finnish young football players is related to their game performance during a 90-minute football match. Furthermore, the aim was to gather more detailed information and to describe the game actions and intensity and youth football. The purpose was also to examine if there is some relationship between the endurance capacity of the players and the amount and nature of fatigue they gain during a match. This study is part of a research project carried out in the Research Institute for Olympic Sports (KIHU) which follows the development of young football players in two years period.

2 PHYSIOLOGICAL ASPECTS OF FOOTBALL

Football is mainly an aerobic sport that includes frequent bouts of physical activity. During a single football match the players perform different types of actions ranging from standing still to maximal running, from jumping to tackling and from passing to shooting. (Bangsbo 1993.)

Time-motion analysis has been used extensively in the analysis of activity patterns and physical aspects of football and it has been reported that in the top level the players cover a total distance of 9-12 kilometers during a match (Ohashi et al. 1988, Bangsbo et al. 1991, Bangsbo 1994, Mohr et al. 2003, Burgess et al. 2006). Furthermore, it has been reported that each player completes about 1000-1100 activities in a match and there is a change in activity every 4-6 seconds (Bangsbo et al. 1991, Mohr et al. 2003).

2.1 Game intensity in football

The average work intensity in football, measured as percentage of maximal heart rate, has been reported to be close to the anaerobic threshold. Bangsbo (1993) reported an average heart rate of 159 beats/min for Danish league players. In the study by Strøyer et al. (2004) the mean heart rate in ten nonelite and nine elite players in their early puberty and seven elite players in their late puberty was 162/157, 177/174 and 178/173 in the first and second half, respectively. Furthermore, in the study by Helgerud et al. (2001) the average heart rate in elite junior players (n=8) was 82.6 % ± 4.1 of maximal heart rate and in the study by Capranica et al. (2001) players' (11 yr) heart rate exceeded 170 beats/min for 88 % of the playing time in the first and 80 % of the second half.

There haven't been many studies in which oxygen uptakes during a football match would have been measured accurately and reliably. Ogushi et al. (1993) measured actual oxygen uptake from two players during a game using the Douglas bags weighting 1200 grams. The values of actual oxygen uptake were 35 and 38 ml/kg/min in the first and 29 and 30 ml/kg/min in the second half. The values corresponded to 56 and 61 % and 47 and 49 % of VO_{2max}. These values are in contrast with the findings by Strøyer et al. (2004) who found the oxygen uptake to range from 70 to 80 % of VO_{2max} when estimated from the measured heart rate. Thus, it could be suggested that in the study by Ogushi et al. the equipment used limited the performance of the players, especially as the distances covered during the game were shorter when wearing the Douglas bags (Table 1).

TABLE 1. The average distance covered and the distance covered wearing Douglas bags in 5 min average period. (Modified from Ogushi et al. 1993)

	Average (m/5 min)		**Wearing Douglas bags (m/ 5 min)**	
Subject	**1st half**	**2nd half**	**1st half**	**2nd half**
A	755	561	685	460
B	483	603	381	610

Another method to measure game intensity and indirectly to measure oxygen uptake during a game is to measure heart rate during a game and to establish the relationship between heart rate and VO_2. Bangsbo (1993) has suggested that the relationship between the heart rate and oxygen consumption is valid for intermittent exercise and, thus, for football as well. Using this estimation, Bangsbo found that the average oxygen uptake was 70 % of VO_{2max}. Furhermore, like already mentioned Strøyer et al. (2004) found the game intensity to range from 70 to 80 % of VO_{2max} in young football players.

2.2 Anaerobic periods in football

Despite being mainly an aerobic sport, there are periods in football which require anaerobic metabolism such as short sprints, jumps, tackles and duals (Stølen et al. 2005). It has been reported that for elite male players, the total duration of high-intensity activities during a game is about 7 minutes (Bangsbo 1991).

Stølen et al. (2005) presented the lactate profiles of elite and non-elite football players in two halves of the game in their study (figure 1). In general they concluded that the elite players place more demands on anaerobic energy system than the nonelite players and that the lactate concentrations are lower in the second half when compared to the first one. (Stølen et al. 2005.) Similar blood lactate concentrations have been observed for example in the study by Krustrup et al. (2006) where the blood lactate values were 6.0 ± 0.4 and 5.0 ± 0.4 mM in the first and the second half, respectively. However, the lactate concentrations measured in football are highly dependent on the activity patterns performed by the player just before the blood sampling and lactate concentrations can be very high at certain times during the game (Bangsbo 1993).

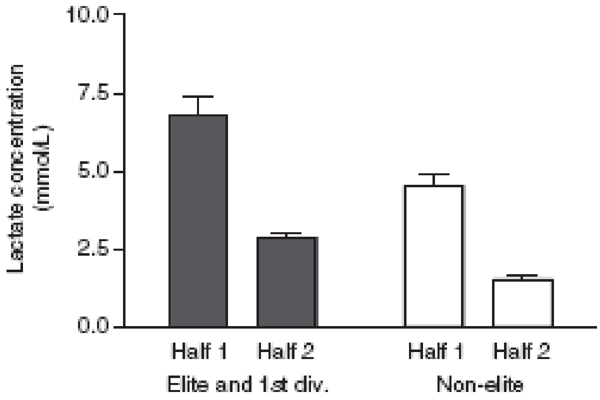

FIGURE 1. Blood lactate concentration in elite and non-elite football players in both halves of the game (Stølen et al. 2005).

2.3 Accumulation of fatigue during a football match

It has been reported, that fatigue occurs at three stages in the football game. First of all, towards the end of the game the performance is reduced. Furthermore, fatigue can occur after short intense periods in both halves and also at the initial phase of the second half. (Mohr et al. 2005.)

2.3.1 Fatigue at the end of the game

It has been well documented that the amount of high-intensity exercises declines towards the end of the second half (Bangsbo et al. 1991, Bangsbo 1994, Mohr et al. 2003). Mohr et al. (2003) reported that both top-class (14-45 %, $p < 0.05$) and moderate level (17-35 %, $p < 0.05$) male players covered significantly less distance in high-intensity running in the last 15 minutes of matches than in the first 15 minutes. Furthermore, the total distance covered in high-intensity running was significantly ($p < 0.05$) higher for both groups in the first than the second half of the match (top-class: 1.27 ± 0.07 vs. 1.15 ± 0.08 km; moderate: 1.01 ± 0.07 vs. 0.90 ± 0.06 km).

Bangsbo et al. (1991) have also documented a 5 % drop in the total distance covered between the halves for Danish players. Castagna et al. (2003) found out a very similar decrease (5.5 %) in total distance covered by young players.

Furthermore, Mohr et al. (2003) reported that only 3 % of the players had their most intense period in the last 15 minutes of the match. Instead, over 40 % of the players had their least intensive period at the end of the game. (Figure 2)

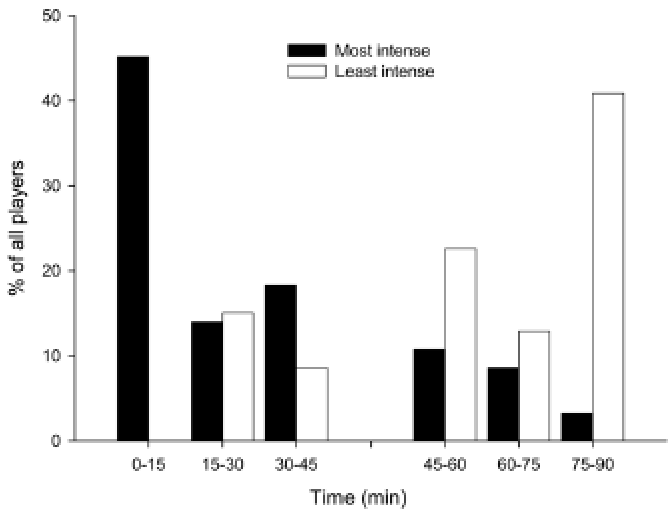

FIGURE 2. Distribution of the 15-min intervals with the most and least intense running for elite players (n=93) (Mohr et al. 2005, modified from Mohr et al. 2003).

Krustrup et al. (2006) examined the sprint performance of players during and after the game and found out that the ability to perform repeated sprints was reduced immediately after the game. The mean time for five 30-m sprints was significantly longer (2.8 ± 0.7 %, $p < 0.05$) after the game compared to the values measured beforehand. Reduced sprinting ability in the second half was also discovered in the study by Mohr et al. (2003).

Based on the findings presented above, it can be concluded that fatigue seems to occur towards end of the football match. It has also been concluded that the development of fatigue towards the end of the game is independent of the playing position, level of play and gender and thus most of the players utilize their physical potential in football matches (Mohr et al. 2005).

It has been suggested that the development of fatigue during a match may be due to depletion of glycogen stores in the muscles (Bangsbo et al. 1992, Krustrup et al. 2006, Mohr et al. 2005). Saltin (1973) found out in his study that the glycogen stores of the players were almost depleted at the half time, when the prematch values were low (~200 mmol/kg dry weight). Even if the players started the game with normal muscle glycogen levels (~400 mmol/kg dry weight), the values at the end of the game were still low (< 50 mmol/kg dry weight).

In the study by Krustrup et al. (2006) the muscle glycogen levels were depleted to 150-350 mmol/kg dry weight at the end of the game and although there were still glycogen available, the histochemical analysis revealed that about the half of type I and type IIa-fibres were almost or entirely depleted of glycogen. Others have found the glycogen levels of ~200 mmol/kg dry weight after the game (Jacobs et al. 1982). Thus, it can be concluded that although muscle glycogen levels may not always be depleted during a game, there is a possibility that depletion in some individual muscle fibres causes fatigue towards the end of the game (Krustrup et al 2006). Also other factors such as dehydration and hyperthermia have been suggested to cause fatigue at the end of the game (Reilly 1997).

2.3.2 Temporary fatigue during the game

Mohr et al. (2003) found out that the amount of high-intensity running in the 5-min period following the most intense 5 minutes of the game was significantly less (12 %, $p < 0.05$) than the average distance covered during all the 5-min intervals in top-class players (Figure 3). Also in the moderate players the distance covered in high-intensity running in the 5 minutes following the most intense period was lower, although not significantly ($p = 0.08$), than the average distance covered in high-intensity.

In the study by Krustrup et al. (2006) the mean sprint time of five repeated 30-m sprints was significantly ($p < 0.05$) longer after the intense periods in the first and second halves when compared to the pre-game values (1.6 ± 0.6 and 3.6 ± 0.5%, respectively). Also the performance of the third, fourth and fifth sprint was reduced significantly ($p < 0.05$) after an intense period in the first half and all five sprints after the intense period in the second half were significantly ($p < 0.05$) slower than before the game. (Krustrup et al. 2006.) Based on the findings of these two studies, it can be concluded that fatigue occurs temporarily in a football game and players' performance is reduced after intense periods of the game (Mohr et al. 2005).

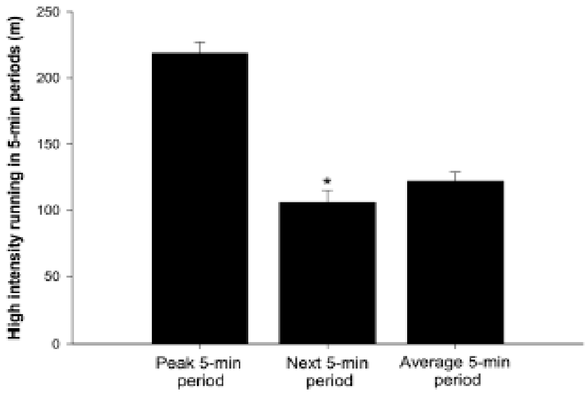

FIGURE 3. The distance covered in high-intensity running in the most intense 5-min period during the game, the next 5-min period following the most intense phase and the average of all the 5 min-intervals for top-class players. * = significantly less than the game average. (Mohr et al 2005, data from Mohr et al. 2003.)

It has been suggested that the accumulation of fatigue after intense periods of the game may be due to high muscle lactate concentrations (Sahlin 1992). However, Krustrup et al. (2006) found no significant relationship between muscle lactate and the reduction of the sprint performance although there were moderate changes in muscle lactate after intense periods of the game. This is in accordance with the study by Krustrup et al (2003) in which it was shown that in the Yo-Yo Intermittent recovery test where athletes perform intense intermittent exercise until exhaustion, muscle lactate measured 1,5 minutes before exhaustion was not different from values measured at exhaustion. Furthermore, in the later study by Krustrup et al. (2006) muscle pH was only moderately reduced and there was no significant correlation between reduced pH and lowered sprinting performance. Based on these findings, it can be concluded that accumulation of lactate does not cause temporary fatigue after intense intermittent exercise (Krustrup et al. 2006). It can also be concluded that low creatine phosphate values do not cause fatigue during the game as in the study by Krustrup et al. (2003) using intense intermittent exercise muscle CP did not change in the last phase of the exercise and the subjects were able to continue exercise despite of rather low CP values. Based on all of these findings, it can be suggested that temporary fatigue occurring during a football game may be due to multifactorial reasons, which all are not clear at the moment (Krustrup et al. 2006).

2.3.3 Fatigue at the beginning of the second half

Mohr et al. (2003) discovered that the distance covered in high-intensity running was significantly ($p < 0.05$) lower in the first five minutes of the second half of the game (130 ± 7 m) when compared to the distance covered in the first five minutes of the first half (160 ± 10 m) . However, there was no significant difference between the second 5-min-periods of the two halves. The same phenomenon has also been discovered in soccer referees (Krustrup & Bangsbo 2001).

The fatigue accumulation at the beginning of the second half can be associated with the decline in muscle temperature in the half-time based on the findings by Mohr et al. (2004). They found out that muscle temperature declined significantly (1.7 ± 0.2 ºC, 37.7 ± 0.1 vs. 39.4 ± 0.1 ºC, $p < 0.05$) at the half time when compared to the values obtained at the end of the first half when the players used passive recovery. Mohr et al. used also sprint tests at the beginning and end of both halves and found out that with passive recovery, the sprint test performance was declined in the half-time. However, in the experimental group (n=8) performing active recovery (re-warm-up period) both the muscle temperature and sprint performance were maintained at the half-time. Thus, it could be concluded that active recovery at the half-time should enable the players to better utilise their capacity at the beginning of the second half and to avoid accumulation of fatigue better at the initial phase. (Mohr et al. 2004)

3 PHYSIOLOGICAL PROFILE OF YOUNG FOOTBALL PLAYERS

3.1 Anthropometric characteristics and endurance capacity

Anthropometric characteristics and maximal oxygen uptake of young football players obtained from previous studies are presented in table 2. The height and weight of young football players is naturally dependent on their age and maturation and varies greatly between different age groups.

TABLE 2. Anthropometric characteristics and maximal oxygen uptake of young football players. # = calculated from the average bodyweight, * = significantly different ($p < 0.05$) from pretraining, ** = significantly different ($p < 0.01$) from pretraining.

Study	n	Age (yrs)	Group	Height (cm)	Weight (kg)	Vo2max (l/min)	Vo2max (ml/kg/min)
Vanderford et al. (2004)	20	13.3 ± 0.1	U-14	163.9 ± 0.4	49.9 ± 0.4	2.64	52.9 ± 1.2#
	19	14.6 ± 0.1	U-15	176.1 ± 0.3	62.8 ± 0.3	3.42	54.5 ± 1.3#
	20	15.7 ± 0.1	U-16	177.1 ± 0.3	68.6 ± 0.4	3.86	56.2 ± 1.5#
Chamari et al. (2004)	34	17.5 ± 1.1		177.8 ± 6.7	67.7 ± 5.0	4.30 ± 0.40	61.1 ± 4.6
Chamari et al. (2005)	21	14 ± 0.4		170.0 ± 5.5	60.2 ± 7.3	3.60 ± 0.6	66.5 ± 5.9
Strøyer et al. (2004)	10	12.2 ± 0.7	Non-elite	153.1 ± 5.1	40.6 ± 6.6	2.35 ± 0.26	58.7 ± 5.3
	9	12.6 ± 0.6	Elite	154.1 ± 8.2	42.5 ± 7.2	2.47 ± 0.28	58.6 ± 5.0
	7	14.0 ± 0.2	Elite	172.2 ± 6.1	57.5 ± 7.2	3.59 ± 0.44	63.7 ± 8.5
Helgerud et al. (2001)	9		Pretraining			4.25 ± 1.9	58.1 ± 4.5
			Posttraining			4.59 ± 1.4*	64.3 ± 3.9*
McMillan et al. (2005)	11	16.9 ± 0.4	Pretraining	177.0 ± 6.4	70.6 ± 8.1	4.45 ± 0.37	63.4 ± 5.6
			Posttraining		70.2 ± 8.2	4.87 ± 0.45**	69.8 ± 6.6**

Maximal oxygen uptake (VO_{2max}) of adult players has been reported to be 56-68 ml/kg/min (Bangsbo 1993, Hoff et al. 2002, Arnason et al. 2004, Chamari et al. 2005, Rampinini et al. 2007). Thus, the values observed with young players seem to be lower than average values of the adults, but there are also some exceptions (Chamari et al. 2004, Chamari et al. 2005, McMillan et al. 2005).

In the study by Chamari et al. (2005) 24 adult and 21 young elite male players had similar Vo_{2max} (66.6 ± 5.2 ml/kg/min and 66.5 ± 5.9 ml/kg/min, respectively) but the running economy of young players was significantly ($p < 0.001$) lower than in adult players when the results were expressed as proportion to body weight. However, when appropriate scaling procedures were used, it was found out that the Vo_{2max} of young players was significantly ($p < 0.05$) lower than in adult players but there was no significant difference in running economy. Thus, it was concluded by Chamari et al. that Vo_{2max} should be expressed in relation to the body mass raised to the power of 0.72 (ml/kg$^{0.72}$/min) when the aim is to compare subjects who differ in body weight.

3.2 Strength and speed characteristics

The strength measurements in football vary in different countries and thus it may be difficult to compare the results between different studies (Stølen et al. 2005). It has been reported that jumping height in vertical counter-movement jump test in young players was 51-55 cm (Helgerud et al. 2001, Chamari et al. 2004, McMillan et al. 2005) and the power per kilogram ~14 W/kg (Vanderford et al. 2004). Furthermore, the jumping height in squat jump has been reported to be ~38 cm (McMillan et al. 2005) and power production ~13 W/kg (Vanderford et al. 2004) in young players.

Helgerud et al. (2001) presented that 1 RM of young players in bench press was 55.8 ± 10.6 and 60.3 ±12.7 kg for the control and training group, respectively, before specific aerobic endurance training. Posttraining values were 55.5 ± 10.4 and 59.8 ± 11.5 kg for control and training group, respectively. 1 RM values in 90º squat were 137.3 ± 25.1 and 129.1 ± 23.3 kg for the control group and 146.1 ± 26.4 and 141.9 ± 25.8 kg for the training group before and after the endurance training respectively.

In addition, various sprint tests have been used in football to measure players' acceleration ability and running velocity. Helgerud et al. (2001) reported the 10-m sprint time to be 1.88 ± 0.06 seconds in junior players (age 18.1 ± 0.8 years). In the study by McMillan et al. (2005) the average 10-m time for elite young players (16.9 ± 0.4 years) was 1.96 ± 0.07 seconds and in the study by Chamari et al. (2004) 1.87 ± 0.10 seconds for young male players (17.5 ± 1.1 years). Furthermore, in the latter study the mean 30-m sprint time for young players was 4.38 ± 0.18 seconds and in the study by Helgerud et al. the 40-m sprint time 5.58 ± 0.16 seconds.

4 GAME PERFORMANCE OF YOUNG FOOTBALL PLAYERS

4.1 Activity profile

Capranica et al. (2001) examined physiological load of 11-year old football players in a eleven-a-side game on a regular-sized pitch. They found out that during the game, players' heart rate exceeded 170 beats/min for 88 % of the first and 80 % of the second half. Heart rate frequency distributions are presented in figure 4.

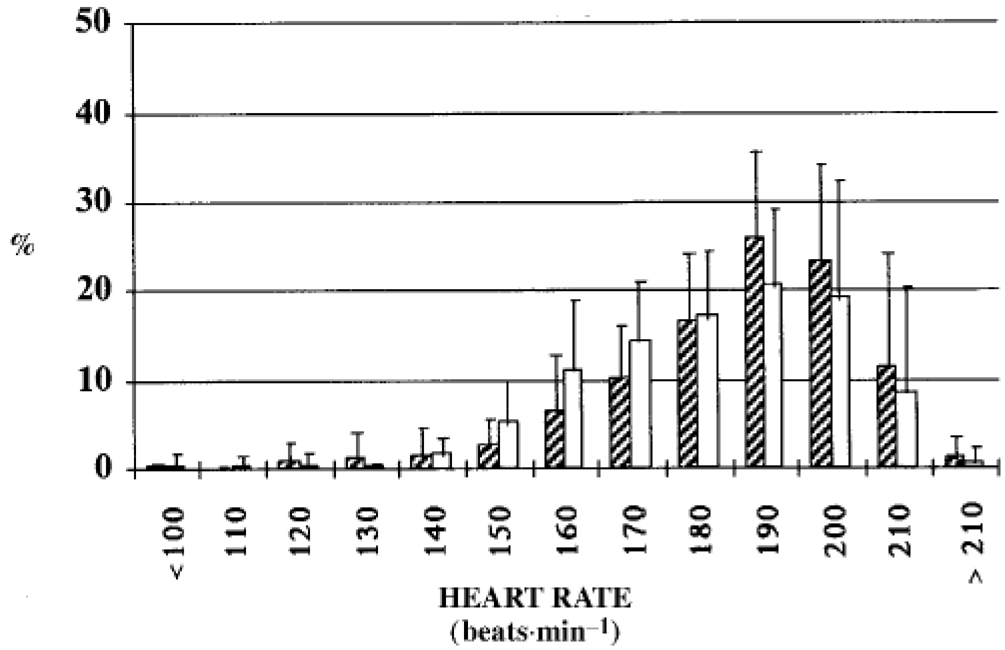

FIGURE 4. Heart rate frequency distribution in 11-year old football players in eleven-a-side game. ▨ = first half, □ = second half. (Capranica et al. 2001.)

Strøyer et al. (2004) observed average match heart rate values of 157-175 for young defenders and 158-182 for midfielders and attackers. It was also shown that the young elite players exercised at a higher heart rate compared to age-matched nonelite players.

Strøyer et al. (2004) also investigated oxygen uptake during the game play by calculating the VO_2 from the individual regression equation between the heart rate and VO_2 obtained in the laboratory testing. The relative aerobic load (%VO_2) obtained during the game was 70-80 % of VO_{2max}. Elite players were able to exercise at a higher level of the relative aerobic load (%VO_{2max}). The values of the relative aerobic loads were in accordance with those obtained in adult players (Bangsbo 1993).

Blood lactate concentrations of 3.1-8.1 mmol/l have been documented in eleven-a-side game in young football players (Capranica et al. 2001). Lactate concentrations were in accordance with values previously measured in adult players (Bangsbo 1994).

When examing the activity profiles, Capranica et al. (2001) found out that young players spent 38 % of the game for walking and 55 % of the time for running. Inactivity accounted for 4 % and jumping for 3 % of time. Moreover, 91 % of running was spent for running forwards and 4 % backwards and 5 % with ball. The amount of time spent for running and walking was in contrast with adult players as Bangsbo (1994) reported that in adult players spent 40 % of the total game time for walking and 43,6 % running. The results by Capranica et al. were also in contrast with Strøyer et al. (2004) who found out that the percentages of total time spent on standing, walking and running were 3.1-9.6, 53.8-63.9 and 26.4-43, respectively, in young nonelite and elite players. The differences in the values between the studies may be partly explained by the use of different analysis methods and game-to-game variations.

Castagna et al. (2003) reported that in a 60 minute game, young players covered the total distance of 6175 ± 318 meters, which would be 8800 meters when extrapolated to the match duration of adult matches (90 minutes). This distance was of course lower than the ones observed with adult players (9-12 km, Ohashi et al. 1988, Bangsbo et al. 1991, Bangsbo 1994, Mohr et al. 2003, Burgess et al. 2006).

The amount of time spent on high-intensity activities (all activities performed at speeds faster than 13 km/h) was reported (Castagna et al. 2003) to be 9 % of the total game time. This agrees with the findings by Bangsbo (1991) on adult players. Furthermore, in the study by Strøyer et al. (2004) the amount of time spent on running on high intensity was 6.8-9.0 % of the game time. Also this agrees with the values obtained with adult players as Bangsbo (1994) has presented that the adult players spent 8 % of the total time for running at high speed.

Castagna et al. (2003) also made an interesting finding in terms of the topographical-coverage analysis. They found out that the young players tended to stay on the small proportions of the pitch as 70 ± 1.3 % of the total distance was covered in one-fourth of the pitch (Figure 5). The reason for this could be a low level of fitness or technical and tactical assignments. It was also suggested (Castagna et al. 2003) that the poor game understanding of young players has an effect. The players with poorer understanding of the game wait the ball to reach them instead of actively looking for it. Thus, those who have better game understanding of the game may be more active in game situations. (Castagna et al. 2003.)

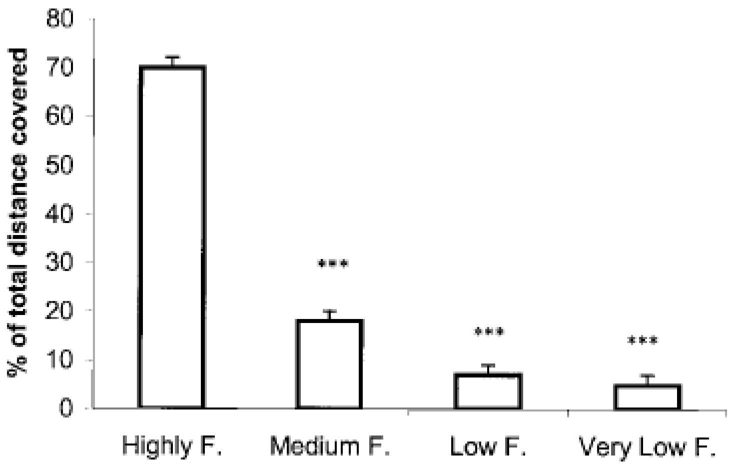

FIGURE 5. Percentage of total distance covered in the sections of the football pitch (highly frequented, medium frequented, low frequented, very low frequented). *** = significantly different from highly frequented. (Castagna et al. 2003.)

4.2 Game actions

In general, the total time the players spend performing on-the-ball actions in a football game is quite small. In fact, it has been reported that one player is usually involved with the ball for no more than 60 seconds out of the match duration of 90 minutes (Bangsbo 1993). In the study by Capranica et al. (2001) the time spent running with the ball was limited to 5 % and the other ball actions consisted of less than 1 % of the total time.

Bangsbo (1994) has presented that in the 1992 European Championships the mean number of passes in a game per player was 35 and the number of interceptions 15. Furthermore, the average number of headers and tackles in top-class adult players was 8 and 11 per player, respectively. In addition, one player had an average of 1.1 shots at goal in one game. (Bangsbo 1994.)

Luhtanen (1996) analysed matches from the 1994 World Cup and presented that the average number of passes in one player during the game ranged from 48 to 59 in the teams of Brazil and Sweden and the successful percentage of passes from 70 to 81 %. The average number of dribbles ranged from 6 to 9 and average number of shots from 13 to 17 per player during the game.

Helgerud et al. (2001) examined the number of ball actions and passes in young elite junior players. The number of passes in one player was in average 25-31 during the game and percentage of successful passes ranged from 67 to 77 %. The total number of involvements with the ball was 47-59 per player. Previously Luhtanen (1988) analyzed football matches in different age groups in young players (age 9-19 years, match duration 40-80 minutes) and reported as an average from all of the analyzed matches that the average duration of ball possession in one situation during the game is 0.9 seconds. Furthermore, in young players from all of the on-the-ball-actions 66 % last less than 1 second. Moreover, the average number of passes in young players during the game was 28 per player, from which 61 % were passes with the first touch. From all of the passes, 50 % were successful. The total number of all attacking actions (passes, receptions, dribbles, shots) was 69 per player and the average number of defensive actions (steals and interceptions) 20 from which 59 % were successful. (Table 3, Luhtanen 1988.). In general, there seems to be a lack of information considering the on-the-ball actions during the actual match play in young players.

Table 3. Average number (No.) and successful percentage (+%) of on-the-ball actions in young players during the game lasting 40-80 minutes. Rec. = receptions, Pass. = passes, Dribb. = dribbles, Def. = defensive actions, steals and interceptions (Modified from Luhtanen 1988.)

	Rec.	**Pass.**	**Dribb.**	**Shots**	**Def.**
No.	34	28	5	2	20
+%	69	50	38	8	59

5 THE EFFECT OF ENDURANCE CAPACITY ON FOOT-BALL PERFORMANCE

Tumilty (1993) examined the relation between different physiological characteristics and game performance of young players. He used a game simulation which represented a vigorous portion of the football game and was based on the data from various game analysis studies. Simulation consisted of a sequence of movements which were carried out according to instructions. One sequence of simulation was the 12 m and 20 m maximal sprints. The results of the game simulation were then compared to the results in the laboratory and field tests, including a maximal oxygen uptake (VO_{2max}) test on the treadmill.

The mean VO_{2max} (ml/kg/min) of the 16 players (16.1 ± 0.7 yr, 177.6 ± 7.3 cm, 71.3 ± 6.7 kg) examined was 61.4 ± 4.0 ml/kg/min. There was a significant negative correlation between maximal oxygen uptake and a decrement in 12 m and 20 m sprint times in the game stimulation in relation to the best times during separate sprint test (-0.59, $p < 0.05$ for 12 m sprints and -0.74, $p < 0.01$ for 20 m sprints) (Tumilty 1988).

Tumilty (1988) conluded that the young players with superior endurance capacity were better able to maintain their performance in the game stimulation. This may be due to a greater number of capillaries in muscles and better ability to utilize lactate aerobically which would improve the removal of lactate from working muscles. (Tumilty 1988.)

Similar conclusions have also been made in other studies. Helgerud et al. (2001) examined the effects of aerobic training on the game performance in male elite junior players (18.1 ± 0.8 yr) . With 8 weeks of specific endurance training, the training group consisting of nine players improved their VO_{2max} from 58.1 ± 4.5 ml/kg/min to 64.3 ± 3.9 ml/kg/min. More importantly, there was a significant improvement in the total distance covered, the number of sprints and the number of involvements with the ball and the average work intensity (percent of maximal heart rate) during the game (table 4). No significant change was observed in the number of passes or in the distribution between successful and not successful passes.

TABLE 4. The effect of 8 weeks of specific endurance training on variables measured during soccer game in male elite junior players (modified from Helgerud et al. 2001). * = significantly different from pretraining, $p < 0.05$. ** = significantly different from pretraining, $p < 0.01$. (Modified from Helgerud et al. 2001.)

	Pretraining	**Posttraining**
Total distance covered (m)	8619 ± 1237	10335 ± 1608**
Number of sprints	6.2 ± 2.2	12.4 ± 4.3**
Number of involvements with ball	47.4 ± 5.5	58.8 ± 6.9*
The average work intensity (% max. heart rate)	82.7 ± 3.4	85.6 ± 3.1*

Based on the findings it can be concluded that the aerobic capacity influences the game performance of the young players as higher maximal oxygen uptake increased the distance covered, level of work intensity, number of sprints and the total number of involvements with the ball during the game (Helgerud et al. 2001).

It has also been proposed that aerobic fitness is an important factor in a football match and high aerobic power (Vo_{2max}) has been found to correlate with work rate during a match (Reilly 1997). To generalize, Vo_{2max} allows the players to run longer, faster and be more involved in the actions of the game (Stølen et al. 2005).

Some studies have also correlated the higher endurance capacity with team success and rank in a national competition. In the study by Apor (1988) the team's rank in the national top division in Hungary was the same as the rank in maximal oxygen uptake (table 5).

TABLE 5. The relation between the mean VO_{2max} and position in the national top division in Hungarian teams (modified from Apor 1988).

Team	**Pos. in the national top division**	**Vo2max (ml/kg/min)**
Ujpesti Dozsa	1st	66.6
FTC	2nd	64.3
Vasas SC	3rd	63.3
Honved SE	4th	58.1

Moreover, in the study by Wisløff et al. (1998) the players of the Norwegian elite league champions Rosenborg had significantly higher maximal oxygen uptake than the players of Strindheim finishing last in the top division (67.6 ± 4.0 vs. 59.9 ± 4.1 ml/kg/min, $p < 0.05$).

Despite it has been presented that the endurance capacity of the players is an important factor of football performance, it must be kept in mind that also other as important or even more important factors influence the performance level of players, especially in young players. Vayens et al. (2006) documented that in young football players, running speed and technical skills are the most important discriminating factors between elite and non-elite U13- and U14-plyers while aerobic endurance is more important in older U15- and U16-players. In the study by Gravina et al. (2008) the most important factor affecting to the selection between first team and reserve team players at the ages of 10-14 years was 30 meters sprint time. Furthermore, Malina et al. (2007) found out that stage of puberty and height but also aerobic resistance are significant predictors of football-specific skill test results in adolescent football players aged 13-15 years. Previously, it has been noted that children and adolescents are able to compensate the relatively weak endurance capacity with strength and speed characteristics and technical skills in many different sports (Vuorimaa & Mero 1990).

6 PURPOSE OF THE STUDY

The purpose of this study was to investigate the relationships between endurance capacity, game performance and estimated accumulation of fatigue during match play in young football players. Furthermore, the aim was to gather more detailed information about the game actions, intensity and accumulation of fatigue in youth football. The study was based on the following study problems:

1. Is endurance capacity of young football players related to the number and outcome of game actions during a 90-minute football match?
2. Is there any relationship between the players' endurance capacity and the amount of fatigue they demonstrate during a match?
3. What is the amount and nature of fatigue young players demonstrate during a football match?
4. Are there differences in the game actions, game intensity and nature of fatigue during a match between different age groups in youth football?
5. Is the Yo-Yo Endurance Test suitable for reliable estimation of VO_{2max} in young players?

Hypotheses for the study were:

1. The players with higher endurance capacity are more involved in the game (Helgerud et al. 2001) and they succeed in their game actions more often compared to their less fit counterparts.
2. The players with higher endurance capacity are better able to sustain their performance during the game, that is, they demonstrate less fatigue during the match play (Tumilty 1988).
3. There is a decrease in game intensity in young football players due to accumulation of fatigue caused mainly by the depletion of muscle glycogen stores.
4. Game intensity increases with age but it doesn't affect much on the number or outcome of the game actions.
5. Yo-yo endurance test cannot be reliably used to estimate VO_{2max} in young football players as previously also documented by Metaxas et al. (2005).

This study is part of a research project carried out in the Research Institute for Olympic Sports (KIHU) which follows the development of young football players in two years period.

7 METHODS

7.1 Subjects

The players used in the study were 11, 13 and 15 year old football players playing in a Finnish club team (JJK Juniorit). The subjects and their parents were notified of the procedures, possible risks and benefits of the study and they signed an informed consent prior to participation in the study. An ethical permission for the study was applied and received from the Ethics Committee of University of Jyväskylä. At the moment of the study the 11-year olds had been training in average of 4.9 ± 1.0, the 13-year olds 7.1 ± 1.1 and the 15-year olds 9.6 ± 0.9 years in a club team. The talent and skill level of the players varied among the groups. The table of subjects' anthropometric characteristics is presented in table 6.

TABLE 6. Antropometric characteristics of the subjects

Group	N	Height (m)	Weight (kg)	Fat%
B-11	12	1.46 ± 0.06	35.1 ± 4.2	11.3 ± 4.1
B-13	11	1.59 ± 0.09	46.5 ± 6.0	11.6 ± 5.1
B-15	8	1.71 ± 0.06	60.4 ± 9.1	8.2 ± 4.3
All together	31	1.57 ± 0.12	45.7 ± 11.8	10.6 ± 4.6

7.2 Endurance performance tests

7.2.1 Maximal oxygen uptake test on the treadmill

The players' maximal oxygen uptake (VO_{2max}, ml/kg/min) was measured on a treadmill test using a breath by breath - gas analyzer (Sensormedics, Vmax, California, USA). The gas analyzer was calibrated before each test using the reference gases and the volume calibration was carried out as instructed by the manufacturer.

During the test, the inclination of the treadmill was set and kept constant at 1°. The starting velocity in the test was 6 km/h for the 11 year-old players and 7 km/h for the 13 and

15 year old players. The lower starting velocity was selected for the youngest group to ensure the players would get used to the treadmill and for that the overall duration of the test would not be too short. The velocity was increased by 1 km/h every minute. The test was terminated when exhaustion was reached or the subject wanted voluntarily to stop the test. During the test players' maximal heart rate was measured using a heart rate monitor (Suunto T6, Suunto, Vantaa, Finland).

7.2.2 Yo-Yo Endurance Test Level 1

The players were also tested in Yo-Yo Endurance Fitness Test Level 1 to estimate their aerobic capacity from the distance covered in the test (Bangsbo 1996). This test was used along with the treadmill test as it is one of the most common ways to measure endurance performance of the football players.

The Yo-yo Test consists of continuous 20-meter shuttle runs performed at increasing speed. Yo-yo Endurance Test Level 1 audio tape was used to set the speed of the subjects. Illustration of the Yo-yo endurance test track is presented in figure 6.

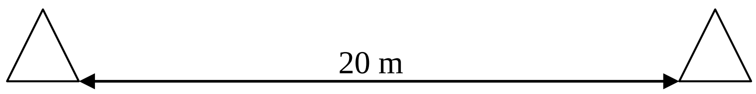

FIGURE 6. A simple illustration of the Yo-yo endurance test track. (Modified from Bansbo 1996.)

The subjects began to run forwards for 20 meters at the time of the first signal and adjusted their speed so that they would reach the 20 meter marker at the exact time of the next sound signal. At the 20 meter marker the subjects turned and run back to the first marker which once again had to be reached at the time of the next audio signal. This was then repeated time after time. The speed of the subjects was increased regularly according to the Yo-Yo Endurance Test Level 1 audio tape, that is, the time between the two signals was decreased.

The test ended when the participant failed twice to reach the 20-meter line in time with the audio sign or when he voluntarily stopped the test. The subjects were however encouraged to give their best at the test. During the test subjects' maximal heart rate was measured using Suunto T6 heart rate monitor.

Maximal oxygen uptake (VO_{2max}, ml/kg/min) of the subject was estimated from the test result (meters) based on the instructions and values presented in the handbook of the Yo-Yo test (Bangsbo 1996, appendix 1).

7.3 Test Matches

7.3.1 Test Match Procedures

In a 11-a-side test match the players played in their own age group on a full-sized indoor pitch (90 x 54 m) for a total duration of 90 minutes (2*45). Thus, a total of 3 test matches were organized, one for each age group. The subjects of the study were divided into the two playing teams according to their playing positions so that each player played in the position best suitable for him. The best position for each player was decided after discussing with the club coach of the players. During the match the position of the players was not altered so every player played the whole match at the position in which he started the match. Additional, age-matched players were used to fill the available positions and to complete the 11-a-side teams. The distribution of the subjects according to their playing positions in the test match is presented in table 7. Goalkeepers and those players who were not able to play the whole match were excluded from the study.

TABLE 7. The distribution of defenders, midfielders and forwards in the test matches for each age group.

Group	N	Defenders	Midfielders	Forwards
B-11	12	6	5	1
B-13	11	5	4	2
B-15	8	2	4	2
All together	31	13	13	5

In all age groups, both teams played with 4-4-2-formation (4 defenders, 4 midfielders, 2 forwards) and according to a zonal marking tactics in the defence. The players were instructed to give everything they were able to during the match and play the whole 90 minutes at their maximal level. The instructions given to players were similar in each of the age groups, that is, before every single game.

During the matches the players' average heart rate (beats/min) was measured with Suunto T6 heart rate monitor. The heart rate data was analysed using the Firstbeat Pro-software (Firstbeat Technologies Oy, Jyväskylä, Finland). The average relative heart rate (%max) was counted based on the maximal heart rate measured during the tread-mill or Yo-Yo test. Oxygen consumption was estimated using the Firstbeat-program based on the heart rate data (for more information, see http://www.firstbeat.fi/files/VO2_Estimation.pdf). To be able to estimate the nature of possible accumulated fatigue, average heart rates and oxygen consumptions were ana-lysed and will be presented for the first and second half and also for the first and last 15-minute periods of both halves.

In the B-11 group the heart rate data of two subjects was corrupted and thus, in heart rate variables the total number of subjects was 29 and in B-11 the number of subjects was 10.

7.3.2 Game Analysis

Each test match was filmed using a Canon XH-A1 HD video camera (Canon Inc, Tokyo Japan). The test matches were then analyzed using Dartfish TeamPro 4.5.1-video analy-sis software (Dartfish, Fribourg, Switzerland). A notational analysis system was created for the program to complete the analysis. An illustration of the notational analysis sys-tem used is presented in appendix 2.

The number and outcome (successful/not successful) of passes, receptions, all attacking actions (passes, receptions, dribbles, shots), all defensive actions (interceptions and steals) and all actions in total were analysed during the first and second half and the whole game in total. For passes, a pass reaching the target player was coded as success-ful. Reception was coded as successful if the player was able to maintain the control over the ball after the contact. Dribbles were described as movement of the player with the ball using at least two touches and successful if the player maintained the possession of the ball also after the dribble. All shots heading towards the goal were coded as successful. In defensive actions, interception was coded successful if the player was able to intercept opponent's pass and to gain the ball to his own team and steal was coded successful if the player was able to win the ball from the opponent's possession to his own team.

7.4 Measured variables and statistical analysis

All the measured variables are presented in table 8.

TABLE 8. The measured variables.

Test	**Measured variables**
Treadmill test	VO_{2max} (ml/kg/min, l/min)
Yo-Yo Endurance Test Level 1	Test result (m)
	VO_{2max} (ml/kg/min, estimated)
Test match	AvHR (beats/min, %max)
	VO_{2av} (ml/kg/min, % max, estimated)
Test match, game analysis	Passes (no., +/-)
	Receptions (no., +/-)
	All attacking actions (no., +/-)
	All defensive actions (no., +/-)
	Total number of all actions

All data was analysed using Microsoft Office Excel 2007 for Windows and SPSS 13.0 for Windows softwares. Pearson's correlation coefficient was used to evaluate relationships between the variables. Paired-samples T-test was used to detect differences between the halves in each age group and independent-samples T-test to detect differences in the relative changes between the groups. The differences in variables between the 15-minute periods of the game were analysed using repeated measures ANOVA with Bonferroni post-hoc test. One-way ANOVA with Bonferroni post-hoc test was used to detect the differences between the groups. The level of significance at $p < 0.05$, so that $p < 0.05$ = *, $p < 0.01$ = ** and $p < 0.001$ = ***. Borderline significance was set at 0.05 – 0.09 = °.

8 RESULTS

8.1 Game actions and game intensity in different age groups

VO_{2max} of the groups differed between the groups (B-11-B13 $p < 0.01$, B-11-B15 $p < 0.001$, B13-B-15 $p < 0.001$) in absolute value but not when related to body weight (table 9). Furthermore, the B-15 group differed significantly from B-11 and B-13 in the absolute Yo-yo test result ($p < 0.01$ and $p < 0.05$, respectively) and in VO_{2max} estimated from the Yo-Yo test result ($p < 0.01$ and $p < 0.05$, respectively).

TABLE 9. The endurance performance test results of different age groups and all groups combined together and the significance of differences between age groups.

Group	**VO2max (ml/kg/min)**	**VO2max (l/min)**	**Yo-Yo (m)**	**Yo-Yo (ml/kg/min)**
B-11	53.7 ± 4.1	1.88 ± 0.17	1912 ± 264	48.8 ± 4.1
B-13	53.3 ± 4.2	2.47 ± 0.33	1998 ± 314	50.1 ± 4.9
B-15	54.9 ± 3.7	3.32 ± 0.53	2415 ± 303	56.3 ± 4.2
All together	53.9 ± 3.9	2.46 ± 0.66	2072 ± 352	51.2 ± 5.2
Sig.		**B-11-B-13 ***B-11-B-15 ***B-13-B-15	**B-11-B-15 *B-13-B-15	**B-11-B-15 *B-13-B-15

When the measured VO_{2max} was correlated to Yo-Yo test result (m) and the the VO_{2max} estimated based on the Yo-Yo test result, statistically significant correlations were observed in B-11 ($r = 0.754$, $p = 0.005$ and $r = 0.763$, $p = 0.004$, respectively), B-13 ($r = 0.851$, $p = 0.001$ and $r = 0.856$, $p = 0.001$, respectively) and when examing all the groups together ($r = 0.655$ and $p < 0.001$ and $r = 0.671$, $p < 0.001$, respectively). No significant correlation between the measured and estimated VO_{2max} was observed in B-15.

Game actions. The average number and outcome of game actions for the whole match per player for each group is presented in table 10. Despite the number and successful outcome of the actions varied between the groups, Oneway ANOVA revealed only a borderline difference (p = 0.061) in the total number of passes between B-11 and B-15 and no other statistical differences between the groups . (Table 10.)

TABLE 10. The average number and successful percentage (+%) of game actions per player in the whole game in different age groups and in all groups combined together. Pass. = passes, Rec. = receptions, Att. = all attacking actions, Def. = all defensive actions, All = all actions. ° = borderline difference between B-11 and B-15.

	Pass.	Rec.	Att.	Att. +%	Def.	Def. +%	All
B-11	43.5 ± 11.5	41.9 ± 19.1	99.2 ± 42.2	73.4 ± 8.4	33.3 ± 11.0	70.1 ± 7.4	132.4 ± 46.0
B-13	41.1 ± 14.4	35.5 ± 18.7	83.1 ± 37.5	67.7 ± 8.3	30.5 ± 15.4	67.7 ± 18.3	113.5 ± 39.2
B-15	30.3 ± 7.3°	32.0 ± 9.1	72.5 ± 18.9	61.5 ± 9.3	21.8 ± 10.4	65.1 ± 15.8	94.3 ± 20.7
All	39.2 ± 12.6	37.1 ± 16.9	86.6 ± 36.4	68.3 ± 9.6	29.3 ± 13.1	68.0 ± 13.9	115.9 ± 40.3

Game actions and their outcome per player for first and second half of the game are presented in table 11. Oneway ANOVA revealed a borderline difference between B-11 and B-15 in the number of passes in the first half (p = 0.054) but no statistically significant differences in game actions were observed between the groups. Futhermore, paired samples T-test revealed no significant differences between the halves in any of the actions or their outcome in any of the groups or even when all groups were combined together.

TABLE 11. The average number and successful percentage (+%) of game actions per player in the two halves in different age groups and in all groups combined together. Pass. = passes, Rec. = receptions, Att. = all attacking actions, Def. = all defensive actions, All = all actions. ° = borderline difference between B-11 and B-15.

	Pass. 1.half	Pass. 2.half	Rec. 1.half	Rec. 2.half	Att. 1.half	Att. 2.half	Att +% 1.half	Att. +% 2.half	Def. 1.half	Def. 2.half	Def. +% 1.half	Def. +% 2.half	All 1.half	All 2.half
B-11	23.0 ± 5.3	20.5 ± 9.1	22.5 ± 9.6	19.4 ± 10.8	51.6 ± 18.8	47.6 ± 26.5	72.3 ± 8.4	74.3 ± 12.2	17.0 ± 6.4	16.3 ± 6.4	74.5 ± 9.2	65.4 ± 14.7	68.6 ± 22.8	63.8 ± 27.4
B-13	20.9 ± 8.7	20.2 ± 7.6	17.1 ± 10.3	18.4 ± 10.1	41.9 ± 21.0	41.2 ± 21.4	67.2 ± 9.4	69.2 ± 10.3	14.8 ± 7.4	15.6 ± 8.8	71.5 ± 17.4	67.1 ± 26.6	56.7 ± 22.8	56.8 ± 22.9
B-15	15.1 ± 5.9°	15.1 ± 4.2	16.8 ± 6.1	15.3 ± 5.7	36.6 ± 13.8	35.9 ± 11.8	69.5 ± 13.5	73.2 ± 6.8	11.0 ± 5.8	10.8 ± 7.1	64.8 ± 20.1	66.3 ± 18.7	47.6 ± 16.1	46.6 ± 14.1
All	20.2 ± 7.4	19.0 ± 7.7	19.1 ± 9.2	18.0 ± 9.3	44.3 ± 19.0	42.3 ± 21.6	69.8 ± 10.2	72.2 ± 10.3	14.7 ± 6.8	14.6 ± 7.6	70.9 ± 15.5	66.2 ± 19.9	59.0 ± 14.0	56.9 ± 13.7

However, a tendency of increased percentage of successful attacking actions was found between the halves. In B-11 the average percentage of successful attacking actions increased relatively by 2.8 %, in B-13 3.0 % and in B-15 5.4 %. There was also a tendency of decrease in the total number of attacking actions per player (7.8 % in B-11, 1.7 % in B-13, 2.0 % in B-15 and 4.5 % in all together). In average percentage of the successful defensive actions there was a decrease in B-11 (12.2 %), B-13 (6.2 %) and all groups together (6.6 %). There was also a tendency to decrease in the total number of all actions per player between the halves (decrease of 6.9 % in B-11, 2.1 % in B-15 and 3.5 % in all groups together) However, as already mentioned, these changes were not statistically significant. (Table 11.)

When examing all the groups together, there was a significant correlation between VO2max estimated from the Yo-Yo test result and the relative change in the successful defensive actions ($r = 0.438$, $p = 0.014$). Furthermore, in the B-13 group, there was a significant correlation between the Yo-Yo test result and and the relative change in successful defensive actions ($r = 0.781$, $p = 0.005$) and between the measured VO2max and the relative change in successful defensive actions ($r = 0.756$, $p = 0.007$). In addition, there was a borderline correlation in B-13 between the measured VO_{2max} and the total number of defensive actions ($r = 0.539$, $p = 0.087$). There was also a significant correlation in B-15 between the measured VO_{2max} and the relative change in successful percentage of passes ($r = 0.623$, $p = 0.031$).

Game intensity. The measured heart rate and VO_2 variables during the first and second half of the game are presented table 12. Oneway ANOVA revealed statistically significant differences between B-11 and B-15 in average absolute heart rate in the first half , in average absolute VO_2 in the first half and second half and in average VO_2 related to bodyweight in first half (table 12). Furthermore, there was a borderline difference between B-11 and B-15 in average relative heart rate (%max, $p = 0.060$). Paired samples T-test revealed a statistically significant decrease between the halves in absolute (beats/minute) and relative (%max, determined in the treadmill or Yo-Yo test) heart rate in B-13, B-15 and all groups combined. The average absolute and relative VO_2 decreased significantly in B-15 and all groups together. (Table 12.)

TABLE 12. Average heart rates (AvHR beats/min and %max) and VO_2 (VO2av ml/kg/min and $\%VO_{2max}$) during the two halves of the game for each age groups and for all groups combined together. * = significantly different from first half, $p < 0.05$, ** = significantly different from first half, $p < 0.01$ and *** = significantly different from first half, $p < 0.001$. # = significantly different from B-11, $p < 0.05$, $ = significantly different from B-11, $p < 0.01$, £ = borderline difference between B-11 and B-15.

	AvHR 1	**AvHR 2**	**AvHR (%max) 1**	**AvHR (%max) 2**	**VO2av 1**	**VO2av 2**	**VO2av (%max) 1**	**VO2av (%max) 2**
B-11	164.5 ± 13.5	163.4 ± 11.7	79.9 ± 6.1	79.2 ± 4.7	34.4 ± 6.3	34.3 ± 4.9	66.4 ± 9.4	66.3 ± 7.2
B-13	169.3 ± 9.5	165.1 ± 7.1*	83.7 ± 5.4	81.5 ± 4.7*	38.8 ± 3.5	37.6 ± 3.4	73.2 ± 8.1	70.9 ± 7.9
B-15	180.8 ± 9.6 #	172.6 ± 7.3** £	86.8 ± 4.0	82.9 ± 3.7**	42.8 ± 4.2 $	39.4 ± 4.2**	78.0 ± 5.7 #	71.8 ± 5.5** #
All	170.8 ± 12.6	166.6 ± 9.5***	83.2 ± 5.8	81.1 ± 4.6***	38.4 ± 5.7	37.0 ± 4.5**	72.2 ± 9.0	69.6 ± 7.2**

When average heart rate was analysed in the 15-minute periods a significant decrease was observed in absolute average heart rate in B-15 between the first and last 15 minutes of the game ($p < 0.05$). A similar significant decrease in average absolute heart rate was observed in B-13 between the last 15 minutes of the first half and the first 15 minutes of the second half ($p < 0.05$) and between the last 15 minutes of the two halves ($p < 0.05$). (Figure 7.)

When all groups were combined, significant differences were observed in average absolute heart rate between the first 15-minute periods of the two halves, between 30-45 min and 45-60 min and between the last 15-minute periods of the two halves. A borderline significance were observed between the difference in average heart rate between the first and last 15 minutes of the game ($p = 0.051$). (Figure 7.) Similar differences in average heart rate were observed in relative terms also. As the VO_2 of the players was estimated based on the heart rate data, similar significant decreases were observed in VO_2. The average VO_2-values for each group during the 15-minute periods are presented in table 13.

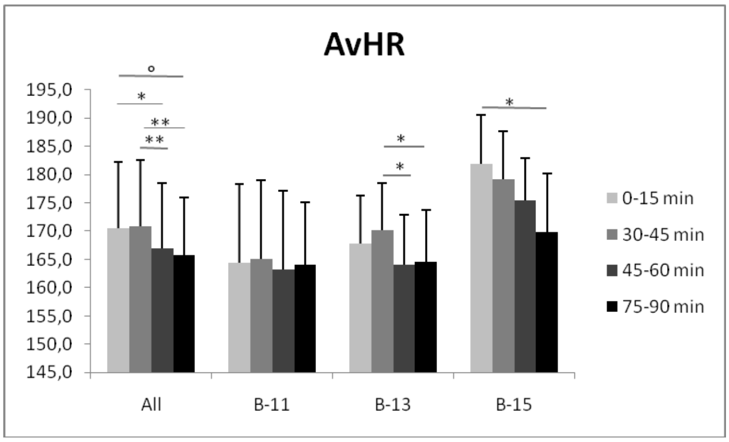

FIGURE 7. Average heart rate (beats/min) in the first and last 15-minute periods in the first and second half for each age group and all groups combined together. * = statistically significant difference between the 15-minute periods, $p < 0.05$, ** = statistically significant difference between the 15-minute periods, $p < 0.01$, ° = boarderline significance between the 15-minute periods, $p = 0.051$.

Table 13. The average VO_2 (absolute, VO_{2av}, and relative, %max) of the players during 15-minute periods of the game. * = statistically significant difference between the 15-minute periods, $p < 0.05$, ** = statistically significant difference between the 15-minute periods, $p < 0.01$, ° = boarderline significance between the 15-minute periods, $p = 0.05$-0.09.

	VO2av 0-15 min	**VO2av 30-45 min**	**VO2av 45-60 min**	**VO2av 75-90 min**	**VO2av (%max) 0-15 min**	**VO2av (%max) 30-45 min**	**VO2av (%max) 45-60 min**	**VO2av (%max) 75-90 min**
B-11	36.4 ± 6.2	36.6 ± 6.2	36.0 ± 5.6	36.3 ± 4.1	70.1 ± 9.2	70.6 ± 8.8	69.5 ± 7.7	70.1 ± 5.3
B-13	39.5 ± 4.1	40.4 ± 2.5 *45-60	38.2 ± 3.4 *30-45	38.6 ± 3.8	74.5 ± 8.0	76.0 ± 5.7 *45-60	72.2 ± 7.7 *30-45	73.5 ± 8.0
B-15	43.5 ± 4.0 °75-90	43.0 ± 3.6	41.9 ± 2.7	40.0 ± 4.5 °0-15	79.1 ± 4.3	78.4 ± 4.1	76.5 ± 4.1	72.9 ± 6.3
All	39.5 ± 5.5 *45-60	39.8 ± 5.0 **45-60 *75-90	38.5 ± 4.6 *0-15 **30-45	38.2 ± 4.2 *30-45	74.3 ± 8.2 °45-60	74.8 ± 7.2 **45-60 *75-90	72.4 ± 7.2 °0-15 **30-45	72.1 ± 6.6 *30-45

When the relative changes in the in game actions and their outcome were correlated with the changes in heart rate and VO_2-variables, a significant correlation was observed in B-11 between the decrease in AvHR (beats/min and %max) and the decrease in the number of defensive actions ($r = 0.719$, $p = 0.019$ and $r = 0.740$, $p = 0.014$, respectively). A significant correlation was also observed in B-11 between the decrease in VO_2 (ml/kg/min and %max) and the decrease in the number of defensive actions (r = 0.777, p = 0.008 and r = 0.063, p = 0.010, respectively).

8.2 Game actions and game intensity in different endurance capacity groups

As no differences were observed between the age groups based on relative VO_{2max} (ml/kg/min), all the subjects were combined, ranked and divided into 'Higher VO_{2max}'-group (n = 14) and 'Lower VO_{2max}'-group (n = 15) based on their measured VO_{2max} . The players were evenly matched in the two groups so that the distribution of subjects' age and playing position of these two variables did not differ between the groups. Players with corrupted heart rate data were excluded from this analysis. (Table 14.)

TABLE 14. The VO_{2max} , age distibution and the distribution of the playing position of the players in the 'Higher VO_{2max}' - and 'Lower VO_{2max}' - groups. *** = significantly different from 'Higher VO_{2max}' – group.

Group	**VO2max (ml/kg/min)**	**Age (y)**	**No. of B-11**	**No. of B-13**	**No. of B-15**	**No. of Def.**	**No. of Mid.**	**No of For.**
Higher VO_{2max} (N = 14)	57.0 ± 2.8	12.86 ± 1.66	5	5	4	6	6	2
Lower VO_{2max} (N = 15)	51.0 ± 2.7***	12.87 ± 1.60	5	6	4	6	6	3

In the two different VO_{2max} - groups, a strong correlation was observed when the measured VO_{2max} was correlated to Yo-Yo test result and to VO_{2max} estimated from Yo-Yo test result (r = 0.796, p < 0.001 and r = 0.819, p < 0.001, respectively) in the subjects with the lower VO_{2max}, but no significant correlation was found in the group with higher VO_{2max}.

Game actions. The game actions of 'Higher'- and 'Lower VO_{2max}' – groups are presented in table 15. There were no differences in values between the groups, nor there were any significant changes in any of the variables between the halves inside these two groups.

In the group with the higher VO_{2max}, there was an increase of 6.0 % in the number of passes, whereas in the group with lower VO_{2max} a decrease of 16.0 % was observed. This difference in relative change was at borderline (p = 0.059). No significant differences in relative changes between the halves between the groups were observed. However, in the total number of defensive actions there was an increase of 5.9 % in 'Higher VO_{2max}'-group, but a decrease of 4.6 % in 'Lower VO_{2max}' – group. Moreover, in the total number of all actions there was a decrease of 5.7 % in 'Lower VO_{2max}' – group, but no change in the 'Higher VO_{2max}' between the halves (increase of 0.5 %). (Table 15.)

TABLE 15. Game actions and their outcome in the two halves in the 'Higher VO_{2max}' (High., N = 14) and 'Lower VO_{2max}' (Low. N = 15) –groups. Pass. = passes, Rec. = receptions, Att. = all attacking actions, Def. = all defensive actions, All = all actions.

	Pass. 1.half	**Pass. 2.half**	**Rec. 1.half**	**Rec. 2.half**	**Att. 1.half**	**Att. 2.half**	**Att +% 1.half**	**Att. +% 2.half**	**Def. 1.half**	**Def. 2.half**	**Def. +% 1.half**	**Def. +% 2.half**	**All 1.half**	**All 2.half**
High.	20.1 ± 8.9	21.3 ± 6.2	21.0 ±10.5	19.9 ± 9.8	47.0 ±22.8	46.4 ±21.8	72.4 ±11.3	75.4 ± 8.4	14.6 ± 7.4	15.4 ± 6.7	69.8 ±17.2	67.7 ±16.2	61.6 ±26.6	61.9 ±23.5
Low.	19.6 ± 5.9	16.5 ± 8.8	17.0 ± 7.8	16.1 ± 9.3	40.5 ±15.0	38.1 ±22.7	66.5 ± 8.8	69.4 ±12.0	14.5 ± 6.2	13.9 ± 9.0	70.0 ±14.4	64.9 ±23.8	55.1 ±17.2	51.9 ±24.4

Game intensity. The measured average heart rate and VO_2variables during the first and second half of the game in 'Higher VO_{2max}' and 'Lower VO_{2max}' – groups have been presented in figures 8 and 9 and in table 16. Paired-samples T-test revealed only a borderline decrease both in average absolute (p = 0.054, figure 8) and relative (p = 0.056, figure 10) heart rate in 'Higher VO_{2max}'- group. Furthermore, the decrease observed in VO2-values in 'Higher VO_{2max}'-group was not statistically significant (table 16). In the 'Lower VO_{2max}'-group there was a statistically significant decrease in absolute and relative average heart rates (figures 8 and 9). Also average oxygen consumption decreased signficantly in the players with lower VO_{2max} between the halves both in absolute terms and when related to body weight (table 16).

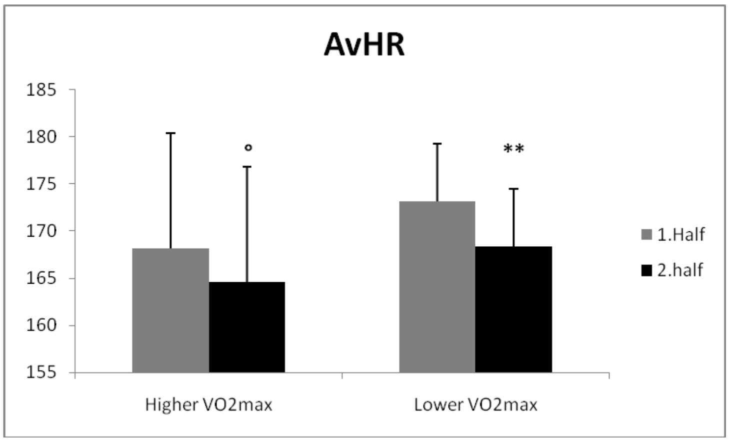

FIGURE 8. Average heart rate (beats/min) in first and second half for ‘Higher VO_{2max}’ - and ‘Lower VO_{2max}’ – groups. ** = significantly different from first half, $p < 0.01$, ° = boardeline significance between the first and second half, $p = 0.054$.

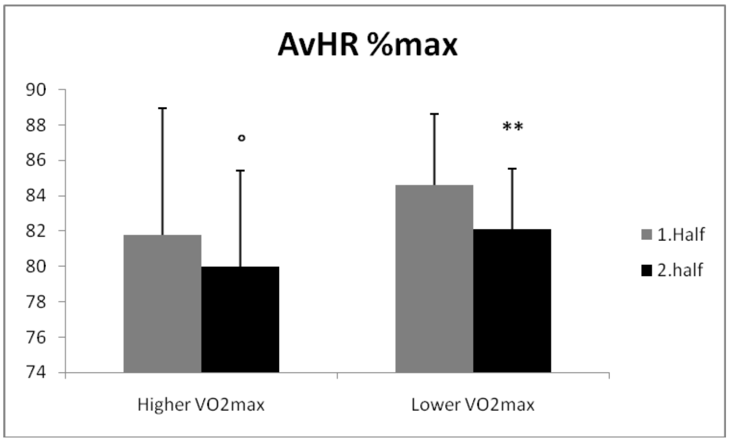

FIGURE 9. Average heart rate (% max) in first and second half for ‘Higher VO_{2max}’ - and ‘Lower VO_{2max}’ – groups. ** = significantly different from first half, $p < 0.01$, ° = boardeline significance between the first and second half, $p = 0.056$.

Oneway ANOVA revealed significant differences between the two groups in relative average heart rate during the first and second half ($p < 0.05$ and $p < 0.01$, respectively) and in average absolute heart rate during the second half ($p < 0.05$) and in average relative VO_2 during the first and second half ($p < 0.05$ and $p < 0.01$, respectively). Furthermore, there was a borderline difference ($p = 0.056$) between the groups in average absolute heart rate during the first half. (Table 16.)

TABLE 16. Average heart rate (beats/min and %max) and VO_2 (ml/kg/min and $\%VO_{2max}$) during the two halves of the game for 'Higher VO_{2max}' (High., N = 14) and 'Lower VO_{2max}' (Low. N = 15) –groups. * = significantly different from High., $p < 0.05$, ** = significantly different from High, $p < 0.01$ and ° = borderline difference between High. and Low. £ = significantly different from first half, $p < 0.05$, $ = significantly different from first half, $p < 0.01$.

	AvHR 1	**AvHR 2**	**AvHR (%max) 1**	**AvHR (%max) 2**	**VO2av 1**	**VO2av 2**	**VO2av (%max) 1**	**VO2av (%max) 2**
High.	166.2 ± 15.5	162.6 ± 10.9 £	80.6 ± 6.3	78.8 ± 4.2 £	38.4 ± 7.3	36.9 ± 5.5	68.1 ± 10.1	65.7 ± 7.1
Low.	175.1 ± 7.3	170.3 ± 6.3 $	85.3 ± 4.3	83.3 ± 3.8 $	38.3 ± 4.1	36.9 ± 3.5 £	76.0 ± 6.0	73.1 ± 5.4 £
	° high	* high	* high	** high			* high	** high

When the average heart rate data was analysed in 15-minute periods, a significant decrease was observed in the players with lower VO_{2max} in absolute and relative average heart rates between 30-45 minutes and 45-60 minutes ($p < 0.05$) and borderline decrease between 30-45 minutes and 75-90 minutes ($p = 0.071$ and $p = 0.074$, respectively). No significant changes in absolute or relative average heart rate were observed with the players with higher VO_{2max}. (Figures 10 and 11.)

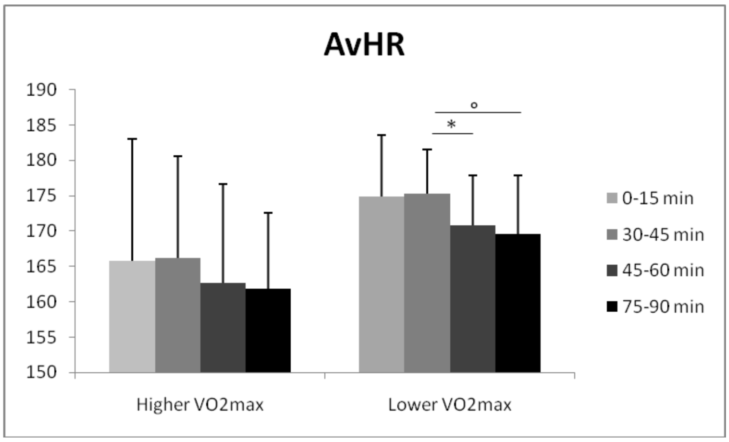

FIGURE 10. Average heart rate (beats/min) in the first and last 15-minute periods in the first and second half for 'Higher VO_{2max}' - and 'Lower VO_{2max}' – groups. * = statistically significant difference between the 15-minute periods, $p < 0.05$, ° = borderline significance between the 15-minute periods.

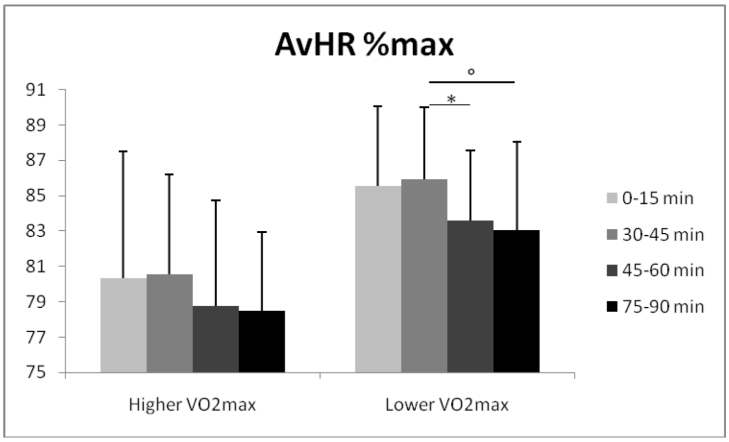

FIGURE 11. Average heart rate (% max) in the first and last 15-minute periods in the first and second half for 'Higher VO_{2max}' - and 'Lower VO_{2max}' – groups. * = statistically significant difference between the 15-minute periods, $p < 0.05$, ° = borderline significance between the 15-minute periods.

In the evaluated oxygen consumption value during 15-minute periods there was a significant decrease in 'Lower VO_{2max}' – group in average VO_2, both in absolute (from 39.4 ± 3.3 to 38.1 ± 3.1 ml/kg/min, $p < 0.05$) and relative (from 78.0 ± 4.2 to 75.7 ± 4.4 % max, $p < 0.05$) terms, between 30-45 and 45-60 minutes. No significant decreases were observed in the players with higher VO_{2max}.

9 DISCUSSION

The main finding of the present study was that the endurance capacity of young football players did not remarkably affect on the number or outcome of their game actions. However, the higher VO_{2max} was associated with game intensity as the players with higher VO_{2max} had lower average physical load in the game and as a consequence were better able to maintain their game intensity. Furthermore, as expected, in young players a decrease in game intensity during the second half was found due to estimated accumulation of fatigue. In addition, findings showed that with increasing age the players were better able to work at a relatively higher heart rate. Finally, it was also found out that the average number and outcome of different actions did not vary according to age.

9.1 Game actions and intensity in different age groups

The total number of attacking actions per player (table 10) in the game were higher when compared to the average values presented by Luhtanen (1988). Also the total number of passes during the whole game were a bit higher when compared to the values presented by Luhtanen, propably due to difference in playing time.

The total number of passes observed in this study was higher when compared to results presented by Helgerud et al. (25-31, 2001) who also analysed young players' matches lasting 90 minutes. In contrast, the total number of passes of this stydy is in line with the study using top-class adult players carried out by Bangsbo (1994), where the total number of passes per player was approximately 35. The average number and succesful percentage of all defensive actions per player are higher when compared to values presented previously by Luhtanen (1988) for young football players.

In general, the total number of game actions varied between different age groups. This could be explained by the within-game effect as only one game for each age group was analysed. Thus, more detailed and precise information about youth football in general was provided when all the groups were combined together and the total number of analysed matches was increased to three to decrease the within-game effect.

The number and succesful percentage of different game actions did not differ between age groups and the variables observed in this study were similar when compared to studies using elite young players. Thus, it can be concluded, that the average number and success in game actions seems not to be dependent on the age and the distribution of these variables is the same independent of the level of the game. In other words, in terms of number and outcome of actions two less skillful and two elite level teams can play against each other in a similar way.

There were no significant differences between the two halves in any of the analysed game actions or outcome (table 11). However, a tendency of increased percentage of successful attacking actions and at the same time a tendency of decreased percentage of successful defensive actions appeared in B-11, B-13 and all groups together. This may imply to fatigue related weakening of the defence. The weakening of defence may create more space for attacking actions, as the defending team does not work as properly as an unit and similarly may react late to different actions. Thus there is no decrease (but an increase) in successful percentage of attacking actions despite the fatigue may certainly have an effect on attacking actions also The theory of fatigue related weakening of defence is also supported by the observed correlation between the decreases in game intensity (AvHR and VO_2) and the number of defensive actions in B-11. Furthermore, there was a decrease in the total number of attacking actions between the halves in all of the analysed groups and a decrease in the total number of all actions in B-11, B-15 and all groups (table 11). Despite these decreases were not statistically significant, it can be speculated that the accumulated fatigue during the game limits the involvement of the players to the game and thus the number of actions is smaller. However, more research considering these topics in game actions would be needed in the future.

It was clearly found that the game intensity gradually increased with increasing age. The average heart rate values (tables 12 and 16) observed in this study are in line with the values (157-182 beats/min) presented by Strøyer et al. (2004). The average relative heart rate ranged from 79.2 ± 4.7 % to 86.8 ± 4.0 % of maximal heart rate which is in accordance with the values presented by Helgerud et al (82.6 ± 4.1 %max, 2001) for elite young players. Average oxygen consumption during the game estimated from the heart rate data (tables 11 and 15) were in line with the values presented by Strøyer et al. (70-80 % of VO_{2max}, 2004) for young football players and by Bangsbo (70 % of VO_{2max}, 1993) for adult players.

9.2 Game actions and intensity in higher and lower endurance capacity groups

There were no significant differences observed between the groups in the relative change in the number or outcome of game actions between the halves in the age-independent comparison of the players based on their VO_{2max}. The difference closest to significance was a borderline ($p = 0.059$) difference observed between the 'Higher VO_{2max}' – and 'Lower VO_{2max}' – groups in the number of passes between the halves (increase of 6.0% in 'Higher VO_{2max}' and decrease of 16.0 % in 'Lower VO_{2max}'). (Table 15.)

Furthermore, there was an increase of 5.9 % observed in 'Higher VO_{2max}'-group in the total number of defensive actions between the two halves of the game. In 'Lower VO_{2max}' – group the total number of defensive actions and the total number of all actions decreased (4.6 % and 5.7 %, respectively) between the halves. (Table 15.) Despite these differences in the changes were not statistically significant, it can be speculated that VO_{2max} may have an effect on the participation of the players to the game in youth football i.e. the young players with higher endurance capacity tend to be more active during the game. Yet, it can be concluded that as there was no statistical significance in these presented results, the effect of endurance capacity on the total number of game actions in young players is perhaps still quite small as the game performance in football is always affected by multiple factors and endurance capacity of the players is only one of them. However, Helgerud et al. (2001) have previously presented in their training study that improving the aerobic capacity of young players influences their match performance and increases the distance covered, level of work intensity, number of sprints and the total number of involvements with the ball during the game.

Furhermore, the endurance capacity of the players did not have an effect on the outcome of the players' game actions. This has also been presented before by Helgerud et al. (2001). Thus, it could be concluded that instead of high endurance capacity, other more important factors, such as skills and game understanding have a greater effect on the successfulness of game actions. According to Miettinen (1990) football is a game with high requirements on skills and talent and one third of the game performance is determined by the skill level of the player. It has also been presented that thus the emphasis of training especially before puberty should be on developing specific football and generic movement skills. The time before puberty has been presented as the optimal timing for this type of training (Mero & Numminen 1990). However, more research and information considering the relationship between endurance capacity and game actions and their outcome in youth football could be carried out in the future.

More than the game actions, the endurance capacity of young players definitely affects the game intensity and physical loading of the game. In the players with higher VO_{2max}, the average relative heart rate was significantly lower during both halves when compared to the players with lower VO_{2max} . Similar differences were observed between the groups in average heart rate and in relative oxygen consumption. (Table 16.). Furthermore, in the players with higher VO_{2max} there was only a borderline decrease inabsolute and relative average heart rate between the halves, whereas in the players with lower VO_{2max} the changes observed were significant (figures 8 and 9). Likewise, both in absolute and relative average oxygen consumption (based on the heart rate data) there was a statistically significant decrease observed between the halves in the 'Lower VO_{2max}' – group, but no statistical significance was observed in players with higher VO_{2max} (table 16). Despite the differences in the relative changes between the halves between the groups were not statistically significant, it can be concluded that in the young players with higher VO_{2max} the average physical load of the match was not as high as it was for the less fit young players and that's why these players were better able to maintain their game intensity during the game. Similar conclusions have been made by Tumilty (1988), who found out that the junior players with superior endurance capacity were better able to maintain their performance in the game simulation. According to Tumilty, one possible explanation for this may be the greater number of capillaries in muscles and better ability to utilize lactate aerobically.

It was observed that the total number of defensive actions increased in ‘Higher VO_{2max}’-group, but decreased in ‘Lower VO_{2max}’ – group between the halves. Furthermore, when examing all age groups together, a significant correlation was observed the Yo-Yo test result and relative change in successful defensive actions. Thus, it can be concluded that the aerobic capacity of the players has a more stronger effect on their defensive performance than on their attacking actions and intensity. As the endurance capacity of the young players seems to limit their game intensity, the players perhaps concentrate more on attacking actions and reduce their movements defensivewise. Also motivational factors may have an affect on weakening of the defence.

9.3 Estimated accumulation of fatigue

When all three age groups were analyzed together, a significant decrease in average heart rate (beats/min and %max) and thus also in estimated average VO_2 (ml/kg/min and %max) was observed between the halves (Table 12). Based on these findings, it can be concluded that in youth football the average intensity of the game decreases significantly during the second half when compared to the first. Similar conclusions have been made in the past in young and adult footballers (Bangsbo et al. 1991, Bangsbo 1994, Castagna et al. 2003, Mohr et al. 2003, Krustrup et al. 2006). The reason for this decline in the game intensity and accumulated fatigue towards the end of the game has been suggested to be due to depletion of muscle glycogen stores (Bangsbo et al. 1992, Mohr et al. 2005 and Krustrup et al. 2006). A diverse set of data has previously presented that in immature subjects the capacity of glycolytic metabolism is poorer than in adults (Rowland 2005, p. 71). Thus, the depletion of glycogen stores during the matches in present study also seems evident, especially as the duration of the matches was 2*45 minutes and thus longer than usually used in matches at these ages.

When all groups were analyzed together in 15-minute periods, a significant decrease was observed in average heart rate between 0-15 and 45-60 minutes and between 30-45 and 45-60 minutes (figure 7). Similarly, statistically significant decreases were observed between 0-15 and 45-60 and 30-45 and 45-60 minutes in average absolute and relative oxygen consumption (table 13). These findings may refer to fatigue accumulation at the beginning of the second half, which has also been documented before and associated with the decline in muscle temperature in the half-time (Mohr et al. 2004). Another reason for this decline in the game intensity at the beginning of the second half may be the glycogen depletion caused already by the first 45-minutes as the duration of the first half and the match in total was longer than usually played at this age. Previously Saltin (1973) has demonstrated that the glycogen stores can be almost depleted even in adult players already at the half time, especially if the prematch stores are low. Moreover, as the glycolytic activity of the children has clearly been presented in numerous publications (e.g. Rowland 2005, p. 76) to be lower, it can be suggested that the glycogen stores of these players were partly depleted already during the first half.

The theory of glycogen depletion, in addition to other factors, can even be strengthened when the higher and lower VO_{2max} - groups were compared in the 15-minute periods. In players with higher VO_{2max}, the decrease in average heart rate (figures 10 and 11) or oxygen consumption was not statistically significant between 0-15 and 45-60 minutes or between 30-45 and 45-60 minutes. In contrast, in the 'Lower VO_{2max}' - group there was a significant decrease in average heart rate (beats/min and %max) and thus also in average oxygen consumption (ml/kg/min and %max) between 30-45 and 45-60 minutes.

As the decline in muscle temperature would occur at similarly no matter what the endurance capacity of the player is, the observed decreases in the game intensity at the beginning of the second half have to be explained with other reasons too. Thus, it can be speculated that in the players with lower VO_{2max}, there was a greater decline in muscle glycogen stores already during the first half and these players were not capable to recover from this decline during the half time. In contrast, in the players with better endurance capacity the decline of glycogen stores had not as great impact on the game intensity at the beginning of the second half. Previously it has been presented, that VO_{2max} quantitatively expresses one's capacity for aerobic resynthesis of ATP. This is one of the most important factors determining a person's ability to sustain high-intensity exercise (such as football match). (McArdle et al. 1996.) Thus, it can be concluded that the players with higher VO_{2max} were better able to utilize energy aerobically during the match without relying as much on their anaerobic energy production through glycolycis.

9.4 Endurance capacity and endurance performance

Maximal oxygen uptake (VO_{2max}) of the subjects related to bodyweight (53.7 ± 4.1 - 54.9 ± 3.7 ml/kg/min) was somewhat lower when compared to the values presented by Chamari et al. (66.5 ± 5.9 ml/kg/min, 2005) and Strøyer et al. (58.7 ± 5.3 – 63.7 ± 8.5 ml/kg/min, 2004) for young footballers but is in line with the values presented by Vanderfjord et al. (52.9 ± 1.2 – 56.2 ± 1.5 ml/kg/min, 2004). VO_{2max} of the players in this study was also lower compared to the values presented for adult players in previous studies (56-68 ml/kg/min, Bangsbo 1993, Hoff et al. 2002, Arnason et al. 2004, Chamari et al. 2005, Rampinini et al. 2007). The lower values compared to the values presented by Chamari et. al (2005) and Strøyer et al. (2004) may perhaps be explained by the bit higher level of the subjects in those two studies when compared to players of the present study.

There were statistically significant correlations between the measured VO_{2max} and the Yo-yo test result in B-11, B-13 and all the groups together. No correlation was observed in B-15. Furthermore, significant correlations were observed in players with the lower VO_{2max} when the measured VO_{2max} was correlated to Yo-Yo test result, but no significant correlation in the group with higher VO_{2max}.

Thus it seems that Yo-Yo Endurance Test is suitable for measuring players' endurance performance but not necessarily accurate for estimating their VO_{2max}. Especially this seems to be the case with the players with higher endurance capacity. The present findings are in accordance with the previous study carried out in young football players by Metaxas et al. (2005). Furthermore, the absence of correlation between the measured and Yo-Yo test result in B-15 may imply that players at this age group rely on their neuromuscular factors during the test in addition of their aerobic capacity. The nature of the Yo-Yo test requires a lot of turns of short sprints and thus, neuromuscular factors have an effect to the results, especially in the B-15 group where the biological age of the players varies and the group is heterogeneous.

9.5 Conclusions and practical implications

In contrast to what was hypothized, the endurance capacity of the young players did not have a great effect on the number and outcome of game actions. In the beginning of the study it was also hypothized that an accumulation of fatigue would cause a decrease in the game intensity and this was fulfilled. There was a significant decrease in game intensity in these young players during the game. Furthermore, in the players with higher VO_{2max} the average physical load of the match was not as high as in players with lower VO_{2max} and as a consequence they were better able to maintain their game intensity. In addition, it was found that with increasing age the game intensity also gradually increases, that is, the older players are able to work with higher relative heart rate and closer to their maximal level during the game. Interestingly, also the average number of different actions and their outcome per player was independent of the players' age.

It has been previously presented that the VO_{2max} of young football players can be improved by small-sided games (Impellizzeri et al. 2006) and football specific interval training (McMillan et al. 2005). As it was presented in the present study that the higher endurance capacity of the players improves the game intensity, these methods of training can be recommended as they also improve other important factors of game performance, mainly football skills and game understanding. In general, it must be emphasized that the main focus in young players' training should still be on development of football skills and game understanding as the higher endurance capacity does not seem to affect the successfulness of game actions during the game and it can be improved at the older age also. Future research concentrating on game performance, level of work intensity, and the involvements with the ball in youth football is still needed to gather more detailed information about youth football.

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APPENDIX 1. CONVERSION OF YO-YO ENDURANCE TEST LEVEL 1 RESULTS TO MAXIMAL OXYGEN UPTAKE

Conversion of test results to maximal oxygen uptake

Scientific studies have shown a relationship between an individual's test result from the Yo-Yo endurance test (performed indoors) and his or her maximal oxygen uptake ($\dot{V}O_2$ max; expressed per kg of body mass). Thus, the test results from the Yo-Yo endurance test provide a good indirect measure of an individual's maximal oxygen uptake. Table 1 can be used to convert the test result to maximal oxygen uptake (both for the level 1 and the level 2 test).

Test results (speed level: repetitions)	$\dot{V}O_2$ max (ml O_2 per minute per kg b.m.)	Test results (speed level: repetitions)	$\dot{V}O_2$ max (ml O_2 per minute per kg b.m.)
5:2	27.1	11:4	48.5
5:4	28.0	11:6	49.2
5:6	28.6	11:8	49.9
5:9	29.9	11:11	50.9
6:2	30.5	12:2	51.4
6:4	31.4	12:4	52.0
6:6	32.2	12:6	52.6
6:9	33.2	12:8	53.1
7:2	34.0	12:10	53.7
7:4	34.6	12:12	54.2
7:6	35.5	13:2	54.9
7:8	36.1	13:4	55.5
7:10	36.7	13:6	56.0
8:2	37.5	13:8	56.6
8:4	38.3	13:10	57.1
8:6	39.1	13:12	57.7
8:8	39.7	14:2	58.1
8:10	40.6	14:4	58.7
9:2	41.1	14:6	59.2
9:4	41.6	14:8	59.8
9:6	42.4	14:10	60.4
9:8	43.0	14:13	61.2
9:11	43.9	15:2	61.7
10:2	44.4	15:4	62.2
10:4	45.0	15:6	62.8
10:6	45.7	15:8	63.3
10:8	46.3	15:10	63.9
10:11	47.4	15:13	64.7
11:2	47.9	16:2	65.2

Test results (speed level: repetitions)	$\dot{V}O_2$ max (ml O_2 per minute per kg b.m.)	Test results (speed level: repetitions)	$\dot{V}O_2$ max (ml O_2 per minute per kg b.m.)
16:4	65.8	19:6	77.5
16:6	66.3	19:8	78.1
16:8	66.9	19:10	78.6
16:10	67.4	19:12	79.2
16:13	68.2	19:15	80.0
17:2	68.7	20:2	80.5
17:4	69.2	20:4	81.1
17:6	69.8	20:6	81.6
17:8	70.3	20:8	82.1
17:10	70.9	20:10	82.7
17:12	71.4	20:12	83.2
17:14	72.0	20:15	83.8
18:2	72.6	21:2	84.5
18:4	73.1	21:4	85.1
18:6	73.6	21:6	85.6
18:8	74.2	21:8	86.1
18:10	74.8	21:10	86.7
18:12	75.3	21:12	87.2
18:14	75.9	21:14	87.8
19:2	76.4	21:16	88.3
19:4	77.0		

Values for elite athletes

The table shows mean values and variations for elite runners and elite soccer players who have performed the level 2 test outdoors.

	Elite runners	Elite soccer players
Average	18:2 (3621 m; 72.6)	15:5 (2822 m; 61.7)
Variation	17:1 – 20:8 (3320-4320 m; 68.7-82.1)	13:9 – 18:2 (2460-3340 m; 57.1-72.6)

The values in brackets show the total distance covered in metres and the corresponding maximum oxygen uptake (ml O_2 per minute per kg b.m.).

FIGURE 12. Conversion of Yo-Yo Endurance Test Level 1 results to maximal oxygen uptake. (Bangsbo 1996.)

APPENDIX 2. THE NOTATIONAL ANALYSIS SYSTEM USED FOR GAME ANALYSIS

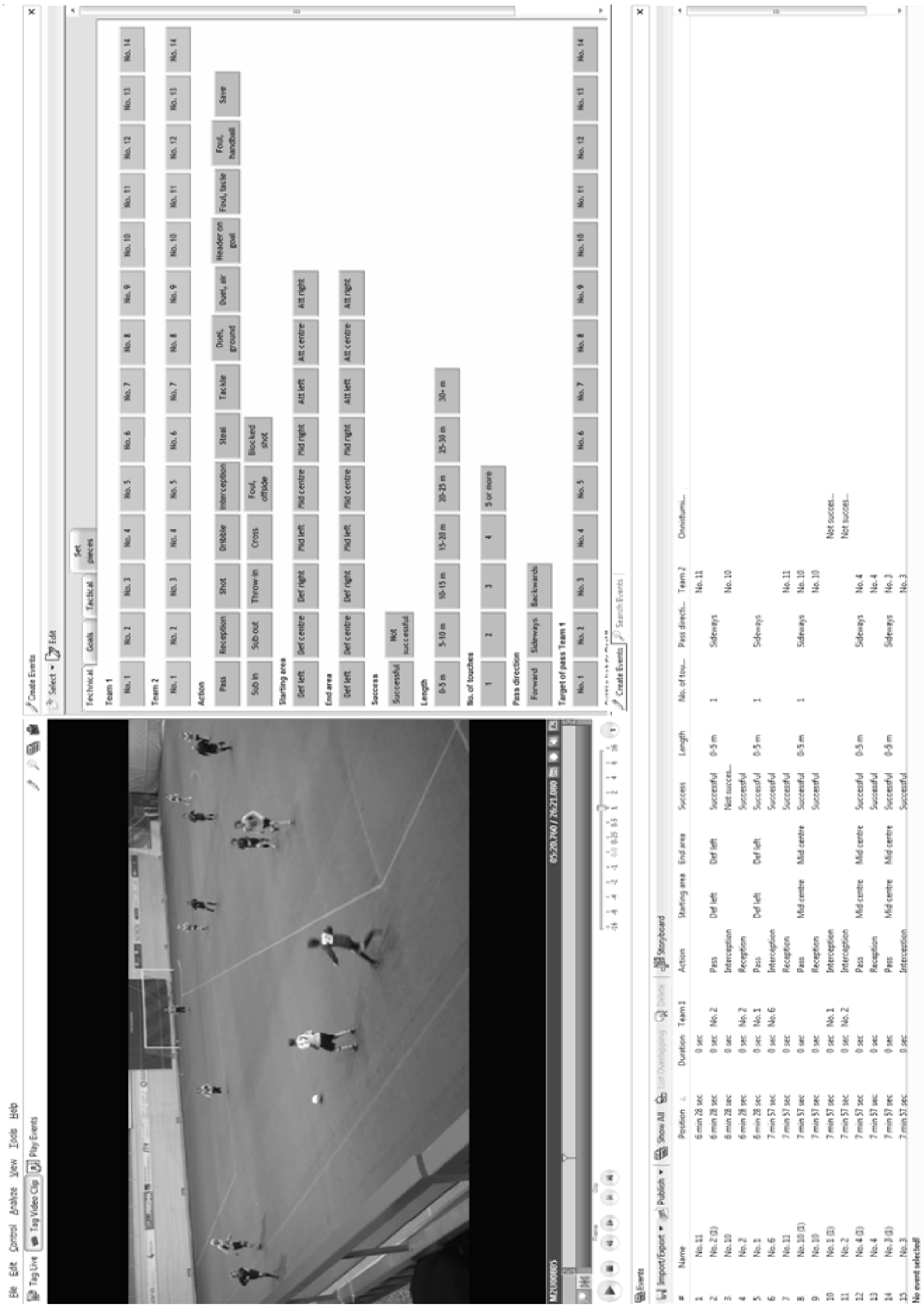

FIGURE 13. The notational analysis system used for game analysis.