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"Age-related differences in agility and speed performances between the first team and youth players in male amateur soccer - to what extent are agility performance, change of direction performance and linear sprinting speed related skills in amateur soccer?"

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Abstract

The aim of this study was to compare male amateur soccer players in different age groups and thus, with a different standard of play in linear sprinting speed, change–of–direction speed and agility performance. The main research question is, therefore, if there is a relation between those skills, especially between agility and linear sprinting speed. In total, sixteen first team players and ten youth players from the same club participated and completed three different tests for assessing each ability without and with dribbling a ball. There are statistically significant differences ($p < 0.05$) between first team players and youth players in all tests except for agility performance testing with a ball ($p= 0.200$) and in the change – of–direction test with a ball ($p= 0.11$), whereas the first team players always yielded faster results. Furthermore, there is a statistically significant ($p < 0.05$) moderate correlation between linear sprinting and agility performance without a ball displayed Pearson´s coefficient $r= 0.7$ and the common variance $R^2= 0.49$. There is also a significant moderate correlation between sprinting and agility performance ($r= 0.52$; $R^2= 0.27$) while dribbling a ball. Because of the lower common variance of 27%, it could be assumed that it does make a difference in the performance if a ball is included or not and that agility and sprinting with a ball are different physical qualities.
Key words: amateur soccer, agility, change of direction, linear sprint, age-related differences

Zusammenfassung

Ziel dieser Studie war es, die altersspezifischen Unterschiede zwischen männlichen Kampfmannschaftsspielern und Nachwuchsspielern im Amateurfußball in Hinblick auf die lineare Sprintschnelligkeit, die planbare Richtungswechselgeschwindigkeit, sowie die unvorhersehbare Richtungswechselgeschwindigkeit („agility“) festzustellen. Zugleich wurde überprüft, ob es einen Zusammenhang zwischen den einzelnen Fähigkeiten gibt und wie groß dieser ist. 16 Spieler aus der Kampfmannschaft und 10 Jugendspieler nahmen an der Studie teil und absolvierten 3 verschiedene Tests, jeweils mit und ohne Ball. Es zeigten sich bei allen sechs Testungen signifikante Unterschiede ($p< 0.05$) zwischen Kampfmannschafts- und Nachwuchsspielern. Außer bei den Testungen von vorhersehbarer und nicht- vorhersehbarer Richtungswechselgeschwindigkeit mit Ball, waren die Kampfmannschaftsspieler im Durchschnitt bei allen Tests schneller. Es konnte ebenso ein signifikanter, moderater Zusammenhang ($r= 0.7$; $R^2= 0.49$) zwischen der linearen Sprintschnelligkeit, sowie der unvorhersehbaren Richtungswechselgeschwindigkeit ohne Ball festgestellt werden. Bei denselben Testungen mit Ball trat ebenso ein signifikanter, moderater Zusammenhang ($r= 0.52$; $R^2= 0.27$) auf. Da der Anteil der gemeinsamen Varianz mit 27% aber geringer ausfällt als ohne Ball (49%), lässt sich daraus schließen, dass die Leistung auch sehr von den technischen Qualitäten (mit Ball) abhängig ist und dementsprechend auch Unterschiede in Hinblick auf die lineare Sprintschnelligkeit und der unvorhersehbaren Richtungswechselgeschwindigkeit bestehen.

Stichwörter: Amateurfußball, Gewandtheit, Richtungswechselgeschwindigkeit, linearer Sprint, altersspezifische Unterschiede

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1. Introduction

Soccer is the world's most popular sport. As stated by FIFA, the International Federation of Association Football "265 million male and female players in addition to 5 million referees and officials make a grand total of 270 million people – or 4% of the world's population – who are actively involved in the game of football.". (FIFA, 2007). Because of the intermittent character of the game, there are many different physical and physiological demands required. For the success of a soccer team, a certain amount of high-intensity running or sprinting is essential, even though just 1-12% of the total distance covered in a match involves sprinting. (Di Salvo et al., 2010; Stølen, Chamari, Castagna, & Wisløff, 2005).

As a matter of fact, players at a superior standard of play perform more sprints or high-intensity runs compared to lower class athletes. (Bradley et al., 2013; Mohr, Krustrup, & Bangsbo, 2003). The amount of high-intensity activities is, therefore, a good indicator for match performance as stated by Bradley, Di Mascio, Peart, Olsen, & Sheldon (2010). As recent studies show, high-level players perform 28% more high-intensity running than moderate or standard soccer players. (Bradley et al., 2010). In general, the development of the game over the past years shows that high-intensity activities increased, while the total covered distance did not change substantially. (Barnes, Archer, Hogg, Bush, & Bradley, 2014).

Just like in other team- or field sports, soccer involves not only linear sprinting or repeated short sprinting, but players also perform many frequent turns and twists. Thus, change - of - direction speed (CODS) and agility performance are important skills for team - sport athletes. Agility testing and training is relatively new in the field of sport science and the latest definition of agility was specified by J. Sheppard & Young (2006) and is comprised as: "a rapid whole-body movement with change of velocity or direction in response to a stimulus" (J. Sheppard & Young, 2006). Traditional agility tests commonly involve directional changes around cones and are, in fact, pre-planned and therefore not suitable for assessing agility referring to the definition above. To receive results that are more specific and assess reactive agility as a response to a stimulus, numerous tests that include cognitive components have been developed. For coaches, it is important to adapt the whole process of testing and training to the physical demands required in order to establish a successful team.

This work highlights the importance of agility in the field of soccer and discusses the relation as well as the differences between agility, change – of - direction and linear sprinting speed. Furthermore, there is an additional emphasis on the age-related differences in those abilities. In order to answer the research question, a study was conducted for which visual stimuli were used to assess agility and change of direction speed. The testing procedure consisted of three different testing systems, one for testing the linear sprinting speed, one for change – of - direction speed and the other for testing the soccer-specific agility. An amateur team as well as youth players of the first national league of Lower Austria were tested. For that reason, it is possible to notice age-related differences in linear sprinting speed, change of direction speed and agility performance with and without a ball. To be as sport-specific as possible, all three tests were performed as field tests on a soccer pitch wearing soccer shoes.

First, an overview of the characteristics and physiological demands of soccer is given. Additionally, a profile of soccer-specific requirements is outlined and the kinds of performance diagnostics relevant in the field of soccer are described. Later, the terms *agility*, *change – of - direction speed* and *linear sprinting speed* are defined. In the further parts of this thesis, the main focus is on testing agility and training and on improving agility performance in the field of soccer. A brief overview of agility in other team sports is given as well. The whole testing procedure and the study design are outlined in the methods chapter, followed by the presentation of results and a final discussion.

2. Characteristics of the team sport soccer

Soccer is an intermittent team sport, which is usually played over 90 minutes with two halves of 45 minutes each, separated with a 15-minute break (Russell, Rees, Benton, & Kingsley, 2011). In Soccer, diverse motoric skills including for example running, dribbling, jumping, tackling and kicking are involved and the performance generally depends on various factors such as biomechanical, tactical, mental and physiological parts. (Haugen & Seiler, 2015). According to Haugen and Seiler (2014), technical and tactical skills are main factors, but in order to become a successful player, individual physical capabilities have to be well developed, too (Haugen, Tønnessen, Hisdal, & Seiler, 2014). Usually five subgroups of players, according to their game position, can be distinguished: goalkeepers, defenders as centre- backs or full- backs, midfielders and strikers. Each one of these positions has different physiological characteristics, which will be illustrated in the following paragraphs (Boone, Vaeyens, Steyaert, Bossche, & Bourgois, 2012).

2.1 Physiological demands

The physiological demands in the game of soccer are expressed by the intensity of actions, which appear during match-play. Conferring to Hoff and Helgerud (2004), soccer players run about 8-12 km during a 90-minute game and the average intensity of a soccer game is close to the lactate threshold, which is about 80-90% of maximal heart rate. (Hoff & Helgerud, 2004). More recent studies show that the total covered distance per match is between 9-14 km with mainly low-intensity activities. (Bradley et al., 2010). As research shows, a good parameter for the physical performance is the amount of high-intensity activities. Actually, elite players perform 28% more high-intensity running than moderate or standard soccer players (Bradley et al., 2010).

Because of the game duration and the submaximal physical stress, the energy mainly comes from the aerobic metabolism, according to Boone et al. (2012). Anaerobic energy is needed when performing high-intensity bouts such as short sprints, jumps, tackles and duel play. Such sequences with high- intensity activities, such as sprinting, lead to an accumulation of lactate. During low-intensity phases, the removal of lactate proceeds. (Boone et al., 2012). About 12% of the total covered distance are short and sprint-type activities (Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009). As studies report, elite players can tax the anaerobic system to a higher degree than non-elite players, which is the reason why the gameplay is generally faster in higher divisions. (Stølen, Chamari, Castagna, & Wisløff, 2005). In the second half of the game, the intensity is reduced and the distance covered is 5-10% less, compared to the first half as mentioned by Stølen et al.

(2005). Additionally, the high-intensity running distance is reduced close to the end of the game as well as after intense phases during the play (Bradley et al., 2010).

Sprinting constitutes 1-11% of the total match distance, happens every 90 seconds and lasts about 2 to 4 seconds as stated in the article by Stølen et al. (2005). Moreover, each player performs about 1000 - 1400 mainly short activities that change every 4 - 6 seconds. These activities are at an average “10-20 sprints, approximately every 70 seconds high-intensity running, 15 tackles, 10 headings, 50 involvements with the ball, 30 passes as well as changing pace and sustaining forceful contractions to maintain balance and control of the ball against defensive pressure”(Stølen et al., 2005, p. 503).

Just as important as endurance in soccer are strength and power for successful performing. To stay balanced against defensive pressure or other forceful contractions, which might happen during a match, it is also important for a soccer player to have strength and power. Power is defined as “the ability to produce as much force as possible in the shortest possible time” conferring to Stølen et al. (2005, p. 523). For developing muscular strength, there are two different mechanisms, muscular hypertrophy and neural adaptions. There is no ideal training method for soccer players, but if the players already have experience with strength training, neural adaption training should be preferred as it has more advantages according to the authors. The difference between these two is that hypertrophy training occurs as an increase in myofibrils in the fibres, while neural adaption also leads to an “increased recruitment of motor units and an increased co-contractions of agonists” as stated in Stølen et al. (2005, p. 524). It is a fact, that there is a significant relation between the 1- repetition-maximum, acceleration and movement velocity, which is important for soccer skills such as turning, sprinting and changing velocity. Therefore, maximal strength is an elementary quality, which influences power performance and by increasing the available force of muscular contraction in appropriate muscles or muscle groups, acceleration and speed might be improved, which are important skills for turning, sprinting and changing pace. Another important benefit of high levels of maximal strength is the prevention of injuries in soccer (Stølen et al., 2005).

To find out how the physical and technical demands of soccer developed over the last years, a study within the English Premier League (EPL) was conducted. Barnes, Archer, Hogg, Bush, & Bradley (2014) collected game data from 7 EPL seasons (2006/ 2007 to 2012/ 2013) with a total number of 14,700 observed match performances. As the findings demonstrate, total covered distance was ~2% lower in 2006/2007 compared to the season 2012/2013, while high-intensity running distance and actions increased by ~30% (890 ± 299 vs. 1151 ± 337 m, $p < 0.001$; ES: 0.82) and ~50% (118 ± 36 vs. 176 ± 46, $p < 0.0001$; ES: 1.41). Sprint distance and number of sprints increased by ~35% (232 ± 114 vs. 350 ± 139 m, $p < 0.001$; ES: 0.93) and ~85% (31 ± 14 vs. 57 ± 20, $p < 0.001$; ES: 1.46). Additionally, mean sprint distance was shorter in 2012/ 2013 in comparison to 2006/ 2007, while the number of explosive sprints was increasing (34 ± 17 vs. 47 ± 9%, $p < 0.001$; ES: 1.31). (Barnes et al., 2014). These results support the statement that the physical and technical demands of the game increased over the last years. To conclude, it is important for coaches to understand this development and to adapt the training practises to those new demands in order to get the best results from the soccer team.

2.2 Profile of requirements in respect to different playing positions

The chapter above listed the different physiological demands in the game of soccer in general. The following abstracts deal with the specific physical and physiological requirements of soccer players concerning different playing positions.

As diverse studies revealed there are differences in the player positions as well as between professional and non–professional players. Referring to the overall running distance during a soccer game, midfielders run the longest distances during a match. Moreover, professional soccer players run more kilometres than non-professionals, according to these researches. Conferring to Boone et al. (2012), midfielders cover 5-15% more overall distance than full-backs, forwards and centre-backs. What is more, they run 20-40% more distance at high-intensity in comparison to forwards and centre-backs. Compared to midfielders and centre-backs, forwards and full-backs sprint 20-40% more of the total time. The average distance covered by a goalkeeper is about 4 km (Boone et al., 2012).

As presented in many studies, 8-12 % of the total covered distance consist of high- intensity running or sprinting. Comparing the player positions, wide midfielders and external defenders perform more high intensity running and sprinting than players in other positions. Haugen et al. (2014) mentions that sprinting test results showed that forwards are faster than defenders, midfielders and goalkeepers. Therefore, there might be a relation between sprinting ability and the player´s position on the field. In a study by Bradley et al. (2010), 100 elite domestic and 10 international players from elite European teams were monitored in order to determine high-intensity activities of soccer players with different performance levels and different positions. The outcomes demonstrate that wide and central midfielders, full- backs and attackers covered a greater distance ($p <0.01$) in high-intensity running than central defenders (3,243 ± 625, 2,949 ± 435, 2,806 ± 408, 2,618 ± 745 vs. 2,034 ± 284 m). Wide midfielders also covered a greater distance ($p <0.01$) in very high-intensity running compared to central midfielders, fullbacks, attackers and central defenders (1,273 ± 257 vs. 941 ± 235, 1,046 ± 196, 996 ± 268, and 638 ± 154 m). (Bradley et al., 2010).

In the study by Boone et al. (2012), a group of 289 high-class soccer players from Belgium were tested in order to achieve representative output. The players, who were championship level at that time, did various anaerobic and aerobic laboratory-based tests to get a physical and physiological profile for each playing position. The anaerobic tests consisted of a 10-m sprint, a 5x10-m shuttle run for testing agility, a squat jump and a counter-movement jump. To screen the aerobic performance and the speed at the anaerobic threshold an incremental running test was performed. The main purpose of this study was to investigate the physical and physiological profile of elite Belgian soccer players with the focus on the players' position on the field. The findings revealed the different physical and physiological requirements due to a variety of positions in the field. In contrast to the field players, goalkeepers need relatively low demands from the aerobic energy metabolism, because most actions, like sprinting and jumping, are performed by using anaerobic power. In this study, the goalkeepers had a significantly lower VO_2max and performance at the anaerobic threshold in comparison to other playing positions. Concerning the field players, the centre-backs cover the shortest distance during a game. According to the findings, the physiological profile matches the specific requirements of these positions. For instance, centre-backs require a strong positional play and need a good head play. Compared to other positions, they do fewer explosive sprints and mainly move to the front for the corner kicks or the free kicks. From all field players the centre-backs have the lowest VO_2max and running speed at the anaerobic threshold. Moreover, their anaerobic sprint performance and agility performance is rather low as the results from this study show. Boone et al. (2012) assume one reason for this might be their larger body size compared to other players. While the anaerobic power for jumping is higher, their height also positively affects their good head play. From all positions, the midfielders and full-backs cover the largest distance in general, on average 10.5-11,5 km, as it is mentioned in the article by Boone et al. (2012). This study shows that these players had the highest aerobic power and performance at the anaerobic threshold compared to other players. However, full-backs had a slightly higher sprinting ability and their agility performance was lower compared to the midfielders. In the game, full-backs need speed to pass an opponent along the line, whereas midfielders need to change direction fast and accelerate within this change. In this study, the strikers had the best sprinting performance and the best agility in comparison to the other positions, as stated by the authors. Concerning the covered distance during a match, the strikers are in between the defenders and the fullbacks and midfielders with an average distance of 9.5 to 10km. The jumping performance of the strikers was better than the jumping performance of midfielders and full-backs, but lower in comparison to defenders. During the game, strikers need a high anaerobic sprinting performance and a quite high aerobic performance in combination with a relatively high anaerobic jumping performance in order to control the long pass or to head the ball to one of their teammates (Boone et al., 2012).

The study of Mohr, Krustrup and Bangsbo (2003) investigated the activity pattern of high-standard soccer players in relation to their game position and level of performance as well as the development of fatigue during a match and the match performance at different periods of the season. The results illustrate that high-class players perform more high-intensity running than soccer players from lower levels. In addition, the amount of low-intensity runs, high-intensity runs and sprints was higher for top-class players compared to moderate players. Comparing the two halves of the game, top-class athletes ran and sprinted more in the first than in the second half. Moreover, the total covered distance during the match was 5% more in the top-class players than moderate players, with midfielders, full-backs and attackers covering a greater distance than defenders. Lastly, the study showed that after periods with high-intensity activities and towards the end of the game the physical performance was reduced in both levels, which might mean that fatigue occurs temporarily during and at the end of the match as the authors mentioned (Mohr et al., 2003).

For the match result, especially high-intensity activities are important, since they are essential for efforts such as winning a ball or agility performances in general. The aim of the study from Di Salvo et al. (2009) was to investigate high-intensity activities as well as the influence of high-intensity running on the team's success. It showed that the total high-intensity running distance was linked to the position of the players. Midfielders covered the highest distance, while central defenders covered the lowest. Another result was that high-intensity running did affect the success of the team (Di Salvo et al., 2009).

Hence, the study results, it should be kept in mind that different positions also lead to different physical demands and therefore different training loads (Haugen et al., 2014).

2.3 Performance diagnostics

Performance diagnostics in general include all types of interventions, tests and testing procedures and need to be done in order to control the following process of training.

This chapter contains information about different diagnostic methods and tests for measuring soccer-specific performances regarding endurance, strength and speed. Most tests are determined to get values of VO_2max, anaerobic threshold, work economy, maximal aerobic performance, strength and power, anaerobic energy production and talent identification. For testing the soccer-specific endurance most tests have an intermittent exercise pattern. There are many different testing systems varying from time to cover a distance, distance covered in a restricted amount of time or time to fatigue (Stølen et al., 2005).

In the following paragraphs, different field and laboratory tests will be presented and their applicability will be explained.

First, the Yo-Yo intermittent recovery test is known to be well correlated with the amount of high-intensity running by soccer players during a high-standard soccer match. It consists of repeated 2x20 m runs back and forth between a start and a finish line. The running speed increases gradually and is controlled by audio bleeps from a tape- recorder. The 10-second active rest period between the running sessions consists of 2x5 m jogging. The test is over when the athletes failed to reach the finish line in time twice and then the covered distance represents the result (Mohr et al., 2003; Stølen et al., 2005). As sprinting speed is very important for the soccer performance, the testing of single sprints should be part of the evaluation of soccer players as well. To assess the sprinting ability of each player, usually 10m, 20m or 30m sprints are used, preferably with a “flying start” (Svensson & Drust, 2005).

The laboratory test for determination of maximal oxygen uptake or maximal aerobic power, VO_2max, is important for soccer players because most of the energy comes from the aerobic system during a 90-minute game as mentioned above. The oxygen transport system is also important for a fast recovery between high-intensity periods. To be sport specific, a VO_2max test should be performed on a treadmill. The primary criterion to make sure O_2max is reached is the achievement of a plateau in VO_2. However, if such a plateau does not occur, there are other criteria for maximal effort such as the respiratory exchange ratio (RER) being above 1.15 or blood lactate concentration above 8 mmol, as it is stated in Svensson & Drust (2005). Various studies showed that the VO_2max is correlated to the total distance covered during a soccer match (Stølen et al., 2005).

Another laboratory test is the lactate threshold test. The lactate threshold or anaerobic threshold is defined as “the highest exercise intensity, HR or VO_2 where the production and clearance of lactate is equal” (Stølen et al., 2005, p. 530). The lactate threshold also marks the changeover between moderate and heavy exercise and is therefore an indicator for the accumulation of lactate in the blood. However, the lactate threshold is not strongly correlated to a player´s performance during a soccer game. Therefore, the test is good for testing the endurance capacity of a player during the training or to control the training but not as a predictor of physical performance during a match (Svensson & Drust, 2005).

3. Sprinting speed

Speed is defined as “the shortest time required for an object to move along a fixed distance, which is the same as velocity, but without specifying the direction” (Harman & Garhammer, 2008, quoted in Horicka, Hianik, & Simonek, 2014).

It is a matter of fact that soccer players are becoming faster and faster over the last years. There is a notable difference, though, in the performance of linear sprinting, agility tasks and repeated sprints between all kinds of levels. Therefore, the anaerobic demands of the sport get more and more important and the testing and training of these skills. Linear sprinting contains the part of acceleration, maximum running velocity and deceleration. Regarding to Haugen et al. (2014), especially acceleration performance is a very important skill in soccer, because, as studies revealed, more than 90% of all sprints are under 20m. Also, the chances of dribbling an opponent out of position or defending an attack are higher with better acceleration and sprinting speed (T. A. Haugen et al., 2014). Even though the aerobic metabolism is dominant, as mentioned before, the anaerobic metabolism is responsible for crucial match situations. Bradley et al. (p. 2344, 2010) suggested, that the “ability to accelerate and reach maximal speeds quickly is an essential component of game-deciding situations in soccer”.

Professional soccer players are faster over the first 10 to 15m compared to amateurs, whereas the 30m sprint performance is quite similar, as a study by Indeed, Cometti et al. (quoted in Stølen et al., 2005, p.526) showed (Stølen et al., 2005). Table 1 below compares the sprinting performance in male and female soccer players of different levels found in diverse studies.

Table 1 source: Sprinting performance in male and female soccer players from Stølen et al., (2005). Physiology of Soccer – An Update. Sports Med 2005; 35 (6):501-536).

Study	Level/country (sex)	n	Sprinting performance (sec) [± SD]					
			5m	10m	15m	20m	30m	40m
Brewer and Davis[161]	Professional/England (M)	15			2.35 ± 0.07			5.51 ± 0.13
	Semi-professional/England (M)	12			2.70 ± 0.09			5.80 ± 0.17
Chamari et al.[68]	Junior/Tunisia-Senegal (M)	34		1.87 ± 0.10			4.38 ± 0.18	
Cometti et al.[162]	Division 1/France (M)	29		1.80 ± 0.06			4.22 ± 0.19	
	Division 2/France (M)	34		1.82 ± 0.06			4.25 ± 0.15	
	Amateur/France (M)	32		1.90 ± 0.08			4.30 ± 0.14	
Diallo et al.[113]	12–13 years/France (M)	10				5.56 ± 0.10		
	After reduced training (M)	10				5.71 ± 0.20		
Dupont et al.[163]	International level/France (M)	22						5.55 ± 0.15
	After training period	22						5.35 ± 0.13
Gorostiaga et al.[115]	Young players/Spain (M)	21	0.95		1.09			
Helgerud et al.[10]	Juniors/Norway (M)	9		1.88 ± 0.06				5.58 ± 0.16
	Division 1/Norway (M)	21		1.87 ± 0.06		3.13 ± 0.10		
	After training period (M)	21		1.81 ± 0.07		3.08 ± 0.09		
Hoff and Helgerud[72]	Division 2/Norway (M)[a]	8		1.91 ± 0.07				5.68 ± 0.21
	After training period (M)	8		1.81 ± 0.09				5.55 ± 0.16
Kollath and Quade[164]	Professional/Germany (M)	20	1.03 ± 0.08	1.79 ± 0.09		3.03 ± 0.11	4.19 ± 0.14	
	Amateur/Germany (M)	19	1.07 ± 0.07	1.88 ± 0.10		3.15 ± 0.12	4.33 ± 0.16	
Little and Williams[165]	Division 1 and 2/England (M)	106		1.83 ± 0.08				
MacMillan et al.[75]	Youth team/Scotland (M)	11		1.96 ± 0.06				
Mohr et al.[34]	Division 4/Denmark (M)	8					4.45 ± 0.04	
Siegler et al.[118]	High school teams/US (F)	17				3.00 ± 0.15		
Tumilty and Darby[100]	National/Australia (F)	20				3.31 ± 0.11		
Wisløff et al.[26]	Division 1/Norway (M)	17		1.82 ± 0.30		3.00 ± 0.30	4.00 ± 0.20	

a Including elite juniors.

F = female; **M** = male.

In addition, repeated sprint ability is another important aspect for soccer or team sport in general. RSA is defined as a couple of sprints separated by a short period of time as described in Chtara et al. (2017). In this thesis, repeated sprint ability will not be addressed in more precise terms.

According to the review of Haugen et al. (2014), there are four principles of sprint training and improving sprint performance: specificity, individualisation, familiarisation, progression and periodization. Moreover, integration of sprint training and physical coaching expertise are also highlighted as important principles for a successful sprint training in soccer. The principle of specificity means that short sprint training, with a distance under 30m, improves short sprint ability, whereas longer sprints, with a distance over 40m, improve the maximum sprint velocity. Agility tasks improve the performance of agility and repeated sprints will improve the RSA, referring to the author, just as linear sprint training does not improve sprints with directional changes. There are also studies with less specific training methods that also affect the performance of soccer players. For example, contrast training, which is a combination of strength, power and sport- specific drills, leads to an improvement of soccer- specific sprinting. The principle of individualisation is hard to realize in soccer practice, because organising individual training for different physical requirements of each player is challenging. Therefore, most coaches carry out the same training interventions for the whole field players, without realizing the individual differences between the players. As Haugen et al. (2014, p. 9) claim: “However, it is unlikely that similar training doses lead to similar responses for players belonging to opposing extremes.” The third and fourth principle, familiarisation, progression and periodization, is mainly about the prevention of injuries due to increasingly developing sprint training tasks in terms of intensity and repetitions. In contrast to strength training, where periodization is clear and well established, there is hardly any literature concerning progression in sprint - training (Haugen et al., 2014).

4. Agility with special emphasis on soccer

The term *agility* is relatively new in the field of sport science, hence different definitions of agility occurring over the last years. Many authors defined agility typically “as the ability to change direction rapidly” and also “as the ability to change direction rapidly and accurately” (Barrow & McGee, 1971; Johnson & Nelson, 1969, quoted in Sheppard & Young (2006)). Later, several authors added “whole-body change of direction as well as rapid movement and direction of limbs” (Baechle, 1994; Draper & Lancaster, 1985, quoted in Sheppard & Young (2006)) to the classic definition (J. Sheppard & Young, 2006).

Finding a precise definition of agility has always been a problem due to the wide range of disciplines within sport science. An overall definition should include the physical demands, the cognitive processes and the technical or biomechanical skills, as they are all involved in agility performance. Sheppard and Young (2006) defined agility on a new level: “a rapid whole-body movement with change of velocity or direction in response to a stimulus”. The authors criticised that some definitions or classifications of agility are referring to other skills than agility performance, particularly activities which are pre-planned and do not involve any response to a stimulus. In the definition above, it is also important to recognise the two elements “change in velocity or direction” as well as “response to an external stimulus”, which means that an agility task contains not only acceleration, but also deceleration in response to the opponent´s behaviour. For instance, when a player reduces his speed in order to get more space between him and another player (W. B. Young, Dawson, & Henry, 2015).

Chelladurai (1967, quoted in Sheppard & Young, 2006) came up with four different forms of agility including the perceptual and decision-making components involved in sports such as simple, temporal, spatial and universal. Because of this classification, tasks can easily be assigned to one of these four categories. This can be important for distinguishing between the demands of different kinds of sports. The sprint starts for instance in track and field and is also classified as an agility task, because they involve a fast response to an audio stimulus. This task is, in fact, pre-planned and therefore not an open skill. The definition from Sheppard and Young (2006) includes on the one hand the cognitive components such as visual scanning and decision-making and on the other hand, all the physical performances like acceleration, deceleration and changes of direction. To give an example of agility in the field of soccer, a player who rapidly accelerates in a straight line to dodge an opponent could be named. The soccer player reacts not pre-planned in response to the movements of the other player, which is considered an open skill. (J. Sheppard & Young, 2006).

Young, James and Montgomery (2002) created a model of agility framing two main components of agility, change-of-direction speed (CODS) and perceptual and decision-making factors. This model is especially related to running sports that include fast changes of direction such as team sports. The perceptual and decision-making factors consist of visual scanning, anticipation, knowledge of situations and pattern recognition. On the other hand, the sub-components of the change-of-direction speed are technique, anthropometry, linear sprinting speed as well as leg muscle qualities (W. B. Young, James, & Montgomery, 2002). The different components of agility performance will be displayed more detailed in the next chapter.

4.1 Different components of agility

As mentioned in the previous chapter, there are two main components of agility, change-of-direction speed (CODS) and perceptual and decision-making factors. To distinguish from agility, change-of-direction speed is a closed skill that is pre-planned. (W. B. Young et al., 2015). Change-of-direction speed is influenced by several factors such as straight speed, leg muscle qualities and running technique (Chaalali et al., 2016).

The other components of agility, that is, perceptual and decision-making factors, are also crucial for a good agility performance. In soccer or other invasion sports such as rugby or basketball, it is important to notice relevant information about the actions of the opponent and to react quickly and precisely to the different types of incidents, which might occur in their environment (W. B. Young et al., 2015).

Spiteri, McIntyre, Specos, & Myszka (2018, p. 39) define decision-making as "the ability to rapidly and accurately identify task-relevant cues from a variety of stimuli within the environment, process the incoming information, and select the appropriate response". The authors suggested that agility performance might be influenced by organismic, task and environmental constraints. Figure 1 at the end of this abstract shows the constraints, which might influence agility performance. Regarding organismic constraints, the focus is on the physical and technical qualities as well as on the perceptual-cognitive qualities, which are all individual characteristics of an athlete. Physical qualities describe all anthropometrical data of the athletes as well as all motor abilities, which have an impact on agility performance. Although there are weak correlations between anthropometrical data and agility performance, according to latest research, the authors mentioned that "athletes, who produce a faster agility performance possessed greater lean body mass and lower total body mass" (Spiteri et al., 2018, p. 40). It is a matter of fact that lean body mass is increasing when doing strength training. Therefore, strength training is also an important indicator for contributing in a good agility performance. The same authors referred to technical qualities as the ability to systemically coordinate force and impulses by arranging appropriate muscle actions and preserving proper body positions. Concerning task constraints, the authors stated everything "influences the control of movement and the effectiveness of movement outcomes" (Spiteri et al., 2018, p.41). As presented in Figure 1, task constraints are, for instance, the number of players, speed of the movement, object manipulation or presentation of a visual stimulus. Environmental constraints are related to the sport-specific setting and to the way the external stimuli influence the movement output. In the terms of soccer, this might be for example the surface, artificial or grass, the weather conditions in general or the atmosphere of the crowd (Spiteri et al., 2018).

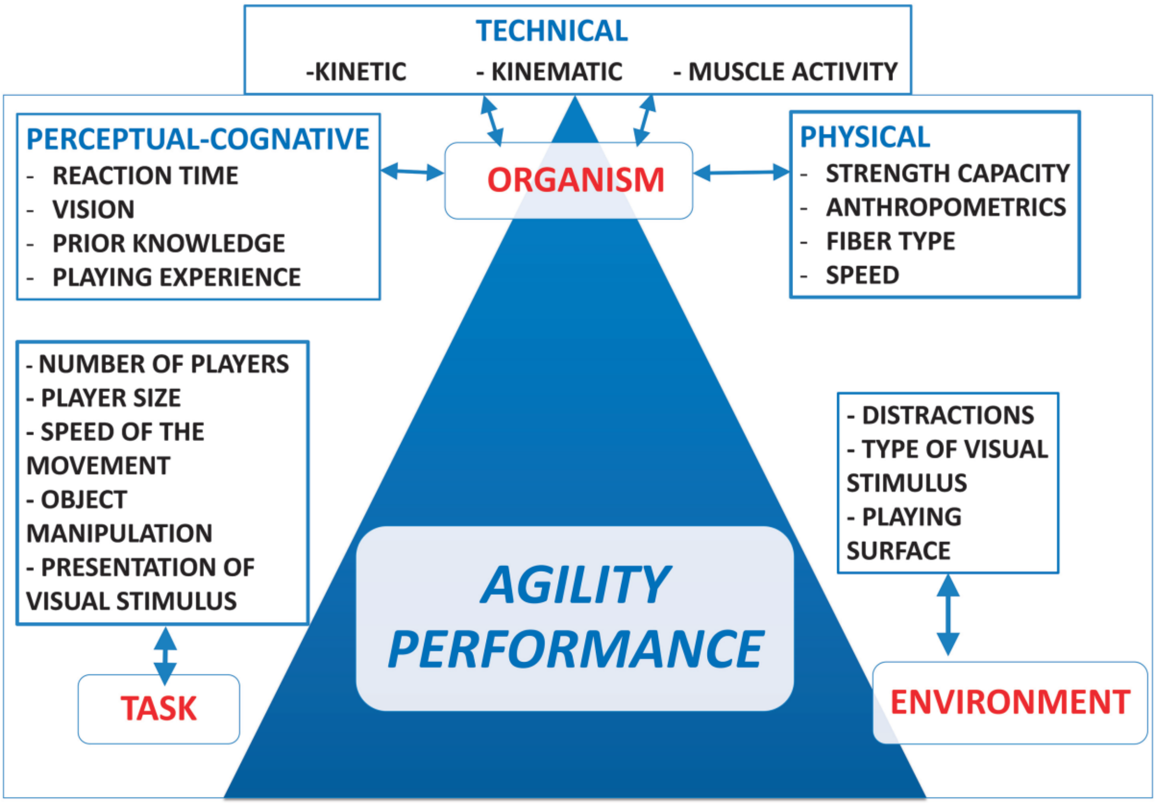


Figure 1 source: Specific organismic, task and environmental constraints influencing an individual athlete´s agility performance (Spiteri et al., 2018).

4.2 Physical relationships with agility

In this chapter, relationships between planned and unplanned agility as well as other physical abilities are represented.

There are many studies, which investigated the correlation between linear sprinting speed and change-of-direction speed. Draper and Lancaster (1985, quoted in Sheppard and

Young, 2006) found a statistically significant low to moderate correlation between the Illinois agility test, which is a test for assessing agility performance, and a 20m sprint. Another study from Young et al. (1996, quoted in Sheppard and Young, 2006) compared linear sprinting, sprinting while bouncing a football and sprinting with directional changes. The reported correlations between them were all very low, which indicated that sprinting, sprinting while bouncing a ball and sprinting with change-of-direction were different and specific qualities. Because linear sprinting and change-of-direction speed are different qualities, the training should also be different as there is no transfer from one skill to another. This means that linear sprint training does not necessarily improve performance in sprints with directional changes and vice versa. Usually, the more directional changes, the less the transfer from linear sprint training to change-of-direction speed, as shown in a study by Young et al. (2001, quoted in Sheppard and Young, 2006). Another thing to bear in mind is that soccer involves running with a ball or dribbling which affects the performance of athletes as well, because of the increasing complexity of the task. Therefore, it is necessary to do sport- specific tests and trainings that address these complex skills to increase validity (Sheppard & Young, 2006).

Comparing agility performance and change-of-direction speed, several studies found that the correlations between those skills are very low and therefore, independent from each other. W. B. Young et al., (2015, p. 161):"In all of these studies, the correlation between the agility and CODS test yielded Pearson coefficient´s of r= 0.68, r= 0.32, r= 0.434, r= 0.70, and a Spearman correlation of -0.08". The authors suggested that the main difference between agility and change-of-direction in these studies were the cognitive components, which are a characteristic part of agility performance as already stated (W. B. Young et al., 2015).

Several studies found low and non-significant correlations between change-of-direction speed and leg muscle strength and power. According to Sheppard and Young (2006), strength and power do have an influence on change-of-direction speed, but only when the directional change is performed over a short distance, such as in soccer goalkeeping. Sheppard and Young (2006) assume that eccentric muscle function might have a strong relatedness with deceleration, which is an element of field running and court sports (J. Sheppard & Young, 2006). A study conducted by Wisløff, Castagna, Helgerud, Jones, & Hoff (2004) determined a correlation between maximal strength with sprint performance and vertical jump height. Seventeen elite male soccer players were tested for maximal strength in half squats (1 repetition maximum) and sprinting ability (0-30m and 10m shuttle run) as well as vertical jumping height using a force platform. The results showed a strong correlation between maximal strength, sprinting and jumping performance and therefore, it is suggested that “elite soccer players should focus on maximal strength training with emphasis on maximal mobilisation of concentric movements, which may improve their sprinting and jumping performance” (Wisløff et al., 2004, p. 288).

Bilateral reactive strength shows a stronger relation with change-of-direction speed, because of its stretch-shortening cycle as Young et al. (2002) report. Furthermore, they stated that lower-extremity muscle imbalances affect change-of-direction speed. In the study, participants were significantly slower in changing direction off the weaker leg while accomplishing a unilateral drop jump test for reactive strength (W. B. Young et al., 2002).

However, further research is required for a better understanding of the relationship between strength and power and change-of-direction speed. The effects of plyometric training exercises on agility performance and other trainings methods are discussed in a separate chapter.

4.3 Importance of agility in soccer

There are many reasons why a good agility performance of soccer players is essential for a good match performance. As Young, Dawson and Henry (2015, p. 160) stated: “…agility skill is beneficial to attackers to evade their opponent´s pressure or tackled, and for defenders to reduce space on the field or court to limit attacking movements, or potentially achieve a turnover”. In soccer or team sports in general the players need to perform rapid changes in body direction in combination with quick movements of the limbs in order to be successful. This performance depends on many factors such as visual processing, timing, reaction time, perception and anticipation. All these factors are combined to the players on-field agility. However, there are some situations in soccer that involve set-plays with pre-planned actions as well, for example a free kick outside the penalty box. In such a case, the team strategy may be pre-planned, but the player who gets the ball must accomplish unpredictable moves in response to the opponent´s actions, which is confirmed as an agility task. As Young, Dawson and Henry (2015, p.160) mentioned: “… a defender will watch the attacker´s movements carefully in order to quickly react to any evasive action” (W. B. Young et al., 2015).

As mentioned in a chapter above, decision-making and cognitive skills are important factors for a good agility performance. Soccer players with a superior decision-making ability are therefore able to react faster to a specific game situation and to avoid a possible collision with an opponent. This might imply that players with a good agility performance are not as prone to injuries because of their ability to recognise such situations and act preventively.

However, further research needs to be done to gather more information about the relationship between agility and injuries (Paul, Gabbett, & Nassis, 2016).

4.4 Agility in other team sports

This chapter focuses on the importance of agility in other team sports which show similarities to soccer regarding the physical and physiological requirements. The difference between rugby league and rugby union will be explained and an overview of the importance of agility in those invasion sports as well as in basketball will be given. Also, a current state of research in those sports regarding agility will be presented and how agility tests were constructed for this type of team sports. It is important to have a certain expertise on all types of team sports and on how they are testing specific performances since they are alike to a certain degree. Therefore, performance diagnostics can easily be transferred from one sport to another.

4.4.1 Rugby League and Rugby Union

The demands of the collision sport rugby league are identical to those in soccer. High-intensity sprinting, tackles and other offensive and defensive skills are essential for a good performance during the match. As noted by Gabbett, Kelly and Sheppard (2008, p. 174), "the ability to recognize patterns of play and execute effective decisions under pressure and fatigue is an attribute of successful players." The same authors conducted a study to investigate the relationship between speed, change-of-direction speed and reactive agility and how the tests discriminate higher and less skilled players. Forty-two rugby league players performed a 20m sprint, change-of-direction tests and a test for reactive agility performance. The results showed that higher skilled players had faster speed ($p < 0.05$), movement ($p < 0.05$, effect size $= 0.73$) and decision times (effect size $= 0.54$) on the reactive agility test, short RAT, than players of a lower grade. However, there were no significant differences ($p > 0.05$, effect size $= 0.28$ to 0.32) regarding the change-of-direction speed. Considering speed, change-of-direction and reactive agility, the 5m, 10m and 20m sprinting times were significantly correlated ($p < 0.05$) with the performance on the 505 tests. Moreover, movement times were significantly related ($p < 0.05$) to 10m and 20m sprint times as well as change-of-direction speed. Decision time on the RAT was also significantly related ($r = 0.58$, $p < 0.05$) to response accuracy. Between response accuracy and movement speed on the RAT existed an inverse relationship ($r = -0.05$, $p < 0.05$). No relationship was measured among linear speed and change-of-direction speed (Gabbett et al., 2008).

Serpell, Ford, & Young (2010) conducted a study to develop a reliable and valid agility test for rugby league using a video stimulus. The aim was to create a sport specific reactive agility test, which simulated the demands during the game. Video clips with various sport specific scenarios were constructed for example an attacking opponent, and the participants had to react to that video by changing direction as they would in such a match situation in the role of playing a defender. Eight trials were completed, each one with a different randomised video clip. The change-of-direction speed test was the same, but with no video clip playing. Instead, the participants were told which directional change they should make. Moreover, a lower performance group (LPG) was tested twice in order to determine the test-retest reliability. Later, the results were compared with the results from a higher performance group (HGP) for determining the validity. As the results showed, the RAT used in this study was reliable and valid, whereas the change-of-direction test was not valid. The mean RAT total agility time was significantly faster for the higher performance group in comparison to the lower performance group (1.79 ± 0.12; 1.98 ± 0.16). On the other hand, there was no difference in mean total agility time between the groups on the change-of-direction test. Also, mean response and perception time were measured. The results show a significantly faster mean perception and response time for the higher performance group than for the lower performance group (-0.01 ± 0.14; 0.25 ± 0.14). The authors assume that the differences in total time in the RAT might be referred to perception and response time. As stated by Serpell et al. (2010, p. 3275):

> *It is likely that participants from the HPG were able to identify key sport-specific kinematic cues earlier than participants from the LPG and react quicker; hence their perception and response time were faster and, subsequently, so was their RAT total agility time.*

To sum up, the study highlighted the importance of perceptual skills and reaction ability for agility performance, especially when discriminating between lower skilled and higher skilled players. Therefore, such reactive agility tests with video stimulus are recommended for talent identification as well as performance monitoring (Serpell et al., 2010).

Rugby Union differs from rugby league in one main point, namely the game concept. Each team consists of 8 forwards and 7 backs and they need to perform their specific roles and positions for the whole game in order to preserve possession of the ball. Green, Blake and Caulfield mentioned (2011, p.1256): “Forwards are frequently involved in tackling and physical contests such as rucks and mauls to gain possession of the ball thus requiring optimal levels of strength and power, whereas backs frequently carry the ball, which requires speed and agility.” The same authors conducted a study to compare linear sprinting, change-of-direction speed and reactive agility speed in rugby union players with different playing abilities. In total, 28 rugby union players between 18 and 23 years of the All-Ireland League were tested. The linear sprinting test was performed three times on 30m with a standing start and measured with electronic time gates. The 10m and 30m distances were recorded. Between the trials, there was a resting period of three minutes. The change-of-direction test and reactive agility test were also measured with electronic timing gates and were arranged in a “Y-shape”.

In the change-of-direction test, the players had to run forward 5m and then perform a 45° change of direction either to the left or to the right finish gate. The players were informed verbally, to which side they had to run. Overall, the participants performed three attempts to the left and three to the right with a resting period of three minutes between each trial. The reactive agility test was measured as the change-of-direction test, but the players were coached to visually scan the flashing gate and sprint towards it. The players had to react to the flashing gate spontaneously and had to run through it. The main purpose of this study was to compare players of different levels of rugby ability. The players were separated into one academy group ($n= 17$) and a club group ($n= 11$). The test results showed that the academic group was faster ($p <0.001$) in 10m ($ES =2.86$), 30m ($ES= 1.61$) as well in the linear sprinting test. Moreover, academic athletes were faster ($p < 0.05$) in the change-of-direction ($ES= 2.23$) and RAS ($ES= 1.14$) tests. In summary, all tests showed a significant difference between players with various abilities. Because of the fact that the high-levelled group was faster in the RAS compared to the low-performance group, the authors suggested that “cognitive and perceptual components of agility will discriminate between players of varying skill levels than LS and CODS tests” (Green et al., 2011, p.1260).

The study also investigated the reliability and validity of rugby union field test protocols. The test-retest analysis revealed correlations between $r= 0.87$ and $r= 0.97$ for the different tests. This indicated that the test protocol which was used for this study had acceptable reliability. The valid test protocol of linear speed, change-of-direction speed and reactive agility speed can also be transferred to other team sports and is therefore useful for all coaches in such areas. The tests demonstrate the strengths and weaknesses of each player, especially regarding agility performance. This is important for more individualised agility training and achieving higher performance levels in general (Green et al., 2011).

4.4.2 Basketball

Basketball is characterised as a typical extensive intermittent court based team sport with high intensity activities and unique movements. Due to the small court, basketball players need to make rapid changes in maximal runs as well as changing direction, therefore, agility performance is an important aspect. In a study by Scanlan, Humphries, Tucker, & Dalbo (2014) the influence of physical and cognitive factors on reactive agility in male basketball players was examined. 12 players performed multiple sprints, change-of-direction tests and reactive agility test trials. The results showed that cognitive components such as response time and decision-making time had the greatest influence on reactive agility performance. In addition, there was only a weak relation between morphological and physical performance variables and reactive agility. This emphasised the statement that cognitive qualities influence the open-skill agility performance in basketball players, which leads to the conclusion that reactive and decision-making drills should be starred in training programmes (Scanlan et al., 2014).

Similar to soccer, high-levelled basketball players perform more movement changes such as running, jumping, shuffling or dribbling than players from a lower level. Lockie, Jeffriess, Mcgann, Callaghan, & Schultz (2014) conducted a study to find out if 10m sprinting, planned and reactive agility may distinguish between semi-professionals and amateur basketball players. The 10m sprint was used to assess linear acceleration, the Y-shaped agility test to evaluate planned agility performance and for measuring reactive agility performance, the Y- shaped agility test was used with visual stimuli. Both agility tests assessed agility performance in both directions, with a 45° cut to the left and right. The Y-shaped agility test is explained in detail in the next chapter. For this study, they used flashing gates as a visual stimulus and the basketball players had to visually scan the flashing gate and run through it after performing a 5m sprint through a gate that triggered the light stimulus. The results showed that the semi-professional group of players was significantly faster in the reactive test with a left cut (P= 0.36, EF= 1.02) and a right cut (P= 0.29, EF= 1.06) than the amateur players. The strongest correlation was found between the 10m sprints and planned agility task (r= 0.590 - 0.860). This study also underlined the fact that in order to discriminate between different levels of players, perceptual and decision-making factors should be included for testing, because as the results showed only reactive agility results discriminated between semi-professionals and amateur players, while planned agility tasks did not. The results also supported the statement that reactive and planned agility performance are separated physical qualities in basketball as well as in other team sports as research shows. Coaches should also test reactive agility and not only planned agility, because reactive agility tasks can distinguish between higher and lower-level athletes as stated by Lockie et al. (2014). This can also be an important aspect in the field of talent-identification or for assessing ideal playing positions for the athletes (Lockie et al., 2014).

4.5 Testing agility

In this chapter, some methods used in similar studies for agility testing are listed and described. A short overview of following tests will be given:

- Zig zag running test
- 15m agility run test
- 5-0-5 agility test
- Reactive agility test
- Illinois agility test
- Y-shaped agility test
- Speedcourt-system

Most agility tests in soccer are without cognitive challenges and therefore mainly assess the change-of-direction speed. However, considering the definition by Sheppard and Young (2006), agility is related to both physical and cognitive components. As mentioned in the article by Haugen et al. (2014, p.5):

> *The vast majority of agility tests in soccer are designed to evaluate the physical qualities of the players, without cognitive (i.e. choice reaction) challenges. Zig zag runs, 90-180° turns, shuttle runs, sideways, and backwards running with maximal intensity are commonly used drills*.

Zig zag running tests, for example, are used as a classical method to evaluate agility. However, these tests are closed skill tests, because all movements within the tests can be pre-planned and need no reaction to a stimulus and, thus, are not really sport specific (J. M. Sheppard, Young, Doyle, Sheppard, & Newton, 2006).

The 15m agility run test is a field test where players run through a 3m slalom section, which is marked by three aligned sticks placed 1.5m apart. A 0.5m hurdle is placed 2m beyond the last stick and must be cleared. They start the test 3m behind the initial set of photocell gates and run 3m straight before entering the slalom. After the slalom, the players run 7m to break the other set of gates in order to stop the time. To get more sport specific, the 15m ball-dribbling test is identical and includes dribbling with a ball. The players kick the ball under the hurdle right after the slalom part. Then the player kicks the ball towards one of two goals which are positioned diagonally 7m on the right and left side of the hurdle and then finishes the 7m straight sprint.

The 5-0-5 agility test is a typical test to examine the performance in quick directional changes. The test is constructed by setting up markers at 5m and 15m from a line marked on the ground. The players run from the 15m marker towards the line and through the 5m markers. They turn at the line and run back through the 5m markers. The time is measured between the first 5m markers and the second one (Chaalali et al., 2016).

The reactive agility test, short RAT, can be carried out with or without a ball. The RAT includes anticipation tasks as well as decision-making components. Sheppard et al. (2006) conducted a study to evaluate the reliability and validity of this test. The evaluation consisted of measures of test-retest reliability and inter-rater reliability. Thirty-eight Australian football players were classified in two groups, one high performance group and one low performance group. To determine the validity of the RAT, these two groups were compared and a correlation analysis between a straight sprinting test, a change-of- direction speed test and the agility test was done (J. M. Sheppard et al., 2006). The test consisted of four scenarios, which were provided randomly to each player in two series. The athletes had to react as quickly as possible. The four possible options were:

1. *Step forward with the right foot and change direction to the left.*
2. *Step forward with the left foot and change direction to the right.*
3. *Step forward with the right foot, then the left foot, and change direction to the right.*
4. *Step forward with the left foot, the right foot, and change direction to the left.*

(Chaalali et al., 2016, p. 348).

In another study by Sheppard et al. (2006) the tester, who stood on a timing-mat to the opposite of the athlete, began a movement and started the timer. The player had to react to the movements initiated by the tester and stopped the timer as soon as he triggered the timing beam on the sides. Figure 2 demonstrates the organisation of the testing system. 5m to each side timing gates were positioned. The athlete began 2m before the start line. The four scenarios listed above were presented randomly, but each player had an equal amount of each scenario. Totally, the test protocol involved 12 trials and the players were asked to sprint forward prior to any change-of-direction in reaction to the movement of the tester. They had to identify the cues as fast as possible and react by changing direction and sprinting through the time gates to either side. The results of this research were that the reactive agility test is a suitably reliable test when considering both test-retest reliability as well as inter-rater reliability. Moreover, the agility test was valid in discriminating athletes of two different performance groups in Australian football, whereas the 10m straight sprinting test and change-of-direction test were not (J. M. Sheppard et al., 2006).

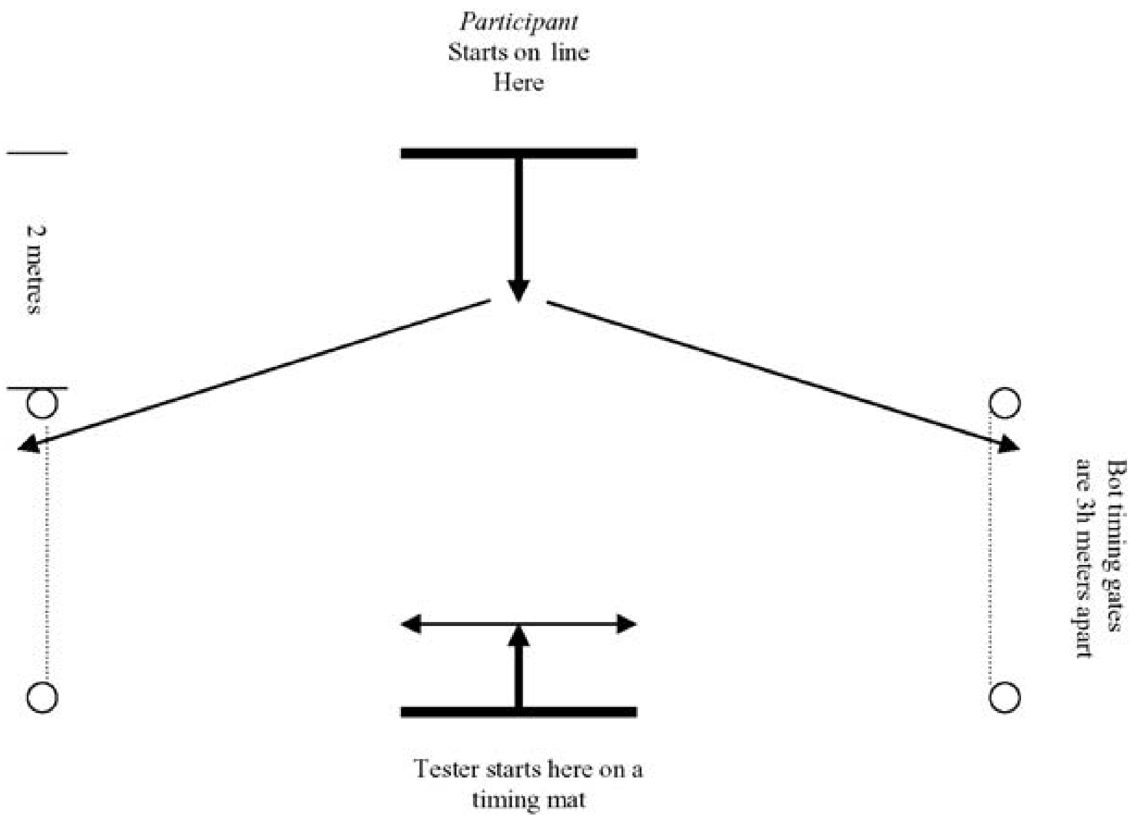


Figure 2 Reactive Agility Test (J. M. Sheppard et al., 2006).

The study conducted by Young & Willey (2010) assessed the reactive agility test by recording the decision-times of the athletes and evaluated the relation between the total time and various other components. Thirty- one male Australian Rules football players from a semi-professional Victorian Football League Club were tested using the reactive agility test and recorded by a dual beam infra-red timing light system. Tester time, decision-time and response-movement-time, which result in total time, were recorded. The tester time was defined as the first forward move of the tester to indicate the stimulus to change direction, decision-time was the time taken by the athlete to respond to the stimulus and response movement time was defined as the time taken by the participant to change direction and sprint to the left or right. The results demonstrated that decision-time had the greatest relation to total time, which might lead to the conclusion that perceptual skills do affect agility performance to a high degree. For coaches and training implementation it might be important to recognise that perceptual skills should be addressed in agility training and testing in order to improve the decision-making time and therefore, to ensure the success (Young & Willey, 2010).

Another common test for assessing agility performance is the Illinois agility test. This test is frequently used to determine acceleration, deceleration, turns to different directions and running at different angles. The testing system is constructed in an area of 10m x 5m and four cones are placed to mark the start, the finish and the turning points. Four cones are placed in the centre of the testing field, each one 3,3m apart from the other. In figure 3, the design of the test is demonstrated. The athletes start the test lying face down and hands by their shoulders. On a command of the coach the player starts the run and time is stopped either by a stopwatch or, more accurately, by using photocell gates. One advantage of this test is that it is quite simple to conduct and easy for coaches to assess agility performance without much equipment (Miller, Herniman, Ricard, Christopher, & Michael, 2006).

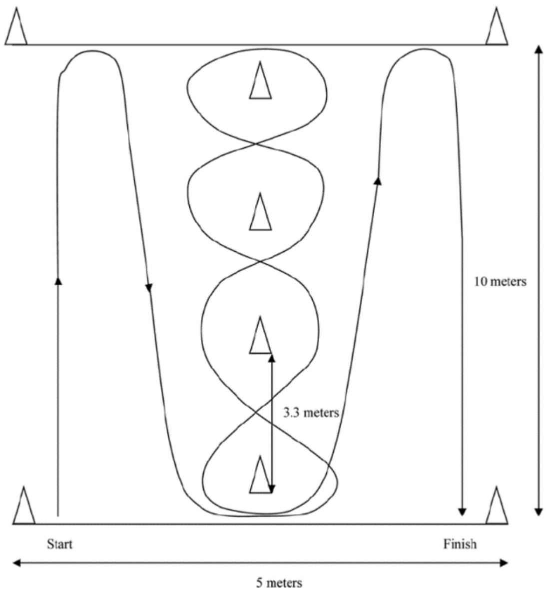


Figure 3 Illinois Agility Test (https://www.researchgate.net/figure/Illinois-agility-run-dimensions-and-completion-route_fig2_26331808

The Y-shaped agility test can also be found in some works. It can be used for measuring either planned or reactive agility. The task is to sprint 5m through a trigger timing gate, followed by a 45° cut and 5m sprint to the right or to the left target gate. In figure 4, the construction of the test is represented. All gates are set 1,5m apart. Participants start their sprint 30 cm behind the starting line and run as fast as possible through the first gate. For testing planned agility, participants are told in which direction they must turn when reaching the first gate. For reactive agility trials, the subjects need to react to an external stimulus. Light stimuli are frequently used in such a setting, because they are easily available and according to studies, they are also a valid and reliable assessing tool. Instead of using light stimuli, video projections can also be used or even a live opponent. As mentioned in the article by Lockie et al. (2014, p. 766) "In each instance, the reactive- agility drill was able to discriminate between athletes of different playing levels". The Y-shaped agility test is common for assessing reactive agility in all types of team sports such as netball players, Australian football players or rugby players (Lockie et al., 2014).

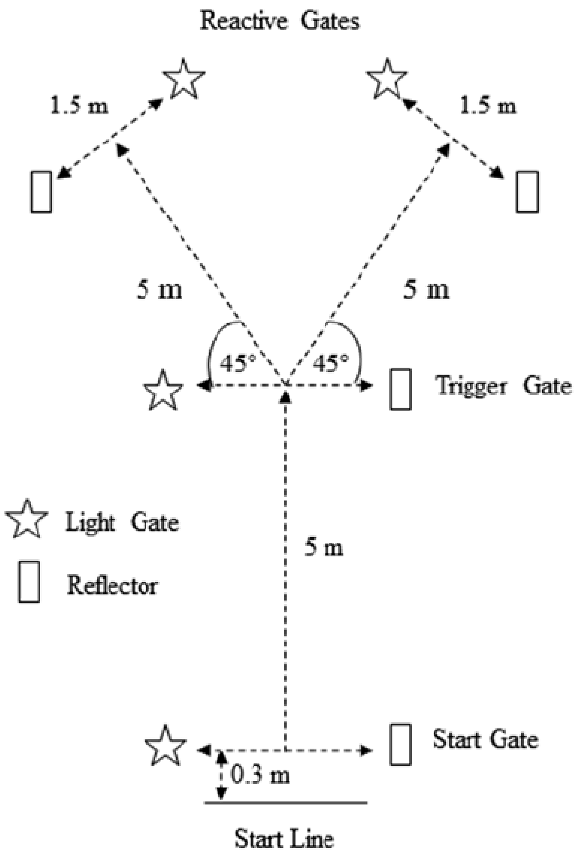


Figure 4 Y-shaped agility test (https://www.researchgate.net/figure/The-Y-shaped-agility-test-Participants-ran-5-m-through-the-start-gate-to-pass-the_fig1_258526078).

The most recent assessment tool for change-of-direction and agility performance might be the so-called "Speedcourt" (Globalspeed GmbH, Hemsbach, Germany). The Speedcourt consists of a square platform with nine or twelve contact plates. The running paths for the players are demonstrated on a screen in front of the testing area, which is connected to the platform (Born, Zinner, Düking, & Sperlich, 2016).

A study conducted by Matlák, Tihanyi, & Rácz (2016) used the Speedcourt to assess the relationship between reactive agility and change-of-direction speed among amateur soccer players. Both pre-planned, reactive and in response to a visual stimulus, running tests with four directional changes-of-direction were performed. The results showed that the average total time in the reactive agility test was longer than total time in the change-of-direction test ($p < 0.0001$). A non-significant relationship and a low common variance ($v^2 = 0.03 - 0.18$) between reactive agility and change-of-direction speed are indicators that different abilities are required for performing either a pre-planned or a reactive running task. It also highlights the importance of perceptual and decision-making factors in agility performance (Matlák et al., 2016).

5. Training and improving agility performance

As already mentioned above, reactive agility and change-of-direction speed are two distinct skills, consequently, the training needs to be different as well. First, it needs to be considered which of these skills is more important for match performance. One study stated in the review by W. B. Young et al. (2015) came to the conclusion that higher- skilled players from Australian football and rugby league tend to be better ($p < 0.05$) in an agility test, but not better ($p > 0.05$) in a change-of-direction test in comparison to lower-skilled players. Hence, the assumption is that agility is more related to a good performance in these team sports than change-of-direction speed. Other studies mentioned in the same review compared decision-making time in higher- and lower-class players and found that players with a higher standard of play generate faster decisions ($p < 0.05$) than lower-standard players, but the difference, in this case, is not always statistically significant. However, the perceptual and decision-making elements should be a major factor in training and improving agility performance (Young et al., 2015). In this chapter, different methods for improving agility performance in the field of soccer, such as small-sided games or the benefits of plyometric training on agility performance will be presented.

Small-sided games are very popular training drills of sports coaches from all kinds of team sports. They are typically played on a smaller pitch and commonly involve a reduced number of players in contrast to the match play. Moreover, the rules can be modified as well. Such games represent the game play and thus, sport-specific skills and tactics can be developed. Furthermore, the compliance and motivation of each player is enhanced by these games. Many other benefits of small-sided games are mentioned by Hill-Haas, Dawson, Impellizzeri, & Coutts (2011, p.201): "…they appear to replicate the movement demands, physiological intensity and technical requirements of competitive match play, whilst also requiring players to make decisions under pressure and fatigue" (Hill-Haas et al., 2011). Because of all these effects of small-sided games, it could be concluded that such games also play a role in improving reactive agility performance. A study conducted by Young & Rogers (2014) determined the effects of small-sided games and change-of-direction training on reactive agility and change-of-direction speed in Australian football. Players from the Australian Football League (AFL) were separated in a small-sided-games group (n=13) and a change-of-direction group (n=12). After the initial testing 11 training sessions were completed over 7 weeks. The change-of-direction training consisted of pre-planned and short maximum effort sprints around different paths built up with cones or poles. The sprinted distance before and after a directional change was between 2m and 5m. All players performed individually or with a partner to race against with in order to arouse ambition and maximise intensity. In one session, they also dribbled a ball and finished with a kick at goal. The training with the small-sided-games group involved games with 4 versus 4 players on a 20m x 23m field or 2 versus 2 players on a 15m x 15m field as explained in the article by W. Young & Rogers (2014). Furthermore, the duration of the game was set with 30 to 45 seconds and with the same recovery period. For the whole game handballing only was allowed. For scoring, the players had to run with the ball into a 5m wide scoring zone at the end of the pitch. In the second game, a point was scored when the player who carried the ball evaded his opponents. Additionally, the number of handballs was limited up to a maximum of four in order to encourage agility skills. The findings revealed that the small-sided-games group improved significantly in total time ($p = 0.008$, $ES = 0.93$), whereas the change-of-direction training led to minor improvements. The authors suggested the improvement in the agility training group was attributed to a large reduction in decision time ($p < 0.001$, $ES = 2.32$). Along with that, the results also showed that 100% of the players from the agility-training group reached some improvements in decision time, while only 58% athletes from the change-of-direction training group improved. All these results led to the conclusion that “small-sided games improve agility performance by enhancing the speed of decision- making rather than movement speed”, as mentioned by Young and Rogers (2014, p. 307). In addition, the authors claim that it is recommended for coaches to develop games that offer an equal and consistent training stimulus for all players. This could be done by using a small number of players, such as 3 versus 3 (Young & Rogers, 2014). However, to what extent small-sided games improve agility performance in the field of soccer is relatively new and therefore, further research and studies are required.

A study conducted by Chaouachi et al. (2014) analysed how the use of small-sided games as a training affected change-of-direction speed and agility in elite male youth soccer over a six-week period. Thirty-six players were randomly separated into two intervention groups with either change-of-direction sprints or small-sided games and one control group. While the small-sided games group performed exercises using 1 vs.1, 2 vs. 2 and 3 vs. 3 over a 10m x 20m, 20m x 20m and 20m x 30m playing ground, the change-of-direction group did pre-planned change-of-direction drills. In the small-sided games group ball contacts were also limited depending on the pitch size. The results showed that the small-sided games group improved in linear sprinting (+1.5%) and change-of-direction speed (+5.1%), whereas the change-of-direction group increased even more with 4% and 6.7%. Addressing the agility test, the small- sided games group improved significantly higher (+6.2%) than the change – of – direction group (+4.2%) and the control group (+3.7%). Moreover, the change – of – direction group reached significantly higher improvements in jumping tests (+3.5%) than the small- sided games group (1.9%) and the control group (1.5%). With the results from this study it could be concluded, that small- sided games have a superior effect on agility performance in youth soccer and additionally provide improvements in sprinting, pre-planned change – of – direction tasks and leg power (Chaouachi et al., 2014).

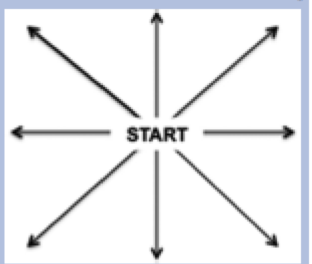
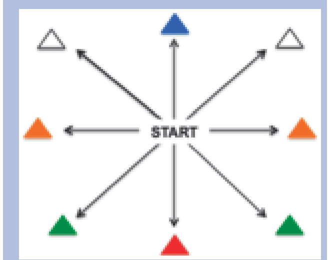
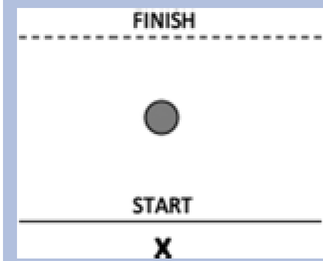
Respecting the different components of agility, as stated in a chapter above, it can be assumed that paying attention to perceptual and decision-making factors during training, might also improve agility performance. In their paper, Spiteri et al. (2018) focused on the importance of internal and external perceptual information and the following movement outcome during agility performances. This term is also referred to as perception-action coupling and should also be respected in the training. Table 2 shows how an agility development programme may look like. In order to take full advantage of the transfer from agility training to the on-field performance, players must be able to identify stimuli and the current situation and response to it as fast as possible with a controlled movement. The authors suggested to start with a closed-skill training. For instance, athletes recognising a non-specific stimulus, such as coloured cones, lights or voices with a following reaction to it. As mentioned by Spiteri et al. (2018, p. 42): "For example, allocating a different directional change to a coloured cone and verbally cueing which colour cone to move to, requires the athlete to visually identify the correct cone and execute the appropriate movement response." To get more sport-specific, the stimulus should be related to the sports or to the game. As stated in Table 2, man-on-man drill is used as an example. The players need to identify kinematic cues from an opponent and react by performing directional changes to evade the opponent. Coaches can regulate the intensity of such drills by setting a timer, increasing the number of defenders or making use of sport- specific equipment, such as dribbling a ball. This training will lead to a development of the athlete's ability to recognise an environmental situation and to remember and transfer their movement solutions from training to the game. The authors also mentioned the value of feedback while training agility. Feedback can be distinguished in intrinsic and extrinsic feedback. According to the authors, starting with closed-skill agility training, coaches should use extrinsic feedback more often. The knowledge of result (KR) is a form of extrinsic feedback and is related to the outcome of a movement. Knowledge of Performance (KP) is the second form of extrinsic feedback and describes the quality of the movement. Intrinsic feedback, on the other hand, refers to sensory information that comes from inside the athlete´s body and becomes more important in an open-skill training. Spiteri et al. (2008, p. 44) also stated:

> *External cues during agility training such as 'accelerate away from the opponent as quick as possible' or 'push off the ground as hard as possible' has been shown to increase agility performance by*

creating an external focus of attention allowing motor behaviour to occur automatically.

(Spiteri et al., 2018)

Table 2 source: Development of agility performance progressing from movement-orientated (basic) to perception- action coupling (advanced) training using a structured practical framework (Spiteri et al., 2018).

Training aim	Movement competency and identification of limitations in physical and technical capacity	Create a "controlled reactive setting": training ability to recognize and respond to a stimulus (reaction)	Allow athletes to explore movement solutions in response to a movement problem
Environment	Closed →		Open
Stimulus type	No stimulus	Introduce nonspecific stimulus (light, whistle, voice commands, and colored cones)	Sport-specific/context-specific stimulus (another team mate) Responding to movement of an object used in the game
Practice conditions	Random practice (order of drill repetition) Part-to-whole practice Manipulate the environment (distance of movement execution) Manipulate the task (speed of movement execution)	Random practice Temporal variability (timing of the stimulus changes) Alter the type of stimulus Time constraints	Random practice Temporal and spatial variability (timing and location of the stimulus) Vary environmental and task constraints
Feedback and cueing	Extrinsic feedback (coach or trainer) KR (outcome of the movement) Cueing: external focus (movement cues)	Extrinsic feedback (start to decrease) Intrinsic feedback (start to increase) KR KP (quality of the movement) Cueing: external focus (movement cues)	Intrinsic feedback KR KP Cueing: external focus (movement and perceptual cues)
Example drill progression	Star drill: emphasis deceleration body control—"stick and hold" on deceleration One repetition forward running One repetition backward pedaling One repetition 45° forward running One repetition lateral shuffle One repetition 45° backward pedaling  *Can manipulate the size of this drill	Reactive star drill: emphasis deceleration body control—"stick and hold" on reactive deceleration Forward running (blue cone) Backward pedaling (red cone) Lateral shuffle (orange cone) 45° backward pedaling (green cone)  *Randomly alternate movement by cueing cone color	Man-on-man drill (space restricted): athlete must perform a variety of directional changes to bypass a defensive opponent and reach the finish line  *Can implement a time constraint, size of the drill, add an object (eg, basketball), or increase the number of defensive or offensive opponents

KP = knowledge of performance; KR = knowledge of results.

To achieve a maximum of agility performance, it is, therefore, essential to implement drills containing perception-action coupling in order to develop faster decision-making and performing faster and more appropriate movement solutions. The authors recommend to start with closed skill training before heading to sport specific open-skill training for yielding the best results (Spiteri et al., 2018).

Another approach for improving agility performance might be plyometric training. As it says in the article by Miller, Herniman, Ricard, Christopher, & Michael (2006, p. 459):" Plyometric drills usually involve stopping, starting, and changing directions in an explosive manner. These movements are components that can assist in developing agility." The same authors conducted a study to determine how a 6-week plyometric training may improve performance in agility tests. The findings showed that plyometric training increased the times in the agility tests significantly, which led to the conclusion that such a training, even just 6 weeks long, can lead to a higher agility performance. As the authors mentioned, coaches should bear in mind that it might be beneficial to add plyometric exercises to the training in the last preparatory phase before the season starts. Plyometric drills are for example side-to-side ankle hops, lateral jumps over barriers, cone hops with a turn, single leg bounding or other exercises including eccentric action followed by a concentric or shortening action of the same muscle to increase neural adaptions. (Miller et al., 2006). As stated in the article of W. B. Young et al. (2015, p. 164): "Reactive strength may be expected to correlate highly with CODS because changing direction (…) involves a relatively small knee flexion with a short ground contact time, and a high eccentric loads during the leg extensor muscle stretch- shortening cycle". To summarise, plyometric forms of training can be useful for improving agility performance, as well as change-of-direction speed (Young et al., 2015).

Milanovic, Sporis, Trajkovic, James, & Samija (2013) did a study to analyse the effects of a 12-week conditioning training on agility performance in young soccer placers. The training programme included speed, agility and quickness (SAQ) training. As the results demonstrated, the 12-week SAQ training programme positively influenced agility performance with and without a ball in young soccer players. The exercises used in this programme involved many complex coordination exercises including a ball to be more soccer specific. For coaches it is recommended to do speed and agility training as a part of the trainings process in general, because speed, quickness and agility are among the most important components for a good match performance. Because of the fact that some coaches do not recognise the importance of agility training, it is necessary to make them aware of the positive benefits the right trainings could have. The authors also claim that further research is necessary to investigate at which point during the season SAQ training should be done in order to get the best results and to what extent agility training should be performed (Milanovic et al., 2013).

Table 3 below shows the exercises used in the programme. In total, the players performed 48 SAQ workouts.

Table 3 source: framework of SAQ programme (Milanovic et al., 2013).

Dynamic flexibility	**Mechanics**	**Innervations**
Toe Walk	**Arm mechanics-Arm Drive**	*Single Walk*
Heel Walk	*Partner Drills*	*Single Run*
Jogging and Hug	*Arm Drive for Jumping*	*Single Lateral Steps*
Small Skip	*Buttocks Bounce*	*Up and Back*
Wide Skip	**Leg Mechanics**	*Lateral Step In-Out*
Single Knee Dead-Leg Lift	*Knee-Lift Development*	*Small Dead Leg Run*
Knee-Across Skip	*Dead Leg Run*	*Icky Shuffle*
Lateral Running	*Leading Leg Run*	*Double Run*
Pre-Turn	*Pre-Turn*	*Hopscotch*
Carioca	*Quick Sidestep*	*Two Step Forward and One Step Backward*
Hurdle Walk	*Sidestep*	*Single Space Jumps*
Russian Walk	*1-2-3 Lift*	*Two Jumps Forwards and One Jump Backward*
Walking Lunges	*Single Jumps*	*Twist Again*
	Single Jump Over and Back	*Hop In and Out*
	Single Jump with 180-degree Twist	*Carioca*
	Lateral Single Jumps	*Spotty Dogs*
	Forward Multiple Jumps	***Line Drills***
	Lateral Multiple Jumps	*Line Drills (Spit Steps)*
	Multiple Hops	*Two-footed Jumps*
	180 - Degree Twist Jumps	***Box Drills***
		Split Step
		Two-Footed Jumps
Accumulation of potential	**Explosion**	**Expression of potential**
Agility Disc	**Vision and Reaction**	*Robbing the nest*
Seated Agility Disc	*Fast Hand Games*	*Shadow*
Swerve Development Runs	*Reaction Ball*	*Cone Game*
Fast Feet Zigzag Run	*Get-Ups*	*Fielding Skill - Specific*
Four Turn, Four Angle Run	*Chair Get-Ups*	
Combination Runs	*Let-Goes*	
Team Combination Runs	*Parachute Running*	
	Ball Drops	
	Buggy Runs	
	Flexy Cord - Overspeed	
	Flexy Cord - Out and Back	
	Side-Steper – Resisted Lateral Runs	
	Side-Stepper-Jockeying Throw and Catch Drill	

To sum up, Paul et al. (2016) gave three recommendations for improving agility performance in their review. First, the importance of perceptual and decision-making exercises in response to an appropriate stimulus is highlighted. They also mention that the focus should be more on small-sided games than on change-of-direction training as explained in the study above. The authors suppose that the small pitch might lead to a faster decision-making time than training of movement speed. Lastly, they recommend small-sided games and strength trainings as a warm-up for improving agility performance (Paul et al., 2016).

6. Research question and aim of the study

In this study, amateur soccer players of the fourth league in Austrian soccer performed three tests with different tasks. The 20m sprint tested the linear sprinting speed whereas the agility and change-of-direction speed test was used for testing the agility performance and change-of-direction speed. Soccer players from the first team, who were between 18 and 35 years old by the time of testing, were tested as well as youth players from the U15 squad. Therefore, the main research question is if there are any age-related differences in agility, change-of-direction speed and linear sprinting speed performances between the first team and youth players in male amateur soccer. It also leads to the question to what extent agility performance and linear sprinting speed are related skills in amateur soccer. Is there a correlation between linear sprinting speed and change-of-direction speed after all? Furthermore, the question arises if soccer players who are good sprinters are also good in performing agility. Lastly, how do technical demands affect performance in agility, change-of-direction speed and linear sprinting speed tests?

To answer the questions above, the general purpose of this study was to analyze the relation between linear sprinting speed, change-of-direction speed and agility performance. Furthermore, the difference in performance with and without a ball was examined. In addition, the difference between youth soccer players and players from the first team was investigated.

6.1 Hypothesis

$H0_1$: There is no significant difference in the 20m linear sprinting time while dribbling a ball between the first team and the youth players.

$H0_2$: There is no significant difference in 20m sprinting time without a ball between the first team and the youth players.

$H0_3$: There is no significant difference between the time in the COD-test and in the agility test without a ball.

$H0_4$: There is no significant difference between the first team and the youth players in agility and COD with dribbling a ball.

$H0_5$: There is no significant correlation between the time in the 20m linear sprinting and COD test without a ball.

$H0_6$: There is no significant correlation between the 20m sprint with a ball and the agility test with a ball.

$H0_7$: There is no significant correlation between the 20m sprint with a ball and the COD- test with a ball.

$H1_1$: There is a significant difference in the 20m linear sprinting time with dribbling a ball between the first team and the youth players.

$H1_2$: There is a significant difference in 20m sprinting time without a ball between the first team and the youth players.

$H1_3$: There is a significant difference between the time in the COD-test and in the agility test without a ball.

$H1_4$: There is a significant difference between the first team and the youth players in agility and COD with dribbling a ball.

$H1_5$: There is a significant correlation between the time in the 20m linear sprinting and COD test without a ball.

$H1_6$: There is a significant correlation between the 20m sprint with a ball and the agility test with a ball.

$H1_7$: There is a significant correlation between the 20m sprint with a ball and the COD-test with a ball.

7. Method

In order to answer the research question, an empirical study was conducted. The participants of this study were amateur soccer players from a first team and youth players of the same soccer club. The test procedure took place as a field test on a grass soccer pitch, which is also the training pitch of the team. For data collection, each player performed three different tests, one for assessing agility performance, one change-of-direction speed performance test and one test for determining linear sprinting speed. The tests took place on three different days during the season, but always on the third day after the match between 4pm and 7pm during their regular training sessions. For analysing the data, the software programmes Microsoft Excel and IBM SPSS Statistics (v26) were used.

7.1 Subjects

Sixteen male amateur soccer players from the first team (age: 25.5 ± 5.0 years; height: 1.80 ± 0.06 m: body mass: 78.9 ± 5.2 kg) of a soccer club participated in the study as well as ten youth players (age: 14.1 ± 0.6 years; height: 1.62 ± 0.12; body mass: 59.4 ± 7.3) from the same club. The first team is currently competing in the first national league of Lower Austria, which is the fourth division in Austrian soccer. The players from the first team are usually training three times per week, sometimes four times, during the season. In the first team, the players' most played position was also reported. The group of subjects from the first team consisted of goalkeepers (n=2), defenders (n=3), midfielders (n=8) and forwards (n=3). The midfielders were also divided in attacking or defending as well as wide or central midfielders.

Each subject refrained from strenuous exercise for 24 hours before performance testing in order to avoid unnecessary fatigue. All participants performed well hydrated and abstained from consuming food for at least two hours before the testing started. Players were instructed to wear the same soccer boots for all the tests.

All participants and their coach were informed about the testing procedures and potential risks. Additionally, approval from parents had been provided for the players under 18. The consent form, which was signed before the testing started, can be found in the attachments.

7.2 Study design

Before performance assessment, anthropometric measurements (body height and body mass) of all participants from the first team were carried out using a stadiometer (seca 213, Germany) and a calibrated, electronic scale (seca 877, Germany) to calculate BMI (kg/m^2). Anthropometric measurements were performed indoors, barefoot and with minimal clothing. The testing subjects were instructed to stand as straight as possible, with their heels together looking straight ahead. The height of the subjects was recorded to the closest centimetre. Furthermore, the players' position was determined.

7.3 Progress of testing

Body mass index assessing body mass relative to height was calculated using height and weight measurements of the subjects by following equation:

$$\text{BMI (kg/m}^{-2}\text{)} = \text{body mass (kg) / height squared (m}^2\text{)}$$

Before the testing session started, the players did a supervised as well as the team´s standardised pre-match warm-up for 20 minutes, including skipping exercises and preparatory sprint drills with progressive speed increase. Before the agility test, the players performed a trial round in order to become familiar with the system. Both tests were performed with and without a ball, with a random sequence. The players were randomly divided in two groups and during the test in smaller groups of three each. Each player of the group of three did all four trials before the next group started to reduce the resting period.

Assessment of Sprint Performance

The first test was the 20m linear sprint test to measure the linear speed. The time was measured after 5m as well as after 10m. The other part of the test included dribbling a ball while sprinting 20m. The minimum number of touches of the ball was defined with four touches. The 20m straight sprint test was measured using a wireless timing system with double photocells (Witty, MicroGate, Bolzano, Italy) so that only the simultaneous interruption of both photocells generates a signal. Each player started from a standing position 30 cm in respect to the first photocell gates with their preferred foot forward. The starting line was marked. The unit of time was measured with 1/100s accuracy and speed in m/s. Two test trials for both tests, with and without a ball, separated by a resting period of at least 30 second were performed. The best result of each test was used for further analysis.

Assessment of Agility Performance and Change-of-Direction Performance

The assessment for agility and change-of-direction speed performance was performed using a light stimulus. The players were randomly separated into two groups with one group starting with the agility test and the other group with the test for assessing CODS. For testing the agility performance and CODS, the Witty SEM System from MicroGate (Bolzano, Italy) was used. Each test consisted of four indicators which were positioned in a marked field with the size of 10mx10m. Figure 5 demonstrates the test design and how the indicators were placed exactly.

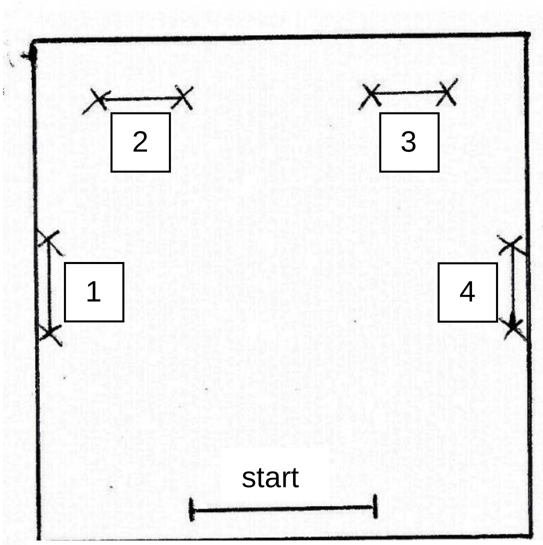


Figure 5 named test design

The starting gates were placed two meters apart and a cone placed 30 cm behind the gates marked the starting place or where the ball has to be laid down.

The gates 1 and 4 were placed either 5 m right or left from the starting gate, and 5m to the front. The gates 2 and 3 were positioned 3 m from gate 1 or 4 to the middle and 4m to the back. The indicators were interconnected with the photocell-gates as well so the players triggered the signal as soon as one body part reached through the gates.

To find an ideal way for testing, a new test was programmed using the Witty Software. The Witty SEM indicators can display different symbols or colours. For this study, the colour red was chosen. The players had the task to “catch” the red light, which means, they had to run as fast as possible to the indicator with the red light. When the proximity sensor of the indicator was triggered by running through the gate, another indicator switched to a red light. The players had to stop, turn around and change direction as fast as possible. In total, the test consisted of four light impulses. The overall number of impulses was programmed with five, because the first impulse was the starting gate. The athletes were free to start whenever they were ready to. The red light appeared completely randomised. For testing the change-of-direction speed the construction remained the same. The only difference was that the indicators were numbered from 1 to 4 and the players had to turn the lights off in a specific sequence which was defined right before testing so that the directional changes were pre-planned. Lists with a randomised sequence for each trial and each athlete were generated before the testing. For both tests, the players started in a standing position on a marked line. Again, the players did two trials with the ball first and then two trials without the ball. The best result was used for further analysis. Both tests were programmed using the Software Witty Manager (Version 1.4.66).

8. Results

In this chapter, all results from the test are presented. First, the descriptive statistics for each performance test are outlined, followed by the inferential statistics. Before using any parametrical tests, the assumption of normality was verified using the Shapiro-Wilk Test. For all tests, significance was set at $p < 0.05$. The data analysis was done using Microsoft Excel and IBM SPSS Statistics (V.6).

Following data are represented as means ± standard deviation (SD) as well as minimum and maximum. All in all, 16 players (n=16) from the first team and 10 youth players (n=10) took part in this study. Table 4 below illustrates that the players from the first team were on average 25.5 (±5.0; min= 17, max=35) years old, whereas the youth players were on average 14.1(±0.6; min= 13, max=15) years old. The average height with standard deviation of first team players was 1.8 (± 0.06) meters, whereas youth players had a mean value with standard deviation of 1.62 (± 0.12) meters. Regarding their body mass, first team players weighed on average 78.9 (± 5.2) kg and youth players 59.7 (± 7.3) kg.

Table 4 statistical overview of the age and anthropometrical data of the participants

	number (n)	age (mean ± SD; min; max)	height (cm, mean ± SD; min; max)	weight (kg, mean ± SD; min; max)
first team	16	25.5 (± 5.0; min=17; max=35)	1.8 (± 0.06; min=1.7; max=1.92)	78.9 (± 5.2; min=72.6; max=91.6)
youth players	10	14.1 (± 0.6; min=13: max=15)	1.62 (± 0.12; min=1.45; max= 1.8)	59.4 (± 7.3; min=50.2; max=73.1)

8.1 Sprint Performance

In this paragraph, the mean times of both sprint performance tests are represented. As table 5 reveals, the mean time of sprinting while dribbling a ball is 3.07 (SD= 0.74; min= 2.96; max= 3.22) sec. for the first team and 3.71 (SD= 0.27; min= 3.32; max= 4.23) sec. for the youth players. The mean times of sprinting without a ball are 2.96 (SD= 0.10; min= 2.74; max= 3.06) sec. in the first team and 3.37 (SD= 0.24; min= 3.03; max= 3.76) in the team of youth players. In the figure below, figure 6, the comparison of the mean values in seconds of linear sprinting while dribbling a ball and without a ball with standard deviation between both teams are demonstrated.

Table 5 Comparison of sprinting time with and without a ball for each team (own table design)

	first team (n=15)				youth players (n=9)			
	M	SD	MIN	MAX	M	SD	MIN	MAX
Sprint with ball [sec]	3.07	0.7	2.96	3.22	3.71	0.27	3.32	4.23
Sprint without ball [sec]	2.96	0.1	2.74	3.06	3.37	0.24	3.03	3.76

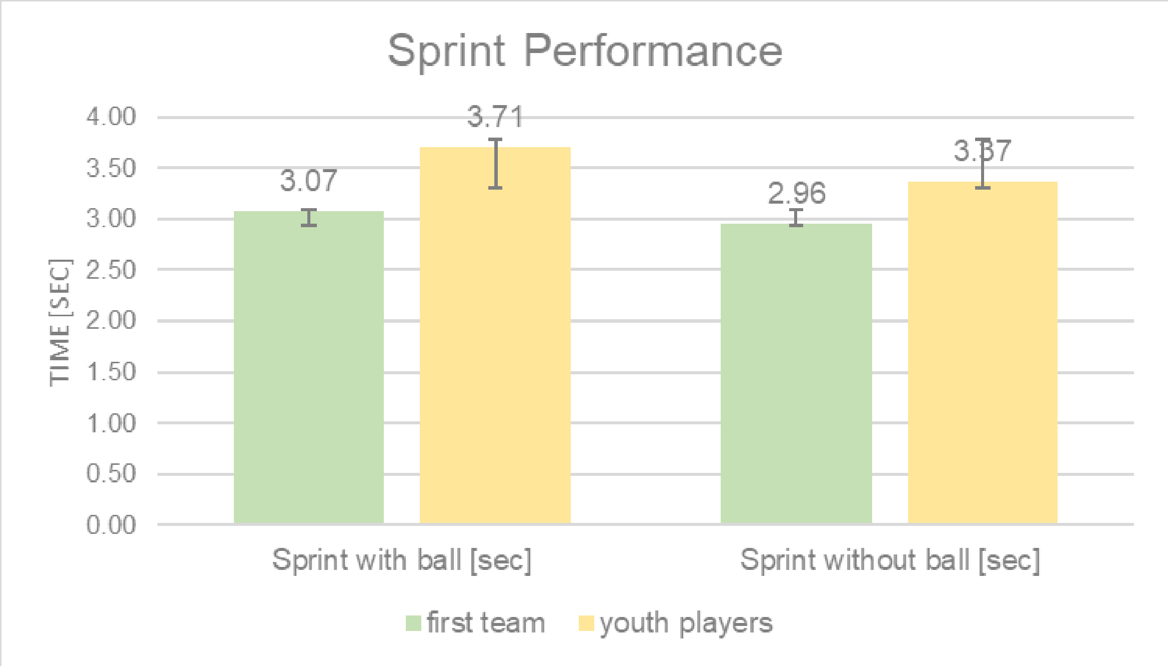


Figure 6 Comparison of sprint performance between first team and youth players (own design)

8.2 Agility Performance

Table 6 shows the mean times in seconds of the agility tests with and without dribbling a ball. Regarding the first team, the mean time is 11.79 (SD= 0.79; min= 9.95; max= 12.95) sec. for the test with the ball and 7.92 (SD= 0.71; min= 6.83; max= 9.63) sec. without dribbling a ball. The youth players have a mean time of 12.59 (SD= 1.87; min= 10.14; max= 15.99) sec. on the test with a ball and 9.72 (SD= 0.88; min= 8.69; max=11.22) on the agility test without a ball. The graphical representation of mean values with standard deviation for each team in comparison can be found in figure 7 below.

Table 6 Comparison agility performance with and without a ball for each team (own table design)

	first team (n=15)				youth players (n=8)			
	M	SD	MIN	MAX	M	SD	MIN	MAX
Agility with ball [sec]	11.79	0.79	9.95	12.95	12.59	1.87	10.14	15.99
Agility without ball [sec]	7.92	0.71	6.83	9.63	9.72	0.88	8.69	11.22

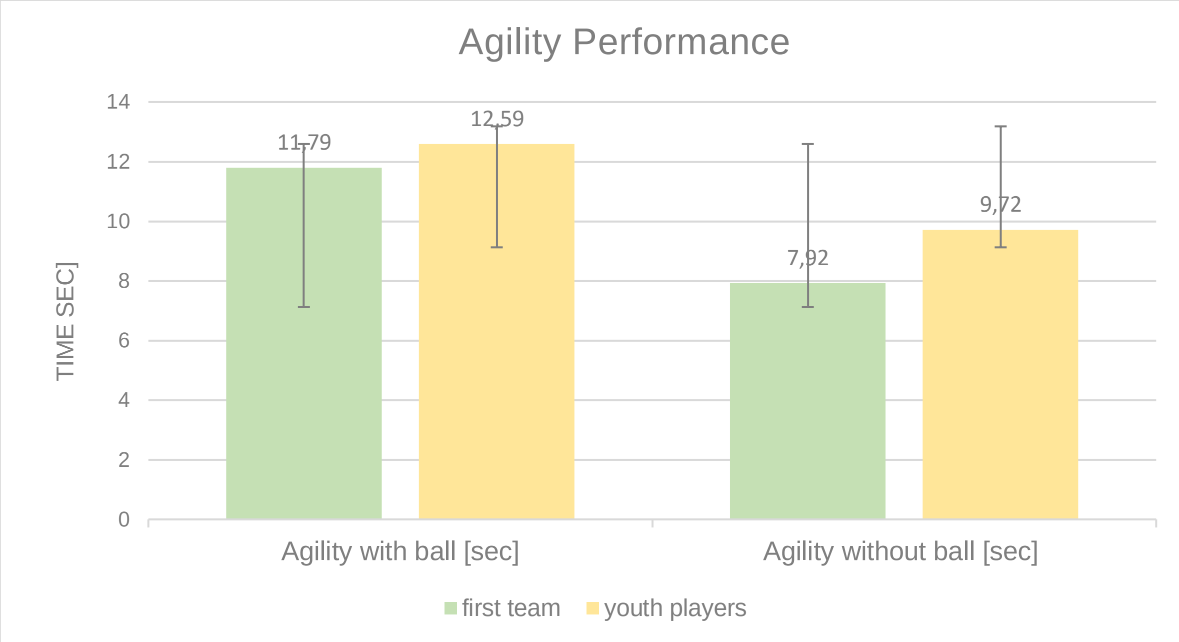


Figure 7 Comparison of agility performance between first team and youth players (own design)

8.3 Change-of-direction Performance

Table 7 demonstrates the mean times in seconds on the change-of-direction tests. As it shows, mean times for the first team are 9.89 (SD= 1.07; min= 8.41; max= 12.25) sec. while dribbling a ball and 5.35 (SD= 0.84; min= 4.26; max= 7.05) sec. for the change-of-direction test without a ball. Considering the youth players, the mean time is 10.60(SD= 0.896; min= 9.11; max= 11.86) sec. for testing with a ball and 7.81 (SD= 0.78; min= 6.80; max= 9.11) sec. without a ball. Figure 8 below shows the comparison of change-of-direction performance between both teams graphically.

Table 7 Comparison COD performance with and without a ball for each team (own table design)

	first team (n=13)				youth players (n=9)			
	M	SD	MIN	MAX	M	SD	MIN	MAX
COD with ball [sec]	9.89	1.07	8.41	12.25	10.6	0.89	9.11	11.86
COD without ball [sec]	5.35	0.84	4.26	7.05	7.81	0.78	6.8	9.11

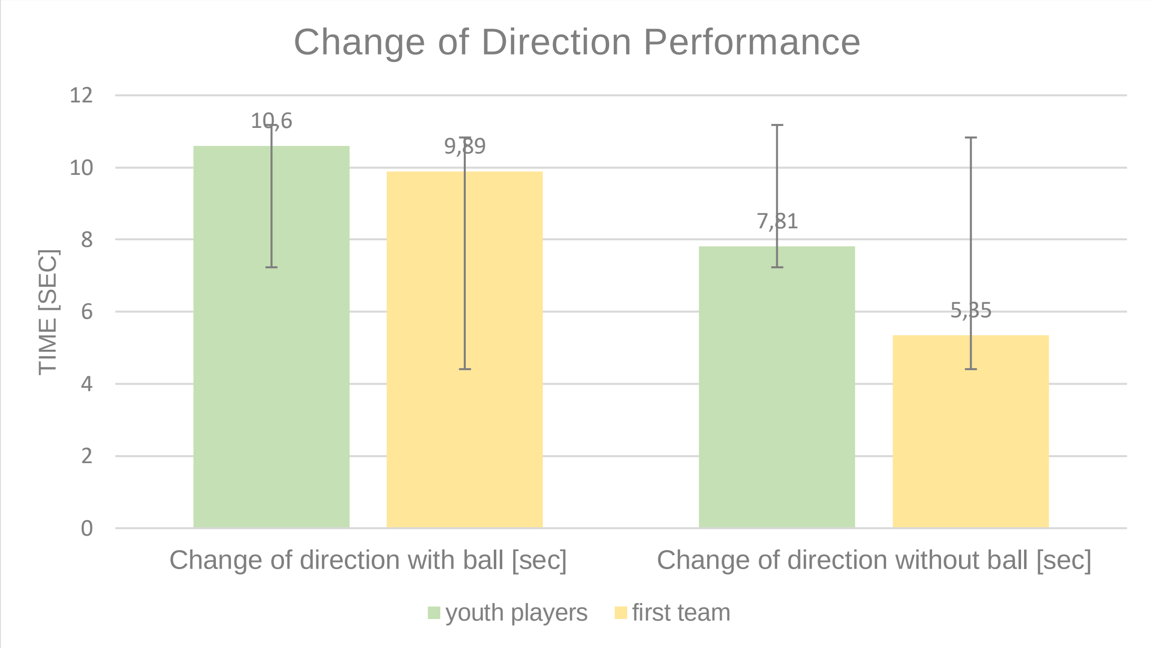


Figure 8 Comparison change of direction performance between first team and youth players (own design)

8.4 Differences and correlations

Before using further statistical tests, the assumption of normality for each performance assessment was conducted using the Shapiro-Wilk Test, since the number of participants is below n= 30. All results, with one exception, are normally distributed (> 0.05). Only the results of the agility test without a ball from the first team are not normally distributed (p = 0.006) as expressed in the tables in the attachment.

8.4.1 Differences

For analysing any difference in the data, a multivariate analysis of variance was done. As the tables (multivariate tests and tests of between- subject effects) in the attachment show, there are statistically significant (p <0.05) differences in all tests, except for the agility (p = 0.200) and change-of-direction (p = 0.114) test with dribbling a ball. The following tables show the outputs from the independent samples test. According to Table 8, there was a statistically significant difference in linear sprinting time with a ball between first team players and youth players, with a mean time of 0.64 seconds (95% - CI [- 0.79, - 0.49] lower for the first team players, t (22) = - 8.69, p < 0.01.

Table 8 Independent samples test for sprinting with a ball

			t	df	Sig. (2-tailed)	mean difference	std. error difference
Sprint with ball [sec]			-9	22	0	-0.64	0.07
95% CI	-0.79	-0.49					

Conferring to table 9, there was also a statistically significant difference in 20m linear sprinting time without a ball between first team players and youth players, with mean time of 0.42 seconds (95% - CI [- 0.56, - 0.27] lower for the first team players, t (22) = - 5.93, p < 0.01.

Table 9 Independent samples test for sprinting without ball

			t	df	Sig. (2-tailed)	mean difference	std. error difference
Sprint without ball [sec]			-5.93	22	0	-0.42	0.07
95% CI	-0.56	-0.27					

Based on the results presented in Table 10, there is no statistically significant difference between first team players and youth players in change-of-direction speed with a ball (p = 0.12 > 0.05).

Table 10 Independent samples test for change-of-direction with a ball

			t	df	Sig. (2-tailed)	mean difference	std. error difference
COD with ball [sec]			-2	20	0.12	-0.71	0.43
95% CI	-1.61	0.19					

Whereas, table 11 shows a statistically significant difference in change-of-direction time without a ball between first team players and youth players, with mean time 2.45 seconds (95% - CI [- 3.19, - 1.72] lower for the first team players, t (20) = - 6.93, p < 0.01.

Table 11 Independent samples test for change-of-direction without a ball

			t	df	Sig. (2-tailed)	mean difference	std. error difference
COD without ball [sec]			-6.93	20	0	-2.45	0.35
95% CI	-3.19	-1.72					

For analysing agility without a ball, the Mann-Whitney-U test was used because the data is not normally distributed. As stated in Table 12, there is a statistically significant difference in agility performance without a ball between the first team and youth players, U= 7.0, Z= -3.42, p = 0.001 < 0.05. The Z- value suggests, that first team players have significant faster times than the youth players.

Table 12 Mann- Whitney- U test for difference in agility without a ball

	Agility without ball [sec]
Mann-Whitney U	7.0
Z	-3.42
Asymp. Sig. (2-tailed)	0.001

As Table 13 shows, there is no significant difference between youth players and first team players in agility performance testing with a ball (p= 0.28 > 0.05). But yet, the first team players are faster on the average than the youth players as figure 7 above shows.

Table 13 Independent samples test for agility performance with ball

			t	df	Sig. (2-tailed)	mean difference	std. error difference
Agility with ball [sec]			-1.16	21	0.28	-0.8	0.69
95% CI	-2.38	0.78					

To summarize, there are statistically significant differences between first team players and youth players in linear sprinting with and without a ball, change- of- direction speed without a ball and agility performance without a ball. In all six tests, the first team was faster on the average than the youth players. The mean difference in all tests with a statistical significance is summed up in the table below. For analysing the difference in agility without a ball, a non- parametric test was used, therefore there is no mean difference evaluated.

Table 14 Mean difference between both teams using independent samples test

	mean difference (first team < youth players)
Sprint without ball [sec]	-0.42
Sprint with ball [sec]	-0.64
Change-of-direction without ball [sec]	-2.45
Change-of-direction with ball [sec]	-0.71
Agility without ball [sec]	/
Agility with ball [sec]	-0.8

8.4.2 Correlations

In order to find out if there is a correlation between linear sprinting, agility performance and change-of- direction speed for both teams, the Pearson correlation coefficient r was used. First, a general view of correlations is demonstrated. Afterwards, a more detailed analyzation of the results is presented. Table 15 below, shows an overview of the attained correlation coefficients between first team players and youth players in all tests. The strongest correlation was observed in the change- of- direction speed and linear sprinting speed without a ball (r= 0.77). Whereas, the lowest correlation was found in agility performance with a ball and change- of- direction performance with a ball (r= 0.27). The correlation significance was set at 0.05 level (p < 0.05).

Table 15 Pearson correlation coefficient (r) and coefficients of determination (R^2) between first team and youth players in general

	r	R^2
Change-of- direction with ball Sprint with ball	0.35	0.12
Change-of- direction without ball Sprint without ball	0.77	0.6
Agility with ball Sprint with ball	0.52	0.27
Agility without ball Sprint without ball	0.7	0.49
Agility with ball Change-of-direction with ball	0.27	0.07
Agility without ball Change-of- direction without ball	0.66	0.44

*correlation is significant at $p < 0.05$

As stated above, the strongest is a significant ($p < 0.05$) linear positive correlation is between 20m linear sprinting speed and change-of-direction speed without a ball (r= 0.77). As figure 9 represents, there is linear positive correlation between sprinting speed and change-of-direction speed without a ball as the dependent variable among whole sample (R^2= 0. 6), meaning a prediction value of around 60%.

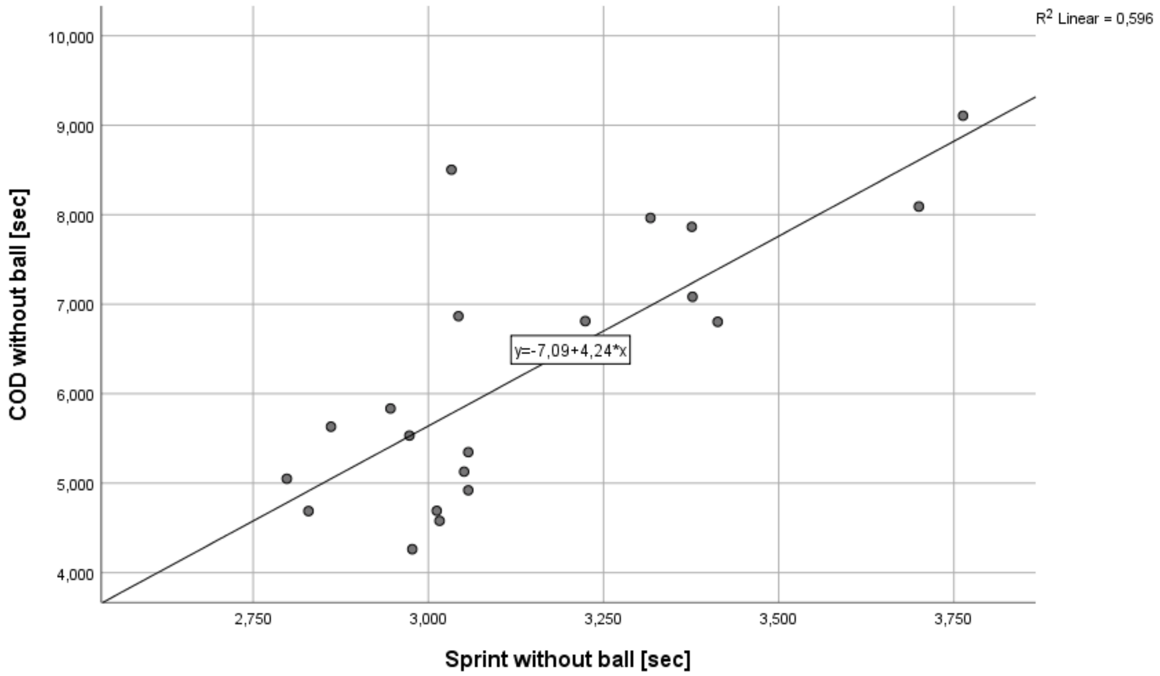


Figure 9 Scatter diagram with a regression line for COD and sprinting without a ball

Furthermore, there is a slightly positive linear correlation (r =0.35) with a common variance of R^2 =0.12 between change-of-direction speed and sprinting with a ball. Figure 10 shows there is a slightly positive linear correlation with a common variance of R^2 =0.12, although it is not significant (p= 0.13 >0.05) when analysing with the ANOVA, which can be found in the attachment below (table 17).

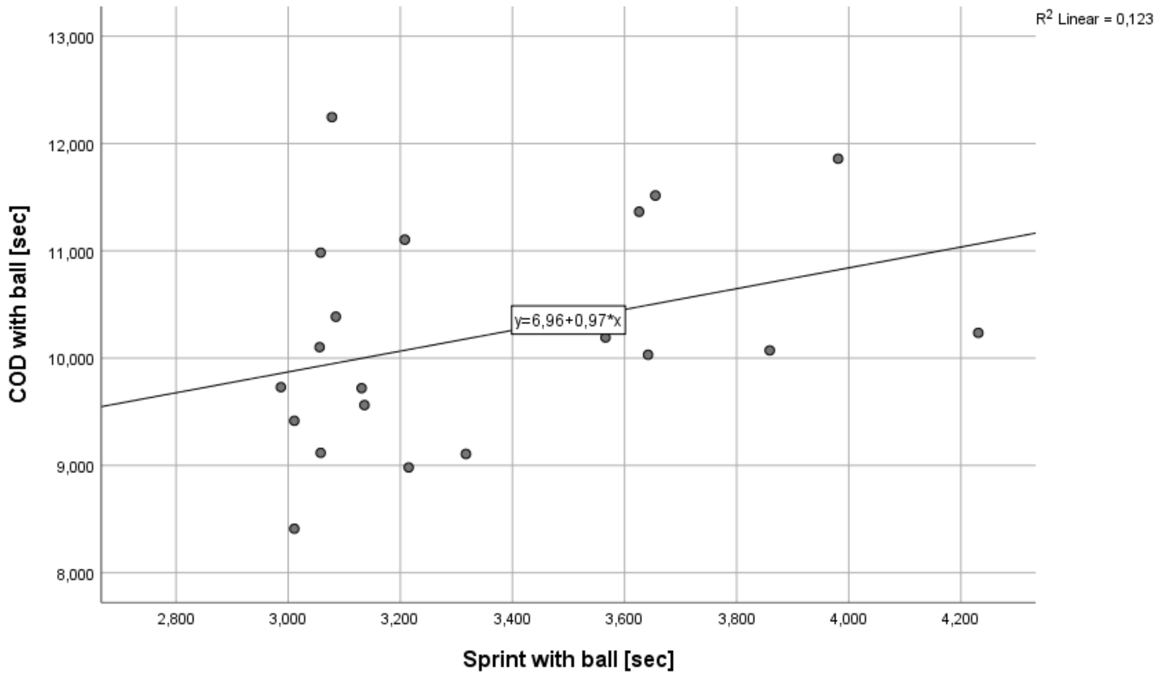


Figure 10 Scatter diagram with a regression line for COD and sprinting with a ball

As the results show, there is a significant ($p < 0.05$) moderate correlation ($r = 0.7$) between linear sprinting speed and agility performance without a ball among whole sample. Figure 11 demonstrates that there is positive linear correlation with a common variance of $R^2=0.49$, which means there is prediction value of about 49%.

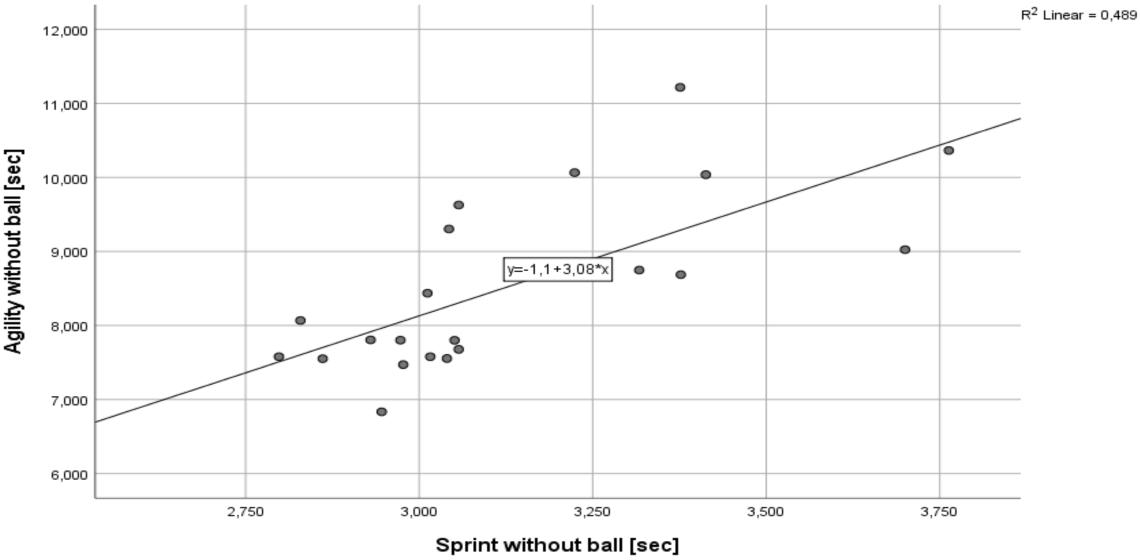


Figure 11 Scatter diagram with a regression line for linear sprinting and agility performance without a ball

Also, there is a significant ($p <0.05$) moderate correlation ($r =0.52$) between linear sprinting speed with dribbling a ball and agility performance with a ball. The scatter diagram in figure 12 shows, that there is a positive linear correlation with a common variance of $R^2= 0.27$ between sprinting speed and agility performance with a ball.

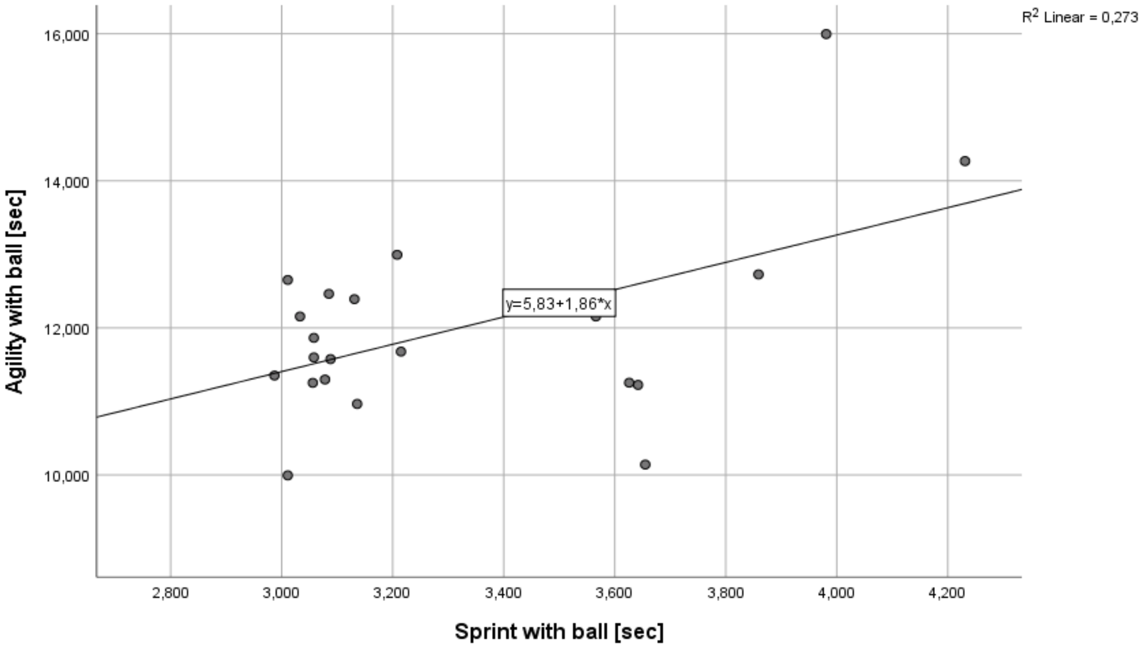


Figure 12 Scatter diagram with a regression line for linear sprinting and agility with a ball

In the following paragraphs, the correlations between agility performance and change-of-direction speed among the whole sample as well as divided by each team are analysed. Table 16 below gives a comparative overview of the two teams.

Table 16 Pearson correlations coefficients (r) separated by each team and coefficients of determination (R^2)

		r	R^2
first team	Change- of- direction without ball Agility without ball	0.11	0.01
	Change- of- direction with ball Agility with ball	0.22	0.05
youth players	Change- of- direction without ball Agility without ball	0.13	0.02
	Change- of- direction with ball Agility with ball	0.15	0.02

Regarding the whole sample, there is a moderate correlation (r =0.66) between agility performance and change-of-direction speed without a ball as it is displayed in table 15 above. Also, the correlation is significant ($p < 0.05$) according the ANOVA, which can be found in the attachment below (table 18). Analysing the scatter diagram (Figure 13), it shows that there is a linear positive correlation with a common variance R^2 = 0.44.

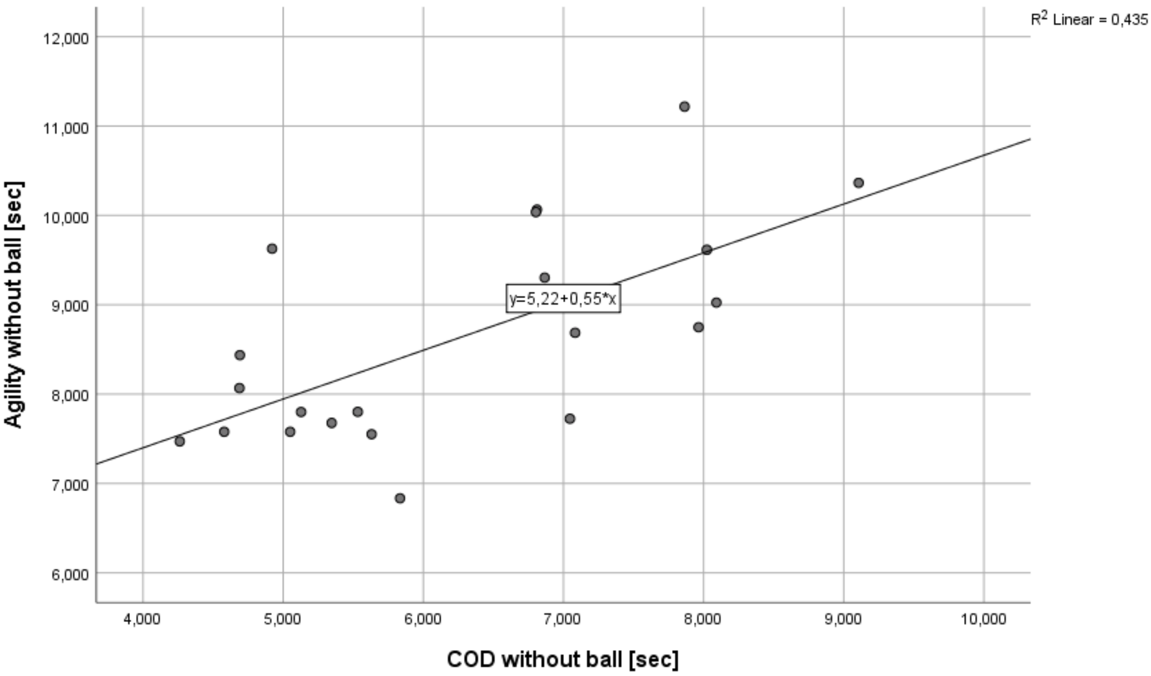


Figure 13 Scatter diagram with a regression line for agility and COD without a ball for whole sample

After dividing the sample by team, there is a non-significant ($p < 0.05$) very low correlation between agility performance and change-of-direction speed without a ball in both teams ($r = 0.11$ for the first team and $r = 0.13$ for the youth players).

In comparison, Figure 14 and Figure 15 below show the scatter diagram with a regression line after the sample was split by team. The correlation is still positive, but lower among first team ($R^2 = 0.01$) and among youth players ($R^2 = 0.02$).

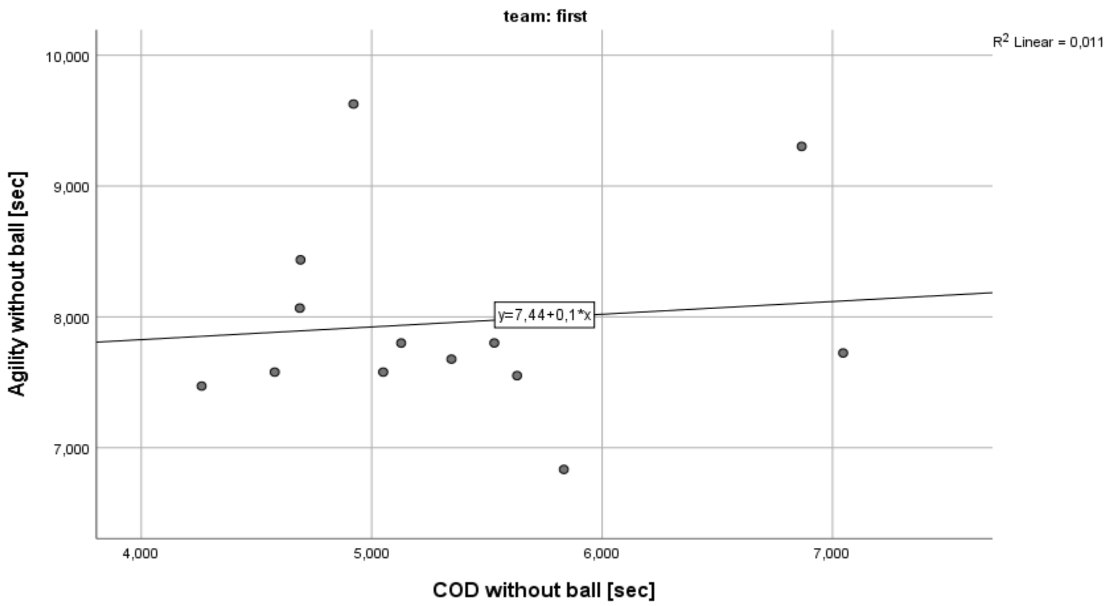


Figure 14 Scatter diagram with a regression line for agility and COD without a ball in first team

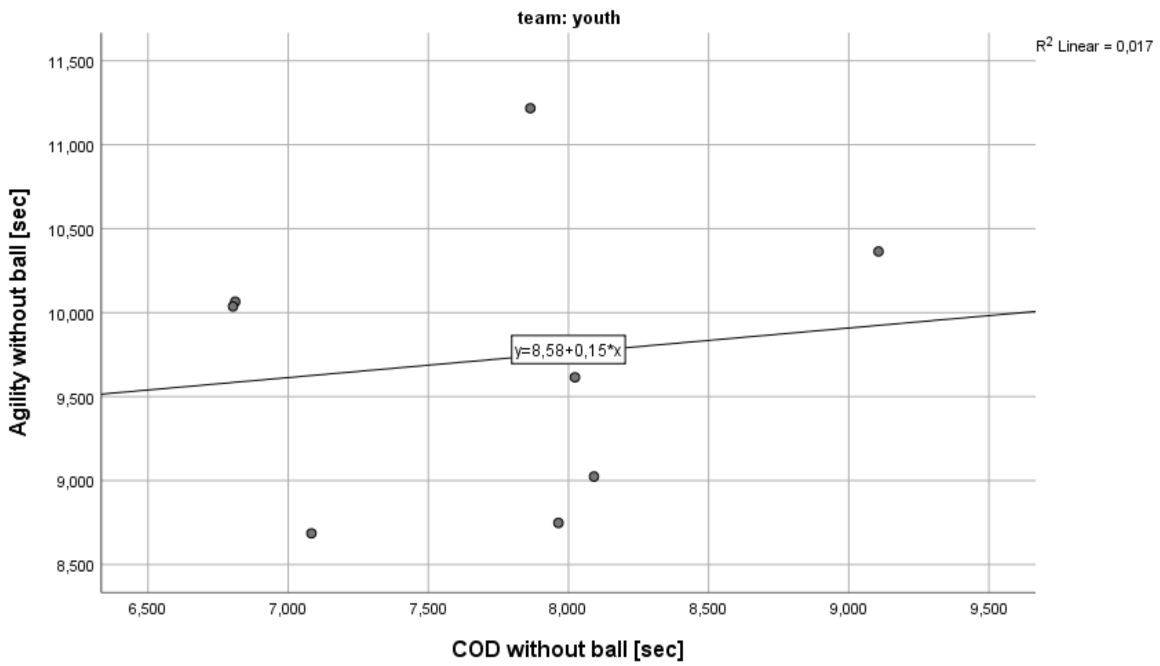


Figure 15 Scatter diagram for agility and COD without a ball in youth players

As table 15 above shows, there is a low non- significant ($p > 0.05$) correlation ($r = 0.27$) in whole sample between agility performance and change-of-direction speed while dribbling a ball. Figure 16 illustrates that there is a slightly positive linear correlation with a common variance $R^2= 0.07$, between agility performance and change-of-direction speed in whole sample undivided.

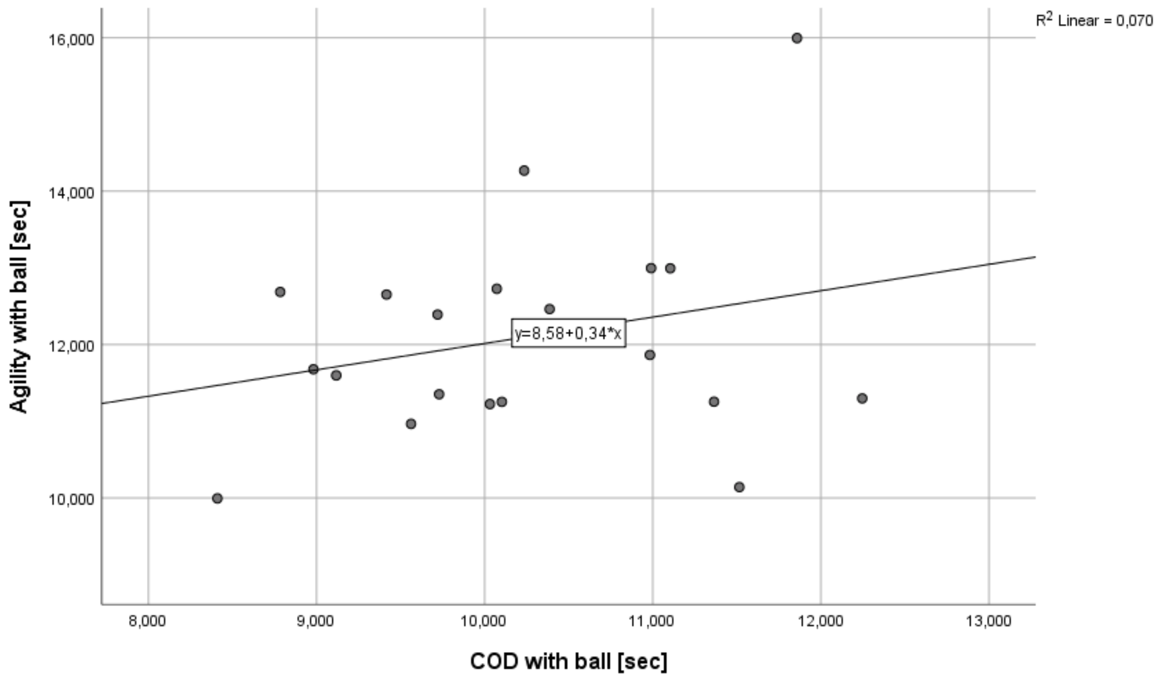


Figure 16 Scatter diagram for agility and COD with a ball among whole sample

In the following abstract the correlations between agility performance and change-of-direction speed while dribbling a ball, divided by first team and youth players are demonstrated. As Table 16 shows, there is a low correlation ($r=0.22$) between both variables among the first team and a very low correlation ($r=0.15$) between agility and change-of-direction speed with a ball among the youth players.

According to the ANOVA in the attachment below (table 19), there is no significant correlation between agility performance and change-of-direction speed with a ball regarding first team players and youth players ($p >0.05$).

As the two following figures present, there is a minor positive linear correlation ($R^2= 0.05$) between agility and change-of-direction speed with a ball within the first team (figure 17) and an even smaller positive linear correlation ($R^2= 0.02$) between both tests among youth players (figure 18).

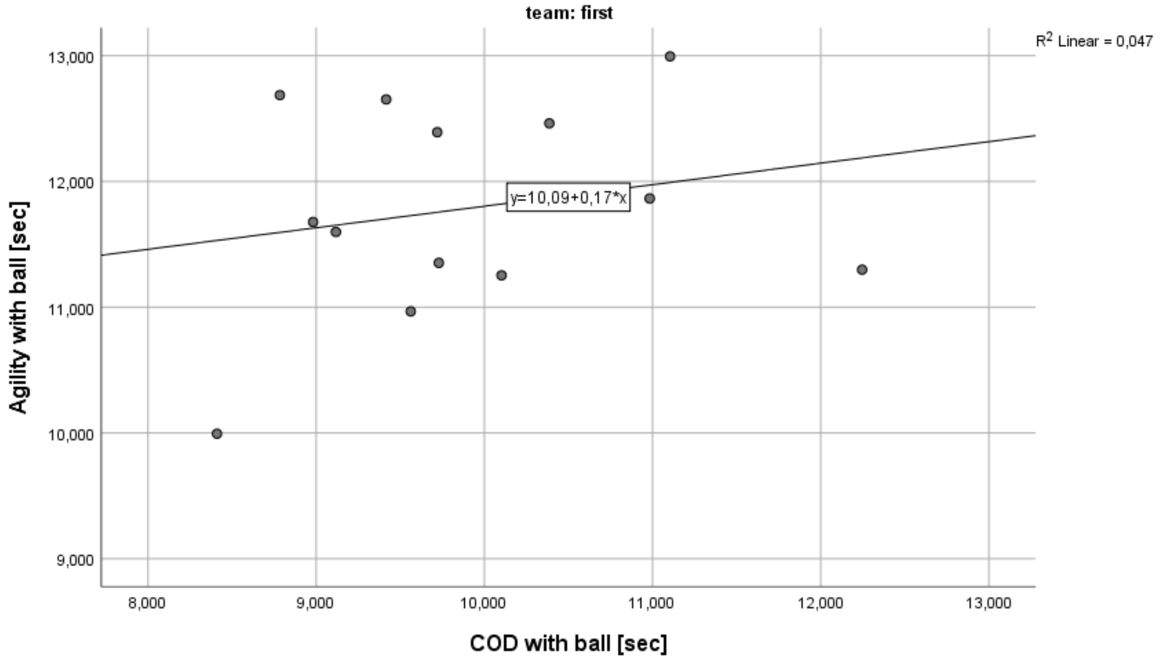


Figure 17 Scatter diagram with a regression line for agility and COD with a ball for the first team

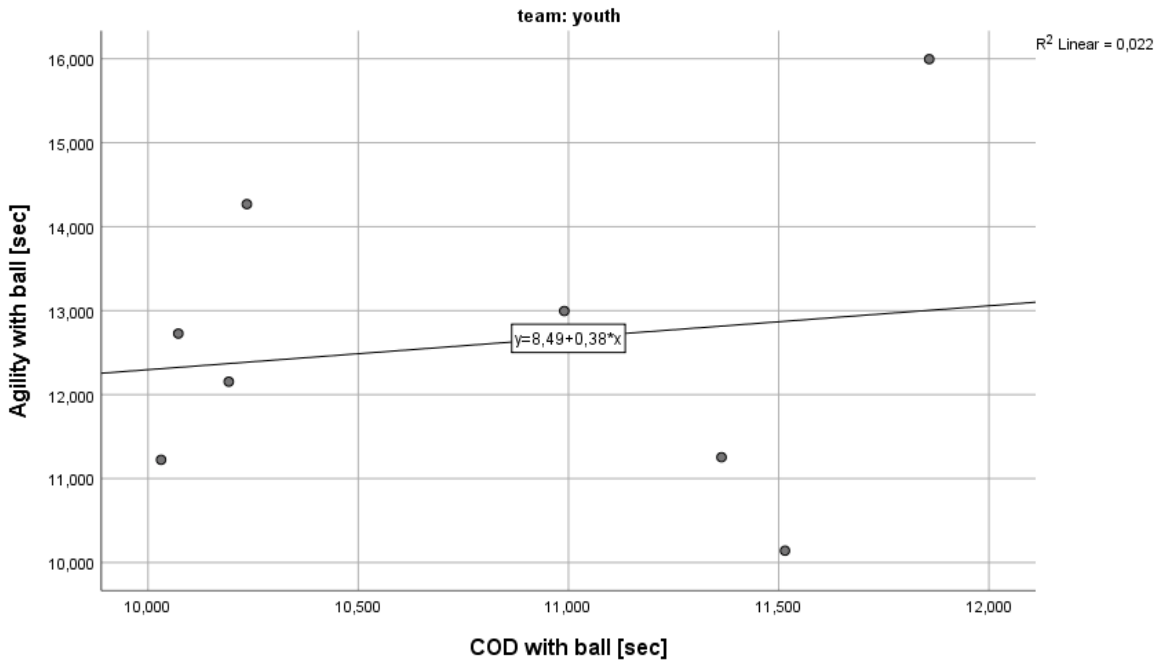


Figure 18 Scatter diagram with a regression line for agility and COD with a ball for youth players

9. Discussion

The main purpose of this study was to find out if there are any age-related differences in linear sprinting, change-of-direction speed and agility performance in Austrian amateur soccer players. Because all tests were done with and without a ball, it was possible to compare between motor ability development, such as speed and agility, and technical skill development, such as dribbling with a ball. Additionally, it was examined if there are correlations between linear sprinting speed, change-of-direction speed and agility performance with and without dribbling a ball and with and without group separations.

Regarding the differences between both age groups, the first team is faster on average in comparison to the youth players in all six tests. As the results show, the test outcomes without including a ball are always better than the tests done with a ball. One reason for the faster times in the tests without a ball could be that while dribbling a ball further technical skills are required. Only two players from the first team were faster with a ball in one test trial of the 20m linear sprinting test. Those two players are forwards and especially as a striker it is an advantage to be fast with a ball during a match play. Additionally, the first team is always faster with a ball than the youth team because of their better developed technical abilities. These findings underline the results from another study, which compared lower- and higher classed players from all types of team sports and concluded that athletes with a higher standard of play are faster in general and perform more high-intensity runs compared to lower classed athletes. (Bradley et al., 2010; Stølen et al., 2005). Also, the study by Green et al. (2011) on rugby players showed that there was a difference between players of various performance groups. Because of the fact that the higher-performance group was faster in the reactive agility test than the lower-performance group, the authors suggested that cognitive and perceptual skills are important to distinguish between players of different playing abilities (Green et al., 2011).

As assumed, the average total time in the change-of-direction test is shorter than in the agility test for both groups with and without a ball. The reason for this might be the pre-planned characteristics of the change-of-direction test in comparison to the agility test, which was not a pre-planned task. To the same conclusion came another investigation conducted by Matlák et al. (2016) and performed by amateur soccer players: “Average total time in the reactive agility test was longer than total time in the CODS test ($p < 0.0001$)” (Matlák et al., 2016. p. 1550).

According to the multivariate analysis of variance, there are statistically significant differences between first team players and youth players in all tests except for agility performance testing with a ball ($p = 0.200$) and in the change-of-direction test with a ball (p

= 0.114). The independent t- tests came to the same outcome as the multivariate variance analysis. There is a statistically significant difference in the 20m linear sprinting time while dribbling a ball between both teams ($p < 0.01$) and in the 20m linear sprinting without a ball ($p < 0.01$). The differences in change-of-direction speed ($p < 0.01$) and in agility testing time ($p < 0.01$) are also statistically significant between the two teams. Gabbett et al. (2008) came to similar findings in their study conducted with rugby players. They distinguished between first grade and second grade players and as their results showed first grade players had faster ($p < 0.05$) sprint times than second grade players. However, there were no significant differences between first grade players and second grade players for change-of-direction speed (Gabbett et al., 2008). The findings of the study conducted for this thesis support the statement that players with a superior decision- making ability are faster in agility performance testing (Paul et al., 2016). Players from the first team simply have more experience and practice and therefore, are able to react faster to specific stimuli during match situations or under a testing condition than youth players. The statistically non-significant difference between both groups in agility performance and change-of-direction speed with a ball could be reasoned by the low number of test persons in this study. Another reason might be the running route which was completely randomised. Some players might have ran shorter distances than others, which led to faster results. This issue could be solved by doing more test trials and determining a mean value from all results or trying to programme the testing system in a different way so every athlete has the same conditions with the same running paths.

Considering the correlation between linear sprinting speed, agility performance and change-of-direction speed, findings show that there is a statistically significant ($p < 0.05$) strong correlation between linear sprinting speed and change-of-direction speed without a ball, yielded Pearson´s coefficient of $r = 0.77$. The common variance resulted in $R^2 = 0.596$, which indicates that linear sprinting speed and change-of-direction speed are similar skills when there is no ball included, because of the value being slightly over 50%. According to the study conducted with Rugby players by Gabbett et al. (2008), they also found a significantly correlation ($p < 0.05$) between sprint times and performances on change-of-direction tests (Gabbett et al., 2008).

However, looking at the results from the tests involving the ball, there is a non-statistically significant ($p = 0.064 > 0.05$) low correlation between change-of-direction speed and linear sprinting while dribbling a ball with Pearson´s coefficient of $r = 0.35$. Also, the common variance $R^2 = 0.12$ is very low, which indicates that linear sprinting and change-of-direction speed are independent skills when there is a ball included. The lower prediction value (12%) might occur because of the technical skills involved by testing with a ball. As stated earlier, Young et al. (1996, quoted in Sheppard and Young, 2006) carried out a study to assess differences in linear sprinting, sprinting while bouncing a football and sprinting with directional changes. The results revealed very low correlations between those activities. Thus, the authors suggested that sprinting, sprinting while bouncing a ball and sprinting with directional changes were different and specific qualities (J. Sheppard & Young, 2006).

Regarding the findings in this piece of work, there is a statistically significant ($p < 0.05$) moderate correlation between linear sprinting and agility performance without a ball displayed Pearson´s coefficient $r = 0.699$. The common variance is $R^2 = 0.49$, which is almost at 50%. Likewise, in 1985, scientists have already found statistically significant low to moderate correlations between an agility test and a linear sprinting test (Draper and Lancaster 1985, quoted in Sheppard and Young, 2006).

The findings also demonstrate a statistically significant ($p < 0.05$) moderate correlation ($r = 0.52$) between linear sprinting and agility performance with a ball. However, the prediction value ($R^2 = 0.27$) of around 27% is lower compared to the value of performance testing without a ball, which is around 49 %. This also confirms the statement that agility tasks and sprinting with a ball are different skills in comparison to performing those tasks without a ball. A non- significant ($p > 0.05$) moderate correlation ($r = 0.66$) was found between agility performance and change-of-direction speed without a ball. Among the whole sample the common variance $R^2 = 0.44$ suggests that agility and change-of-direction without a ball are independent skills. Separating the data by teams, an even lower value can be found with $R^2 = 0.01$ for first team players and $R^2 = 0.02$ for youth players. Similar results were stated in the review by W. B. Young et al. (2015). The authors found five studies which compared agility and change-of-direction with the same movement pattern. The results from the studies demonstrated in this review by W. B. Young et al. (2015, p. 161) were the following: "…r = 0.68, r = 0.321, r = 0.434, r = 0.70 and a Spearman correlation of -0.08. The common variance (…) from the first four studies varied from 10 – 49% (mean = 29%)". However, none of these studies were conducted in the field of soccer, only in other team sports (W. B. Young et al., 2015). Equal to the results from this study, the publication cited above also concludes that agility and change-of-direction are independent skills. In addition, a non-significant ($p > 0.05$) low correlation with Pearson´s coefficient $r = 0.27$ occurred between change-of-direction speed and agility performance with a ball. Nonetheless, the common variance $R^2 = 0.07$ is clearly below 50%, which suggests that agility and change-of-direction require different physical qualities, especially when there is a ball included. Comparing the correlations of both teams, there is no statistically significant, but low correlation ($r = 0.22$) with a common variance of $R^2 = 0.05$ between those tests in first team players and a non-significant very low correlation ($r = 0.15$) with a common variance of $R^2 = 0.02$ in youth players. A study similar to this one also found non-significant correlations between reactive agility and change-of-direction times (Matlák et al., 2016). The authors claimed one reason for this might be the testing procedure in general as stated in their study: "…the reactive agility test in our study contained four directional changes in a row, whereas participants in other studies had to react and change direction only once while sprinting" (Matlák et al., 2016, p. 1550). Like the results from the study in this work, the findings investigated by Matlák et al. (2016) showed that the average total time in the reactive agility test was longer than total time in the change-of-direction test ($p < 0.0001$). The authors pointed out that the non-significant relationship and the low common variance ($v^2 = 0.03 - 0.18$) between reactive agility and change-of-direction are an indicator that for performing pre-planned and reactive running tasks different physical and physiological abilities are required. It also highlights the importance of perceptual and decision-making factors in agility performance (Matlák et al., 2016).

10. Conclusion

There are hardly any studies which compare youth players and adult soccer players from the first team in physical performance testing. Thus, it was a challenge to develop a study design which considered both teams. Another point which had to be considered was that the testing systems needed to be as sport specific as possible. Therefore, the whole testing procedure took place as a field test on a soccer pitch, which has pros and cons. One disadvantage, for example, was the change of weather conditions, which were slightly different on each testing day. Because of the rain, the grass was very damp on one day and players from the latter groups therefore faced worse conditions than the first groups. This problem would not occur in a hall. Consequently, it should be considered that recorded times might be a little different when doing such tests indoor. However, during a match play soccer players need to perform several directional changes in all weather conditions, mostly unplanned in reaction to the opponent´s behaviour. In this study, players had to react to four visual stimuli in a row with four possible options in every directional change in the reactive agility test. Therefore, the cognitive components of agility were also considered. For the change-of-direction test the structure remained the same, the only difference was that the players knew the running route.

To answer the research question, it was revealed that there are age-related differences in agility performance, change-of-direction speed and linear sprinting speed between the first team and youth players in male amateur soccer. As the findings showed, first team players have better results in all three tests, whether with or without dribbling a ball. According to the results, there is a significant moderate correlation between linear sprinting speed and agility performance without a ball. Therefore, it could be assumed that players who are fast in linear sprinting are also fast in tasks with unplanned directional changes, at least when there is no ball included. Concerning the results with a ball, there is also a significant moderate correlation, but with lower correlation values as it is demonstrated in the chapter above. It could be concluded that those tasks require different physical qualities depending on the inclusion of a ball. A significant strong correlation was found between change-of-direction speed and linear sprinting speed without a ball, which implies that linear sprinting speed and change-of-direction speed are similar skills when there is no ball included. On the other hand, a non-significant low correlation was observed between those skills while dribbling a ball.

To sum up, the findings show that it makes a difference if there is a ball included or not. While dribbling a ball, technical demands are higher and therefore, the activity becomes more difficult. The average total time is longer in the test performances when a ball is included compared to completing the tasks without dribbling a ball as it is presented in the chapter above. Thus, it leads to the conclusion that technical demands indeed affect the performance in linear sprinting speed, change-of-direction and agility performance. Moreover, first team players who have more experience in the game are always faster than the youth players. This might be because of their better developed physical and technical abilities, but also due to their faster decision-making. For practical application, specific agility training in soccer should also involve movement patterns with a ball and not only sprint drills with some directional changes without a ball. Lastly, to give practical application it is necessary for coaches to create sport-specific scenarios that include decision-making tasks. For instance, all types of small-sided games are a suitable form of exercise for practising decision-making under pressure and for enhancing reactive agility performance.

However, future research is necessary and should be done with a focus on agility performance with a ball in order to address the technical demands required in soccer or other team sports.

List of tables, figure and graphics

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Attachments

Tests of normality

Tests of Normality for sprinting

	team	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Sprint with ball [sec]	first team	.159	15	.200*	.952	15	.560
	Youth players	.250	9	.112	.094	9	.604
Sprint without ball [sec]	first team	.175	15	.200*	.875	15	.040
	youth players	.208	9	.200*	.939	9	.576

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality for change – of – direction

	team	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
COD with ball [sec]	first team	..	13	.200*	.949	13	.587
	youth players	.214	9	.200*	.941	9	.595
COD without ball [sec]	first team	.143	13	.200*	.905	13	.156
	youth players	.197	9	.200*	.926	9	442

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality for agility performance								
team		Kolmogorov-Smirnov[a]			Shapiro-Wilk			
		Statistic	df	Sig.	Statistic	df	Sig.
first team	Agility with ball [sec]	.112	15	.200*	.960	15	.689
	Agility without ball [sec]	.298	15	.001	.818	15	.006
youth players	Agility with ball [sec]	.165	8	.200*	.960	8	.807
	Agility without ball [sec]	. 161	8	.200*	.939	8	.602
*. This is a lower bound of the true significance.								
a. Lilliefors Significance Correction								

Multivariate Tests

Multivariate Tests[a]							
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.999	2566286[b]	6.000	12.000	.000	.999
	Wilks' Lambda	.001	2566.286[b]	6.000	12.000	.000	.999
	Hotelling's Trace	1283.143	2566.286[b]	6.000	12.000	.000	.999
	Roy's Largest Root	1283.143	2566.286[b]	6.000	12.000	.000	.999
team	Pillai's Trace	.940	31.552[b]	6.000	12.000	.000	.940
	Wilks' Lambda	.060	31.552[b]	6.000	12.000	.000	.940
	Hotelling's Trace	15.776	31.552[b]	6.000	12.000	.000	.940
	Roy's Largest Root	15.776	31.552[b]	6.000	12.000	.000	.940
a. Design: Intercept + team							
b. Exact statistic							

Tests of Between-Subjects Effects							
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared

Corrected Model	Sprint with ball [sec]	2.217[a]	1	2.217	91.377	.000	.843
	Sprint without ball [sec]	1.038[b]	1	1.038	52.795	.000	.756
	Agility without ball [sec]	13.656[c]	1	13.656	18.895	.000	.526
	Agility with ball [sec]	3.039[d]	1	3.039	1.622	.220	.087
	COD with ball [sec]	2.640[e]	1	2.640	2.778	.114	.140
	COD without ball [sec]	26.839[f]	1	26.839	47.612	.000	.737
Intercept	Sprint with ball [sec]	209.295	1	209.295	8626.990	.000	.998
	Sprint without ball [sec]	182.287	1	182.287	9272.399	.000	.998
	Agility without ball [sec]	1386.848	1	1386.848	1918.906	.000	.991
	Agility with ball [sec]	2598.995	1	2598.995	1386.986	.000	.988
	COD with ball [sec]	1900.256	1	1900.256	1999.275	.000	.992
	COD without ball [sec]	734.025	1	734.025	1302.130	.000	.987
team	Sprint with ball [sec]	2.217	1	2.217	91.377	.000	.843
	Sprint without ball [sec]	1.038	1	1.038	52.795	.000	.756
	Agility without ball [sec]	13.656	1	13.656	18.895	.000	.526
	Agility with ball [sec]	3.039	1	3.039	1.622	.220	.087
	COD with ball [sec]	2.640	1	2.640	2.778	.114	.140
	COD without ball [sec]	26.839	1	26.839	47.612	.000	.737
Error	Sprint with ball [sec]	.412	17	.024			
	Sprint without ball [sec]	.334	17	.020			
	Agility without ball [sec]	12.286	17	.723			
	Agility with ball [sec]	31.855	17	1.874			
	COD with ball [sec]	16.158	17	.950			

	COD without ball [sec]	9.583	17	.564			
Total	Sprint with ball [sec]	215.482	19				
	Sprint without ball [sec]	189.522	19				
	Agility without ball [sec]	1439.174	19				
	Agility with ball [sec]	2777.234	19				
	COD with ball [sec]	2020.586	19				
	COD without ball [sec]	747.689	19				
Corrected Total	Sprint with ball [sec]	2.629	18				
	Sprint without ball [sec]	1.372	18				
	Agility without ball [sec]	25.942	18				
	Agility with ball [sec]	34.895	18				
	COD with ball [sec]	18.798	18				
	COD without ball [sec]	36.423	18				
a. R Squared = .843 (Adjusted R Squared = .34)							
b. R Squared = .756 (Adjusted R Squared = .742)							
c. R Squared = .526 (Adjusted R Squared = .499)							
d. R Squared = .087 (Adjusted R Squared = .033)							
e. R Squared = .140 (Adjusted R Squared = .090)							
f. R Squared = .737 (Adjusted R Squared = .721)							

ANOVA

Table 17Correlation between COD and sprinting with a ball - Anova

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2,476	1	2,476	2,533	,129[b]
	Residual	17,595	18	,977		
	Total	20,071	19			
a. Dependent Variable: COD with ball [sec]						
b. Predictors: (Constant), Sprint with ball [sec]						

Table 18 Correlation between agility and COD without a ball for whole sample - Anova

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12.061	1	12.061	14.622	.001[b]
	Residual	15.673	19	.825		
	Total	27.734	20			
a. Dependent Variable: Agility without ball [sec]						
b. Predictors: (Constant), COD without ball [sec]						

Table 19 Correlation between agility and COD with a ball separated by teams - Anova

ANOVA[a]							
team	Model		Sum of Squares	df	Mean Square	F	Sig.
first	1	Regression	.402	1	.402	.547	.475[b]
		Residual	8.087	11	.735		
		Total	8.490	12			
youth	1	Regression	.549	1	.549	.138	.723[b]
		Residual	23.882	6	3.980		
		Total	24.432	7			
a. Dependent Variable: Agility with ball [sec]							
b. Predictors: (Constant), COD with ball [sec]							

Consent form:

TeilnehmerInneninformation und Einwilligungserklärung zur Teilnahme an der Studie:

(da an der Studie nur männliche Probanden teilnehmen, wird im folgenden Text nicht gegendert)

Altersspezifische Unterschiede bei linearer Schnelligkeit und Richtungswechselgeschwindigkeit/ Gewandtheit zwischen Kampfmannschaftspielern und Nachwuchsspielern im Amateurfußball

Sehr geehrter Teilnehmer,

wir laden Sie ein, an der oben genannten Studie teilzunehmen.

Ihre Teilnahme an dieser Studie erfolgt freiwillig. Sie können jederzeit, ohne Angabe von Gründen, Ihre Bereitschaft zur Teilnahme ablehnen oder auch im Verlauf der Studie zurückziehen. Die Ablehnung der Teilnahme oder ein vorzeitiges Ausscheiden aus dieser Studie hat keine nachteiligen Folgen für Sie.

Diese Art von Studie ist notwendig, um verlässliche neue *wissenschaftliche* Forschungsergebnisse zu gewinnen. Unverzichtbare Voraussetzung für die Durchführung von Studien ist jedoch, dass Sie Ihr Einverständnis zur Teilnahme an dieser Studie schriftlich erklären. Bitte lesen Sie den folgenden Text sorgfältig durch und zögern Sie nicht, Fragen zu stellen.

Bitte unterschreiben Sie die Einwilligungserklärung nur

- wenn Sie Art und Ablauf der Studie vollständig verstanden haben,
- wenn Sie bereit sind, der Teilnahme zuzustimmen und
- wenn Sie sich über Ihre Rechte als Teilnehmer an dieser Studie im Klaren sind.

1. Was ist der Zweck der Studie?

Es wird analysiert, ob es einen altersspezifischen Unterschied in Bezug auf die lineare Schnelligkeit und Richtungswechselgeschwindigkeit/ Gewandtheit im Fußball gibt und inwiefern diese zwei Fähigkeiten zusammenhängen.

Ebenso wird untersucht, ob es Unterschiede in der Leistung mit und ohne Balldribbling gibt.

2. Wie läuft die Studie ab?

Es werden drei Testungen an drei Tagen durchgeführt, wobei die Testungen einen Mindestabstand von einer Woche haben. Vor den Testungen werden anthropometrische Daten (Größe, Gewicht) erhoben, sowie die bevorzugte Spielposition ermittelt. Die erste Testung ist ein 20m Sprint mit Zwischenzeitmessung auf 5m und 10m, um die Beschleunigung berechnen zu können. Es werden insgesamt 2 Läufe mit Ball und 2 Läufe ohne Ball durchgeführt. Beim Lauf mit Ball ist zu beachten, dass mindestens 4 Ballberührungen erfolgen müssen. Die anderen Testungen zielen auf die Gewandtheit (nicht planbare Richtungswechsel), sowie auf die Schnelligkeit bei vorhersehbarem Richtungswechsel ab. Hier werden ebenso 2 Läufe mit Ball und 2 Läufe ohne Ball durchgeführt. Alle Testungen werden innerhalb zufällig gewählter 3er Gruppen durchgeführt, damit die Pausenzeit nicht zu lange ist. Alle Teilnehmer (Kampfmannschaft und Nachwuchs) absolvieren vor allen Testungen ein 20-minütiges Aufwärmprogramm. Pro 3er Gruppe werden bei der Testung ca. 5- 10 Minuten in Anspruch genommen, daher ist der Zeitaufwand der Testung nicht allzu groß.

Die Testung erfolgt am Ausportplatz (Trainingsplatz des Vereins) und immer zur selben Uhrzeit.

Die Teilnehmer sollten 24h vor der Testung auf übermäßige körperliche Anstrengung verzichten und auf eine reichliche Flüssigkeitszufuhr achten.

Für die Testung werden Lichtschranken (Witty, MicroGate, Bolzano, Italy) und Indikatoren mit Lichtimpulsen von Witty SEM (MicroGate) verwendet. Um sich mit dem Testverfahren vertraut zu machen, werden im Zuge des Trainings 2 Testdurchgänge durchgeführt.

Die Studie erfolgt im Rahmen des Masterstudiums Sportwissenschaften an der Universität Wien im Bereich der Trainingswissenschaften unter der Betreuung von Univ.- Prof. Mag. Dr. Harald Tschan.

3. Worin liegt der Nutzen einer Teilnahme an der Studie?

Die Teilnehmer erlangen durch ihre Teilnahme an der Studie interessante Daten in Bezug auf ihre Schnelligkeitsleistung und die Fähigkeit für schnelle vorhersehbare bzw. unvorhersehbare Richtungswechsel. Die Testungen erfolgen im Rahmen des regulären Trainingsbetriebes und die gewonnen Daten können auch in Hinblick auf die Trainingssteuerung dienen. Mit Einverständnis der Athleten, bzw. im Falle der Minderjährigen, mit Einverständnis der Erziehungsberechtigten werden die Daten den Trainern übermittelt. Eventuelle individuelle Stärken und Defizite können ermittelt werden und so dem Trainer in Hinblick auf Trainingssteuerungen- und Planungen hilfreich sein.

Es wird nicht erwartet, dass ein gesundheitlicher Nutzen aus dieser Studie gezogen werden kann, da jeder Test nur einmal durchgeführt wird und kein spezielles Training in einem längeren Zeitraum absolviert wird welcher Trainingsanpassungen erlauben würde.

Für die wissenschaftliche Forschung wird diese Studie möglicherweise wichtige Daten in Bezug auf die Gewandtheit und Richtungswechselgeschwindigkeit in einem sportspezifischen Kontext liefern. Da die meisten Studien diese Tests ohne Ball durchführen, können hier auch neue Erkenntnisse erwartet werden und Vergleiche aufgestellt werden.

4. Gibt es Risiken bei der Durchführung der Studie und ist mit Beschwerden oder anderen Begleiterscheinungen zu rechnen?

Grundsätzlich sind unter korrekten Voraussetzungen (Aufwärmprogramm) keine gesundheitlichen Risiken zu erwarten die über jenen einer üblicherweise durchgeführten Trainingseinheit liegen. Die einzigen Ausschlusskriterien sind akute Infekte oder diverse Sportverletzungen, die eine schmerfreie Trainings- und Wettkampfteilnahme nicht ermöglichen.

Gesundheitliche Vorbelastungen oder der Probleme müssen von den Teilnehmern persönlich mitgeteilt werden, da diese zu einem Ausschluss aus der Studie führen können.

Die Dauer der Belastung beim Sprint wird ungefähr zwischen 2 und 3 Sec. betragen, bei den *anderen Testungen wird die Dauer auf 8-10 Sec. geschätzt. Der Lauf soll so schnell wie möglich erfolgen, daher ist die Belastung kurz aber intensiv. Die Pausenzeiten sind so gewählt, dass man beim 2. Versuch auch noch mit 100% Leistung laufen kann.*

5. Hat die Teilnahme an der Studie sonstige Auswirkungen auf die Lebensführung und welche Verpflichtungen ergeben sich daraus?

Die Teilnahme an der Studie hat keinerlei Auswirkung auf die Lebensführung der Teilnehmer. Es wird lediglich darauf hingewiesen, dass 24h vor der Testung keine größer körperliche Belastung erfolgen darf.

6. Was ist zu tun beim Auftreten von Beschwerdesymptomen, unerwünschten Begleiterscheinungen und/oder Verletzungen?

Falls während oder nach der Testung Beschwerdesymptome, unerwünschte Begleiterscheinungen und/ oder Verletzungen auftreten die direkt mit der Testung zusammenhängen wird gebeten, sich an eine zuständige Kontaktperson zu wenden. (Verweis auf Punkt 10.)

7. Wann wird die Studie vorzeitig beendet?

Die Teilnahme an der Studie kann jederzeit, auch ohne Angabe von Gründen, widerrufen und aus persönlichen Gründen abgebrochen werden ohne, dass daraus Nachteile entstehen.

Ebenso kann die Studienleitung entscheiden, ob die Teilnahme einer Person beendet wird.

Mögliche Gründe hierfür können sein:

a) Der oder die Teilnehmer kann den Erfordernissen der Studie nicht entsprechen;

b) Die Studienleitung hat den Eindruck, dass eine weitere Teilnahme an der Studie nicht im Interesse des bzw. der Teilnehmer ist.

8. In welcher Weise werden, die im Rahmen dieser Studie gesammelten Daten verwendet?

Die Daten werden über das Testsystem (Witty, MicroGate, Bolzano, Italy) erfasst und gesammelt. Anschließend erfolgt die Sicherung der Daten auf einen externen Speicher, damit *die Daten vom Testsystem gelöscht werden können und keine fremde Person Zugriff auf die Daten hat.*

Die Weitergabe der Daten erfolgt ausschließlich zu statistischen Zwecken und die Teilnehmer werden ausnahmslos nicht namentlich genannt. Auch in etwaigen Veröffentlichungen der Daten dieser Studie werden die Namen der Teilnehmer nicht genannt und es können keine Rückschlüsse auf die Teilnehmer gezogen werden.

Z. B.: Ihre Daten werden pseudonymisiert (durch Zuweisung einer ID-Nummer, unter der die Daten gespeichert werden), sodass für all jene, die nicht den „Schlüssel" haben, kein Rückschluss auf Ihre Person möglich ist.

Es wird darauf hingewiesen, dass bei zwei Testungen Videoaufnahmen erfolgen, um einzelnen Zeitabschnitte genauer festlegen zu können. Die Aufnahmen werden nach erfolgter Analyse sofort gelöscht.

Nur das an der Studie mitwirkende Personal hat Zugang zu den Daten hat und ist zudem zur Verschwiegenheit verpflichtet. Falls die Daten mit Einverständnis den Trainern übermittelt werden, sind diese allerdings dazu verpflichtet, diese Daten nicht an Dritte weiterzugeben.

9. Entstehen für die Teilnehmer/Innen Kosten? Gibt es einen Kostenersatz oder eine Vergütung?

Durch Ihre Teilnahme an dieser Studie entstehen für Sie keinerlei Kosten.

10. Möglichkeit zur Diskussion weiterer Fragen

Die Studienleitung steht für etwaige Fragen gerne zur Verfügung.

Etliche Fragen, die die Rechte als Teilnehmer/in an der Studie betreffen, werden selbstverständlich beantwortet.

Namen der Kontaktperson bzw. der Kontaktpersonen:

Leiter/in	Name: E-Mail: Tel.:

11. Einwilligungserklärung

Name der teilnehmenden Person in Druckbuchstaben: ....

Geb. Datum: ....

Ich erkläre mich bereit, an der Studie „Altersspezifische Unterschiede bei linearer Schnelligkeit und Richtungswechselgeschwindigkeit/ Gewandtheit zwischen Kampfmannschaftspielern und Nachwuchsspielern im Amateurfußball“ teilzunehmen.

Ich bin von *Name der Leiterin* ausführlich und verständlich über Zielsetzung, Bedeutung und Tragweite der Studie und die sich für mich daraus ergebenden Anforderungen aufgeklärt worden. Ich habe darüber hinaus den Text dieser Teilnehmerinformation und Einwilligungserklärung gelesen, insbesondere den 4. Abschnitt (Gibt es Risiken, Beschwerden und Begleiterscheinungen?). Aufgetretene Fragen wurden mir von der Studienleitung verständlich und ausreichend beantwortet. Ich hatte genügend Zeit, mich zu entscheiden, ob ich an der Studie teilnehmen möchte. Ich habe zurzeit keine weiteren Fragen mehr.

Ich werde die Hinweise, die für die Durchführung der Studie erforderlich sind, befolgen, behalte mir jedoch das Recht vor, meine freiwillige Mitwirkung jederzeit zu beenden, ohne dass mir daraus Nachteile entstehen. Sollte ich aus der Studie ausscheiden wollen, so kann ich dies jeder Zeit schriftlich oder mündlich bei *Name der Leiterin* veranlassen.

Ich bin zugleich damit einverstanden, dass meine im Rahmen dieser Studie erhobenen Daten aufgezeichnet und ausgewertet werden.

Ich stimme zu, dass meine Daten dauerhaft in pseudoanonymisierter Form elektronisch gespeichert werden. Die Daten werden in einer nur der Projektleitung zugänglichen Form gespeichert, die gemäß aktueller Standards gesichert ist.

Sollte ich zu einem späteren Zeitpunkt, die Löschung meiner Daten wünschen, so kann ich dies schriftlich oder telefonisch ohne Angabe von Gründen bei *Name der Leiterin* veranlassen.

Den Aufklärungsteil habe ich gelesen und verstanden. Ich konnte im Aufklärungsgespräch alle mich interessierenden Fragen stellen. Sie wurden vollständig und verständlich beantwortet.

Eine Kopie dieser Teilnehmerinformation und Einwilligungserklärung habe ich erhalten. Das Original verbleibt bei der Studienleitung.

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Statutory declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

date signature

Eidesstaatliche Erklärung

Ich erkläre, dass ich die vorliegende Arbeit selbstständig verfasst habe und nur die ausgewiesenen Hilfsmittel verwendet habe. Diese Arbeit wurde weder an einer anderen Stelle eingereicht (z. B. für andere Lehrveranstaltungen) noch von anderen Personen (z. B. Arbeiten von anderen Personen aus dem Internet) vorgelegt.

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