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Effects of training at 90 vs. 100 % sprint speed on repeated-sprint ability in high level junior soccer players

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## **Abstract**

**Background:** Repeated sprint ability (RSA) is one of many important determinants for optimal performance in soccer. In the later years, several training studies have examined how to improve this parameter for gaining an optimal performance on the court. No studies have before examined the effect of training at lower intensities. Thus, the aim of this study was to examine if there were any improvements in RSA when training repeated sprint once in a week for seven weeks on different intensities and if the improvements on RSA were the same when training on lower intensity.

**Methods:** 41 well-trained male soccer players of age ( $\pm$ SD) 16.7 ( $\pm$  1.0) years, body mass 71.1 ( $\pm$  9.4) kg, and stature 181.2 ( $\pm$ 6.1) cm participated in the study. They were randomized either to the 100 % intensity group (100 % group) (n=16), the 90 % intensity group (90 % group) (n=15) or the control group (CON) (n=10). In addition to normal training, the 100 % group and the 90 % group completed 1 repeated sprint training session per week for a total of 7 weeks. The 100 % group performed 15 laps (20 meters) on 100 % intensity with one minute breaks between them. The 90 % group performed 30 laps (20 meters) on 90 % intensity with one minute between them. Before and after intervention, performance was assessed by a repeated 20 m \*15 shuttle sprint ability test, where mean and best times were measured. A yo-yo intermittent recovery test (IR1) and counter movement jump (CMJ) test was also conducted.

**Results:** Within-group results showed statistical improvements for 100 % group in steplength (SL), step frequency (SF) and lactate. Between-group differences showed no statistically marked improvements for 100 % group or 90 % group against CON in any of the parameters. The effect of the training was only trivial to small in the performance parameters.

**Conclusion:** Taking the results in this study into consideration, it can't be recommended to train 20 meter repeated sprint for gaining improvements in RSA for young high level soccer players. Other training methods could be preferred for gaining improvements even though genetics probably are most important in terms of sprinting ability. There is a need of more studies were a higher extent of individualization is made.

## Table of context

Abstract .....	3
Index of tables and figures .....	5
1.0 Introduction.....	7
2.0 Theory .....	9
2.1 Repeated sprint ability in soccer .....	9
2.2 Decisive factors for repeated sprint ability .....	10
2.2.1 Initial sprint performance .....	11
2.2.2 Neural muscular factors .....	11
2.2.3 Muscle fiber size.....	13
2.2.4 Elastic strength .....	14
2.2.5 Metabolic pathways .....	14
2.3 How to improve RSA performance in soccer .....	20
2.3.1 Training strategies for optimizing initial sprint performance .....	21
2.3.2 Training strategies to resist fatigue during repeated sprints.....	23
2.4 Physiological testing of soccer players.....	25
3.0 Methods .....	29
3.1 Experimental approach to the problem.....	29
3.2 Subjects .....	29
3.3 Testing procedures.....	31
3.3.1 Familiarization .....	31
3.3.2 Repeated Sprint test (RST) .....	31
3.3.3 The yo-yo intermittent test.....	32
3.4 Training protocol .....	32
3.4.1 Training performance.....	33
3.5 Validity and reliability.....	34
3.6 Statistics .....	35
4.0 Results .....	36
4.1 Difference between rated perceived exertions .....	36
4.2 Changes within and between groups.....	36
4.3 Correlations.....	39
5.0 Discussion.....	41
6.0 Conclusion .....	47
References.....	48
Appendices .....	65

## **Index of tables and figures**

<b>Table 1: Time overview of testing and training.....</b>	<b>29</b>
<b>Table 2: Training characteristics of different groups.....</b>	<b>30</b>
<b>Table 3: Training period for the 90 % group and the 100 % group.....</b>	<b>33</b>
<b>Table 4: Effort related variables in maximal (100 % group) and sub-maximal (90 % group) sprinting.....</b>	<b>36</b>
<b>Table 5: Difference within groups in a variety of physiological measures for the 100 % group.....</b>	<b>37</b>
<b>Table 6: Difference within groups in a variety of physiological measures for the 90 % group.....</b>	<b>37</b>
<b>Table 7: Difference within groups in a variety of physiological measures for the CON % group.....</b>	<b>38</b>
<b>Table 8: Difference between groups in a variety of physiological measures.....</b>	<b>38</b>
<b>Table 9: Correlation values across analyzed parameters.....</b>	<b>39</b>
<b>Figure 1: Decisive factors that may have an effect on repeated sprint ability.....</b>	<b>10</b>
<b>Figure 2: The time course of strength gain showing percental contribution of neural factors and hypertrophy.....</b>	<b>14</b>
<b>Figure 3, 4 and 5: Intensity distribution for the 90 % group.....</b>	<b>33</b>
<b>Figure 6: Individual changes in 15*20 m mean sprint form pre- to post-test.....</b>	<b>39</b>
<b>Figure 7: Change in mean sprint time from week to week (100 % group).....</b>	<b>39</b>

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## 1.0 Introduction

Soccer performance is determined by a variety of skills. Technical and tactical characteristics are considered most important, and Bradley, Lago-Peñas, Rey and Gomez (2013) reported that pass completion, frequency of forward and total passes, balls received and average touches per possession separated players of varying standard. Apparently, aerobic endurance and jumping capabilities should reach an “optimal” baseline (Tønnessen, Hem, Leirstein, Haugen, Seiler 2013, Bradley et al., 2013), while sprinting skills seem even more crucial (Haugen, Tønnessen, Hisdal, Seiler 2013a). There are different forms of sprinting skills in soccer: acceleration, peak velocity, agility and repeated sprint ability. Acceleration and peak velocity are important abilities for winning duels and reaching the ball first (Haugen et al., 2013a). In a team sport like soccer, maximal sprints are performed frequently with short breaks in between (Spencer, Bishop, Dawson and Goodman 2005), so called repeated sprint ability (RSA). If a player can't complete these sprints with a high quality at the end of a game, it may affect the match result (Spencer et al., 2005). Faude, Koch and Meyer (2012) observed that straight sprinting is the most frequent action in goal situations, and sprinting skills should therefore be included in fitness testing and training.

Sprinting abilities are heavily dependent upon genetic factors (Deason et al., 2012), and sprinting skills over short distances seems hard to improve within the constraints of overall soccer conditioning (Haugen et al., 2013a). Even though several studies have reported improved sprinting skills after conducting different interventions, no specific training methods have emerged as superior (Haugen et al., 2013a). Some studies have to some extent reported improvements in maximum sprint and RSA when performing specialized repeated sprint training with maximal intensity (Tønnessen, Shalfawi, Haugen and Enoksen 2011; Shalfawi et al., 2012; Harrison & Bourke, 2009). Unfortunately, maximal sprinting is the most frequent situation associated with hamstring injuries in soccer (Ekstrand, Hägglund, Waldén 2011a), and a large number of players have had their entire season ruined because of such injuries (Arnason, Gudmundsson, Dahl, Jóhannsson 1996). It is reasonable to ask if players should perform repeated sprint training with reduced intensity and higher volume in order to

prevent for hamstring injuries. The combination of reduced intensity and thereby higher volume is common practice in both strength and endurance training (Faude et al., 2013; Schoenfeld et al., 2014, Kraemer, Ratamess, French 2002). Sprinting seems to be regulated by a complex interaction of multiple factors we fully don't understand yet, and there is probably a gap between science and best practice regarding sprint development of soccer players (Haugen et al., 2013a).

The purpose of this study was therefore to compare the effects of training at 90 and 100 % sprint speed on repeated-sprint ability in high level junior soccer players. The secondary aim was to compare the effects of this intervention on maximal sprint ability, countermovement jump (CMJ) and Yo-Yo Intermittent Recovery test Level 1 (Yo-Yo IR1). To the author's knowledge, a systematic comparison of these training regimes has so far not been conducted.



## 2.0 Theory

### 2.1 Repeated sprint ability in soccer

In elite soccer, the distance covered is about 10-12 km for field players (Stølen, Chamari, Castagna and Wisløff 2005). Of this distance, sprinting constitutes of 1-11 % (Wisløff, Castagna, Helgerud, Jones, Hoff 2004) The frequent bouts of dribbling, running, tackling, and jumping all put great demands on the energy delivery systems (Mohr, Krustup, Bangsbo 2005). The amounts of high-intensity running decrease markedly during matches, and this decrease is related to training status (Mohr, Krustup, Bangsbo 2003; Krustup et al., 2003; Krustup, Mohr, Ellingsgaard, Bangsbo 2005). Average sprint distance during a soccer game is about 15 m (Vescovi, 2012) and more than 90 % of all sprints in matches are shorter than 20 m. (Vigne, Gaudino, Rogowski, Alloatti and Hautier 2010). Di Salvo et al., (2010) reported that 76-78 % of all sprints are leading (gradual acceleration). Acceleration from low or zero speed (explosive) and sprints from already high speed (leading) are important physical abilities for a player.

Spencer et al., (2004) reported that goals are often scored during periods with repeated sprints, which underline the importance of maintaining a very high intensity in critical periods during a match. Wings and strikers perform more sprints than the center-backs and central midfielders (Reilly, Bangsbo and Franks 2000; Stølen et al., 2005). Regardless of the position, the importance of RSA is crucial in elite soccer.

The aim of the present theory is to summarize the research that has been undertaken so far regarding physiological determinants of RSA. Knowledge of these determinants and how to train them are important to improve overall performance. There will also be discussed how to measure performance on court.

It is necessary to define two different types of exercise in soccer: intermittent-sprint and the repeated sprint ability (RSA) (Girard, Mendez-Villanueva and Bishop 2011). Intermittent-sprint exercise or single maximum sprints can be characterized by short-duration sprints (<10 seconds), and with recovery periods long enough (60–300 seconds) to have a complete recovery of sprint performance (Balsom, Seger, Sjödin, Ekblom 1992; Duffield, King, Skein 2009). RSA on the other side, is characterized by

short-duration sprints (<10 seconds) interspersed with brief recovery periods (usually <60 seconds) (Bradley et al., 2009). Intermittent-sprint exercise is associated with little or no performance decrement. In contrast, RSA is associated with marked performance decrement (Bishop, Edge, Davis, and Goodman 2004). However, when performing other activities with near maximal effort during a game, the ability to complete single maximum sprints is reduced at the end (Krustrup et al. 2006). The player's ability to run with a high velocity when she or he is tired is therefore very important for making successful actions at the end of a match.

## 2.2 Decisive factors for repeated sprint ability

Repeated sprint performance in soccer is determined by a myriad of factors and it challenges the coaches to train these to enhance the performance in athletes. Bishop, Girard & Mendez-Villanueva (2011) developed a model that shows the factors which may be decisive for RSA (figure 1).

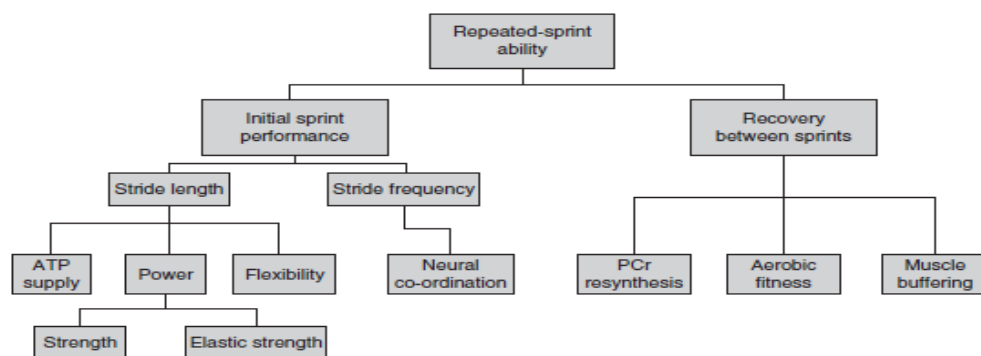


Figure 1: Decisive factors that may have an effect on repeated sprint ability.<sup>1</sup>

Tests that are performed both before and after soccer matches show that the ability to make repeated sprints with maximal or near maximal intensity have a significant decrease simultaneously with a higher fatigue (Mohr, Krustrup, Nybo, Nielsen & Bangsbo 2004; Krustrup et al., 2006). As shown in figure 1, this fatigue can occur as a result of muscular factors where there is a decrease in muscle excitability, limited energy supply (phosphocreatine, anaerobic glycolysis and oxidative metabolism) or by neural factors such as reduced motor drive or changes in the muscle recruitment hierarchy. However, other factors may also inhibit the RSA. The most important ones

<sup>1</sup> From "Repeated-sprint ability - part II: recommendations for training" by Bishop D, Girard O, Mendez-Villanueva A 2011, Sports Med. 2011 Sep 1. Reprinted with permission.

that may be decisive for the RSA and the ability to perform these sprints with high quality will be discussed further.

### **2.2.1 Initial sprint performance**

Sprint velocity is the product of stride length (SL) and stride frequency (SF). For elite athletes, SF is considered as the main limiting performance factor. Among athletes of lower sprint standard, SL is considered as the most limiting factor (Armstrong, Costill and Gehlsen 1984 Mero and Komi 1986; Mero, Komi and Gregor 1992). Furthermore, sprinting ability is determined by acceleration, maximal velocity and the ability to maintain velocity against the onset of fatigue (Ross, Leveritt, and Riek 2001a). High intensity efforts are critical to the outcome of matches as they relate to activities that are keys to the final match results (Mohr, Krustup, Bangsbo 2003; Faude, Koch and Meyer 2012). In this context it means the players movements to win the ball and the ability to go past defending players (Stølen et al., 2005). A soccer player's acceleration ability is very important in match context, and training of this ability is recommended (Vigne et al., 2010). Power development and technique are the two major components for gaining the highest maximum speed as possible, but it is important to note that speed seems to be a genetic skill and resistant to training (Ross et al., 2001a). However, in soccer players with little or no sprint training experience, specialized training on running speed may result in significant improvements (Tønnessen et al., 2011). Muscle fiber type is essential for sprint ability. There are 3 types of fibers: I (slow twitch), IIa (fast-twitch oxidative-glycolytic) and IIb (fast-twitch glycolytic). Sprinters have a larger percentage of type II fibers than other athletes with thoughts of performance on their respective field (Costill et al., 1976). It is important for a soccer player to resist fatigue during repeated sprint exercise and sprint training resulting in a transition towards IIa (I → IIa ← IIb) may be preferred (Haugen 2012; Ross & Leveritt 2001).

### **2.2.2 Neural muscular factors**

Sprinting needs a high level of neural activation and coordination. Thus the ability to voluntarily fully activate the working musculature and maintaining muscle recruitment and rapid firing over several sprint repetitions could be decisive for RSA (Ross, Leveritt and Riek 2001). A higher activation and better synchronizing of nerve signals are

considered as important (Ross Leveritt, Riek, 2001a). There is a neurally-mediated mechanism who may affect the fatigue resistance and therefore the RSA (Ross et al., 2001a; Bishop et al., 2011; Mendez-Villanueva, Hamer, Bishop 2007; Mendez-Villanueva et al., 2008). This means that in situations with high fatigue development (sprint decrement score and fatigue index < 25 %), the failure to fully activate the contracting musculature may be an important limiting factor when performing repeated sprints (Bishop et al., 2011). Furthermore, the ability to fully activate fast twitch motor units with maximal firing frequency in task specific movements in soccer may be a limiting factor, especially among untrained athletes (Gabriel, Kamen, Frost 2006; Ross et al., 2001a). A well-trained soccer player can be considered as untrained in terms of sprint training (Haugen et al., 2013a). It is not possible from available studies to conclude whether reported improvements are due to neural or muscular factors. Other factors such as disruption of optimal temporal sequencing of agonist and antagonist muscle activation (muscle coordination patterns), motoneuron excitability and reflex adaptation (how readily the motoneuron pool is activated to a given input) and nerve conduction velocity (a higher nerve conduction velocity can reduce muscle contraction time and improve sprint performance) may limit the RSA (Ross et al., 2001a; Bishop et al., 2011)

When performing sprint training, it may be possible to obtain an improved activation and timing of agonist and antagonist muscles as a result of selective recruitment of muscle fibers and muscle groups that can contribute to optimal performance (Ross et al., 2001a). This can be an improved technical performance of sprint movements and are related to the nervous system and its control of muscles. Another neural adaptation is the muscle's ability to reach maximal activation more quickly in the entire muscle mass, which is determined by the high-threshold devices firing rate.

Studies have shown that both eccentric strength and plyometric training can improve the degree of activation and thereby give a higher athletic performance (Gabriel et al. 2006; Mikkola, Rusko, Nummela, Pollari, Häkkinen 2007; Murray et al., 2007). It is reasonable to assume similar adaptations for repeated sprint training. Repeated sprint exercise seems to induce neural muscle adaptations, especially in the early stages of a

sprinting conditioning program (Gabriel et al., 2006). However, there is a need for more specific studies to examine whether the improvements are caused by neural or metabolic adaptations.

### **2.2.3 Muscle fiber size**

Increase in available force of muscular contraction in relevant muscles or muscle groups may improve abilities such as acceleration and running speed in soccer (Cometti et al., 2001). To improve acceleration performance, rapid muscle contractions must be performed with great force. Furthermore, to improve the ability to reach a higher maximum speed, an athlete must be able to develop greater power based on a high contraction speed in the muscles (Raastad, Paulsen, Refsnes, Rønnestad & Wisner, 2010). To increase muscle ability to develop great power, a soccer player should increase the cross-sectional area or recruitment of type II fibers (Raastad et al., 2010; Ross & Levitt, 2001; Ross et al., 2001a). Sprint training intervention over 6-7 weeks has shown no increase in muscle fiber size, even though performance improvements have been reported (Linossier, Dormois, Geysant, Denis 1993; Allemeier et al., 1994). Longer interventions have reported significant increases in both type I and type II muscle fiber area. This indicates that short-term performance improvements are due to neural factors, while long term effects are due to muscular adaptations (Cadefau et al. 1990; Sleivert et al., 1995). Moritani and deVries (1979) also confirms this (figure 2). World class sprinters have well-developed hip extensor muscles and it could be discussed whether this is a result of specific repeated sprint training, resistance / strength training, or both (Haugen 2012).

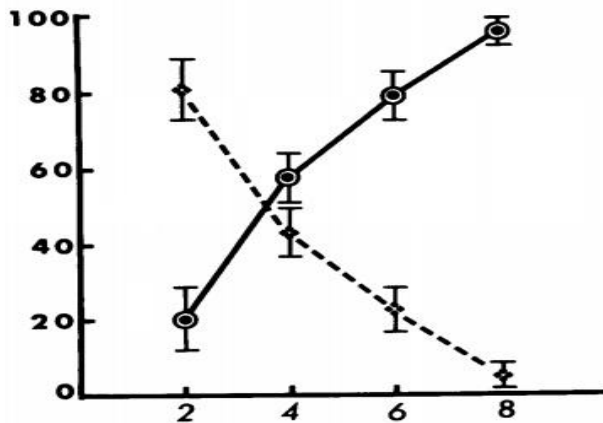


Figure 2: The time course of strength gain showing percental contribution of neural factors (squares and broken lines) and hypertrophy (circle dots and solid lines) over 8 weeks. <sup>2</sup>

#### 2.2.4 Elastic strength

Another factor that may be important when performing maximum sprints (and repeated maximum sprints) is the storage and release of elastic energy (Roberts & Azizi 2011). Constant braking and subsequent new acceleration causes the muscles to go through rapid transitions between eccentric and concentric contraction. This means that there is a stretch/shortening-cycle in active muscles (Enoka 1996). When muscles are stretched during the eccentric contraction energy will be absorbed. Optimal utilization of stored energy leads to a higher power output (Enoka 1996). During various phases of the sprint running stride (cycle), storing of elastic energy can be a factor for a more efficient technical execution of movements, and exploit a potentially major force in the push against the surface (Enoka 1996).

#### 2.2.5 Metabolic pathways

Because the majority of the game is within low to moderate intensity, it is mainly covered by the aerobic energy system (Bangsbo, 1994). The recovery between high-intensity periods is also reliant on the aerobic metabolism, and the aerobic energy system is an important performance factor in soccer where it accounts for more than 90 % of the total energy consumption (Bangsbo 1994; Billaut, Bishop 2009). Glycogen in the working muscle seems to be the most important substrate for energy production during a soccer match, but also muscle triglycerides, blood free fatty acids and glucose

<sup>2</sup> From “Neural factors versus hypertrophy in the time course of muscle strength gain” by Moritani T, deVries HA 1979, Am J Phys Med. Jun 1979. Reprinted with permission.

are used as substrates for oxidative metabolism in the muscles (Bangsbo, 1994). Even though the aerobic system stands for most of the energy consumption, it is important to note that anaerobic energy production plays an essential role during soccer matches. It is shown that phosphocreatine (PCr), and to a lesser extent the stored adenosine triphosphate, is utilized during the most intensive exercise periods of a game (Bangsbo, 1994). Maximum workout under 10s primarily uses the anaerobic processes (ATP, PCr and glycolysis) as energy substrate in the muscles (Gastin, 2001; Ross & Living Ritt, 2001).

#### ***2.2.5.1 Phosphocreatine stores***

Because of the brief recovery time between repeated sprints, the phosphocreatine stores will only be partly restored (Dawson et al., 1997; Bogdanis, Nevill, Boobis, Lakomy 1996). The ability to resynthesize these stores may be an important determinant of the ability to reproduce high sprint performance (Bogdanis, Nevill, Boobis, Lakomy 1996; Bogdanis, Nevil, Boobis, Lakomy, Nevill 1995). Phosphocreatine stores can be reduced to 35–55 % of resting levels and the complete resynthesis of the stores can require more than 5 minutes after a maximal 6-second sprint (Girard, Mendez-Villanueva, Bishop 2011; Gaitanos, Williams, Boobis, Brooks 1993; Dawson et al., 1997; Bogdanis, Nevill, Boobis, Lakomy, Nevill 1995; Tomlin, Wenger 2001). Bogdanis et al., (1996) and Bogdanis et al., (1995) found a strong relationship between phosphocreatine resynthesis and the recovery of performance during both repeated, 30 second and all-out exercise bouts. An unpublished study from Mendez-Villanueva et al., (2011) revealed a high correlation between phosphocreatine resynthesis and the recovery of performance during repeated 6 s sprints. RSA may be improved by training interventions that increase the rate of phosphocreatine resynthesis (Bishop et al., 2011).

The oxidative metabolism pathway is important for phosphocreatine resynthesis (Bishop et al., 2011; Haseler, Hogan, Richardson 1999). Individuals with a higher aerobic fitness (high  $\text{VO}_2 \text{max}$  or lactate threshold) have the ability to resynthesize phosphocreatine more rapidly between repeated sprints than persons with lower aerobic fitness (Bishop et al., 2011). To gain a better phosphocreatine resynthesis, several studies have shown that endurance training may enhance this parameter through low-

intensity exercise (Bogdanis et al. 1996; Yoshida, Watari 1993(a); McCully, Boden, Tuchler, Fountain, Chance 1989; McCully, Vandenborne, DeMeirleir, Posner, Leigh 1992; Yoshida, Watari H 1993(b); McCully, Kakihira, Vandenborne, Kent-Braun 1991). Interval training may also have an effect on the phosphocreatine resynthesis. Bishop, Edge, Thomas and Mercier (2008) found improvements during the first 60 seconds after high intensity training on 6 active female sport science students. Other studies did not report a change in phosphocreatine resynthesis (Mohr, Krstrup, Nielsen, Nybo, Rasmussen, Juel, Bangsbo 2007; Stathis, Febbraio, Carey, Snow 1994). In Mohr et al., (1994), the participants performed intervals (8\*30 seconds) at 130 % of  $\text{VO}_{2 \text{ max}}$  with 90 seconds rest and intermittent sprint training (15\*6 seconds sprint) with 1 minute rest. In Stathis et al., (1994) the subjects trained 4-7 intervals\* 30 seconds all out with 3-4 minutes rest. These results could be explained by the absence of any change in  $\text{VO}_{2 \text{ max}}$  performing this type of training or that these studies measured the phosphocreatine resynthesis 3-minutes post-exercise where the resynthesis is nearly completed and less influenced by the training amount (Bishop et al., 2011). To summarize, optimal training intensity has not yet been established, but it seems that improvements in aerobic fitness are needed to enhance the phosphocreatine resynthesis (Bishop et al., 2011). Repeated sprint training may improve aerobic fitness (Ferrari et al., 2008). However, more studies is needed to determine whether this type of training also increase the fast component (first 60 seconds) of the phosphocreatine resynthesis. It is also a question whether this type of training is better than performing interval training (Bishop et al., 2008).

#### ***2.2.5.2 Muscle glycogen levels***

Less high intensity running at the end of games may be explained by lower glycogen levels in individual muscle fibers. Muscle glycogen is probably the most important substrate for energy production and an important substrate for a soccer player (Bangsbo, Mohr and Krstrup 2006). The fatigue towards the end of a soccer game may be related to depletion of glycogen in the fibers (Bangsbo et al. 2006). There has also been seen an increase of blood free-fatty acids (FFAs) during a game, probably trying to compensate for the progressive lowering of muscle glycogen (Bangsbo et al., 2006).



Saltin (1973) discovered that muscle glycogen stores were almost empty at half-time when the pre-match values were low ( $\sim 200 \text{ mmol} \cdot \text{kg dry weight}^{-1}$ ). Some players started the game with normal muscle glycogen concentrations ( $\sim 400 \text{ mmol} \cdot \text{kg dry weight}^{-1}$ ), with values still being rather high at half-time, but under  $50 \text{ mmol kg dry weight}^{-1}$  at the end of the game. However, concentrations of  $\sim 200 \text{ mmol kg dry weight}^{-1}$  have been reported after a game, indicating that muscle glycogen stores are not always emptied in a soccer match (Jacobs, Westlin, Karlsson, Rasmusson & Houghton 1982; Krstrup et al. 2006; Smaros 1980). A significant number of muscle fibers were empty or partly empty at the end of a match, indicating that this could influence maximal performance (Krstrup et al., 2006). Balsom, Wood, Olsson and Ekblom (1999) reported that the carbohydrate content of the diet influenced the amount of high intensity exercise performed during a small-sided soccer game. They suggested that a high carbohydrate diet should be administered in preparation of intense training and competition to optimize performance.

#### *2.2.5.3 Anaerobic glycolysis*

During a single sprint, there is a large drop in the intramuscular phosphocreatine combined with an increased inorganic phosphate ( $P_i$ ) and adenosine monophosphate that stimulate the fast activation of anaerobic glycolysis (Crowther, Carey, Kemper and Conley 2002). This anaerobic glycolysis is an important source for adenosine triphosphate resynthesis (ATP) during a single sprint (Bishop et al., 2011; Gaitanos, Williams, Boobis, Brooks 1993). However, when more sprints are performed short recoveries, there is a large drop in the ATP production. Gaitanos et al., (1993) reported that when performing several laps after each another, glycolysis accounted for 44 % of total anaerobic ATP provision during the first sprint, but in the tenth sprint, it only stood for 16 % of it. This reduced glycogen level in the muscle when performing repeated sprints is probably caused by an accumulation of acidosis (Bogdanis, Nevill, Boobis, Lakomy, Nevill 1995; Sahlin, Ren 1989). The question is whether an increase of the maximal anaerobic glycolytic system and the glycolytic rate will cause improvements of RSA. If a person increases the ability to supply ATP from the anaerobic glycolysis through training, this may have a negative effect on RSA. The reason for this is the negative correlation between anaerobic ATP production during the

first sprint and sprint decrement during a repeated sprint test (Bishop et al., 2011; Gaitanos et al 1993; Mendez-Villanueva, Hamer, Bishop 2008). However, athletes with a higher glycogenolytic rate have a greater initial sprint performance (Gaitanos et al., 1993). There is a good positive correlation between initial sprint performance and final sprint performance/total sprint performance during RSA tests (Bishop, Lawrence, Spencer 2003; Pyne, Saunders, Montgomery, Hewitt, Sheehan 2008). Bishop and Schneiker (2007) point out difficulties with interpreting contrasting effects of the various RSA test indices, but increasing the anaerobic contribution may improve both initial and mean sprint performance. In the end, this may improve the ability to perform repeated sprints (Bishop et al., 2011). Some studies found an increase in glycolytic enzymes after sprint training but no increase in sprint performance Jacobs, Esbjörnsson, Sylvén, Holm, Jansson 1987; Parra, Cadefau, Rodas, Amigó, Cussó 2000). More training studies need to be conducted for gaining more information about the relationship between improvements in anaerobic ATP production and RSA (Bishop et al., 2011; Parra et al., 2000).

#### **2.2.5.4 H<sup>+</sup> accumulation**

During sprint with short recovery type, the increase of H<sup>+</sup> accumulation in muscle and blood may impair performance (Bishop et al., 2003; Bishop et al., 2006; Edge et al., 2006; Spencer, Dawson, Goodman, Dascombe, Bishop 2008; Ratel, Williams, Oliver, Armstrong 2006; Spriet, Lindinger, McKelvie, Heigenhauser, Jones 1989). Significant correlations between sprint decrement, muscle buffer capacity (B<sub>m</sub>) and changes in muscle and blood pH have been reported. Thus, an increased removal of H<sup>+</sup> from the muscle would probably improve repeated sprint ability (Mohr et al 2007; Bishop, Spencer 2004; Bishop, Edge, Goodman 2004; Bishop, Edge, Davis, Goodman 2004; Bishop et al. 2006). Removal of H<sup>+</sup> from the muscle under intense skeletal contractions like repeated sprints seems to be done through intracellular buffering (B<sub>m</sub> in vitro) and by different membrane transport systems like the monocarboxylate transporters (MCTs). These transporters are probably the most important ones and are the dominant regulator of muscle pH during and after high intensity exercise (Juel 1998; Bishop et al., 2011). By improving the muscle pH regulating systems and thereby improve the RSA, it seems that high-intensity interval training (80-90 % VO<sub>2 max</sub>) with shorter rest periods

than the work periods probably is the best stimuli. In this type of training the muscles are required to contract with a reduced pH (Bishop et al., 2011; Edge et al., 2006a; Edge, Bishop, Goodman 2006b). To gain improvements in important transporters like the MCTs, intermittent-sprint training and interval training have the same positive effect for increasing MCT1 content, and both training methods could be recommended (Bishop et al., 2011; Mohr et al., 2006).

#### **2.2.5.5 Aerobic metabolism**

The contribution of oxidative phosphorylation to total energy expenditure during a single short sprint is as small as 10 % (Girard et al., 2011, McGawley, Bishop 2008; Parolin, Chesley, Matsos et al., 1999). However, when sprints are repeated, the level of aerobic ATP provision progressively increases so that the aerobic metabolism may contribute up to 40 % of the total energy supply during the final repetitions of repeated sprint exercise (Girard et al., 2011, McGawley et al., 2008)

Physiological adaptations such as increased mitochondrial respiratory capacity, faster oxygen uptake kinetics, accelerated post sprint muscle re-oxygenation rate, higher lactate threshold, and higher  $VO_{2\text{ max}}$  may increase the reliance of aerobic metabolism. This could improve the ability to resynthesize ATP and thereby resist fatigue during repeated sprints (Thomas, Sirvent, Perrey, Raynaud, Mercier 2004; Dupont, Millet, Guinhouya, Berthoin 2005; Rampinini Sassi, Morelli, Mazzoni, Fanchini, Coutts 2009; Buchheit, Ufland 2011; Bishop, Edge, Goodman 2004; Bishop, Edge 2006; McMahan, Wenger 1998; Tomlin, Wenger 2002; Bishop et al., 2011).  $VO_{2\text{ max}}$  is moderately correlated ( $0,62 < r < 0,68$ ;  $p < 0,05$ ) with RSA, both in terms of mean sprint performance and sprint decrement (Rampinini et al., 2009; Bishop, Edge, Goodman 2004; Bishop, Spencer 2004; McMahan et al., 1998). Individuals with higher  $VO_{2\text{ max}}$  have a better ability to resist fatigue during repeated sprint exercise, especially in the last sprints when the subjects reach their  $VO_{2\text{ max}}$  (McGawley, Bishop 2008; Thébault, Léger, Passelergue 2011; Bishop et al., 2011). Thus a player may improve RSA by enhancing  $VO_{2\text{ max}}$  capacity, and thereby contribution during repeated sprints (Bishop et al., 2011). However, other studies have not observed a linear relationship between  $VO_{2\text{ max}}$  and various repeated-sprint fatigue indices (Bishop et al., 2003; Hoffman 1997). The

question is whether  $\text{VO}_{2 \text{ max}}$  should be maximized or optimized in team sports like soccer (Bishop et al., 2011).

Lactate threshold, running economy and oxygen kinetics are relatively independent of  $\text{VO}_{2 \text{ max}}$  but should be taken into consideration when assessing a player's aerobic fitness. Intervals training may be effective since this type of training improve the rate of phosphocreatine resynthesis and the muscle buffer capacity (Bishop et al., 2008; Edge et al., 2006). According to the above mentioned research, an individual soccer player should train high intensity interval training at 80-90 % of  $\text{VO}_{2 \text{ max}}$  with rest periods that are shorter than the work periods for increasing the aerobic fitness in team-sports like soccer (Bishop et al., 2011).

### **2.3 How to improve RSA performance in soccer**

As shown in the previous sections, many factors determine RSA. According to Bishop et al., (2011), determination of this ability can be divided into two main parts: initial sprint performance and the ability to resist fatigue (figure 1). It then raises the question which one of these contradicting abilities that should be prioritized. If an individual wants to improve his initial sprint performance, large proportion of type II fibers is desirable. If he or she wants to improve the ability to resist fatigue, large proportion of type I fibers is required. There are also differences in metabolic pathways and energy supply. During an initial sprint the relative energy system contribution from ATP is 6-10 %, PCr 46-55 % and anaerobic glycolysis 32-45 % (Spencer et al., 2005; Girard et al., 2005). When sprints are repeated, the relative contribution from aerobic processes increases while PCr depletion decreases. Game analyses and cross-sectional studies have shown that both single sprint performance and the ability to resist fatigue are important in soccer (Faude et al., 2012; Haugen et al., 2013a). The question is what to prioritize for gaining best possible performance. Haugen et al., (2013a) emphasize the principle of individualization, meaning that training strategy must be based upon each player's baseline. Thus, slow players with well-developed aerobic capacity should strive to improve their maximum sprint performance. Conversely, fast players that can't hold out for long should improve their endurance capacity. Adaptation towards high percentage of IIa muscle is perhaps optimal for soccer players as such fibers are fast and

also have a certain degree of stamina. There are several ways to improve initial sprint performance and the ability to resist fatigue during repeated sprints. This will be discussed further in the following sections.

### **2.3.1 Training strategies for optimizing initial sprint performance**

Repeated sprint ability, measured as mean time or total sprint time, is highly correlated with single sprint performance (Pyne et al., 2008). Ross & Levitt (2001) pointed out the uncertainty regarding what kind of exercise is best for the development of sprint ability, but rest and recovery are probably underestimated in this context. Specific speed training is one obvious strategy for gaining better sprint performance in soccer and other team sports (Haugen, Tønnessen, Hisdal & Seiler 2013). Previous studies have shown that sprinting distance  $\leq 30$  m improves short sprint performance (Spinks, Murphy, Spinks, Lockie 2007), while  $\sim 40$  m sprints develop maximal sprint velocity (Tønnessen, Shalfawi, Haugen, Enoksen 2011). Longer sprints ( $\geq 30$  s) have limited or no effects on acceleration and peak velocity (Gunnarson, Christensen; Holse, Christiansen & Bangsbo 2012). All these studies confirm the principle of specificity. Since sprints occur continuously during games, it has been suggested to implement blocks of sprints during practice to develop fatigue resistance (Abt, Siegler, Akubat & Castagna, 2011). Intensity and fatigue depends on sprinting distance, recovery duration and number of sprints. In addition, the activities carried out during the breaks may affect recovery between sprints (Buchheit, Cormier, Abbiss, Ahmaidi, Nosaka & Laursen, 2009).

Harrison and Bourke (2009) reported a significant improvement in rugby players' running speed after resisted sprint training. Thus, it might be beneficial to train repeated sprint training with resistance, aiming to increase initial acceleration from a standing start. However, sprint training with resistance may have a negative effect on the movement pattern, and it is not recommended to exaggerate this type of training (Lockie, Murphy, Spinks 2003).

It is shown that strength training improves running speed in young soccer players (Chelly et al., 2009; Buchheit, Mendez-Villanueva, Delhomel, Brughelli, Ahmaidi 2010; Delecluse et al., 1995; Delecluse 1997 and Newman, Tarpinning and Marino

2004). Chelly et al., (2009) observed improvements in jumping, dynamic strength and sprinting (40 m) after 8 weeks of half squat training with heavy loads 2 sessions per week. Bogdanis et al., (2011) observed improved RSA in professional soccer players after training half-squats 3 times per week for 6 weeks when performing 4 x 5 repetitions at 90% of 1RM. Another group in the study performed 4 x 12 repetitions at 70% of 1RM and did not improve as much as the first group. However, this study did not have a control group and performed the repeated sprint test on cycle ergometer. Thus, the results should be interpreted with caution.

Newman, Tarpinning & Marino (2004) found a strong relationship between maximal strength and single-sprint performance in team-sport athletes ( $r = 0.71$ ). Wisløff et al., 2004 reported high correlation between 1 RM squat and short sprint performance, indicating that strength training is beneficial for sprint performance. However, it has been shown that strength training alone not always improves sprint performance. Kotzamanidis et al., (2005) found that combined strength and speed training resulted in a higher 30 m sprint performance compared to strength training alone. Edge et al., (2006) reported that their resistance training program (3-5 sets x 15-20 repetitions, 20 s recovery between series) improved both first-sprint performance (8–9%) and sprint decrement score in moderately trained objects. This study included a control group, but the repeated sprint test was performed on a cycle ergometer. Heavy resistance training has in some cases shown to increase the initial but not the later performance during repeated sprints (Costill, Coyle, Fink, Lesmes, Witzmann 1979). Although these results indicate that heavy resistance training may improve initial sprint, it may not improve overall repeated-sprint performance (Edge et al., 2006).

Strength training with heavy weights does not always improve sprinting capabilities (Loturco, Ugrinowitsch, Tricoli, Pivetti, Roschel 2013; Jullien et al. 2008; López-Segovia, Palao Andrés, González-Badillo 2010). It is also important to note that not all training programs consisting of exercises with maximum mobilization and light weights lead to enhanced acceleration performance. This may be due to a lack of specificity of the exercises (Raastad et al. 2010). Sedano et al. (2011) stated that improved explosive

strength can be transferred to acceleration capacity, but an athlete needs time in order to transfer these improvements.

Mujika, Santisteban and Castagna (2009) reported that contrast training (combination of strength, power and sport specific drills) once a week for seven weeks in season provided positive effects on soccer-specific sprint performance (15 m sprint).

Performing such training twice a week did not provide better results than one weekly session (Maio Alves, Rebelo, Abrantes, Sampaio 2010). Even though strength training may have positive effects on sprint performance, specific sprint training seems to be most efficient in a short-term perspective (Kristensen, van den Tillaar, Ettema 2006).

Repeated sprint training regimes performed with maximal intensity have shown positive performance effects in soccer players when training once a week (Tønnesen et al. 2011; Shalfawi, Tønnesen, Haugen, Enoksen 2013). In this study, the authors observed improvements in RSA and 20–40 m speed, but not for 0–20 m acceleration. However, in a study by Shalfawi et al., (2013) using identical indices, but training twice times a week, interesting results were observed. By using conventional statistics (p-values), there were no significant differences between the groups in 0–20 m sprint time and CMJ. However, when calculating effect size by the scale developed by Batterham and Hopkins (2006), the effect of repeated sprint training on the training group was moderate and close to large in 0–20 m sprint time (1,1) and CMJ (1,1). This shows that repeated sprint training with maximal intensity may give a positive effect on initial sprint performance. No studies have so far examined the effects of initial sprint performance when training repeated sprints with reduced intensities.

### **2.3.2 Training strategies to resist fatigue during repeated sprints**

Several training methods are suggested in research literature to reduce sprint decrement score/fatigue index during repeated sprints. Repeated sprint training with short breaks and low-intensive activity during the recovery periods may lead to metabolic changes that can delay fatigue in the muscles and possibly give a higher performance (Spencer, Dawson, Goodman, Dascombe, Bishop 2008; Signorile et al., 1993). However, it has been debated whether aerobic interval training is better than repeated sprint training. Only a few studies have compared these two different training methods. Some studies

have reported that a combination of high-intensive interval training and heavy strength training improves sprint performance in soccer players (Wong et al., 2010; Helgerud et al., 2011). However, the interventions in these studies were extensive and time consuming, include at least four weekly training sessions. Other authors recommend high-intensive aerobic interval training (80-90% of  $VO_{2\text{ max}}$ ) combined with repeated sprints to improve RSA (Dupont et al., 2004; Spencer et al., 2005; Bishop et al., 2011). Ferrari et al., (2008) observed that repeated sprint training provided better outcomes than high-intensive interval training in terms of aerobic and soccer specific training adaptations. Tønnessen et al., (2011) demonstrated that male soccer players were able to perform repeated sprints with intensity closer to maximum capacity after repeated sprint conditioning once a week, without additional high-intensive intervals.

Several studies have reported enhanced  $VO_{2\text{ max}}$  (5-6 %) after 5-12 weeks of repeated sprint training (Dawson et al. 1998; Ferrari Bravo et al. 2008; Schneiker, Bishop 2008). Schneiker et al., (2008) and Ferrari Bravo et al., (2008) observed similar increase in  $VO_{2\text{ max}}$  for both the repeated sprint training group and the interval training group. Other studies have reported > 10 % increase in  $VO_{2\text{ max}}$  as a result of interval training (Edge, Bishop, Goodman, Dawson 2005; Helgerud, Engen, Wisloff, Hoff 2001). More studies needs to be conducted in order to compare repeated sprint training with interval training to find out which type of training is the best for improving the  $VO_{2\text{ max}}$  in team-sport athletes (Bishop et al., 2011). It is still unclear whether repeated sprint training improves physiological factors like the ion-regulation and PCr resynthesis. However, when comparing improvements in terms of mean sprint time or best sprint time, it seems that repeated sprint training is superior to interval training (Ferrari et al., 2008; Mohr et al., 2007; Schneiker et al., 2008; Buchheit et al., 2010). Interval training seems to have a greater effect on fatigue resistance in terms of sprint decrement score/fatigue index (Mohr et al., 2007; Schneiker et al., 2008). A combination of these two types of training may give the best effect on repeated sprint ability.

It has also been discussed whether small-sided games have positive effect on RSA. Studies by Buchheit et al., (2009) and Hill-Haas et al., (2009) revealed no significant



differences in RSA when small-sided game conditioning was compared with generic training (Buchheit et al., 2009; Hill-Haas, Coutts, Rowsell, Dawson 2009). Bishop et al., (2011) claim that small-sided games have a positive effect on H<sup>+</sup> regulation and PCr resynthesis. It has also been shown that such training improves VO<sub>2 max</sub> and technical skills (Impellizzeri et al., 2006; Gabbett 2006).

In summary, several factors determine RSA, and it is difficult to recommend one type of training for improving this ability in team-sports. It is important that the demands of the sport and each athlete's capacity have to be taken into account when creating a training program. Combinations of different training methods may be required in many cases. Firstly, it is important to include training for improving single-sprint performance. This includes specific sprint training, strength/ power training and contrast training to increase the anaerobic capacity. It is also important to include some aerobic interval training to improve the ability to recover between sprints. High-intensity (80–90% VO<sub>2 max</sub>) interval training with rest periods < work periods is efficient to enhance aerobic fitness in terms of VO<sub>2 max</sub> or lactate threshold (Bishop et al., 2011; Bishop, Edge 2005). It is important to note that the interaction between exercise mode, distance, intensity, recovery type, sets x repetitions, recovery duration and session frequency determines the total training load (Haugen et al., 2013a). In strength- and endurance training it has been reported that training intensity could be compensated with increased volume to enhance performance and this could also be a way to improve the repeated sprint ability (Kraemer, Ratamess, French 2002).

## **2.4 Physiological testing of soccer players**

Previous sections show that soccer depends upon both aerobic and anaerobic capacity. Physical fitness testing is conducted several times per year to evaluate the development of different physical qualities in soccer players (e.g. aerobic fitness, speed, agility, and strength and power), which are related to match performance (Mendez-Villanueva, Buchheit 2013).

Anaerobic capacity is important in soccer because a player performs many high intensity sprints with relatively short intervals. Gabbett & Mulvey (2008) found that

players sometimes had short rest periods between sprints (< 20 s) with active “recovery” as the players had to get in position again. Most RSA test protocols tries to stimulate the most intensive game periods based on the short recovery periods between each sprint in games. This this could lead to an overemphasis of the aerobic demands (Haugen et al. 2013a). A high correlation between total time in a RSA and single sprint performance has been reported (Pyne et al. 2008), indicating that RSA probably is more related to short sprint than endurance capacity (Haugen et al., 2013a). Repeated sprint test protocols with higher total volume should perhaps then be used to detect the sprint endurance component. Researchers usually perform repeated 20–30 m tests that incorporate numerous split times including the determination of acceleration, maximal sprint parameters and fatigue resistance (Harley et al., 2010). It has been reported that sprint testing/training without prior gradual progression increases the risk of hamstring injuries, which accounts for 12-14 % of all injuries in soccer. (Elliott, Zarins, Powell, Kenyon 2011; Opar, Williams and Shield 2012; Ekstrand, Hägglund, Waldén 2011; Hawkin, Hulse, Wilkinson, Hodson, Gibson 2001) This could explain the relatively small total volume of sprinting in most repeated sprint test and training protocols (Haugen et al., 2013a).

Aerobic capacity has been tested in several different ways in soccer, and it has been heavily debated what measurement is the best indicator. Legèr shuttle run test (Léger, Lambert 1982), the Loughborough intermittent shuttle test (Nicholas, Nuttall & Williams, 2000) the yo-yo intermittent recovery (IR) tests (Bangsbo et al. 2008; Bangsbo, 1994) and maximum oxygen uptake ( $\text{VO}_{2\text{ max}}$ ) test have been used.  $\text{VO}_{2\text{ max}}$  has traditionally been used to monitor the players aerobic capacity. However, the importance of  $\text{VO}_{2\text{ max}}$  in soccer is a controversial topic. Tønnessen et al., (2013) analyzed  $\text{VO}_{2\text{ max}}$  tests for a total of 1545 male soccer players in the years 1989-2012. The conclusion of their study was that 62-64  $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  would satisfy the aerobic requirements in male professional soccer, as  $\text{VO}_{2\text{ max}}$  did not distinguish players of different playing standard. The authors concluded that other performance variables like technical and tactical skills, linear sprint speed, repeated sprint ability and agility should be prioritized, as long as the aerobic capacity ( $\text{VO}_{2\text{ max}}$ ) reached a certain minimum.

Because the validity of  $VO_{2\max}$  has been questioned over the years, other tests have been developed to simulate the activity patterns during soccer games (Bangsbo et al., 2008).

The Yo-yo intermittent recovery tests have been used extensively in soccer the last decade. Here, athletes perform repeated exercise bouts of 2\*20 m runs with progressively increasing speeds, interspersed with 10-s active rest periods (Krustrup et al., 2003). This test is considered finished when the subjects are exhausted and can't reach the finish line in time for the second time. It is possible to perform this test at two different levels with differing speed profiles (level 1 and 2). The YO-YO IR1 test are made for athletes of lower standard and adolescents while the YO-YO IR2 test are for athletes of higher standards (e.g. professionals) (Bangsbo et al. 2008). A significant relationship between Yo-Yo test performance and the amount of high intensity exercise in professional players during a game have been reported, suggesting that these might be valid tests to monitor soccer specific endurance (Bangsbo et al., 2008; Krustrup and Bangsbo 2001; Bangsbo et al., 1991; Ekblom 1986; Krustrup et al., 2003; Krustrup et al., 2005). Large Yo-Yo test improvements have been observed after training regimes including aerobic / anaerobic high intensity running or speed endurance training (Bangsbo et al., 2008). A correlation of 0.7 between  $VO_{2\max}$  and the YO-YO IR1 test have been reported and it has been discussed whether  $VO_{2\max}$  can be calculated or estimated from the YO-YO IR1 results (Krustrup et al., 2003). However, it has been shown that individuals with identical  $VO_{2\max}$  may differ by extensive margins in Yo-Yo tests (Bangsbo et al., 2003). This is not surprising, since the YO-YO tests test also evaluate anaerobic components of running performance. Poor aerobic capacity can be compensated for with great anaerobic capacity and vice versa (Mendes-Villanueva and Buchheit 2013). It seems that the Yo-Yo tests reflects the ability to perform repeated intense exercise more than aerobic capacity in terms of  $VO_{2\max}$  (Krustrup et al. 2003; Bangsbo et al., 2008; Krustrup, Bangsbo 2001). However, it should be mentioned that the Yo-Yo IR tests are associated with moderate test-retest reliability (CV 5-10 %) compared to other endurance tests such as the  $VO_{2\max}$  (Bangsbo et al., 2008; Krustrup

et al., 2003). Start running before the beep, turning before the line and what body part shall apply the finish line are possible sources of errors.

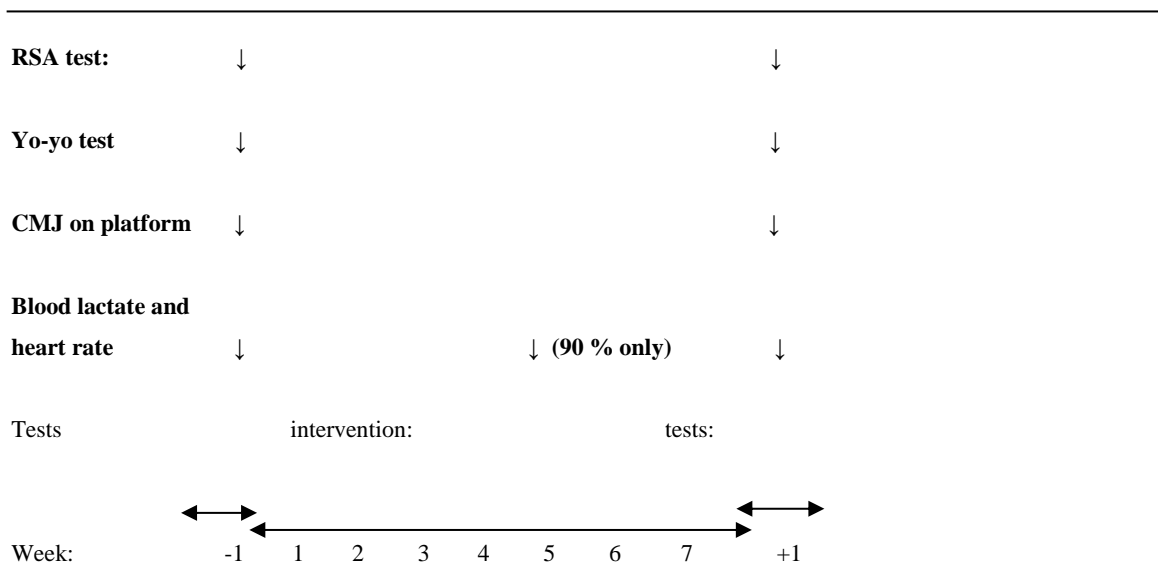
It has been debated whether physical and physiological testing of athletes is relevant. Most coaches already know how fast a player can run or how high stamina the person has (Mendez-Villanueva, Buchheit 2013). Physical capabilities in soccer must be seen in relation to playing roles and tactical demands. As long as a player does his or her “job” on the field, all other physical considerations are secondary (Mendez-Villanueva, Buchheit 2013; Delgado-Bordonau & Mendez-Villanueva, 2012). A better understanding of the factors which influence a poor test and, in turn, diminish potential soccer ability, would be more valuable for coaches in their striving to create individual training programs (Mendez-Villanueva, Buchheit 2013). Testing should not only be performed to confirm evidence, but also to improve the of players’ physiological capacity. Therefore, physical testing of soccer players should include soccer-specific movement patterns (Mendez-Villanueva, Buchheit 2013). A combination of isolated physical capacity tests and soccer-specific movements should perhaps be preferred. For example, even though VO<sub>2</sub> max is less soccer-related (involves continuous running without changes of direction). This is the only physiological test that reflects a player’s maximal aerobic power, integrated with his or her running economy (di Prampero et al. 1986). In contrast to Yo-Yo IR tests, VO<sub>2</sub> max can be used as a reference for programming high-intensity training (Dupont, Akakpo, & Berthoin, 2004).

### 3.0 Methods

#### 3.1 Experimental approach to the problem

There was conducted a 7 week long intervention on high level junior football players from the age 15-19 years. Repeated sprint ability (RSA), endurance performance (yo-yo test), lactate, heart rate and CMJ were measured both before and after the intervention. There was one day of restitution between the RSA test and the yo-yo test. The players were randomized into 3 groups by drawing. One group (n=16) trained 15\*20 meters laps with 100 % intensity with one minute between each lap, while another group (n=15) trained 30\*20 meters laps with 90 % intensity with one minute between each lap. The last group (n=10) worked as control and carried out the regular football training program as usual. After the training intervention, the same tests were conducted and results from pre to post were compared. This study was conducted in accordance with the declaration of Helsinki.

**Table 1: Time overview of the testing and training.**



#### 3.2 Subjects

41 high level junior male football players ( $16.7 \pm 1.0$  yr.,  $71.1 \pm 9.4$  kg and  $181.2 \pm 6.1$  cm) were recruited to this project. The recruitment was through different top football junior teams who had their training fields in Oslo and nearby the Norwegian school of

sport science (NIH). The majority of the recruiting was done by two master students from NIH who showed up at the training sessions to the various teams and informed about the project. Those who reported interest for this study received an information sheet that they could read through for gaining more knowledge about the study before they signed it. There was also an information meeting where they could ask any questions. The subjects were also informed that they could withdraw at any time during the study without having to give a reason. The subjects were paired for clubs and randomized into 3 groups through a drawing by an NIH student who didn't were involved in the project before the intervention started. By pairing for clubs and then randomize, the study eliminated the influence of varying overall football conditioning. There were 2 training groups and one control group. The subjects in the training groups conducted a 7-week intervention including testing before and after. There were 6 players who withdrew from extraneous reasons not related to the project. 2 were from the 90 % intensity group, 3 from the 100 % intensity group and 1 from control. Some of the participants are not included in analyzes because of injury or that they didn't completed enough of the training sessions. The 7-week training protocol and testing was carried out in the autumn 2013 (October to mid-December).

**Table 2: Training characteristics of the different groups.**

<b>Group</b>	<b>CG</b>	<b>90 %</b>	<b>100 %</b>
<b>Weekly training sessions</b>	<b>4,4 ± 2,3</b>	<b>4,5 ± 2,4</b>	<b>4,4 ± 2,3</b>
<b>Games/week</b>	<b>0,4 ± 0,4</b>	<b>0,4 ± 1,0</b>	<b>0,3 ± 0,7</b>
<b>Total training volume (h/week)</b>	<b>6,8 ± 3,3</b>	<b>7,0 ± 3,5</b>	<b>6,6 ± 3,8</b>

The training groups performed repeated sprint training (RST) 1 time at the week in addition to normal training. The program consisted of 15 or 30 laps where the 100 % group performed 15 laps, while the 90 % group performed 30 laps. The control group trained as usual and was tested before and after the intervention with the training groups. Furthermore, the study controlled for training characteristics by asking the subjects every training session how many weekly training session they had, how many games they had played and the total amount of training volume (table2). The subjects

had to complete at least five out of seven training sessions in addition to the performance tests for being included in further analyzes.

### **3.3 Testing procedures**

#### **3.3.1 Familiarization**

There was not included familiarization sessions in this study because of the control group that controlled for the learning effect for the different testing procedures. None of the athletes had previous experience with this kind of testing or training from before.

#### **3.3.2 Repeated Sprint test (RST)**

The repeated sprint test was performed on a sprinting court at Olympiatoppen (OLT). A standardized warm-up program with 10-12 minutes of running, 4 minutes of high knee-lifts and kickbacks with the legs and 3-4 maximum sprints were completed before the testing.

Before the RST, the subjects tested their jumping ability on an AMTI force platform (ORG6-5-1, Watertown USA) where they performed 3 counter movement jumps (CMJ) and the best result was written down. The players stood on a force platform mat with the plantar part of the foot contacting the ground, and with hands on hip, and from an erect standing position on the force platform with a knee angle of  $180^\circ$ , a countermovement down until the knee angle around  $90^\circ$  was performed before they jumped. Calculation of jump height is described by Haugen et al., (2012)

All the subjects performed 15 laps on 20 meters with 100 % intensity in each run with one minute breaks between them. 2 pairs of double infrared photocells, which were connected via cables and connected to a computer (PC Pentium 3), were used to measure the time. These cells measures the time to the nearest 0.001 second. Pulse and hart rate was measured between each run. After completing the 15 laps, the subjects measured their blood lactate (LactatePro LT-1710, Arkay KDK, Kyoto, Japan). Video-analysis was used on each lap to measure the number of steps for each subject by a Sony HDR-HC9E. The recordings were analyzed in ProSuite, version 5.5 (Dartfish, Switzerland) to determine stride count and derive average stride length. For precision, the digital ruler in the analyzer window was used to interpolate the last step across the

finish line. For example; if the 12<sup>th</sup> and 13<sup>th</sup> ground contact occurred 0,8 m in front of and 1,2 m beyond the finish line, the recorded number of strides was registered as 12,4. Mean SL was calculated by dividing the number of steps by the distance. Mean SF was calculated from mean velocity and mean SL. A high speed camera was also used the first and last lap for measuring contact time and levitation time for the players. Moreover, EMG was used for measuring muscular activity in muscles related to running (m. gastrocnemius, m. soleus, m. vastus lateralis and m. biceps femoris). Both the high speed camera and the EMG gave insufficient measures and could not be used in further analysis.

### **3.3.3 The yo-yo intermittent test**

The second day, the subjects performed the football-specific Yo-Yo IR1 endurance test and was set up as described by Bangsbo (1996). The same test leader was used for all participants, and was therefore evaluated on the same level. A standard warm-up protocol was performed on pre-and post-test. This included a general warm up at low intensity for 10-12 minutes, followed by 5 minutes at higher intensity. Each subject had a marked 2 m wide tread, and the start and twists line was measured with 20 meters from each other. The lines were marked as solid lines from marked handball court. Restitution distance was marked with a cone centered in the tread 5 m basis launch. Heart rate monitors were used during the test for measuring heart rate and intensity level.

### **3.4 Training protocol**

The training consisted of an extra session with repeated sprint training in addition to the team's original training sessions with either 15 runs on 100 % intensity, or 30 runs on 90 % intensity. Photocells were used to control the intensity, and were a fine performance goal for the players. The control group continued to follow the teams' original training plan without the specific training. For comparing the two repeated sprint training sessions used in the present study, session rated perceived exertion (RPE) was recorded for all athletes after the repeated sprints performed in pretest and first training session. Written and verbal instructions regarding its use were provided in advance (Foster 1998)



### 3.4.1 Training performance

Both of the training groups performed one training session per week for seven weeks in the period of October to mid-December. The 100 % group performed 15 laps on 20 meters with one minute between each lap. They were given instructions that they should take themselves completely out in each lap. The 90 % group performed 30 laps on 20 meters with one minute between them. The first session they only completed 25 laps, but after consideration, the trainers decided to expand it to 30 laps because they were afraid that 25 laps on 90 % intensity weren't enough compared to 15 laps of 100 % intensity for gaining the best development in RSA performance. A test was conducted 48 hours after the first training session to examine if the 90 % group received the same training load as the 100 % group. The results are presented in table 4. The subjects in the 90 % group were given a target time based on their best lap from pre-results of the repeated sprint test. On each lap, a trainer told them their time so the players could adjust how fast they should run for hitting their target time. Figure 3.4 and 5 shows intensity distribution for the 90 % group the 3 first sessions. After only one session, most of the sprints were between 87 % and 93 % of maximal sprint velocity.

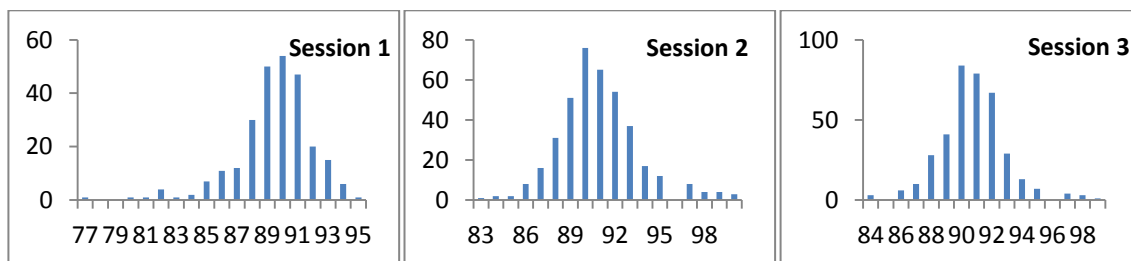


Figure 3, 4 and 5: Intensity distribution for the 90 % group. X-axis= intensity (of maximal sprint velocity), Y-axis = % of all runs.

In the middle of the training period, the 90 % groups also performed a max run at the end of the 30 laps. If the players had a better max time, they would receive a new target time based on this. If there weren't any improvement of the max times, the players kept their originally target time. Lactate and heart rate was also measured in the middle of intervention on the 90 % groups to ensure that the training program was as hard as for those who run on 100 % intensity.

All of the groups performed a 10 minute standardized warm-up with jogging, kickbacks and high knee-lifts before each session started. Every session, there was at least one trainer who oversaw the training and guided the players.

**Table 3: Training period for the 90 % group and the 100 % group.**

<b>Week:</b>	<b>100 % group</b>	<b>90 % group</b>
1	15 laps of 20 meters each 1 minute rest	25 laps of 20 meter each 1 minute rest
2	15 laps of 20 meters each 1 minute rest	30 laps of 20 meter each 1 minute rest
3	15 laps of 20 meters each 1 minute rest	30 laps of 20 meter each 1 minute rest
4	15 laps of 20 meters each 1 minute rest	30 laps of 20 meter each 1 minute rest (lactate and heart rate measurement)
5	15 laps of 20 meters each 1 minute rest	30 laps of 20 meter each 1 minute rest 1 max run at the end
6	15 laps of 20 meters each 1 minute rest	30 laps of 20 meter each 1 minute rest
7	15 laps of 20 meters each 1 minute rest	30 laps of 20 meter each 1 minute rest

### 3.5 Validity and reliability

The validity of the tests is based on the basis of the training interventions main purpose, which is to give the athlete an improved speed that can be used on the football field. Validity is that the test measures what it is actually to measure (Thomas, Nelson & Silverman, 2011). Both acceleration and top speed are two key factors of a player's sprint performance (Di Salvo et al., 2010). When performing 20 meter sprints, the athletes reach their top speed and this test are therefore a valid when researchers wish to examine the player's sprint performance (Haugen et al., 2012) When performing vertical countermovement jump on a force platform which measures the force development in lower extremities, this may have a good relationship with the athlete's maximal strength (Wisløff et al., 2004). The Yo-Yo IR1 test have showed a good correlation with high intensive running during a match, and can therefore be a valid test to evaluate the soccer specific player's endurance (Krustrup et al., 2005; Krustrup et al., 2003). Based on other studies, 20 meter repeated sprint could be valid test measurement in relation to a soccer

player's ability to repeat the single sprints over a period of 15 min (Bradley et al., 2009; Vescovi, 2012).

The reliability of a test tells whether the results are reliable, and that the test measures the same ability with the same accuracy every time (Hopkins 2000). A test cannot be valid unless it is reliable (Thomas et al., 2011). Test re-test reliability is usually performed by calculating intraclass correlation (ICC). Since this study did not include familiarization tests before the intervention, it can't be established a test-retest reliability of the tests used (Thomas et al., 2011). However, Enoksen, Tønnessen and Shalfawi (2009) found in the same instruments that measurement error (reliability) will not be greater than  $\pm 3.2\%$  for CMJ and  $\pm 1.1\%$  for 0-20m sprint in junior soccer players. There is a moderate test, -retest reliability of 5-10 % (coefficient of variation) for the YO-YO-IR test (Bangsbo et al., 2008; Krstrup et al., 2003).

### **3.6 Statistics**

Raw data were transferred to the SPSS 21.0 for Windows and Microsoft Excel for analysis. To detect differences in measurements between the pre- and post-tests, the paired sample t-test was used to evaluate the difference in means between the paired samples (within group). Analysis of covariance (ANCOVA) adjusting for pre-test value and stratification factor (club) was used to examine between group changes. The differences were judged by using estimated marginal means (EMM). Bonferroni corrections were used to adjust p-values for multiple testing. Effect size was calculated and log transformed using Hopkins spreadsheets for analysis (Hopkins, Marshall, Batterham and Hanin 2009). To determine whether the effect size was trivial ( $d > 0.2$ ), small ( $d = 0.2 - 0.6$ ), moderate ( $d = 0.6 - 1.2$ ), large ( $d = 1.2 - 2.0$ ), or very large ( $d > 2.0$ ), the scale developed by Batterham and Hopkins (2006) was used. Pearson's R was used to quantify the relationships among anthropometric and physical parameters. Differences were considered significant at  $P \leq 0.05$ , and the results were expressed as means and standard deviations. The 95 % confidence interval was calculated for all measurements.

## 4.0 Results

### 4.1 Difference between rated perceived exertions

Table 4 shows no differences in RPE between the sessions. There was also no difference in recovery between the groups 48 hours after the respective sprint training sessions. Sprinting at 90% velocity was accompanied with reduced HR peak (17%; very large effect;  $p < 0.001$ ),  $\text{BLa}^-$  (55%; large effect;  $p < 0.001$ ) and SF (11%; very large effect;  $p < 0.001$ ) compared to maximal sprinting. While heart rate plateaued after ~ 10th repetitions during the 30x20 m 90 % sprint training sessions, heart rate increased progressively throughout the 15x20 m 100% sprint sessions.

**Table 4: Effort related variables in maximal (100 % group) and sub-maximal (90 % group) sprinting.  $\Delta$  sprint time 48 h = pre-test time minus sprint time 48 hours after the first training session (mean of first 3 sprints for each time point), RPE = rated perceived exertion, HR peak = peak heart rate,  $\text{BLa}^-$  = blood lactate concentration, SL = stride length, SF = stride frequency, \* = significantly different from 100 % sprinting ( $p < 0.001$ )**

Sprint session	15x20m (100 % group)	30x20m (90 % group)
$\Delta$ sprint time 48 h (s)	0.00 $\pm$ 0.02	-0.01 $\pm$ 0.02
Session RPE	3.8 $\pm$ 1.2	4.0 $\pm$ 1.1
HR peak (beats $\cdot$ min <sup>-1</sup> )	170 $\pm$ 10	141 $\pm$ 10*
$\text{BLa}^-$ (mmol $\cdot$ L <sup>-1</sup> )	4.4 $\pm$ 1.8	2.0 $\pm$ 0.7*
SL (m)	1.55 $\pm$ 0.08	1.56 $\pm$ 0.09
SF (strides/s)	4.36 $\pm$ 0.18	3.87 $\pm$ 0.22*

### 4.2 Changes within and between groups

Table 5, 6 and 7 shows changes in analyzed performance parameters within groups from pre- to post-test. In the 100 % group, there was a significant difference within the group in SF, SL, body mass (weight) and  $\text{BLa}^-$ . No within-group differences were observed in any of the groups for the performance parameters.

Table 8 shows between groups difference from pre- to post-test. No between-group differences were observed. The effect of the training was small to moderate for best sprint, SL, SF, CMJ,  $\text{BLa}^-$  and HR in the 100 % group vs. the control group, and small to moderate in best sprint, CMJ and  $\text{BLa}^-$  in the 90 % group vs. the control group. When the 90 % sprint treatment was used as reference in an ANCOVA analysis, trivial and

non-significant differences were observed. However, the effect of repeated sprint training on the 100 % group vs. the 90 % group was small for SL, SF, Bla- lactate and HR in favor of the 100 % group.

**Table 5: Differences within group in a variety of physiological measures for the 100 % group. Mean results of 15x20m repeated sprint, best sprint time, steplength, step frequency, CMJ, Yo-Yo IR1, weight, BLA- and heart rate within group from pre- to posttest ( $\pm$ SD).**

<b>100 % group</b>				
<b>Variable</b>	<b>Pre-test</b>	<b>Post-test</b>	<b>Mean change</b>	<b>95 % CI</b>
15 x 20m mean (s)	2,98 $\pm$ 0,15	2,98 $\pm$ 0,16	0,00 $\pm$ 0,04	-0,02 to 0,02
Best sprint (s)	2,94 $\pm$ 0,15	2,93 $\pm$ 0,15	- 0,01 $\pm$ 0,04	-0,03 to 0,01
SL (m)	1,56 $\pm$ 0,09	1,51 $\pm$ 0,11	- 0,05 $\pm$ 0,06	-0,08 to -0,02**
SF (strides/s)	4,33 $\pm$ 0,33	4,47 $\pm$ 0,36	0,14 $\pm$ 0,18	0,04 to 0,24**
CMJ (cm)	34,88 $\pm$ 4,75	35,35 $\pm$ 4,24	0,47 $\pm$ 2,62	-1,95 to 1,89
Yo-yo IR1 (meter)	1508,57 $\pm$ 276,85	1605,71 $\pm$ 332,61	97,14 $\pm$ 130,35	0,58 to 193,70
Weight (kg)	65,96 $\pm$ 8,73	66,78 $\pm$ 8,79	0,82 $\pm$ 1,31	0,11 to 1,53*
Lactate (mmol·L <sup>-1</sup> )	4,16 $\pm$ 1,54	5,69 $\pm$ 2,14	1,53 $\pm$ 1,08	0,94 to 2,12**
Heart rate (beats·min <sup>-1</sup> )	166,08 $\pm$ 9,62	167,31 $\pm$ 12,02	1,23 $\pm$ 5,89	-1,97 to 4,43

\* = p<0,05, \*\* = p<0,01, CI=Confidence interval, SF= step frequency, SL= steplenght

**Table 6: Differences within group in a variety of physiological measures for the 90 % group. Mean results of 15x20m repeated sprint, best sprint, steplength, step frequency, CMJ, Yo-Yo IR1, weight, lactate and heart rate within group from pre to post-test ( $\pm$ SD).**

<b>90 % group</b>				
<b>Variable</b>	<b>Pre-test</b>	<b>Post-test</b>	<b>Mean change</b>	<b>95 % CI</b>
15 x 20m mean (s)	2,98 $\pm$ 0,12	2,98 $\pm$ 0,11	0,00 $\pm$ 0,04	-0,02 to 0,02
Best sprint (s)	2,94 $\pm$ 0,12	2,93 $\pm$ 0,11	- 0,01 $\pm$ 0,04	-0,03 to 0,01
SL (m)	1,55 $\pm$ 0,09	1,55 $\pm$ 0,06	- 0,01 $\pm$ 0,07	-0,05 to 0,03
SF (strides/s)	4,34 $\pm$ 0,22	4,35 $\pm$ 0,17	0,01 $\pm$ 0,19	-0,09 to 10,01
CMJ (cm)	33,48 $\pm$ 3,96	33,32 $\pm$ 4,17	- 0,16 $\pm$ 1,60	-1,03 to 0,71
Yo-yo IR1 (meter)	1504 $\pm$ 376,27	1644 $\pm$ 401,09	140 $\pm$ 259,40	-20,78 to 300,78
Weight (kg)	72,23 $\pm$ 5,58	72,47 $\pm$ 5,13	0,24 $\pm$ 1,10	-0,36 to 0,84
Lactate (mmol·L <sup>-1</sup> )	4,25 $\pm$ 1,65	4,82 $\pm$ 2,01	0,57 $\pm$ 1,54	-0,27 to 1,41
Heart rate (beats·min <sup>-1</sup> )	173,54 $\pm$ 9,37	170,15 $\pm$ 13,66	- 3,38 $\pm$ 8,42	-7,96 to 1,20

\* = p<0,05, \*\* = p<0,01, CI=Confidence interval, SF= step frequency, SL= steplenght

**Table 7: Differences within group in a variety of physiological measures. Mean results of 15x20m repeated sprint, best sprint, steplength, step frequency, CMJ, Yo-Yo IR1, weight, lactate and heart rate within group (CON) from pre to post-test ( $\pm$ SD).**

<b>CON</b>				
<b>Variable</b>	<b>Pre-test</b>	<b>Post-test</b>	<b>Mean change</b>	<b>95 % CI</b>
<b>15 x 20m mean (s)</b>	2,97 $\pm$ 0,14	3,00 $\pm$ 0,14	0,02 $\pm$ 0,03	0,00 to 0,04
<b>Best sprint (s)</b>	2,93 $\pm$ 0,13	2,95 $\pm$ 0,14	0,02 $\pm$ 0,03	0,02 $\pm$ 0,03
<b>SL (m)</b>	1,53 $\pm$ 0,08	1,52 $\pm$ 0,07	- 0,01 $\pm$ 0,05	-0,04 to 0,02
<b>SF (strides/s)</b>	4,42 $\pm$ 0,31	4,40 $\pm$ 0,29	- 0,02 $\pm$ 0,19	-0,14 to 0,10
<b>CMJ (cm)</b>	37,33 $\pm$ 3,52	36,61 $\pm$ 3,58	- 0,73 $\pm$ 1,37	-1,63 to 0,17
<b>Yo-yo IR1 (meter)</b>	1546,67 $\pm$ 375,80	1693,33 $\pm$ 355,68	146,67 $\pm$ 236,87	-42,87 to 336,21
<b>Weight (kg)</b>	71,6 $\pm$ 11,22	71,98 $\pm$ 11,44	0,38 $\pm$ 1,20	-0,40 to 1,16
<b>Lactate (mmol·L<sup>-1</sup>)</b>	5,24 $\pm$ 2,67	4,78 $\pm$ 3,17	- 0,47 $\pm$ 1,27	-1,30 to 1,66
<b>Heart rate (beats·min<sup>-1</sup>)</b>	172 $\pm$ 12,19	167,44 $\pm$ 10,37	- 4,56 $\pm$ 6,62	-5,39 to -3,73

\* = p<0,05, \*\* = p<0,01, CI=Confidence interval, SF= step frequency, SL= steplength, CON=control group

**Table 8: Difference between groups in a variety of physiological measures. Mean results of 15x20m repeated sprint, best sprint time, steplength, step frequency, CMJ, Yo-Yo IR1, weight, BLA- and HR between groups from pre- to posttest ( $\pm$  CI).**

<b>Variable</b>	<b>Between group differences in change score</b>								
	<b>100 % group vs. CON</b>			<b>90 % group vs. CON</b>			<b>90 % group vs. 100 % group</b>		
	<b>Diff <math>\pm</math> CI</b>	<b>E.S</b>	<b>p-value</b>	<b>Diff <math>\pm</math> CI</b>	<b>E.S</b>	<b>p-value</b>	<b>Diff <math>\pm</math> CI</b>	<b>E.S</b>	<b>p-value</b>
<b>15 x 20m (mean) (s)</b>	- 0,03 $\pm$ 0,04	0,18	0,57	- 0,02 $\pm$ 0,04	0,17	0,78	0,00 $\pm$ 0,04	0,01	0,83
<b>Best sprint (s)</b>	- 0,03 $\pm$ 0,04	0,22	0,24	- 0,03 $\pm$ 0,04	0,23	0,3	0,00 $\pm$ 0,04	0,02	0,89
<b>SL (m)</b>	0,04 $\pm$ 0,05	0,46	1	0,00 $\pm$ 0,06	0,04	0,54	-0,04 $\pm$ 0,05	0,5	0,96
<b>SF (strides/s)</b>	-0,16 $\pm$ 0,17	0,47	1	-0,02 $\pm$ 0,18	0,09	1	0,14 $\pm$ 0,15	0,46	0,65
<b>CMJ (cm)</b>	-1,20 $\pm$ 1,8	0,27	0,66	-0,57 $\pm$ 1,34	0,12	1	0,63 $\pm$ 1,78	0,15	0,47
<b>Yo-yo IR1 (meter)</b>	49,52 $\pm$ 256,62	0,18	1	6,67 $\pm$ 279,1	0,03	1	-42,86 $\pm$ 206,72	0,15	0,69
<b>Weight (kg)</b>	-0,45 $\pm$ 1,13	0,05	1	0,14 $\pm$ 1,07	0,01	1	0,58 $\pm$ 0,99	0,08	0,23
<b>Lactate (mmol·L<sup>-1</sup>)</b>	-2,00 $\pm$ 1,1	1,15	0,24	-1,04 $\pm$ 1,26	0,63	0,24	0,96 $\pm$ 1,09	0,5	0,08
<b>Heart rate (beats·min<sup>-1</sup>)</b>	-5,79 $\pm$ 5,85	0,49	0,33	-1,17 $\pm$ 6,72	0,08	1	4,62 $\pm$ 5,93	0,46	0,12

\* = p<0,05, \*\* = p<0,01, CI=Confidence interval, SF= step frequency, SL= steplength, CON=control group, ES= Cohen's d (effect size)

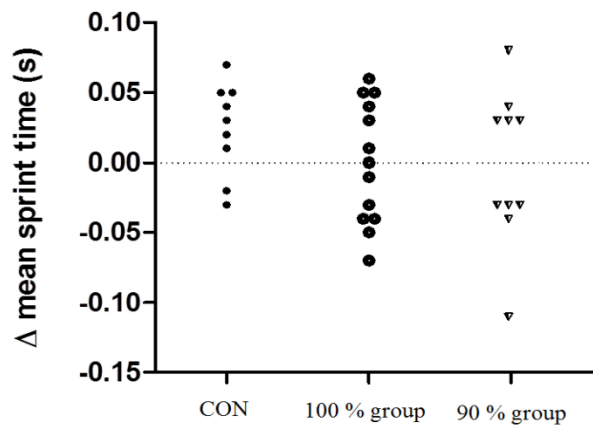


Figure 6: individual changes in 15x20 m mean sprint time from pre- to post-test.

Figure 7 show the development of repeated sprint performance (mean sprint time) for the 100 % group from week to week.

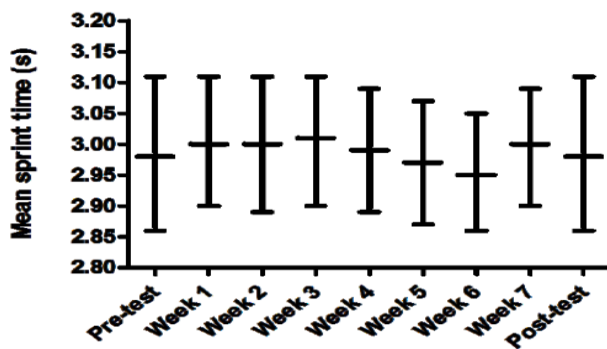


Figure 7: Change in mean time from week to week (100 % group)

### 4.3 Correlations

Table 9 shows correlation values across analyzed variables. Overall, changes in BLA- from pre- to post-test were correlated with changes in HR, sprint times and CMJ performance by moderate to large margins. Changes in best sprint time showed a very large correlation with changes in mean sprint time. Changes in sprint times were moderately correlated with changes in CMJ performance.

**Table 9: Correlation values across analyzed variables. n=35 for all observations. Δ=change pre-post. BLa<sup>-</sup> = blood lactate concentration, CMJ = countermovement jump, SL = stride length, SF = stride frequency. \* = *p* <0.05.**

Variables	Upper r	r	Lower r
Δ BLa <sup>-</sup> (mmol·L <sup>-1</sup> ) vs. Δ CMJ (cm)	0.73	0.53*	0.23
Δ Best sprint time (s) vs. Δ CMJ (cm)	-0.20	-0.45*	-0.66
Δ mean sprint (s) vs. Δ CMJ (cm)	-0.19	-0.42*	-0.63
Δ heart rate (beats·min <sup>-1</sup> ) vs. Δ BLa <sup>-</sup> (mmol·L <sup>-1</sup> )	0.73	0.49*	0.16
Δ best sprint time (s) vs. Δ BLa <sup>-</sup> (mmol·L <sup>-1</sup> )	-0.07	-0.39 *	-0.62
Δ mean sprint time (s) vs. Δ BLa <sup>-</sup> (mmol·L <sup>-1</sup> )	0.01	-0.29	-0.54
Δ SL (m) vs. Δ SF (strides·s <sup>-1</sup> )	-0.90	-0.95*	-0.98
Δ best sprint time (s) vs. Δ mean sprint time (s)	0.94	0.87*	0.78
Yo-yo IR1 (meter) pre vs. mean sprint (s) pre	0.13	0.27	-0.60
Yo-yo IR1 (meter) post vs. mean sprint time (s) post	0.20	0.17	-0.52
CMJ (cm) pre vs. mean sprint pre (s)	- 0.53	-0.73*	-0.86
CMJ (cm) post vs. mean sprint post (s)	- 0.50	-0.70*	-0.83
CMJ (cm) pre vs. best sprint pre (s)	- 0.56	-0.73*	-0.86
CMJ (cm) post vs. best sprint post (s)	- 0.53	-0.69*	-0.84
SL (m) pre vs. SL post (m)	0.86	0.72*	0.52
SF pre (strides·s <sup>-1</sup> ) vs. SF post (strides·s <sup>-1</sup> )	0.89	0.77*	0.58
Best sprint time post (s) vs. BLa <sup>-</sup> (mmol·L <sup>-1</sup> ) post	- 0.27	- 0.48*	- 0.66
Mean sprint time post (s) vs. BLa <sup>-</sup> (mmol·L <sup>-1</sup> ) post	- 0.27	- 0.47*	- 0.66



## 5.0 Discussion

In this study, no significant results were observed when comparing two training groups (100 % group and 90 % group) against a control group after a 7 week sprint training intervention. One weekly sprinting session with maximal or sub-maximal intensity was not sufficient to improve performance outcomes for football related sprinting performance. To the author's knowledge, this is the first study to compare the effects of sprint training at 90 % vs. 100 % intensity.

*Training volume:* In the present training intervention, 1:2 ratio was used for sprint repetition between the 100 % group (15x20 m) and the 90 % group (30x20 m). RPE was rated equally by the subjects in the two different training regimes (Table 4). No differences were found in sprint performance between the 3x20 m sprints performed 48 hours after the first training session for the 100 % training group and the 90 % training group. This indicates a similar recovery status 2 days after performing different training sessions and that the two repeated sprint training sessions were effort matched. To date, no other studies have compared the effects between two different regimes where the training volume and training intensity are different.

*Effect of training at different intensities:* There was a significant change in both SL and SF from pre- to posttest in the 100 % group even though sprint performance remained unchanged (Table 5). This change was higher than the observed typical variation and it is possible that the 100 % group unconsciously shortened SL and increased SF in the chase of velocity enhancement, giving a subjective feeling of running faster. According to Mero and Komi (1986) and Mero, Komi and Gregor (1992), top athletic sprinters should try to improve performance by increasing SF while maintaining SL. However, among athletes of lower sprint standard, SL is considered a more limiting factor (Armstrong, Costill and Gehlsen 1984). There is a possibility that with supervised coaching, this would have ensured a more optimal combination of SL and SF, leading to a higher performance. The correlation values for SL ( $r = 0.72$ ) and SF ( $r = 0.77$ ) across the tests were surprisingly low when all groups were pooled together (Table 8). It seems that the same sprint performance can be achieved with varying locomotion efficiency

among athletes who are untrained in terms of sprinting. This is also in accordance with observations made by Hunter, Marshall and McNair (2004).

In terms of intensity and volume, we cannot conclude that training at 90 % of maximal sprint intensity is sufficient for gaining improvements over short distances when training once a week (Table 6 and Figure 6). It has been shown that reduced training intensity can be compensated for with increased volume to enhance performance in strength- and endurance training (Kraemer et al., 2002, Seiler et al., 2013) However, sub-maximal sprint training is perhaps more appropriate for typical athletic sprinting distances (100-200 m) compared to 0-20 m accelerations used in this study.

*Effect sizes:* Previous studies have shown that sprint training regimes have provided positive results on soccer related sprinting skills and CMJ (Tønnessen et al. 2011, Shalfawi et al. 2012; Harrison and Bourke 2009). In Tønnessen et al., (2011), the subjects performed 40 meter repeated sprint training once a week and only gained improvements in RSA (10x40m) and 20-m maximal speed with a moderate effect compared to the control group, while no improvements in 20 m acceleration occurred. Harrison and Bourke (2009) reported significant improvements in acceleration speed after similar training. The study of Tønnessen et al., (2011) was carried out on elite junior players, and the athletes were only practicing one session per week. This may be a too little stimulant. It could also be that the participants in the study to Harrison and Bourke (2009) completed several maximum sprints up to 20 m in regular rugby training and games. Tønnessen et al., (2011) hypothesized that this may have improved their ability to accelerate. Since Tønnessen et al., (2011) saw improvements over 40 meter, they suggest that longer sprint distances could be a new and unaccustomed stimulant for soccer players, which again may result in positive muscular and neural responses (Mendez-Villanueva, Hamer, Bishop 2008; Ross, Leveritt, Riek 2001a; Tønnessen et al., 2011). However, it is important to note that even though no statistical improvements were found in the present study, there was a small effect size in best sprint (0.22) and CMJ (0.27) for the 100 % group. The 90 % group also had a small effect of the training in best sprint time (0.23). Shalfawi et al., (2012) conducted a similar training study with

soccer players performing two training sessions per week. In this study the athletes performed four sets of 5x40 m with 90 seconds recovery between repetitions and 10 min recovery between sets. The results in this study revealed no significant difference between the sprint training group and the control group in 0–20 m sprint time, CMJ and squat jump (SJ). However, the effect of repeated sprint training on the training group was moderate and close to large in 0–20 m sprint time (1.1) and CMJ (1.1). The question is if other training forms (e.g. intervals, strength training etc.), perhaps in combination, is more effective for soccer players. The current study only revealed trivial to small effects in the 100 % group vs. the CON group and the 90 % group vs. the CON group in most of the parameters (table 8). Based on the modest effect magnitudes, it is not recommended that soccer players should perform training regimes like this under otherwise identical conditions. Since there were no improvements, the players have most likely taken out much of their 0-20 m sprint potential during regular football training and it raises the question if a longer intervention or several sessions per week may have provided greater-improvements. However, the study of Shalfawi et al., (2012) showed that two training session per week were insufficient, and other types of training could be more effective for improving soccer-specific sprint abilities. It is also possible that longer intervention periods will lead to better outcomes. However, most team coaches will probably not “sacrifice” further football training sessions, even in the off-season or early pre-season when presented these results.

*Training intervention:* It is a question whether the recovery time between each sprint in the study of Tønnessen et al. (2011), Shalfawi et al. (2012) and the present study were too long compared to other studies for gaining improvements in the YO-YO IR1 test or mean sprint time (Dupont et al., 2004; Balsom et al., 1992b).

Balsom et al., (1992b) observed that when football players ran 15x40 m at maximal intensity, separated by 30 s recovery, the acute performance decline was 10 %. However, when the same training was performed with either 60 or 120 s recovery, the performance drop-off was reduced to 3 % and 2 % (Balsom et al. 1992b). There is a possibility that with shorter or more active breaks, the alactic system would not have

been completely restored due to PCr and ATP resynthesis. This could have resulted in a higher demand for the aerobic system and in the end, an improvement of the aerobic capacity/YO-YO IR1 performance and mean sprint time. By using shorter recovery periods, the present study would perhaps have provided larger improvements in the YO-YO IR 1 test and mean sprint time because the requirements to the aerobic system would have been higher and possibly leading to an improvement in this parameter. According to Spencer et al., (2005), the recovery intervals used during repeated sprint training should be representative of the most intensive periods during a game, rather than the average of the game as a whole. However, this could lead to an overemphasis on the aerobic endurance aspects of the adaptive signal and underemphasize the importance of acceleration and sprint quality, ultimately influenced the sprinting skills negatively. Coaches must take into account the demands of the sport and each athlete's specific capacity when designing a conditioning program. In a sport like soccer where sprinting skills are crucial, the training must balance between two extremities; the aerobic training should not ruin the quality of speed training. On the other side, the speed training should not be too short and specific so that a player can't hold for an entire match. A training program should therefore be based on the individual status of each players rather than training all players similarly.

*Coaching factor:* There are, to the authors' knowledge no studies that have seen on the effects of specific sprint training when training at lower intensity with coaching. This could be of interest since there has been shown in strength training that coaching could have a positive impact on performance even on simple technically exercises (Mazzetti et al., 2000). The idea of training with expert coaches should be examined further with other types of intervention. Instead of training all athletes in the same way, one should individualize the training to a much greater extent by coaching and instruction. It could also be of interest to examine the effects of gradual increase in intensity during training intervention from 90 % to 100 % sprint speed. In this way, the players gradually adapt to increasing speed and perhaps prevent injuries. This requires specific physiological expertise, and soccer coaches have to consider whether such knowledge should be included in the overall team staff.

*Injuries:* Sprinting in soccer is associated with a high number of hamstring injuries (Arnason et al. 1996; Opar et al., 2012; Ekstrand et al., 2011a; Hawkin et al., 2001; Henderson et al., 2010), and different ways for preventing this should therefore be examined. After 7 weeks of training, none of the drop outs in the 100 % group or the 90 % group were due to injuries related to the training intervention. However, it is reasonable to believe that more weekly training sessions increases the injury risk, at least when performing sprints with maximal intensity. Future studies should focus on how soccer players can enhance sprint performance without increasing the injury rate.

*Correlations across analyzed parameters:* A significant relationship between post mean sprint performance and post best sprint performance against blood lactate was found after the repeated sprint tests (Table 9). Since individual sprint performance depends upon the ability to fully activate fast twitch motor units with maximal firing frequency (Ross, Leveritt and Riek 2001), it is possible that an increased BLa<sup>-</sup> during sprinting reflects a higher neural activation on an individual level. Individuals with higher percentage of type 2 fibers probably have a higher lactate production and glycolytic capacity than individuals with a higher percentage of type 1 fibers (Pascoe, Gladden 1996; Bottinelli, Reggiani 2000). However, it is important to note that the intracellular buffer capacity may vary considerably between individuals (Medbø et al., 1988; Sahlin and Henriksson 1984). In the present study lactate concentration in blood was taken immediately after the test. Medbø et al. (1988) showed that lactate in muscle was 33.6 ml/kg while extracellular lactate concentration (blood) was 10.4 ml/kg immediately after exercise on his subject's. Thus, the results in the present study must be interpreted with caution.

Table 9 shows a high correlation between changes in best sprint time and changes in mean sprint time during 15x20 m sprint from pre- to post test ( $r = 0.87$ ). Pyne et al., (2008) also reported a strong correlation between RSA and maximal sprinting velocity, and it seems that RSA has a stronger relationship to this parameter than endurance capacity. Also when the recovery time between each 20 m sprint was reduced to 25 s,

the difference between mean time results and best time results remains small (Dellal and Wong 2013). Balsom, Seger, Sjödín and Ekblom (1992a) observed that it is more difficult to detect detrimental effects with short sprints compared to slightly longer sprints. There was a high correlation between pre mean sprint and post mean sprint with CMJ and post mean sprint and post best sprint with CMJ (table 9). However, the absolute time differences between best and changes in mean sprint performance were only moderately correlated with changes in CMJ performance among the subjects (Table 9). This is not in agreement with Wisløff et al., (2004) who reported a strong correlation between maximal strength, sprint performance and vertical jump height. However, Salaj & Markovic (2011) concluded that jumping, sprinting and change of direction speed are specific independent variables that should be treated separately. Haugen et al., (2013b) observed that development in sprinting abilities may occur without development in CMJ ability.

No correlation was found between pre Yo-Yo IR1 test and pre mean sprint time (Table 9). There was neither any correlation between post Yo-Yo IR1 test and post mean sprint time (Table 9). This is somewhat surprising, as other studies have found a correlation between high intensity running during a match and the Yo-Yo IR1 performance (Krustrup and Bangsbo 2001; Krustrup et al. 2003; Bangsbo et al., 2008). This could be due to different tests and testing procedures. In most of the studies, video match analysis was used during matches to measure the level of high intensity running and then correlated against the Yo-Yo IR1 test. This study measured 20 m straight line sprinting and correlated with the yo-yo IR1 test. It is difficult to compare these two types of measurements as varying distances and recoveries may have affected the results.

## **6.0 Conclusion**

No significant changes were observed between the groups when following a repeated sprint training program at either 100 % intensity or 90 % intensity over 7 weeks. Taking the effect size on the different parameters in this study into consideration, this type of training can't be recommended under elsewhere same conditions. A higher extend of individualization is probably necessary and a consideration of the baseline for each athlete is important if an individual should gain significant improvements. Probably other types of training (e.g. Strength training, intervals) could be more relevant to train for gaining improvements. However, it seems more difficult to improve speed ability than other abilities such as strength where it seems that the speed is more genetic dependent. However, this study gained important information regarding training volume at lower intensity and more research should be conducted on this field.

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## **Appendices**

- I Article
- II Information sheet
- III Information about the subjects
- IV Approval for publishing figures
- V Rated perceived exertion (RPE)

## Appendix I: Article

### Introduction

Soccer performance is determined by a variety of skills. Technical and tactical characteristics are considered most important, and Bradley, Lago-Peñas, Rey and Gomez (2013) reported that pass completion, frequency of forward and total passes, balls received and average touches per possession separated players of varying standard. Apparently, aerobic endurance and jumping capabilities should reach an “optimal” baseline (Tønnessen, Hem, Leirstein, Haugen, Seiler 2013, Bradley et al., 2013), while sprinting skills seem even more crucial (Haugen, Tønnessen, Hisdal, Seiler 2013a). There are different forms of sprinting skills in soccer: acceleration, peak velocity, agility and repeated sprint ability. Acceleration and peak velocity are important abilities for winning duels and reaching the ball first (Haugen et al., 2013a). In a team sport like soccer, maximal sprints are performed frequently with short breaks in between (Spencer, Bishop, Dawson and Goodman 2005), so called repeated sprint ability (RSA). If a player can't complete these sprints with a high quality at the end of a game, it may affect the match result (Spencer et al., 2005). Faude, Koch and Meyer (2012) observed that straight sprinting is the most frequent action in goal situations, and sprinting skills should therefore be included in fitness testing and training.

Sprinting abilities are heavily dependent upon genetic factors (Deason et al., 2012), and sprinting skills over short distances seems hard to improve within the constraints of overall soccer conditioning (Haugen et al., 2013a). Even though several studies have reported improved sprinting skills after conducting different interventions, no specific training methods have emerged as superior (Haugen et al., 2013a). Some studies have to some extent reported improvements in maximum sprint and RSA when performing specialized repeated sprint training with maximal intensity (Tønnessen, Shalfawi, Haugen and Enoksen 2011; Shalfawi et al., 2012; Harrison & Bourke, 2009). Unfortunately, maximal sprinting is the most frequent situation associated with hamstring injuries in soccer (Ekstrand, Häggglund, Waldén 2011a), and a large number

of players have had their entire season ruined because of such injuries (Arnason, Gudmundsson, Dahl, Jóhannsson 1996). It is reasonable to ask if players should perform repeated sprint training with reduced intensity and higher volume in order to prevent hamstring injuries. The combination of reduced intensity and thereby higher volume is common practice in both strength and endurance training (Faude et al., 2013; Schoenfeld et al., 2014, Kraemer, Ratamess, French 2002). Sprinting seems to be regulated by a complex interaction of multiple factors we fully don't understand yet, and there is probably a gap between science and best practice regarding sprint development of soccer players (Haugen et al., 2013a).

The purpose of this study was therefore to compare the effects of training at 90 and 100 % sprint speed on repeated-sprint ability in high level junior soccer players. The secondary aim was to compare the effects of this intervention on maximal sprint ability, countermovement jump (CMJ) and Yo-Yo Intermittent Recovery test Level 1 (Yo-Yo IR1). To the author's knowledge, a systematic comparison of these training regimes has so far not been conducted.

## **Methods**

### **Experimental approach to the problem**

There was conducted a 7 week long intervention on high level junior football players from the age 15-19 years. Repeated sprint ability (RSA), endurance performance (yo-yo test), lactate, heart rate and CMJ were measured both before and after the intervention. There was one day of restitution between the RSA test and the yo-yo test. The players were randomized into 3 groups by drawing. One group (n=16) trained 15\*20 meters laps with 100 % intensity with one minute between each lap, while another group (n=15) trained 30\*20 meters laps with 90 % intensity with one minute between each lap. The last group (n=10) worked as control and carried out the regular football training program as usual. After the training intervention, the same tests were conducted and results from pre to post were compared. This study was conducted in accordance with the declaration of Helsinki.

## Subjects

41 high level junior male football players ( $16.7 \pm 1.0$  yr.,  $71.1 \pm 9.4$  kg and  $181.2 \pm 6.1$  cm) were recruited to this project. The recruitment was through different top football junior teams who had their training fields in Oslo and nearby the Norwegian school of sport science (NIH). The subjects were informed that they could withdraw at any time during the study without having to give a reason. The subjects were paired for clubs and randomized into 3 groups through a drawing by an NIH student who didn't were involved in the project before the intervention started. By pairing for clubs and then randomize, the study eliminated the influence of varying overall football conditioning. There were 2 training groups and one control group. The subjects in the training groups conducted a 7-week intervention including testing before and after. There were 6 players who withdrew from extraneous reasons not related to the project. 2 were from the 90 % intensity group, 3 from the 100 % intensity group and 1 from control. Some of the participants are not included in analyzes because of injury or that they didn't completed enough of the training sessions. The 7-week training protocol and testing was carried out in the autumn 2013 (October to mid-December).

**Table 1: Training characteristics of the different groups.**

<b>Group</b>	<b>CG</b>	<b>90 %</b>	<b>100 %</b>
<b>Weekly training sessions</b>	<b><math>4,4 \pm 2,3</math></b>	<b><math>4,5 \pm 2,4</math></b>	<b><math>4,4 \pm 2,3</math></b>
<b>Games/week</b>	<b><math>0,4 \pm 0,4</math></b>	<b><math>0,4 \pm 1,0</math></b>	<b><math>0,3 \pm 0,7</math></b>
<b>Total training volume (h/week)</b>	<b><math>6,8 \pm 3,3</math></b>	<b><math>7,0 \pm 3,5</math></b>	<b><math>6,6 \pm 3,8</math></b>

The training groups performed repeated sprint training (RST) 1 time weekly in addition to normal training. The program consisted of 15 or 30 laps where the 100 % group performed 15 laps, while the 90 % group performed 30 laps. The control group trained as usual and was tested before and after the intervention with the training groups. Furthermore, the study controlled for training characteristics by asking the subjects every training session how many weekly training session they had, how many games they had played and the total amount of training volume (table 1). The subjects had to

complete at least five out of seven training sessions in addition to the performance tests for being included in further analyzes.

## **Testing procedures**

### **Familiarization**

There was not included familiarization sessions in this study because of the control group that controlled for the learning effect for the different testing procedures. None of the athletes had previous experience with this kind of testing or training from before.

### **Repeated Sprint test (RST)**

The repeated sprint test was performed on a sprinting court at Olympiatoppen (OLT). A standardized warm-up program with 10-12 minutes of running, 4 minutes of high knee-lifts and kickbacks with the legs and 3-4 maximum sprints were completed before the testing.

Before the RST, the subjects tested their jumping ability on an AMTI force platform (ORG6-5-1, Watertown USA) where they performed 3 counter movement jumps (CMJ) and the best result was written down. All jumps were performed with hands placed on the hips to isolate leg extensor muscles and minimize technical elements. Calculation of jump height is described by Haugen et al., (2012)

All the subjects performed 15 laps on 20 meters with 100 % intensity in each run with one minute breaks between them. 2 pairs of double infrared photocells, which were connected via cables and connected to a computer (PC Pentium 3), were used to measure the time. These cells measures the time to the nearest 0.001 second. Pulse and hart rate was measured between each run. After completing the 15 laps, the subjects measured their blood lactate (LactatePro LT-1710, Arkay KDK, Kyoto, Japan). Video-analysis was used on each lap to measure the number of steps for each subject by a Sony HDR-HC9E. The recordings were analyzed in ProSuite, version 5.5 (Dartfish, Switzerland) to determine stride count and derive average stride length. Mean SL was calculated by dividing the number of steps by the distance. Mean SF was calculated

from mean velocity and mean SL. A high speed camera was also used the first and last lap for measuring contact time and levitation time for the players. Moreover, EMG was used for measuring muscular activity in muscles related to running (m. gastrocnemius, m. soleus, m. vastus lateralis and m. biceps femoris). Both the high speed camera and the EMG gave insufficient measures and could not be used in further analysis.

### **The Yo-Yo intermittent recovery test (IR1)**

The second day, the subjects performed the football-specific Yo-Yo IR1 endurance test and was set up as described by Bangsbo (1996). The same test leader was used for all participants, and was therefore evaluated on the same level. A standard warm-up protocol was performed on pre-and post-test. This included a general warm up at low intensity for 10-12 minutes, followed by 5 minutes at higher intensity. Each subject had a marked 2 m wide tread, and the start and twists line was measured with 20 meters from each other. The lines were marked as solid lines from marked handball court. Restitution distance was marked with a cone centered in the tread 5 m basis launch. Heart rate monitors were used during the test for measuring heart rate and intensity level.

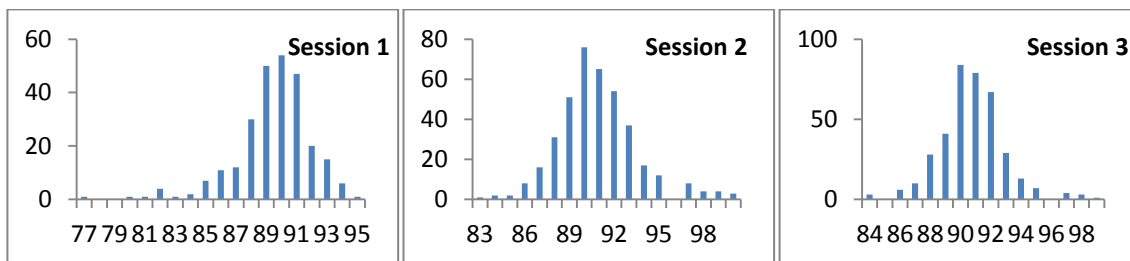
### **Training protocol**

The training consisted of an extra session with repeated sprint training in addition to the team's original training sessions with either 15 runs on 100 % intensity, or 30 runs on 90 % intensity. Photocells were used to control the intensity, and were a fine performance goal for the players. The control group continued to follow the teams' original training plan without the specific training. For comparing the two repeated sprint training sessions used in the present study, session rated perceived exertion (RPE) (appendix V) was recorded for all athletes after the repeated sprints performed in pretest and first training session. Written and verbal instructions regarding its use were provided in advance (Foster 1998).

### **Training performance**

Both of the training groups performed one training session per week for seven weeks in the period of October to mid-December. The 100 % intensity group performed 15 laps

on 20 meters with one minute between each lap. They were given instructions that they should take themselves completely out in each lap. The 90 % intensity group performed 30 laps on 20 meters with one minute between them. The first session they only completed 25 laps, but after consideration, the trainers decided to expand it to 30 laps because they were afraid that 25 laps on 90 % intensity weren't enough compared to 15 laps of 100 % intensity for gaining the best development in RSA performance. A test was conducted 48 hours after the first training session to examine if the 90 % intensity group received the same training load as the 100 % intensity group. The results is presented in table 4 The 90 % intensity groups were given a target time based on their best lap from pre-results of the repeated sprint test. On each lap, a trainer told them their time so the players could adjust how fast they should run for hitting their target time. Figure 3.4 and 5 shows intensity distribution for the 90 % group the 3 first sessions. After only one session, most of the sprints were between 87 % and 93 % of maximal sprint velocity.



**Figure 1, 2 and 3: Intensity distribution for the 90 % group. X-axis= intensity (of maximal sprint velocity), Y-axis = % of all runs.**

In the middle of the training period, the 90 % groups also performed a max run at the end of the 30 laps. If the players had a better max time, they would receive a new target time based on this. If there weren't any improvement of the max times, the players kept their originally target time. Lactate and heart rate was also measured in the middle of intervention on the 90 % groups to ensure that the training program was as hard as for those who run on 100 % intensity.

All of the groups performed a 10 minute standardized warm-up with jogging, kickbacks and high knee-lifts before each session started. Every session, there was at least one trainer who oversaw the training and guided the players.

## **Statistics**

Raw data were transferred to the SPSS 21.0 for Windows and Microsoft Excel for analysis. To detect differences in measurements between the pre- and post-tests, the paired sample t-test was used to evaluate the difference in means between the paired samples (within group). Analysis of covariance (ANCOVA) adjusting for pre-test value and stratification factor (club) was used to examine between group changes. The differences were judged by using estimated marginal means (EMM). Bonferroni corrections were used to adjust p-values for multiple testing. Effect size was calculated and log transformed using Hopkins spreadsheets for analysis (Hopkins, Marshall, Batterham and Hanin 2009). For determine whether the effect size was trivial ( $d > 0.2$ ), small ( $d = 0.2 - 0.6$ ), moderate ( $d = 0.6 - 1.2$ ), large ( $d = 1.2 - 2.0$ ), or very large ( $d > 2.0$ ), the scale developed by Batterham and Hopkins (2006) was used. Pearson's R was used to quantify the relationships among anthropometric and physical parameters. Differences were considered significant at  $P \leq 0.05$ , and the results were expressed as means and standard deviations. The 95 % confidence interval was calculated for all measurements.

## **Results**

Table 4 shows no differences in RPE between the sessions. There was also no difference in recovery between the groups 48 hours after the respective sprint training sessions. Sprinting at 90% velocity was accompanied with reduced HR peak (17%; very large effect;  $p < 0.001$ ),  $BLa^{-}$  (55%; large effect;  $p < 0.001$ ) and SF (11%; very large effect;  $p < 0.001$ ) compared to maximal sprinting. While heart rate plateaued after ~ 10th repetitions during the 30x20 m 90 % sprint training sessions, heart rate increased progressively throughout the 15x20 m 100% sprint sessions.



**Table 4: Effort related variables in maximal (100 % group) and sub-maximal (90 % group) sprinting.  $\Delta$  sprint time 48 h = pre-test time minus sprint time 48 hours after the first training session (mean of first 3 sprints for each time point), RPE = rated perceived exertion, HR peak = peak heart rate, BLa<sup>-</sup> = blood lactate concentration, SL = stride length, SF = stride frequency, \* = significantly different from 100 % sprinting ( $p < 0.001$ )**

<b>Sprint session</b>	<b>15x20m (100 % group)</b>	<b>30x20m (90 % group)</b>
$\Delta$ sprint time 48 h (s)	0.00 $\pm$ 0.02	-0.01 $\pm$ 0.02
Session RPE	3.8 $\pm$ 1.2	4.0 $\pm$ 1.1
HR peak (beats· min <sup>-1</sup> )	170 $\pm$ 10	141 $\pm$ 10*
BLa <sup>-</sup> (mmol·L <sup>-1</sup> )	4.4 $\pm$ 1.8	2.0 $\pm$ 0.7*
SL (m)	1.55 $\pm$ 0.08	1.56 $\pm$ 0.09
SF (strides/s)	4.36 $\pm$ 0.18	3.87 $\pm$ 0.22*

Table 5, 6 and 7 shows changes in analyzed performance parameters within groups from pre- to post-test. In the 100 % group, there was a significant difference within the group in SF, SL, body mass (weight) and BLa<sup>-</sup>. No within-group differences were observed in any of the groups for the performance parameters.

Table 8 shows between groups difference from pre- to post-test. No between-group differences were observed. The effect of the training was small to moderate for best sprint, SL, SF, CMJ, BLa<sup>-</sup> and HR in the 100 % group vs. the control group, and small to moderate in best sprint and BLa<sup>-</sup> in the 90 % group vs. the control group. When the 90 % sprint treatment was used as reference in an ANCOVA analysis, trivial and non-significant differences were observed. However, the effect of repeated sprint training on the 100 % group vs. the 90 % group was small for SL, SF, BLa<sup>-</sup> lactate and HR in favor of the 100 % group.

**Table 5: Differences within group in a variety of physiological measures for the 100 % group . Mean results of 15x20m repeated sprint, best sprint time, steplength, step frequency, CMJ, Yo-Yo IR1, weight, BLA- and heart rate within group from pre- to posttest ( $\pm$ SD).**

<b>100 % group</b>				
<b>Variable</b>	<b>Pre-test</b>	<b>Post-test</b>	<b>Mean change</b>	<b>95 % CI</b>
<b>15 x 20m mean (s)</b>	2,98 $\pm$ 0,15	2,98 $\pm$ 0,16	0,00 $\pm$ 0,04	-0,02 to 0,02
<b>Best sprint (s)</b>	2,94 $\pm$ 0,15	2,93 $\pm$ 0,15	- 0,01 $\pm$ 0,04	-0,03 to 0,01
<b>SL (m)</b>	1,56 $\pm$ 0,09	1,51 $\pm$ 0,11	- 0,05 $\pm$ 0,06	-0,08 to -0,02**
<b>SF (strides/s)</b>	4,33 $\pm$ 0,33	4,47 $\pm$ 0,36	0,14 $\pm$ 0,18	0,04 to 0,24**
<b>CMJ (cm)</b>	34,88 $\pm$ 4,75	35,35 $\pm$ 4,24	0,47 $\pm$ 2,62	-1,95 to 1,89
<b>Yo-yo IR1 (meter)</b>	1508,57 $\pm$ 276,85	1605,71 $\pm$ 332,61	97,14 $\pm$ 130,35	0,58 to 193,70
<b>Weight (kg)</b>	65,96 $\pm$ 8,73	66,78 $\pm$ 8,79	0,82 $\pm$ 1,31	0,11 to 1,53*
<b>Lactate (mmol·L<sup>-1</sup>)</b>	4,16 $\pm$ 1,54	5,69 $\pm$ 2,14	1,53 $\pm$ 1,08	0,94 to 2,12**
<b>Heart rate (beats·min<sup>-1</sup>)</b>	166,08 $\pm$ 9,62	167,31 $\pm$ 12,02	1,23 $\pm$ 5,89	-1,97 to 4,43

\* = p<0,05, \*\* = p<0,01, CI=Confidence interval, SF= step frequency, SL= steplength

**Table 6: Differences within group in a variety of physiological measures for the 90 % group. Mean results of 15x20m repeated sprint, best sprint, steplength, step frequency, CMJ, Yo-Yo IR1, weight, lactate and heart rate within group) from pre to post-test ( $\pm$ SD).**

<b>90 % group</b>				
<b>Variable</b>	<b>Pre-test</b>	<b>Post-test</b>	<b>Mean change</b>	<b>95 % CI</b>
<b>15 x 20m mean (s)</b>	2,98 $\pm$ 0,12	2,98 $\pm$ 0,11	0,00 $\pm$ 0,04	-0,02 to 0,02
<b>Best sprint (s)</b>	2,94 $\pm$ 0,12	2,93 $\pm$ 0,11	- 0,01 $\pm$ 0,04	-0,03 to 0,01
<b>SL (m)</b>	1,55 $\pm$ 0,09	1,55 $\pm$ 0,06	- 0,01 $\pm$ 0,07	-0,05 to 0,03
<b>SF (strides/s)</b>	4,34 $\pm$ 0,22	4,35 $\pm$ 0,17	0,01 $\pm$ 0,19	-0,09 to 10,01
<b>CMJ (cm)</b>	33,48 $\pm$ 3,96	33,32 $\pm$ 4,17	- 0,16 $\pm$ 1,60	-1,03 to 0,71
<b>Yo-yo IR1 (meter)</b>	1504 $\pm$ 376,27	1644 $\pm$ 401,09	140 $\pm$ 259,40	-20,78 to 300,78
<b>Weight (kg)</b>	72,23 $\pm$ 5,58	72,47 $\pm$ 5,13	0,24 $\pm$ 1,10	-0,36 to 0,84
<b>Lactate (mmol·L<sup>-1</sup>)</b>	4,25 $\pm$ 1,65	4,82 $\pm$ 2,01	0,57 $\pm$ 1,54	-0,27 to 1,41
<b>Heart rate (beats·min<sup>-1</sup>)</b>	173,54 $\pm$ 9,37	170,15 $\pm$ 13,66	- 3,38 $\pm$ 8,42	-7,96 to 1,20

\* = p<0,05, \*\* = p<0,01, CI=Confidence interval, SF= step frequency, SL= steplength

**Table 7: Differences within group in a variety of physiological measures for the CON. Mean results of 15x20m repeated sprint, best sprint, steplength, step frequency, CMJ, Yo-Yo IRI, weight, lactate and heart rate within group from pre to post-test ( $\pm$ SD).**

CON				
Variable	Pre-test	Post-test	Mean change	95 % CI
15 x 20m mean (s)	2,97 $\pm$ 0,14	3,00 $\pm$ 0,14	0,02 $\pm$ 0,03	0,00 to 0,04
Best sprint (s)	2,93 $\pm$ 0,13	2,95 $\pm$ 0,14	0,02 $\pm$ 0,03	0,02 $\pm$ 0,03
SL (m)	1,53 $\pm$ 0,08	1,52 $\pm$ 0,07	- 0,01 $\pm$ 0,05	-0,04 to 0,02
SF (strides/s)	4,42 $\pm$ 0,31	4,40 $\pm$ 0,29	- 0,02 $\pm$ 0,19	-0,14 to 0,10
CMJ (cm)	37,33 $\pm$ 3,52	36,61 $\pm$ 3,58	- 0,73 $\pm$ 1,37	-1,63 to 0,17
Yo-yo IRI (meter)	1546,67 $\pm$ 375,80	1693,33 $\pm$ 355,68	146,67 $\pm$ 236,87	-42,87 to 336,21
Weight (kg)	71,6 $\pm$ 11,22	71,98 $\pm$ 11,44	0,38 $\pm$ 1,20	-0,40 to 1,16
Lactate (mmol·L <sup>-1</sup> )	5,24 $\pm$ 2,67	4,78 $\pm$ 3,17	- 0,47 $\pm$ 1,27	-1,30 to 1,66
Heart rate (beats·min <sup>-1</sup> )	172 $\pm$ 12,19	167,44 $\pm$ 10,37	- 4,56 $\pm$ 6,62	-5,39 to -3,73

\* = p<0,05, \*\* = p<0,01, CI=Confidence interval, SF= step frequency, SL= steplength, CON=control group

**Table 8: Difference between groups in a variety of physiological measures. Mean results of 15x20m repeated sprint, best sprint time, steplength, step frequency, CMJ, Yo-Yo IRI, weight, BLA- and HR between groups from pre- to posttest ( $\pm$  CI).**

Variable	Between group differences in change score								
	100 % group vs. CON			90 % group vs. CON			90 % group vs. 100 % group		
	Diff $\pm$ CI	E.S	p-value	Diff $\pm$ CI	E.S	p-value	Diff $\pm$ CI	E.S	p-value
15 x 20m (mean) (s)	- 0,03 $\pm$ 0,04	0,18	0,57	- 0,02 $\pm$ 0,04	0,17	0,78	0,00 $\pm$ 0,04	0,01	0,83
Best sprint (s)	- 0,03 $\pm$ 0,04	0,22	0,24	- 0,03 $\pm$ 0,04	0,23	0,3	0,00 $\pm$ 0,04	0,02	0,89
SL (m)	0,04 $\pm$ 0,05	0,46	1	0,00 $\pm$ 0,06	0,04	0,54	-0,04 $\pm$ 0,05	0,5	0,96
SF (strides/s)	-0,16 $\pm$ 0,17	0,47	1	-0,02 $\pm$ 0,18	0,09	1	0,14 $\pm$ 0,15	0,46	0,65
CMJ (cm)	-1,20 $\pm$ 1,8	0,27	0,66	-0,57 $\pm$ 1,34	0,12	1	0,63 $\pm$ 1,78	0,15	0,47
Yo-yo IRI (meter)	49,52 $\pm$ 256,62	0,18	1	6,67 $\pm$ 279,1	0,03	1	-42,86 $\pm$ 206,72	0,15	0,69
Weight (kg)	-0,45 $\pm$ 1,13	0,05	1	0,14 $\pm$ 1,07	0,01	1	0,58 $\pm$ 0,99	0,08	0,23
Lactate (mmol·L <sup>-1</sup> )	-2,00 $\pm$ 1,1	1,15	0,24	-1,04 $\pm$ 1,26	0,63	0,24	0,96 $\pm$ 1,09	0,5	0,08
Heart rate (beats·min <sup>-1</sup> )	-5,79 $\pm$ 5,85	0,49	0,33	-1,17 $\pm$ 6,72	0,08	1	4,62 $\pm$ 5,93	0,46	0,12

\* = p<0,05, \*\* = p<0,01, CI=Confidence interval, SF= step frequency, SL= steplength, CON=control group, ES= Cohen's d (effect size)

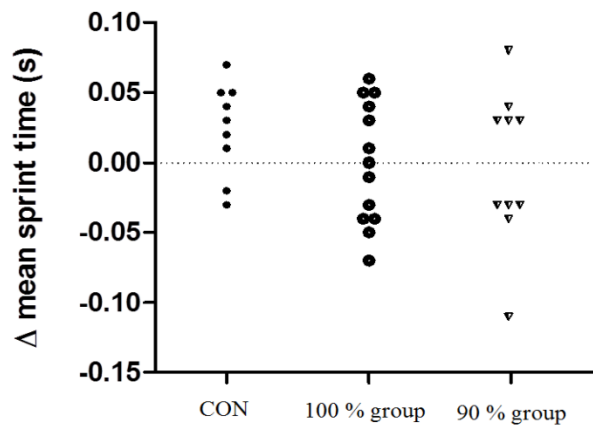


Figure 6: individual changes in 15x20 m mean sprint time from pre- to post-test.

Figure 7 show the development of repeated sprint performance (mean sprint time) for the 100 % group from week to week.

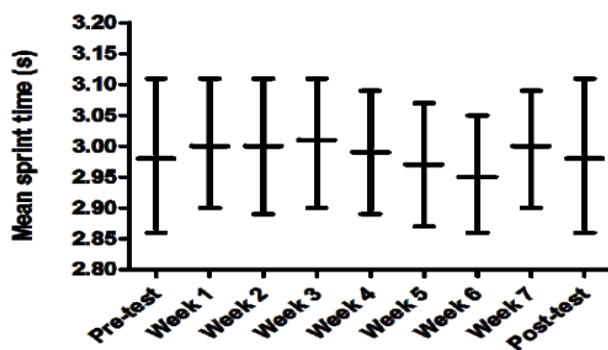


Figure 7: Change in mean time from week to week (100 % group)

Table 9 shows correlation values across analyzed variables. Overall, changes in BLA- from pre- to post-test were correlated with changes in HR, sprint times and CMJ performance by moderate to large margins. Changes in best sprint time showed a very large correlation with changes in mean sprint time. Changes in sprint times were moderately correlated with changes in CMJ performance.

**Table 9: Correlation values across analyzed variables. n=35 for all observations. Δ=change pre-post. BLa<sup>-</sup> = blood lactate concentration, CMJ = countermovement jump, SL = stride length, SF = stride frequency. \* = p <0.05.**

Variables	Upper r	r	Lower r
Δ BLa <sup>-</sup> (mmol·L <sup>-1</sup> ) vs. Δ CMJ (cm)	0.73	0.53*	0.23
Δ Best sprint time (s) vs. Δ CMJ (cm)	-0.20	-0.45*	-0.66
Δ mean sprint (s) vs. Δ CMJ (cm)	-0.19	-0.42*	-0.63
Δ heart rate (beats·min <sup>-1</sup> ) vs. Δ BLa <sup>-</sup> (mmol·L <sup>-1</sup> )	0.73	0.49*	0.16
Δ best sprint time (s) vs. Δ BLa <sup>-</sup> (mmol·L <sup>-1</sup> )	-0.07	-0.39 *	-0.62
Δ mean sprint time (s) vs. Δ BLa <sup>-</sup> (mmol·L <sup>-1</sup> )	0.01	-0.29	-0.54
Δ SL (m) vs. Δ SF (strides·s <sup>-1</sup> )	-0.90	-0.95*	-0.98
Δ best sprint time (s) vs. Δ mean sprint time (s)	0.94	0.87*	0.78
Yo-yo IR1 (meter) pre vs. mean sprint (s) pre	0.13	0.27	-0.60
Yo-yo IR1 (meter) post vs. mean sprint time (s) post	0.20	0.17	-0.52
CMJ (cm) pre vs. mean sprint pre (s)	- 0.53	-0.73*	-0.86
CMJ (cm) post vs. mean sprint post (s)	- 0.50	-0.70*	-0.83
CMJ (cm) pre vs. best sprint pre (s)	- 0.56	-0.73*	-0.86
CMJ (cm) post vs. best sprint post (s)	- 0.53	-0.69*	-0.84
SL (m) pre vs. SL post (m)	0.86	0.72*	0.52
SF pre (strides·s <sup>-1</sup> ) vs. SF post (strides·s <sup>-1</sup> )	0.89	0.77*	0.58
Best sprint time post (s) vs. BLa <sup>-</sup> (mmol·L <sup>-1</sup> ) post	- 0.27	- 0.48*	- 0.66
Mean sprint time post (s) vs. BLa <sup>-</sup> (mmol·L <sup>-1</sup> ) post	- 0.27	- 0.47*	- 0.66

## Discussion

In this study, no significant results were observed when comparing two training groups (100 % group and 90 % group) against a control group after a 7 week sprint training intervention. One weekly sprinting session with maximal or sub-maximal intensity was not sufficient to improve performance outcomes for football related sprinting performance. To the author's knowledge, this is the first study to compare the effects of sprint training at 90 % vs. 100 % intensity.

*Training volume:* In the present training intervention, 1:2 ratio was used for sprint repetition between the 100 % group (15x20 m) and the 90 % group (30x20 m). RPE was

rated equally by the subjects in the two different training regimes (Table 4). No differences were found in sprint performance between the 3x20 m sprints performed 48 hours after the first training session for the 100 % training group and the 90 % training group. This indicates a similar recovery status 2 days after performing different training sessions and that the two repeated sprint training sessions were effort matched. To date, no other studies have compared the effects between to different regimes where the training volume and training intensity are different.

*Effect of training at different intensities:* There was a significant change in both SL and SF from pre- to posttest in the 100 % group even though sprint performance remained unchanged (Table 5). This change was higher than the observed typical variation and it is possible that the 100 % group unconsciously shortened SL and increased SF in the chase of velocity enhancement, giving a subjective feeling of running faster. According to Mero and Komi (1986) and Mero, Komi and Gregor (1992), top athletic sprinters should try to improve performance by increasing SF while maintaining SL. However, among athletes of lower sprint standard, SL is considered a more limiting factor (Armstrong, Costill and Gehlsen 1984). There is a possibility that with supervised coaching, this would have ensured a more optimal combination of SL and SF, leading to a higher performance. The correlation values for SL ( $r = 0.72$ ) and SF ( $r = 0.77$ ) across the tests were surprisingly low when all groups were pooled together (Table 8). It seems that the same sprint performance can be achieved with varying locomotion efficiency among athletes who are untrained in terms of sprinting. This is also in accordance with observations made by Hunter, Marshall and McNair (2004).

In terms of intensity and volume, we cannot conclude that training at 90 % of maximal sprint intensity is sufficient for gaining improvements over short distances when training once a week (Table 6 and Figure 6). It has been shown that reduced training intensity can be compensated for with increased volume to enhance performance in strength- and endurance training (Kraemer et al., 2002, Seiler et al., 2013) However, sub-maximal sprint training is perhaps more appropriate for typical athletic sprinting distances (100-200 m) compared to 0-20 m accelerations used in this study.

*Effect sizes:* Previous studies have shown that sprint training regimes have provided positive results on soccer related sprinting skills and CMJ (Tønnessen et al. 2011, Shalfawi et al. 2012; Harrison and Bourke 2009). In Tønnessen et al., (2011), the subjects performed 40 meter repeated sprint training once a week and only gained improvements in RSA (10x40m) and 20-m maximal speed with a moderate effect compared to the control group, while no improvements in 20 m acceleration occurred. Harrison and Bourke (2009) reported significant improvements in acceleration speed after similar training. The study of Tønnessen et al., (2011) was carried out on elite junior players, and the athletes were only practicing one session per week. This may be a too little stimulant. It could also be that the participants in the study to Harrison and Bourke (2009) completed several maximum sprints up to 20 m in regular rugby training and games. Tønnessen et al., (2011) hypothesized that this may have improved their ability to accelerate. Since Tønnessen et al., (2011) saw improvements over 40 meter, they suggest that longer sprint distances could be a new and unaccustomed stimulant for soccer players, which again may result in positive muscular and neural responses (Mendez-Villanueva, Hamer, Bishop 2008; Ross, Leveritt, Riek 2001a; Tønnessen et al., 2011). However, it is important to note that even though no statistical improvements were found in the present study, there was a small effect size in best sprint (0.22) and CMJ (0.27) for the 100 % group. The 90 % group also had a small effect of the training in best sprint time (0.23). Shalfawi et al., (2012) conducted a similar training study with soccer players performing two training sessions per week. In this study the athletes performed four sets of 5x40 m with 90 seconds recovery between repetitions and 10 min recovery between sets. The results in this study revealed no significant difference between the sprint training group and the control group in 0–20 m sprint time, CMJ and squat jump (SJ). However, the effect of repeated sprint training on the training group was moderate and close to large in 0–20 m sprint time (1.1) and CMJ (1.1). The question is if other training forms (e.g. intervals, strength training etc.), perhaps in combination, is more effective for soccer players. The current study only revealed trivial to small effects in the 100 % group vs. the CON group and the 90 % group vs. the CON group in most of the parameters (table 8). Based on the modest effect magnitudes, it is

not recommended that soccer players should perform training regimes like this under otherwise identical conditions. Since there were no improvements, the players have most likely taken out much of their 0-20 m sprint potential during regular football training and it raises the question if a longer intervention or several sessions per week may have provided greater-improvements. However, the study of Shalfawi et al., (2012) showed that two training session per week were insufficient, and other types of training could be more effective for improving soccer-specific sprint abilities. It is also possible that longer intervention periods will lead to better outcomes. However, most team coaches will probably not “sacrifice” further football training sessions, even in the off-season or early pre-season when presented these results.

*Training intervention:* It is a question whether the recovery time between each sprint in the study of Tønnessen et al. (2011), Shalfawi et al. (2012) and the present study were too long compared to other studies for gaining improvements in the YO-YO IR1 test or mean sprint time (Dupont et al., 2004; Balsom et al., 1992b).

Balsom et al., (1992b) observed that when football players ran 15x40 m at maximal intensity, separated by 30 s recovery, the acute performance decline was 10 %. However, when the same training was performed with either 60 or 120 s recovery, the performance drop-off was reduced to 3 % and 2 % (Balsom et al. 1992b). There is a possibility that with shorter or more active breaks, the alactic system would not have been completely restored due to PCr and ATP resynthesis. This could have resulted in a higher demand for the aerobic system and in the end, an improvement of the aerobic capacity/YO-YO IR1 performance and mean sprint time. By using shorter recovery periods, the present study would perhaps have provided larger improvements in the YO-YO IR 1 test and mean sprint time because the requirements to the aerobic system would have been higher and possibly leading to an improvement in this parameter. According to Spencer et al., (2005), the recovery intervals used during repeated sprint training should be representative of the most intensive periods during a game, rather than the average of the game as a whole. However, this could lead to an overemphasis on the aerobic endurance aspects of the adaptive signal and underemphasize the



importance of acceleration and sprint quality, ultimately influenced the sprinting skills negatively. Coaches must take into account the demands of the sport and each athlete's specific capacity when designing a conditioning program. In a sport like soccer where sprinting skills are crucial, the training must balance between two extremities; the aerobic training should not ruin the quality of speed training. On the other side, the speed training should not be too short and specific so that a player can't hold for an entire match. A training program should therefore be based on the individual status of each players rather than training all players similarly.

*Coaching factor:* There are, to the authors' knowledge no studies that have seen on the effects of specific sprint training when training at lower intensity with coaching. This could be of interest since there has been shown in strength training that coaching could have a positive impact on performance even on simple technically exercises (Mazzetti et al., 2000). The idea of training with expert coaches should be examined further with other types of intervention. Instead of training all athletes in the same way, one should individualize the training to a much greater extent by coaching and instruction. It could also be of interest to examine the effects of gradual increase in intensity during training intervention from 90 % to 100 % sprint speed. In this way, the players gradually adapt to increasing speed and perhaps prevent injuries. This requires specific physiological expertise, and soccer coaches have to consider whether such knowledge should be included in the overall team staff.

*Injuries:* Sprinting in soccer is associated with a high number of hamstring injuries (Arnason et al. 1996; Opar et al., 2012; Ekstrand et al., 2011a; Hawkin et al., 2001; Henderson et al., 2010), and different ways for preventing this should therefore be examined. After 7 weeks of training, none of the drop outs in the 100 % group or the 90 % group were due to injuries related to the training intervention. However, it is reasonable to believe that more weekly training sessions increases the injury risk, at least when performing sprints with maximal intensity. Future studies should focus on how soccer players can enhance sprint performance without increasing the injury rate.

*Correlations across analyzed parameters:* A significant relationship between post mean sprint performance and post best sprint performance against blood lactate was found after the repeated sprint tests (Table 9). Since individual sprint performance depends upon the ability to fully activate fast twitch motor units with maximal firing frequency (Ross, Leveritt and Riek 2001), it is possible that an increased  $BLa^-$  during sprinting reflects a higher neural activation on an individual level. Individuals with higher percentage of type 2 fibers probably have a higher lactate production and glycolytic capacity than individuals with a higher percentage of type 1 fibers (Pascoe, Gladden 1996; Bottinelli R, Reggiani C 2000). However, it is important to note that the intracellular buffer capacity may vary considerably between individuals (Medbø et al., 1988; Sahlin and Henriksson 1984). In the present study lactate concentration in blood was taken immediately after the test. Medbø et al. (1988) showed that lactate in muscle was 33.6 ml/kg while extracellular lactate concentration (blood) was 10.4 ml/kg immediately after exercise on his subject's. Thus, the results in the present study must be interpreted with caution.

Table 9 shows a high correlation between changes in best sprint time and changes in mean sprint time during 15x20 m sprint from pre- to post test ( $r = 0.87$ ). Pyne et al., (2008) also reported a strong correlation between RSA and maximal sprinting velocity, and it seems that RSA has a stronger relationship to this parameter than endurance capacity. Also when the recovery time between each 20 m sprint was reduced to 25 s, the difference between mean time results and best time results remains small (Dellal and Wong 2013). Balsom, Seger, Sjödin and Ekblom (1992a) observed that it is more difficult to detect detrimental effects with short sprints compared to slightly longer sprints. There was a high correlation between pre mean sprint and post mean sprint with CMJ and post mean sprint and post best sprint with CMJ (table 9). However, the absolute time differences between best and changes in mean sprint performance were only moderately correlated with changes in CMJ performance among the subjects (Table 9). This is not in agreement with Wisløff et al., (2004) who reported a strong correlation between maximal strength, sprint performance and vertical jump height. However, Salaj & Markovic (2011) concluded that jumping, sprinting and change of

direction speed are specific independent variables that should be treated separately. Haugen et al., (2013b) observed that development in sprinting abilities may occur without development in CMJ ability.

No correlation was found between pre Yo-Yo IR1 test and pre mean sprint time (Table 9). There was neither any correlation between post Yo-Yo IR1 test and post mean sprint time (Table 9). This is somewhat surprising, as other studies have found a correlation between high intensity running during a match and the Yo-Yo IR1 performance (Krustrup and Bangsbo 2001; Krustrup et al. 2003; Bangsbo et al., 2008). This could be due to different tests and testing procedures. In most of the studies, video match analysis was used during matches to measure the level of high intensity running and then correlated against the Yo-Yo IR1 test. This study measured 20 m straight line sprinting and correlated with the yo-yo IR1 test. It is difficult to compare these two types of measurements as varying distances and recoveries may have affected the results.

## **Conclusion**

No significant changes were observed between the groups when following a repeated sprint training program at either 100 % intensity or 90 % intensity over 7 weeks. Taking the effect size on the different parameters in this study into consideration, this type of training can't be recommended under elsewhere same conditions. A higher extend of individualization is probably necessary and a consideration of the baseline for each athlete is important if an individual should gain significant improvements. Probably other types of training (e.g. Strength training, intervals) could be more relevant to train for gaining improvements. However, it seems more difficult to improve speed ability than other abilities such as strength where it seems that the speed is more genetic dependent. However, this study gained important information regarding training volume at lower intensity and more research should be conducted on this field.

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## Appendix II: Information sheet

### ***“Effekten av repetert sprinttrening på elite juniorspillere i fotball”***

#### **Bakgrunn og hensikt**

Dette er et spørsmål til deg om å delta i en forskningsstudie for å skaffe ny kunnskap om effekten av repetert sprinttrening på elite juniorspillere i fotball. Dette er en gyllen mulighet for å utvikle deg selv som fotballspiller. Vi vil undersøke hvordan repetert sprinttrening påvirker hurtighet, spenst og utholdenhet.

Hurtighet er svært viktig i fotball, og det er også evnen til å løpe hurtig mange ganger etter hverandre med korte pauser (repetert sprint). En hurtig spiller vil ofte nå ballen før andre spillere, og kan dermed skape eller forhindre målsjanser.

Tidligere studier på repetert sprinttrening har vist fremgang både på evnen til å løpe hurtig mange ganger etter hverandre (repetert sprintevne), og på aerob utholdenhet (oksygenopptak) og på agility (evnen til hurtige hastighetsforandringer).

Våre resultater vil kunne få konsekvenser for hvilke treningsmetoder som blir brukt for å få optimal prestasjon på fotballbanen, og det er mulig at dette også kan bli brukt i andre ballidretter.

#### **Hva innebærer studien?**

Det skal rekrutteres minst 60 mannlige elite juniorspillere som spiller fotball på høyt nivå. Selve treningsintervensjonen vil vare i 7 uker (uke 44 til uke 50) og det blir gjennomført tester før og etter treningsperioden (i uke 43 og uke 51). Dere blir tilfeldig fordelt ved loddtrekning i 4 grupper der 3 grupper trener ulike varianter av repetert sprint, mens den siste gruppen er kontrollgruppe.

Repetert sprintgruppene skal trene repetert sprint én gang i uken. Treningen vil foregå i idrettshallen på NIH. Prosjektet inkludert testing vil foregå fra uke 43-51, 2013.

Testingen før treningsperioden foregår i uke 43. Alle må teste 2 dager hver. Dagene som det er mulig å teste før treningsperioden (Pre-test) er tirsdag 22. oktober, onsdag 23.



oktober, torsdag 24. oktober og fredag 25. oktober. Alle må teste på 2 dager hver, vennligst gi beskjed så fort som mulig om hvilke dager som passer for deg. Testingen vil foregå på Olympiatoppen den første dagen og i idrettshallen på NIH den andre dagen. Det må være en hviledag mellom de to testdagene, så du kan enten teste på tirsdag og torsdag eller på onsdag og fredag, eller på torsdag og lørdag. Testdagene før og etter treningsperioden (Pre-test og Post-test) vil bestå av følgende tester:

- Vertikalt spensthopp m/svikt
- 15x20m sprint med start hvert minutt, samt puls, EMG målinger og laktatmålinger underveis
- Yo-Yo IR1, som er en aerob og anaerob utholdenhetstest

De som skal delta i prosjektet må møte uthvilte (ingen aktivitet 1-2 dager før testene) til Pre-test og Post-test. Testing til prosjektet vil utføres av fagansatte på den fysiske seksjonen ved Norges idrettshøgskole (NIH), og prosjektet ledes av Professor Eystein Enoksen tilknyttet seksjonen for fysisk prestasjonsevne, og Dr. Espen Tønnesen som er fagsjef for trening i Olympiatoppen.

Treningsøktene som er én gang i uka vil vare ca. 1 time (inkl. oppvarming, løpsdrill og repetert sprinttrening). Deltakerne må ha et minimum oppmøte på 70 % (5 av 7 totalt) av treningene for å bli inkludert i studien. Dersom forsøkspersonene trener andre ting enn fotballøker under treningsperioden, må dette noteres på et eget skjema som deles ut. Dagen etter første treningsøkt (uke 44) vil du gjennomføre en hurtighetstest for å kontrollere at treningsbelastningen er lik mellom gruppene.

### **Mulige fordeler og ulemper**

Som forsøksperson vil du få et profesjonelt treningsopplegg og nøye oppfølging av kvalifisert personell under treningen. Du får muligheten til å gjennomføre en del tester du ellers ikke ville fått tilgang til, slik at du vet hva du er god på og hva du kan forbedre for å bli en bedre fotballspiller. Du får også ny kunnskap om ulike typer trening slik at du lettere kan trene slike typer øker på egenhånd.

De ulike testene kan gjøre at du blir sliten og medfører tung fysisk belastning.

Forsøksperioden vil til sammen strekke seg over ca. 9 uker, og vil ta endel av din tid og

oppmerksomhet. Det vil være én treningsøkt i uka som hver varer ca. 1 time. Vi vil under hele perioden være samarbeidsvillige for å legge treningstidene til rette for deg. Du vil få et profesjonelt treningsopplegg og nøye oppfølging under hele perioden og dessuten tilbud om oppfølging hvis du ønsker å fortsette med slik type trening når intervensjonen er over. Det er alltid en liten skaderisiko når man driver tung fysisk trening, men med nøye oppfølging av kvalifisert personell under trening, så er denne risikoen minimal.

### **Hva skjer med prøvene og informasjonen om deg?**

Informasjonen du gir blir holdt anonymt. Testresultatene dine vil du og din trener få tilgang på (ved ønske), for alle andre vil resultatene dine holdes anonymt. Du vil få en tallkode på spørreskjemaet ditt. Denne tallkoden vil bli brukt om dataene som skal brukes av andre eller om studien blir publisert, noe som betyr at resultatene dine vil da bli holdt helt anonymt. Tester som blir gjennomført av deg og informasjonen som registreres skal kun brukes slik som beskrevet i hensikten med studien. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten og som kan finne tilbake til deg. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres.

### **Frivillig deltakelse**

Det er frivillig å delta i studien. Du kan når som helst og uten å oppgi grunn trekke ditt samtykke til å delta i studien. Dette vil ikke få konsekvenser for din videre behandling. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Om du sier ja til å delta, kan du senere trekke tilbake ditt samtykke uten at det påvirker din øvrige behandling. Dersom du senere ønsker å trekke deg eller har spørsmål til studien, kan du kontakte en av oss:

Masterstudent i idrettsfysiologi Øyvind Øksenholt, tlf: 908 68 258, epost:  
oyvindoo@student.nih.no eller o\_oksenholt@hotmail.com

Masterstudent i idrettsfysiologi Fredrik Lie Haugen, tlf: 988 01 608, epost:  
fredrikh@student.nih.no

Professor Eystein Enoksen, epost: eystein.enoksen@nih.no

Dr. Espen Tønnesen, epost: espen.tonnessen@olympiatoppen.no

### **Samtykke til deltakelse i studien**

For de som er under 18år, må foreldrene/foresatte godkjenne og signere samtykke.

Jeg er villig til å delta i studien

-----

(Signert av prosjektdeltaker, dato)

Foreldres/foresattes samtykke

-----

(Signert av foresatt, dato)

Jeg bekrefter å ha gitt informasjon om studien

-----

(Signert, rolle i studien, dato)

### **Appendix III: Information about the subjects**

**Navn (bruk blokkbokstaver):**

**Klubb:**

**Fødselsdato:**

**Høyde:**

**Telefonnummer:**

**Mail:**

## Appendix IV: Approval for publishing figures

Hello

My name is Fredrik Lie Haugen and I am a master student at the Norwegian school of sport science in Oslo. At the end of May 2014 I am going to hand my master thesis in, and I have a question regarding your study "Repeated-Sprint Ability – Part II Recommendations for Training". Here, you use a model to explain the factors that may be contributing for the repeated sprint ability. I wonder if I could use this model in my paper since it is relevant for my thesis.

Sincerely  
Fredrik Lie Haugen  
Norwegian school of sports science

Olivier GIRARD [oliv.girard@gmail.com]

Handler

Til:

[Fredrik Lie Haugen](#)

4. mai 2014 18:41

Dear Fredrik,  
There is absolutely no problem.  
Best wishes,  
Olivier

Til:

[Fredrik Lie Haugen](#)

7. mai 2014 20:06

Hi Frederick,

Thanks for the email and congratulations on completing your thesis.

I can't see any problem in using any figures in any of my publications as long as the source is properly acknowledged.

I hope this helps and all the best.

Cheers,

David

Professor David Bishop, Research Leader (Sport)

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## Appendix V: Rated perceived exertion (RPE)

Navn: \_\_\_\_\_

På denne 0-10 skalaen, hvor «hard» var sprinttesten?

Sett ring rundt tallet du synes passer best, ca. 30 min.  
etter at testen er avsluttet.

0	Hvile
1	Veldig, veldig lett
2	Lett
3	Moderat
4	Noe hardt
5	Hardt
6	
7	Veldig hardt
8	
9	
10	Maksimalt hardt







