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Changes in performance and heart rate during a soccer specific repeated sprint protocol, with and without instep-kick.



MASTER THESIS  
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## 2 ABSTRACT

### Purpose of this study

The main purpose of this study was to investigate the magnitude of changes in heart rate, and external parameters such as velocity and power, in young elite soccer players, following a protocol consisting of repeated sprints with directional change.

### Method

20 players, male (mean age 17.6 years  $\pm$  1.1, mean height 181 cm  $\pm$  5.8, mean weight 73  $\pm$  6.7), selected from the junior department of an elite soccer club. Test protocol consisted of 2 test days including 6 sprints with instep-kick, and 6 sprints without instep-kick, separated by 3 minutes recovery. Sprint distance 16+16 meters, start every 30<sup>th</sup> second. Measurements of heart rate using Polar Pulse Team2 systems, and ZXY Sport Tracking motion analysis for registration of velocity parameters. Protocol design AB-BA.

### Results

There is no significant effect on heart rate average and rate of increase ( $p > 0.05$ ) when comparing sprint blocks with and without ball. A significant difference was found for heart rate average with a p-value of 0.006, comparing day 1 with day 2. A significant reduction in peak velocity and peak power acceleration/deceleration (with p-values lower than 0.050) was found occurring mainly between sprint 2 and 3.

### Conclusion

Main findings indicated significant reductions in sprint performance for peak velocity and power around sprint 3. A significant increase was found for heart rate average from block 1 to block 2, thus indicating that heart rate changes was dependent on order. Instep-kick or no instep-kick had no significant impact on performance or heart rate average.

### Key words

Soccer, repeated sprint, intermittent activity, instep-kick, heart rate, accelerometer, velocity, power.

### 3 FREQUENTLY USED ABBREVIATIONS

ATP	Adenosine Triphosphate
BLa	blood lactate
HI	high intensity
HIA	high intensity activities
HR	heart rate
HRavg	heart rate average
HRmax	heart rate maximal
La	lactate
RI	rate of increase
RS	repeated sprints
RSA	repeated sprint ability
O <sub>2</sub>	oxygen
PCr	Phosphate Creatine
PeakPacc	peak positive power
PeakPdec	peak negative power
PeakVreturn	peak negative velocity
PeakVturn	peak positive velocity
RS	repeated sprints
VO <sub>2maks</sub>	maximal oxygen uptake
YYIR2	Yo Yo Intermittent Recovery2

## 4 INTRODUCTION

Current knowledge about soccer indicates that total distance ran by each player in a 90 minutes soccer game ranges 8-12 km, at an intensity near the anaerobic threshold (80-90% heart rate max) (Stølen et al, 2005). A player performs 10-20 sprints, 15 tackles, 10 headings, 50 involvements with the ball and several moderate to high intensity runs (Stølen et al, 2005). There are more than a thousand incidents in a game such as close contact with opponents, directional changes, controlling the ball etc., (Drust et al, 2007). Player involvements during matches are influenced by positional role, tactics, importance of game and motivation of the player (Impellizeri et al, 2005). Ball contact presented in mean time amounts to 0.3-3.1 minutes per player (Bangsbo, 1994).

Modern motion analysis reveals that there is a trend towards more running and higher tempo in international soccer (Carling et al, 2008). Elite players perform 28% more high intensity (HI) runs and 58% more sprints than sub-elite (Mohr et al, 2003). The increased pace of the game has made speed over short distances, alongside with agility, acceleration and deceleration, a requirement for modern soccer players (Reilly et al, 2003, Carling et al, 2008).

Match results are often decided during periods of high intensity activities (HIA), involving HI running and sprints (Carling et al, 2008). Sprints are important in order to reach the ball first, overtake an opponent, move into a space on the field or to create goal opportunities. The number of sprints and short recovery periods, demands high sprint endurance capacity (Hallen, 2008).

Motion studies shows that there are periods of HIA in matches, where a large number of HI running has to be performed. Sprints have an estimated average duration of 4 seconds (Spencer et al, 2005), and with a range in distance of 1.5-105 meters (Little et al, 2005). Sprints have to be repeated in an irregular pattern (Kotzamanidis et al, 2005). Thus an important requirement for team sport athletes is to repeat short sprints (<10 seconds) separated by short recovery periods (<30 seconds) (Edge et al, 2005). This fitness component has been named repeated sprint ability (RSA) (Brown et al, 2007). However, there is a lack of knowledge available on soccer players speed abilities (Kaplan et al, 2009), and what improves or limits RSA (Edge et al, 2005).

Bradley et al (2009) classified various activity categories stating that HI runs occur between 14.4-25.1 km/h, and sprints from 25.2 km/h, whereas others use >30 km/h as a limit for sprinting (Bangsbo, 1994). Findings from Premier League matches 2005-06 season (Bradley et al, 2009) are in accordance with other studies (Carling et al, 2008) with regard to the amount of HIA, suggesting that HIA amounts to approximately 10% of total activity. It is these 10% that distinguish elite from sub-elite (Hallen, 2008).

Repeated sprints (RS) affect sprint performance. But little work has been done on the area specifically related to soccer (Spencer et al, 2005). Despite this, RS are frequently used in soccer training and testing. This due to the logical validity (Impellizzeri et al, 2008), and the fact that RS induce similar metabolic responses as occurring in matches such as reduced pH, Phosphate Creatine (PCr) and Adenosine Triphosphate (ATP) stores, and indications of elevated glycolysis (Bravo et al, 2007).

There is some controversy regarding the precise contribution of energy systems during intermittent soccer activity. Aerob metabolism dominates energy delivery during soccer matches, but the most important movements requires larger contributions from anaerob metabolism (Stølen et al, 2005). The number of jumps and sprints per match makes anaerob contributions important (Chamiri et al, 2004). The degree of aerob contribution in soccer is to a significant effect linked to duration of matches. Thus 90-98% of energy needs are covered by aerob metabolism (Hoff et al, 2002, Bangsbo, 1994). Aerob contribution in single sprints is minimal, but in RS this is progressively increasing (Spencer et al, 2005). Duration and number of sprints, combined with duration of recovery and specificity of activity, influences metabolic responses and physiological recovery (Brown et al, 2007, Bravo et al, 2007). Previous theories indicated that short bouts of intermittent work (<10 seconds) required predominantly aerob metabolism to maintain ATP resynthesis (Glaister, 2005). Furthermore some authors state that a high maximal oxygen uptake ( $VO_{2maks}$ ) may increase contribution of aerob systems to energy production in early stages of exercise and recovery periods (Brown et al, 2007). But opinions regarding the role of aerob factors in increasing performance for RS and recovery from RS are divided (Brown et al, 2007).

Mechanisms causing fatigue in soccer is difficult to identify precisely. By using time-motion analysis, fatigue in soccer has been seen as reductions in amount of HIA (in most cases as reductions in HI runs) both towards the end of matches and in periods during matches (Mohr

et al, 2003). In more detail, these fatiguing periods appear as blocks lasting for 5 minutes, being most pronounced in the subsequent period following the most intense 5 minutes blocks. Thus fatigue is suggested to appear periodically (Krustrup et al, 2003), resulting in reduced performance in HI runs and HIA. Players who are able to repeat sprints at a high level with high intensity, will perform better than those players who fatigue more and are unable to maintain the intensity. Fatigue in RS is manifested by the first sprint being faster than the subsequent sprints (Lakomy et al, 2004). There are several contributing physical factors regarding fatigue in RS. Rapid repeated changes in velocity and powerful turns require high power production (Little et al, 2005), thus increasing physiological demands.

The physiological demands related in particular to intermittent HIA, requires specific tests that resemble match activity, because continuous running patterns in tests cannot immitate the irregularity of intermittent movement patterns in soccer matches adequately (Svensson et al, 2005,). No precise measures of aerobic/anaerobic factors in soccer HIA have so far been put forward (Spencer et al, 2005); indirect measurements such as estimating physiological loads through total distance, oxygen (O<sub>2</sub>) deficiency to calculate anaerobic values, or calculating aerobic values based on relationships found in laboratory settings, have proven unsatisfactory (Bangsbo, 1998, Stølen et al, 2005). Direct measurements of VO<sub>2max</sub> is difficult because that equipment restrict the players' natural movements (Stølen et al, 2005). Direct measurements of anaerobic values are mostly done using invasive methods to establish blood lactate (BLa) values, requiring immediate access to players post exercise. The ability of BLa to indicate anaerobic lactic contribution to ATP production is however limited (Glaister, 2005), and BLa concentration under-rates production of lactate (La) (Bangsbo, 1994). Field tests have high ecological validity (Svensson et al, 2005), but few studies have checked validity of RS protocols (Spencer et al, 2005). However a significant relationship exists between RSA and very HIA in soccer matches (Impellizzeri et al, 2008).

Heart rate (HR) measurements are common in soccer. The equipment is portable, and is of no hindrance to players' movements. HR monitoring has been used in matches (Strøyer et al, 2004), and values are mostly in the range of 150-190 during a match (Bangsbo, 1994). HR is considered a useful indicator of circulatory strain, and thus metabolic activity (Drust et al, 2007, Esposito et al, 2004), and found to be a valid measure of actual exercise intensity in endurance types of training modes (Hoff et al, 2002) and estimation of energy expenditure during intermittent activity (Bangsbo, 1994). However HR does not reflect energy



expenditure in all types of activities, having a lag at the initial stages of activity, and an elevation lasting into resting periods in between activities (Drust et al, 2007). In the literature there are diverging opinions on the value of HR in intermittent activity. Some authors state that the use of HR measurements in RS may prove difficult, due to the intermittent nature of the test (Chamari et al, 2004), whereas others state that HR may be the better method for evaluating RSA, compared to BLA and performance data, due to differences between sprints in aerobic response (Brown et al, 2007). In any way, HR during strenuous non-steady-state physical work (like RS) provides information about the stress on the cardiovascular system, and thereby indirectly about the energy expenditure (but in an ambiguous manner).

Motion analysis is a method of quantifying external training load, and may reveal relevant weaknesses of players (Carling et al, 2008). Motion analysis reveals reduced performance in HIA, but little is stated as to whether these reductions are related to maximal velocity, acceleration/deceleration or other speed components (Bradley et al, 2009). Accelerometers may provide accurate information regarding intensity, frequency and duration of activities (Plasqui et al, 2005). The technological development within the area is rapid, and new features are constantly being added and used in practical settings, without having devices or methods scientifically tested.

To the knowledge of this study, no other studies have combined HR and tracking devices containing accelerometers and positional signal technology, in order to investigate RSA in junior elite players. Thus the main purpose of this study is to investigate the magnitude of changes in HR, and external parameters such as velocity and power, in young elite soccer players, following a protocol consisting of repeated sprints with directional change. This project hypothesizes that the number of sprints will lead to elevated and consistently high levels of HR, and induce reductions in velocity and power parameters. It was not the aim to estimate energy expenditure from HR (and external load). However, because of the practical relevance, this issue will be discussed.

## **5 METHOD**

### **5.1 Participants**

The present field study used players from the junior department in an elite soccer club in the Norwegian top division. 20 male junior elite players (mean age 17.6 years  $\pm$  1.1, mean height 181 cm  $\pm$  5.8, mean weight 73  $\pm$  6.7) participated in the field study. A verbal agreement was obtained by the physical coach of the club, on behalf of the players.

### **5.2 Field test protocol**

The physical coach of the club was in charge of both test days, using the coaches of the junior team as assistants. The subjects performed test 1 on monday, test 2 on wednesday. Both tests were performed at 4.30 p.m. in mid January as part of the preparatory phase in the training season. The 1<sup>st</sup> block included 6 sprints with instep kick and the 2<sup>nd</sup> block included 6 sprints without instep kick on test day 1. The reverse sequence was performed on test day 2. One sprint consist of 16 meters sprint straight forward, then a 180 degrees turn at a cone marking the turning point, then 16 meters sprint straight forward back to the finishing line. Thus total sprint distance for one sprint was 32 meters. The players started a new sprint every 30 seconds, meaning that recovery time would be 30 seconds minus running time. Players were given a verbal feedback 5 seconds prior to start of each new sprint. Recovery time between the 2 sets of sprints for day 1 was 2 minutes 54 seconds, and 2 minutes 40 seconds for day 2. The players were instructed to stand erect and minimize movements when finishing each sprint. This was instructed in order to minimize movements registered by the ZXY Sport Tracking system in recovery periods between sprints, and between blocks. This allowed for clearly identifiable offset signals of the ZXY system.

The sprint distance was measured using tape-measure. Running track was outlined using the 16 meters end-marking line as starting line, and cones marked the turning point. The players were instructed to run forward in a straight line, and turn 180 degrees when their feet were in line with turning point marked with a cone (see figure 3). The players were instructed to use maximum force when performing the instep kick and to aim straight forward. The ball that players kicked was placed on the finishing line. Players were familiar with the running part of the protocol, having used this in their training regime. However, the introduction of the instep kick in the sprint block, was new to all players. The test was used as a part of normal training regime, and not added to the team's weekly training dosage. The team was in the initial stages of the preparatory phase of their season. Prior to sprints subjects performed a warm-up program of approximately 20 minutes duration. Warm-up program consisted of various

routine soccer drills, with and without ball. No specific playing exercises were used. Intensity was not controlled by any means, other than coaches monitoring players and encouraging to light-moderate efforts, and providing drills constructed for this purpose. This program was constructed and led by the head coach of the junior department.

The entire implementation of the test protocol was constructed, and led by the physical coach in Rosenborg Ballklub, and was performed as a normal routine of the training protocol for the junior team. All measurements were led and supervised by the physical coach, and representatives from ZXY Sport Tracking Systems AS. Prior to testing all players were gathered in the club house next to training field. Here instructions on how to apply Polar HR monitoring belt and ZXY monitoring belt were given by head coach. A list containing all names of players and pre-assigned numbers of ZXY and Polar belts were used in order to ensure that the same players wore the same belts at both tests. Master students were assisting when called upon by the physical coach, otherwise an observational status was maintained throughout both test days.

The weather conditions on test day 1 was minus 6 degrees Celcius, test day 2 minus 9 degrees Celcius. There were no snow in the air or on the pitch and otherwise stable conditions. The test was performed on artificial turf with underheating.

### **5.2.1 The instep-kick**

The technique is commonly used in soccer. The kick is purposeful for achieving high ball-velocities, and requires powerful use of leg muscles in order to achieve a rapid forward motion of the swing-leg. This leg is kept as straight as possible when ball contact occurs on the dorsal surface (in the area of shoe laces) of the foot (Kellis et al, 2007).

## **5.3 Measurements**

### **5.3.1 Performance data**

The devices used for sampling of performance data is the ZXY tracking device (ZXY Sport Tracking AS, Trondheim). The ZXY tracking system is a wireless position registration system using Cordis RadioEye<sup>TM</sup> (RadioNor Communications AS, Trondheim). Key features of ZXY Sport Tracking System is the ability to compute and store positions of all players on the soccer field at a sample rate of 40Hz. The system keeps track of all situations on the field and stores this data automatically. The system consists of positioning sensor, sport chip, live

video, PC suite and a server. The calibration of the system was performed using a radio-controlled vehicle with a ZXY sports chip (10 gram, 42·32·12 mm) attached. The resolution of the system for the current data collection was about 50 cm.

The ZXY system records player position in 2 dimensions, and acceleration in 3 dimensions. From this, parameters related to external work load such as position, power, velocity, acceleration and deceleration were obtained. From position, velocity and acceleration, work and power were calculated. Work and power were calculated as; work = mass·acceleration·distance, and power = mass·acceleration·velocity. To calculate force, players mass was obtained. The weight of players were measured by using a digital weight. All players were measured prior to training, wearing normal outdoor training clothing. Clothing was not deducted from total weight, because due to winter conditions players were going to perform test protocol wearing that particular amount of clothing. The acceleration direction and the distance direction must be the same in order to calculate it. Acceleration data were planned to be used for calculation of force and thereby power. To do this with a decent accuracy, the orientation of the accelerometer must be known or assumed to be constant. As the orientation at this stage could not be measured properly, it was decided that sprints were to be performed in a straight line with 180 degrees turns. Still, the data for the horizontal accelerations often resulted in unrealistic values. This was most likely because of inter player differences in upper body movements resulting in differences in orientation of the electronic chip. This should have been tested in laboratory settings prior to field test, in order to establish more accurately the possible effects of upper body movements on accelerometer positioning. Hence, the accelerometer data were decided to be ignored in further analysis, and all values were based on positional data.

### **5.3.2 HR data**

To measure heart rate, Polar Team 2 systems were used. Key features of the system are the ability to record and study HR data in real time for players. The system may provide data relevant for indication of aerob metabolic contribution during the RS-protocol, in order to estimate energy expenditure and thus use HR as one aspect of work load. Polar Team 2 Pro set includes a base station, transmitter charger, transmitters, Team 2 WearLink and the software for PCs. Measurements of HR were performed during exercise and recovery periods. Polar Team 2 system was set to sample heart rate at 0.33 Hz.

### 5.3.3 Processing of performance data;

Prior to analysis of the collected data material, calculations were done in Matlab (R2009b, The MathWorks, Natick, MA).

The start and stop of sprints were determined by visual inspection of the signals obtained (see figure 1). The start of each sprint was identified as when power exceeded the zero level and remained above zero until reaching the earliest distinct peak. The end of each sprint was defined as the last negative power peak. This always occurring close to the initial position of player defined as the starting point. This was determined as the point where breaking power peaked and started to decrease, thus player had reached finishing line. The 0-line represents the line where no activity occurs. Maximal duration of time intervals were set to 9 seconds (thus assuming that no sprint lasted for more than 9 seconds). Peak values for negative and positive power, were determined as the highest peak value, irrespective of when this occurred (turn or return run).

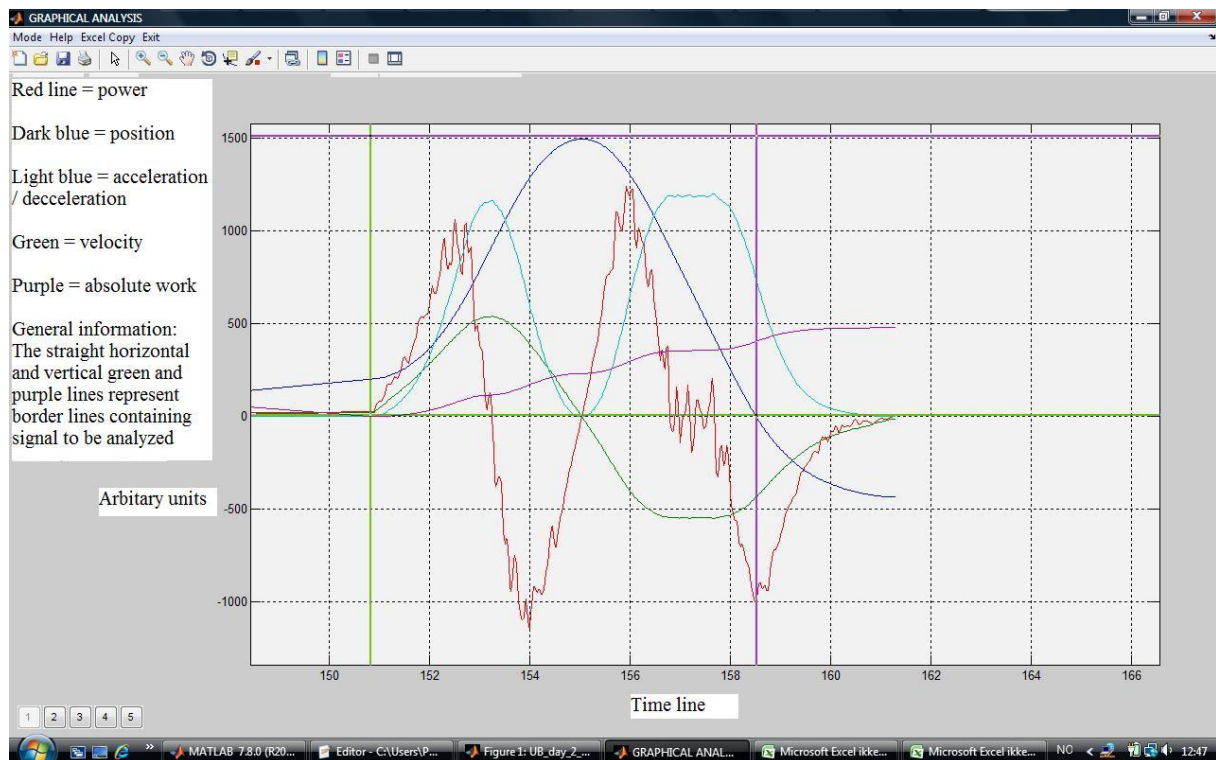


Figure 1. Identification of start and end of sprint, using signals displayed in Matlab. The various colored lines represents power (red), position (dark blue), velocity (green), acceleration/deceleration (light blue), absolute work (purple). The horizontal and vertical straight green and purple lines, represents borderlines containing signals to be analyzed.

The ZXY position data were recorded for both running direction (x) perpendicular to this direction (y) in the horizontal plane. It was assumed that no or little deflection in the time-series of the performance variables in the y-direction would occur, as the players ran in straight lines in one direction. The expectation was confirmed, by checking a small number of signals. Therefore, the y-direction was not considered further in the analysis.

The position data were low pass filtered in the ZXY system (frequency band 0-1Hz), and performance parameters were calculated from these. Power was calculated as the product of velocity, acceleration, and body mass. Both positive and negative power peaks were found. Peak power acceleration (PeakPacc) is produced during acceleration and peak power deceleration (PeakPdec) during deceleration. In the present analysis, the location of occurrence (during turn or return run) of these peak powers was not identified.

Acceleration and velocity were derived by applying a 5-point differentiating filter on the position-time trace once and twice, respectively. Peak velocity turn (PeakVturn) and peak velocity return (PeakVreturn) runs were recorded as positive and negative respectively.

### 5.3.4 Processing of HR data

HR signals were processed using Polar Team 2 software in order to obtain HR values measured during test days (see figure 2). The present project use HR average (HRavg) and rate of increase (RI). HRavg was calculated for each sprint block using values obtained from sprint 1-6. RI was calculated using differentiating filter (3 point).

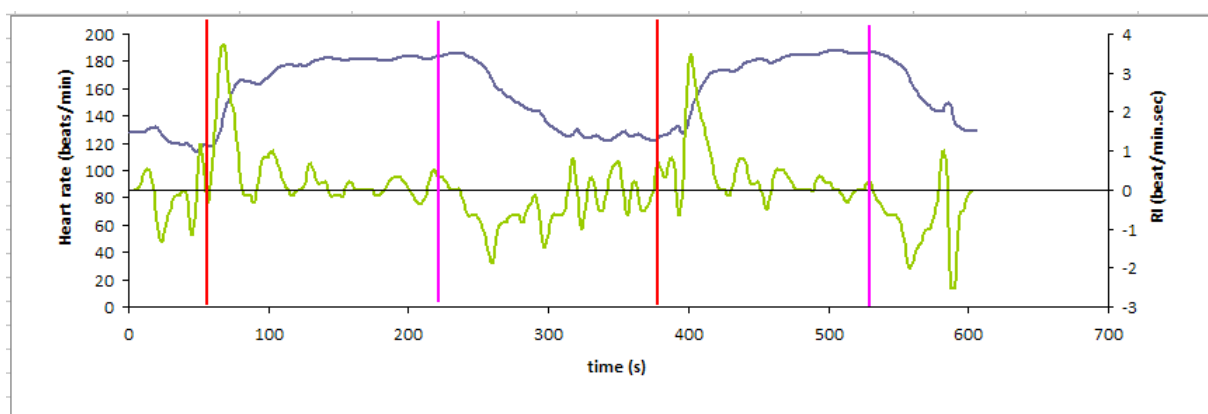


Figure 2. HR values during all sprints 1-6 both blocks day 2. Red vertical line indicate start of sprint 1 block 1 and 2. Purple vertical line indicate end of sprint 6 block 1 and 2.

The club uses a standardized method based on findings by Krustup et al (2003), to estimate players individual maximal HR (HRmax) values. The authors state that peak HR in Yo Yo

Intermittent Recovery2 (YYIR2) test corresponds in  $96\pm 1\%$  to peak HR attained on treadmill tests. HRmax is thus estimated from these HR values obtained at the end of the test, and divided by 0.96. The method is based on findings indicating that at 1720 meters, or towards end of YYIR2-test, soccer players reached an average 96% of peak heart rate. The club performs the YYIR2 test in March/April every season.

## 5.4 Statistical analysis

A Repeated Measures ANOVA was used to test for blocks and day effects in SPSS version 17.0. Results are presented as means and standard error of the mean.

Table 1. Analysis of ZXY data.

	Block 1	Block 2
Day 1	Instep kick ZXY data	No instep kick
Day2	No instep kick ZXY data	Instep kick ZXY data

Table 2. Analysis of HR data.

	Block 1	Block 2
Day 1	Instep kick HR data	No instep kick HR data
Day2	No instep kick HR data	Instep kick HR data

Due to technical reasons, the ZXY data were missing for day 1 block 2. This means that a full 3-way ANOVA (conditions (kick/no kick), day and sprint number) could not be performed. A 2-way ANOVA (day and sprint numbers) was performed for comparing the “kick” condition on day 1 and day 2, where the order of the sprint block was the main difference between days. This test was considered as a kind of test-retest for the conditions (oblique arrow table 1). The main test was the 2 way ANOVA (conditions and sprint numbers) performed on the 2 blocks on day 2 (horizontal arrow table 1).

For HR a complete set of data was obtained for 8 players both days. Therefore a full 2 way ANOVA was performed (conditions and days). Sprint numbers were not included (because of synchronisation limitations and the slow HR response).



Figur 3. Red dots illustrates cones marking start/finish and turning point for sprints. Black line between red dots illustrates running course. Ball was placed on the white 16 meter line when sprint blocks including instep-kick was performed.



## 6 RESULTS

This project performed a field test, using AB-BA test format. Due to lack of complete data day 1 block 2, the format for analysis was changed to A-B-A design.

Table 3. Number of subjects included in analysis.

	Number of subjects included in analysis			
	Day 1 block 1	Day 1 block 2	Day 2 Block 1	Day 2 block 2
PeakVturn	16	none	18	17
PeakVreturn	16	none	18	17
PeakPdec	16	none	18	17
PeakPacc	16	none	18	17
Hravg/RI	8	8	8	8

### 6.1 Performance data

Figures 3, 4, 6 and 7 show the results on velocity and power. The ANOVA statistics on these data are summarised in table 4. Return velocity and both power in acceleration and deceleration show a significant main effect for sprint number. Contrast analysis (difference) revealed that the effect of sprint number occurred mainly between sprint numbers 2 and 3. That is, during sprint 3 a change occurred in comparison with the previous sprint, which remained over the last three sprints. However the differences for the subsequent sprints were smaller (non-significant).

The 2-way ANOVAs between day 1 and day 2 data (test – re-test) showed no significant effect for day (i.e., block order).

Table 4. Summary of main findings on performance data.

Summary main findings ZXY data					
Variable	Sprint number day 2 with/without instep-kick	Kick day 2 with/without instep-kick	Interaction day 2 with/without instep-kick	Test-retest on sprint number	Test-retest on block order
PeakVturn	-	<i>p=0.054</i>	-	p=0.002	-
PeakVreturn	p=0.001	p=0.044	-	-	-
PeakPacc	p=0.001	-	-	-	-
PeakPdec	p=0.016	-	<i>p=0.056</i>	p=0.005	-

Significance level is set to  $p < 0.050$ , hence values in italics are not significant, but close to significant.

Cells containing “-“ has a p-value  $> 0.079$ .

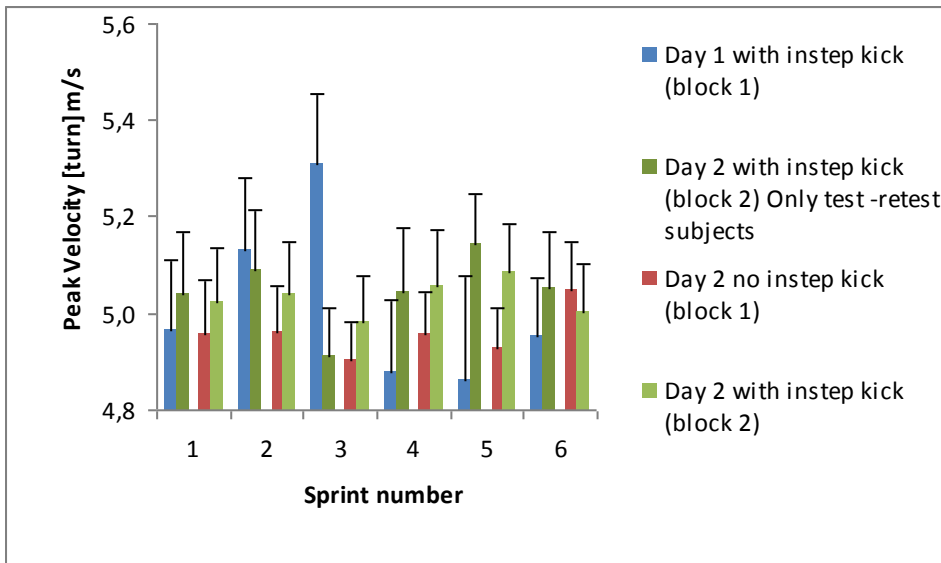


Figure 3. PeakVturn results. The columns represent the mean group values for subjects that were included in statistical analysis of test-retest and of comparison of with or without kick condition. Vertical bars indicate standard error of the mean.

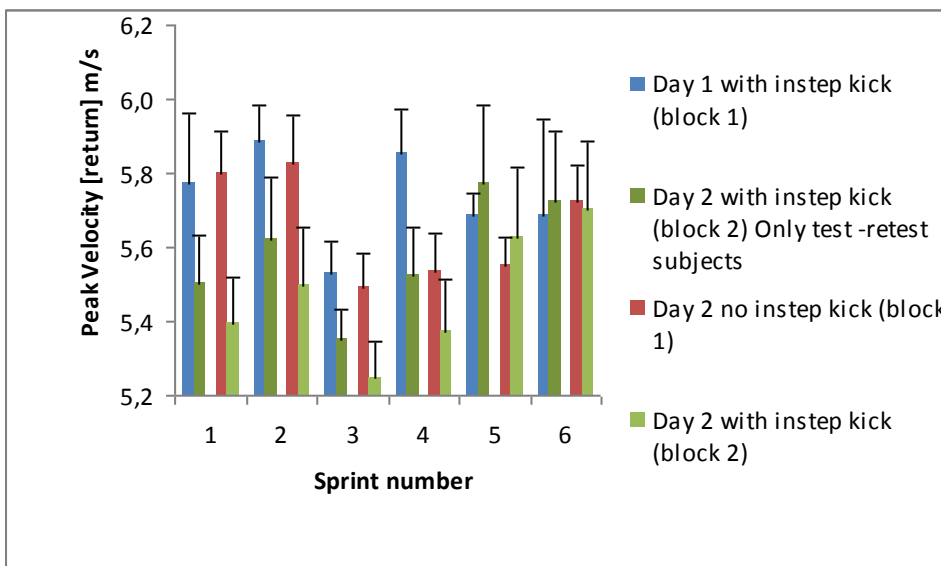


Figure 4. PeakVreturn all sprints. The columns represent the mean group values for subjects that were included in statistical analysis of test-retest and of comparison of with or without kick condition. Vertical bars indicate standard error of the mean.

Figure 5 shows the difference between turn and return velocities. The average values for each player on day 2 were significant (paired t-test,  $p < 0.001$ ). This indicates higher velocity on the return run.

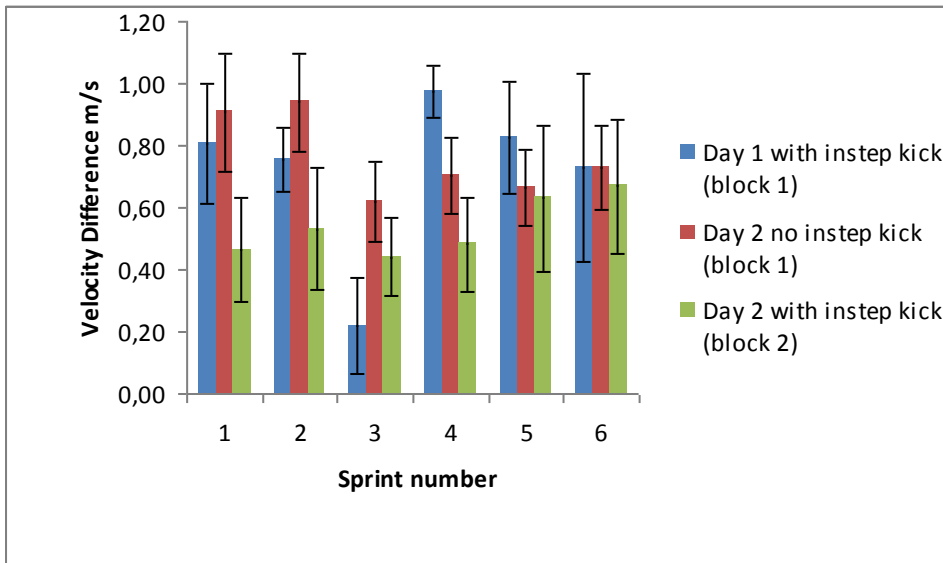


Figure 5. Differences between turn - and return velocities. The columns represent the mean data for all subjects (n=15 day 1 with instep-kick, n=18 day 2 no instep-kick, n=17 day 2 with instep-kick). Vertical bars indicate standard error of the mean.

The main findings for PeakPacc and PeakPdec indicate a similar pattern as for velocity (though not entirely similar): An evident change occurred mainly between sprint number 2 and 3, whereas the difference between other sprint numbers were smaller (not-significant).

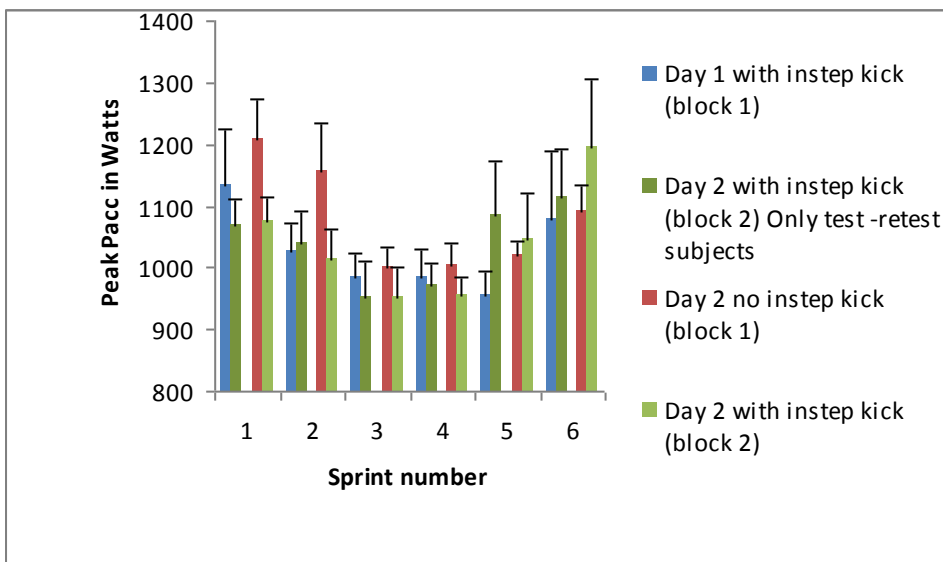


Figure 6. PeakPacc all sprints. The columns represent the mean group values for subjects that were included in statistical analysis of test-retest and of comparison of with or without instep-kick condition. Vertical bars indicate standard error of the mean.

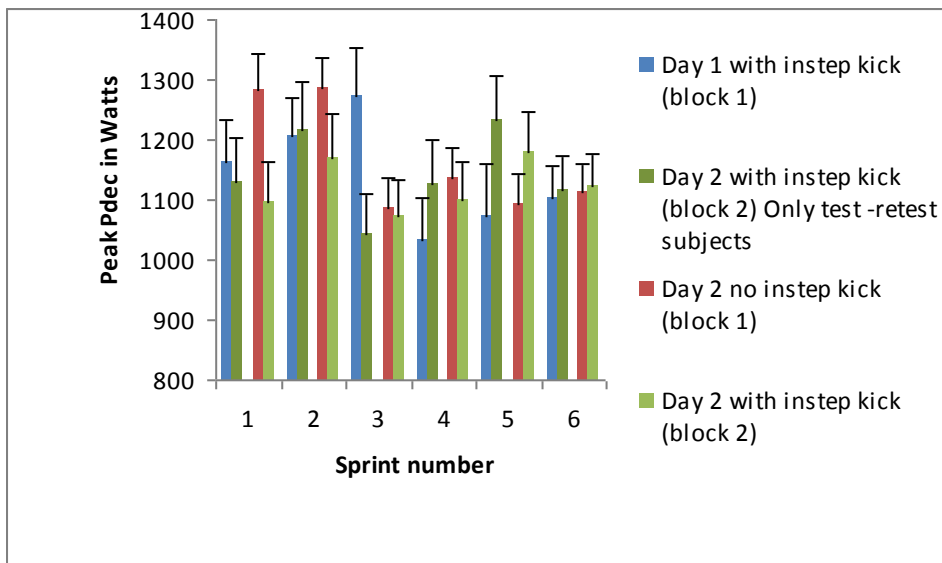


Figure 7. PeakPdec all sprints. The columns represent the mean group values for subjects that were included in statistical analysis of test-retest and of comparison of with or without instep-kick condition. Vertical bars indicate standard error of the mean.

## 6.2 Heart rate

Results for HRavg and RI suggests that when comparing sprint blocks with and without ball, there is no significant effect on HR average and RI ( $p > 0.05$ ) (figure 8-9).

When comparing day 1 and day 2, there is a significant difference in HRavg with a p-value of 0.006, with HRavg being higher on day 1. No such significant difference is found for RI when comparing the 2 days. A significant effect is found for the interaction between the different conditions, and the 2 days, for HR average and RI (p-value=0.002 for both parameters).

HRavg is higher in block 2 compared to block 1, whereas RI is higher for block 1 compared to block 2. The changes between instep-kick and no instep-kick on the separate days (taken in isolation) are likely due to the other essential difference in blocks and the order.

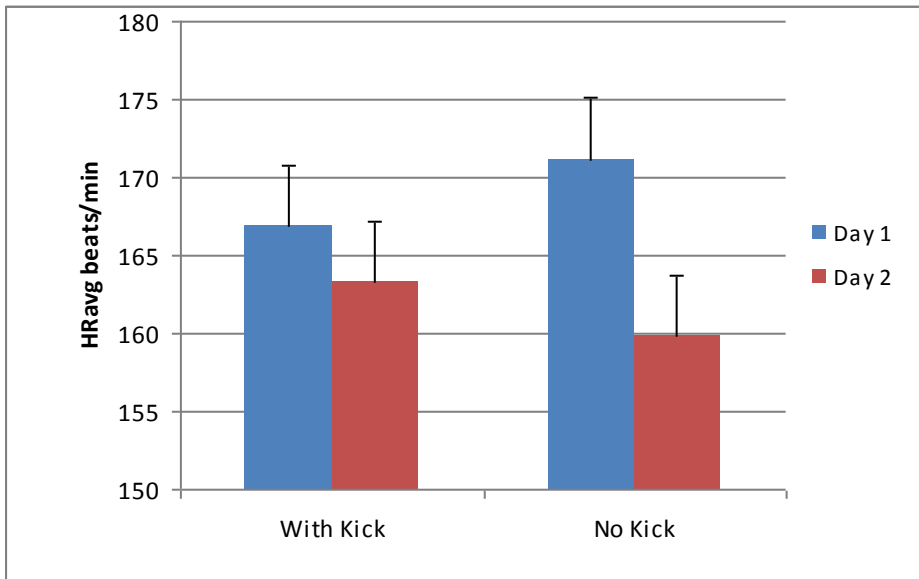


Figure 8. HRavg for sprints 1-6 block 1-2 both days. HRavg day 1 both blocks show HR values of 167 and 171 with a standard error of the mean of 3.94 and 4.01 respectively. HRavg day 2 both blocks show values of 160 and 163, with standard error of the mean of 3.84 and 3.74 respectively.

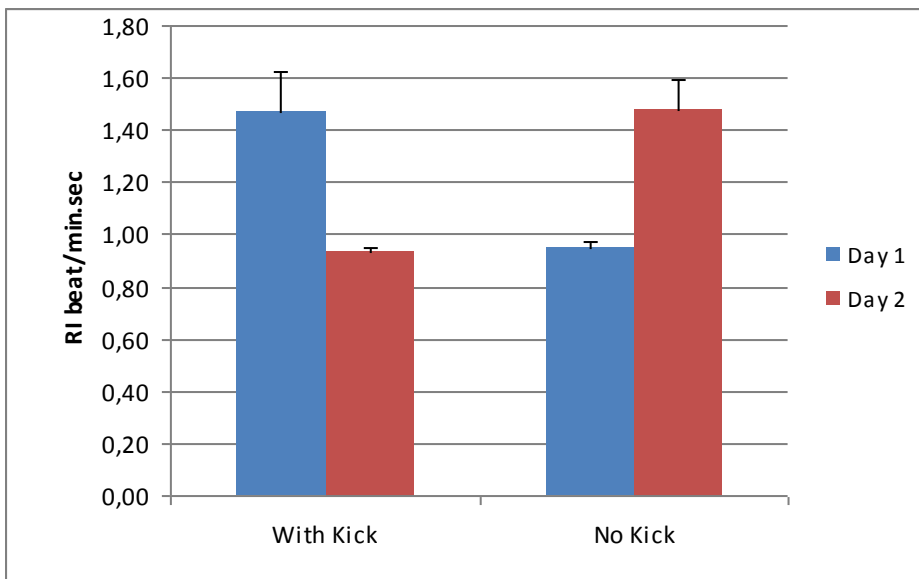


Figure 9. RI for sprints 1-6 both days. Average RI day 1 both blocks show RI values of 1.47 and 0.95 with a standard error of the mean of 0.38 and 0.05 respectively. Average day 2 both blocks show RI values of 1.48 and 0.93, with standard error of the mean of 0.29 and 0.04 respectively.

## 7 DISCUSSION

The main purpose of this study was to investigate the effect of repeated sprints with directional change on performance (velocity and power) and HR (as measure related to physiological internal load) in young elite soccer players.

Main findings indicated reductions in sprint performance for peak velocity and power around sprint 3, and significant differences in heart rate between sprint blocks (1 or 2), regardless of the different conditions (instep-kick/no instep-kick).

### 7.1 Performance data

Velocity is an essential indicator of sprint performance in soccer. Peak velocity and power are to a significant extent reduced at sprint 3 for all sprint blocks in the present project.

Reductions in velocity are associated with fatigue (Lakomy et al, 2004). Hence changes in velocity parameters in the present project, could indicate fatigue experienced by players.

However, findings concerning velocity are not persistent in the sense that they show a persistent decline in velocity in the subsequent sprints (figure 3-4). Variations may be present between sprints, but also within sprints. Other studies have found differences in performance within 30 meters sprints. 2 players may have the same total time, but performance may vary over the first and the last 10 meters (Wisløff et al, 2004).

The trend for the present project indicates a lower velocity in the latter stages of the sprint protocol, regardless of ball involvement. This corresponds to other studies indicating that when considering mean sprint times, the times increases as number of sprints increases. The first sprint is faster than the subsequent sprints (Lakomy et al, 2004). Lakomy et al, (2004) found that deceleration in RS could affect fatigue to a greater extent than protocols demanding less deceleration. Fatigue would be brought about by the amount of eccentric muscle work linked to deceleration phase. This should imply for the present protocol as well, having 2 deceleration phases per sprint. However, according to Lakomy et al, (2004) the latter deceleration phase for the present project, would probably not be sufficiently demanding. The demands of such a phase are closely linked to length of phase, forcing players to decelerate at a higher rate. Velocity data in the present project indicates that players obtain significantly higher velocity on the return run (figure 5). This may be explained by the fact that no other instructions were given for the return run, other than maximal effort. Hence many of the players obtained higher velocity, and the deceleration was started at a later stage in the return-

run, and with a lower rate of deceleration. This in contrast to the turn run, where players had to decelerate at an earlier stage in the turn-run and at a more rapid rate to be able to reduce speed to zero levels when approaching the turning point. 180° turns are also considered to be demanding on the muscles (Svensson et al, 2005). Number of turns and rapid decelerations should place large demands on muscles in lower extremities requiring forceful eccentric contractions. Lakomy et al used 40 meters sprints, thus probably obtaining a higher state of fatigue. There may be differences between players concerning physical parameters. Some are typical sprinters, meaning that they perform well on single sprints. Some are more endurance players, meaning that they are able to repeat their performance at a consistent level. This could affect results. Lakomy et al, (2004), found a progressive decrease (though not significant) in performance as a result of number of sprints. The authors theorized that a higher number of sprints (>6) probably would have produced significant results. The steady progressive reduction in performance was not to the same extent observed in the present project.

The changes seen at sprint 3, may imply that anaerobe energy systems, such as the alactic system, approximated a depletion. As seen by HR values, aerobic metabolism rose to sufficient levels in order to enable players to prevent significant loss of speed. An absolute reduction in PCr contribution may occur in soccer, where recovery periods of 20-30 seconds most likely are inadequate for complete restoration of PCr stores (Svensson et al, 2005). Recovery periods for the present protocol, were on average around 24 seconds (30 seconds recovery time minus sprint time). Reduced speed was found after sprint 3 in a study using a protocol with 40 meters sprints with 30 second recovery (Balsom et al, 1992). The authors concluded that 30 seconds of recovery was not sufficient to maintain performance during 6 seconds RS. Reduction in performance was also seen for the 30 meters RS protocol they used. The authors theorized that this was in part due to acidosis reducing adequate PCr restoration. From velocity values in the present project, no persistent decline in values indicating permanent fatigue, are found. Hence, it seems as there is a partly switch in metabolic systems at this particular stage in the protocol.

In RS power is closely related to fluctuations in velocity, hence being linked to performance. Fatigue may be seen as a progressive reduction in power output. Magnitude of reduction depends on recovery periods (Glaister, 2005). Depletions of PCr stores from 57% of resting values in sprint 1 til 16% after sprint 10 have been found. 30 second of recovery between

sprints is not enough to completely refill PCr stores (Gaitanos et al, 1993). Similar events concerning PCr depletions may be expected in the present study. This then may partially explain findings for both power acceleration and deceleration, suggesting a similar sequence of events as occurred regarding velocity around sprint 3 (figure 6-7). This coincides with findings in a study using 5x6 seconds ergometer sprints with 30 seconds recovery times, resulting in a steady decline in peak power output from sprint 1 to sprint 5 (Edge et al, 2005). This steady decline however, was not the case for the present project. The present project used well trained elite, whereas Edge et al (2005) used moderately trained athletes. Fatigue will probably to a lesser degree affect elite athletes. This is because elite athletes have obtained better metabolic and physiological adaptations due to more involvement in such activities (Lakomy et al, 2004).

## **7.2 HR data**

For all sprint blocks, the initial RI was followed by a levelling off in HR values around sprint 3 or 4 (figure 2) (no statistical analysis was performed, but all traces showed this typical pattern). This coincides with the findings suggesting a decrease in performance variables around sprint 3. This could suggest that increased aerobic contribution is partially able to cover for the loss of anaerobic contribution at this particular stage in the protocol. In a study using 10 sprints, no change in muscle La was found during sprint 10, even though power output was only reduced from 100 to 73% from sprint 1 to 10 (Gaitanos et al, 1993). The authors assumed that an increasing aerobic contribution partially counteracted the decreasing anaerobic contribution. This may seem the case for the present project as well, when viewing the non-significant reduction in performance variables at the end of the sprint blocks, as compared to previous sprints. Furthermore, findings regarding increased HRavg when comparing block 1 and 2, confirms the change in metabolic demand.

To obtain information on whether players achieve intended intensity levels during training, HR data is commonly monitored (Bangsbo, 1994). HR is normally a good indicator of aerobic conditions, but not to the same extent for anaerobic conditions (Esposito et al, 2004, Bangsbo et al, 2006). Since the present test is of intermittent nature, some authors suggest that HR may not provide an accurate measurement of actual intensity (Chamari et al, 2004). But RS are considered to be more an endurance performance due to its repetitive nature. Thus it was expected that HR would reach steady rate levels during the protocol, and measurements would indicate the expected progressive increase in aerobic metabolic contributions as a result of number of sprints. HR measurements have been used at YYIR tests to monitor changes and



estimate aerobic demands (Svensson et al, 2005). HRmax-values may be used to confirm the maximal nature of a test. (Lemmink et al, 2004). However in the present project, HRmax was not the main issue. The recommended HR zone for sprint endurance in %HRmax is >90% (Hallen, 2008). This suggests that RS are not maximal in nature when intensity is measured in HR. HR have been found to be valid for estimation of metabolic demands in soccer within intensity zones of 80-97% in laboratory (Esposito et al, 2004), when factors such as intermittent work and sprint were included. During the present protocol HRavg was used to state the level of aerobic metabolic contributions. From this, energy estimations may be calculated (Bangsbo, 1994). Average %HRmax values, indicated that few players were able to obtain the recommended HR level. Average %HRmax for sprint blocks were in the range of 77.4-92.2% calculated from players individual HRmax. One reason for this result could be self-pacing in order to avoid unpleasant sensations. Furthermore the protocol itself may not have taxed anaerobic systems sufficiently, having a near 3 minute recovery period between sprint blocks and only 6 subsequent sprints in one block, thus allowing for sufficient PCr recovery in order to be able to repeat performance in block 2. However, findings in the present project indicated a higher level of aerobic contribution in block 2 both days (figure 8), thus suggesting taxing of anaerobic systems to such a degree that energy delivery to a greater extent had to rely on aerobic metabolism in block 2. This probably also linked to the fact that PCr stores are not fully replenished after 3 minutes of recovery (Hoffman, 2006). Bogdanis et al (1996) found that after 3.8 min of recovery, PCr was resynthesized to a near 80% of the resting value following 2-30 seconds of ergometer intervals. Bangsbo et al (2002) stated that the degree of change in HR during HIA is more important than average HR. The authors theorize that local factors may play a restrictive role when changing from low intensity activity to HIA. Oxidative capacity may be one such factor in working muscles in lower limbs. Once the HR reached a steady rate around sprint 3-4 (figure 2) in the present project, the degree of change in HR was difficult to distinguish. This was due to low sample rate. One may though observe small changes in the presented graphs, indicating to some extent the degree of change as a result of increasing aerobic contributions during recovery between sprints. With a higher sample rate, these features would most likely have been more pronounced, providing more detailed information regarding the individual sprints and the degree of change in HR and thus aerobic metabolic demands.

In the present project, one may see from figure 2 the development of HR clearly indicating a lag in O<sub>2</sub> kinetics. Normally 1 minute is required to achieve 95% HRmax at continuous running. (Chamari et al, 2004). In the present project, a levelling off in HR is seen around

sprint 3-4. This probably represents the time required for O<sub>2</sub> kinetics to reach optimal functionality. The protocol time duration has at this point lasted for 1-1.5 minutes, and effective total sprint time amounts to 12-18 seconds. This amount of effective sprint time is thus probably covered mainly by anaerobe mechanisms. Anaerobe energy in single sprints (SS), are delivered via 2 means of anaerobe metabolism; the immediate alactic PCr system, and the slightly slower glycolytic lactic system (Svensson et al, 2005). In a 3 second SS stored ATP contribute 3%, PCr 55%, glycolysis 32% and aerobic metabolism 10% (Spencer et al, 2005). This is seen in figure 2 where initial HR response is low in the first 1 or 2 sprints. RS will place increasing demands on aerobe mechanisms (McArdle et al, 2006), as seen by both RI and HRavg in the present project (figure 8-9). Initial work periods in the present protocol lasted just for a few seconds, hence muscles may cover their initial need for O<sub>2</sub> through O<sub>2</sub> stored in myoglobin (Glaister, 2005). As the player performs subsequent sprints, these stores are inadequate and this also coincides with the reductions in PCr stores. Hence aerobe metabolic contributions increase, as may be seen in figure 2. These events may coincide with the reductions seen in performance data around sprint 3 (figure 3-4 and 6-7). Furthermore, rapid reductions of PCr stores will lead to a rapid increase in glycolytic contribution (Glaister, 2005). The glycolytic system becomes more vital as the number of sprints are increased and time for complete PCr resynthesis decreases (Newman et al, 2004). Findings of high BLa values (Newman et al, 2004) and reductions in glycogen stores in RS confirms this (Gaitanos et al, 1993). Resynthesis of PCr and removal of La in muscle, must occur primarily in recovery periods (Glaister, 2005). Aerobe mechanisms are central in this process (Svensson et al, 2005), as one may observe in the present project (figure 2). A high HRavg is maintained throughout sprint blocks, and a tendency to variation is seen. Most of this aerobe contribution constitute a part of actual physiological events occurring during recovery, and reflects anaerobe metabolism, respiratory, circulatory and thermal factors during exercise (McArdle et al, 2006). The lower RI for block 2 on day 1 and 2, may indicate that the circulatory response is not as acute due to that the system is already up and running and reaches peak efficiency at a slower rate (figure 9).

The observed day differences for HRavg and RI (figure 8-9), may be explained by several factors such as nutritional status, training loads prior to day 1 or day 2. Furthermore the warm-up drills were not standardized. However they were of similar lengths and should thus not induce decisive physiological load affecting test outcome. Polar HR measurements indicated that average resting pulse levels prior to start of sprint blocks, were fairly similar,

though higher on day 1 (116 versus 108). This may partially explain differences in HRavg day 1 compared to day 2.

The use of instep-kick had as one would expect no effect on HR. The duration of ball contact was too short to make an impact on HR values, and thus the aerob contribution. One may from this also conclude that the use of ball contact in this magnitude, will not interfere physiological aerobe responses in RS protocols. Thus the physiological training effect is maintained, whilst allowing for technical aspects to be added.

### **7.3 Methodological issues**

Sample rate on Polar systems were set to every 3<sup>rd</sup> second. This will affect the usefulness of such measurements when looking at short sprints combined with short recovery periods. One may observe this in figure 2, where distinguishing the various sprints is difficult.

HRmax for players were estimated using values from YYIR2 tests (Krustrup et al, 2003) done by the club. This project had no control of actual implementation of tests. The accuracy of such estimations versus standardized maximal HR tests, has not been established by other authors as far as this project has been able to verify.

Filtration of the signals obtained from motion analysis, presents some challenges, especially regarding the positional signal. The signal accounts for whole-body movements, and not individual movements of segments. Friction at foot-contact and artificial turf, is not accounted for. As seen from figure 1, the positional signal is not starting from a zero line as the other signals do. This could mean a difference in total distance covered, making conclusions as whether players ran exactly 32 meters or not, difficult.

Test design of this project was originally AB-BA. Due to insufficient data from motion analysis technology on day 1 block 2, this design was changed to A-B-A. Thus a test-retest was performed. This allows for statements regarding correlations and test reliability.

This project had no control of training loads, nutrition or fluid intake prior to test day 1 and between test days. Nutritional status may play a significant role. Insufficient carbohydrate supplementation may lead to low glycogen storage and thus shorter time to fatigue (Welsh et al, 2002). Reductions in glycogen stores in RS may be considerable (Gaitanos et al, 1993). Recovery of glycogen stores may be as long as 2-4 days after strenuous training, and there are also variations between players of 1-3 days, concerning recovery in soccer on parameters such as speed, muscle function and strength (Hallen, 2008). Some of the players may have

experienced insufficient recovery at day 1. Whether this may explain differences in performance, remains uncertain. Fluid status may also play a role in performance, and dehydration may increase HR (Bangsbo, 1994). Players were instructed to drink by coaches, and weather conditions during tests would not require excessive intake (Bangsbo, 1994). Also the tests were performed early in the training session, so fluid loss should be minimal. Recovery times referred to from other studies however, have used senior athletes. Recovery times for seniors may be longer than for juniors, as observed for studies comparing recovery times between multiple sprints (Zafeiridis et al, 2005, Ratel et al, 2006) for boys aged 11-15 and men aged 22-26. Junior and seniors are fairly similar however, when comparing for factors such as aerobic capacity, working load, activity patterns and mean duration of time spent in the different movement categories in matches (Strøyer et al, 2004). But few studies have compared sprint abilities in junior and seniors. Thus any comparison as such, cannot be made regarding the findings in the present project. Weather conditions were fairly similar on the test days, hence this should not inflict on test results. The wintery conditions were familiar for all players, and well within winter temperatures common for outdoor sessions experienced by eg. cross-country athletes (Lumme et al, 2003).

#### **7.4 Ecological validity**

Several factors strengthen the validity of the present protocol. Compensatory measures were taken to ensure that a predetermined running distance of 30 meters per sprint were obtained during the RS protocol. Thus 2 times 16 meters were used. Furthermore players were familiar with this protocol, having used this in training several times. The only modification done was adding the instep-kick for one of the sprint blocks. The adding of ball involvement, increases sport specific value of the protocol (Lakomy et al, 2004). Also, the present protocol is in accordance with other RS protocols containing sprints ranging 20-40 meters, 6-18 repetitions and recovery periods of 15-25 seconds (Wragg et al, 2000).

Acceleration and deceleration phases are becoming more important in modern soccer (Carling et al, 2008). The protocol of the present project is well adapted to the purpose of developing such physical parameters, which has been found to require a high degree of specificity during training or testing (Little et al, 2005). This may also be indicated by peakVturn/return velocities (<6 m/s), compared to maximal velocities of 7.6 m/s found in matches (Bradley et al, 2009), indicating the inability of players to reach their maximal speeds during the present protocol.

Most sprints in soccer are from flying start (Svensson et al, 2005). Thus this should be used in tests as well. This would increase ecological value, which is generally high for field tests (Svensson et al, 2005). However flying start was not chosen for the present project. Subjects were instructed to stand still between sprints, in order to keep data collected from motion studies technology to a minimum and thus similar for all players. The present project assumed that this would simplify identification of start when analysing data post testing.

Field tests have greater specificity but less accuracy compared to laboratory tests. Thus field tests may to a greater extent make a statement concerning performance in soccer. However standardisation is essential in order to reassure reproducibility (Svensson et al, 2005), and this was not the case for the warm-up procedures for the present project.

The recovery periods between sprint blocks in the present project, were of different lengths. Recovery time on the 1<sup>st</sup> day was 2 minutes and 54 seconds, whereas on the 2<sup>nd</sup> day 2 minutes and 40 seconds. However, this time difference of 14 seconds, should not have any influence on physiological recovery (Bogdanis et al, 1996, Hoffman, 2006).

## **8 CONCLUSION**

Results in the present study indicate that RS training may be performed including ball handling at high speeds, such as an instep-kick, this in order to practice soccer specific technique, without ball handling having any negative effect on the intended training load imposed by RS. Furthermore, results confirm findings in other studies (Glaister, 2005) that aerobic contribution increases with number of sprints. Reductions in sprint performance for peak velocity and power occur around sprint 3. However methodological issues concerning data collection and number of subjects, requires caution considering strength of findings.

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