



Correlation Between 3000-meter Running Performance, Yo-Yo IR1 & Submaximal Treadmill Jogging Test

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Bachelor's Thesis In Exercise Biomedicine, 15 credits

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Abstract

Background: Physiologic functional capacity through maximal oxygen uptake ($\dot{V}O_{2\max}$) can be measured in many different ways depending on sport and qualities needed to be assessed. In handball a demanding 3000 meter (m) running test is used to evaluate $\dot{V}O_{2\max}$. If this test is sport specific or if it could be replaced by a less strenuous test is unknown. **Aim:** The aim of this study was to compare performance on 3000-meter running with predicted $\dot{V}O_{2\max}$ from a submaximal treadmill jogging test (SMTJ) and performance of the Yo-Yo intermittent recovery test 1 (IR1). **Methods:** Male handball players (n = 12) performed the 3000 m running test, the Submaximal Treadmill Jogging test and the Yo-Yo Intermittent Recovery test level 1. Measurements in seconds (s), $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and meters were collected and correlated using Pearson r, interclass correlation. **Results:** A strong significant linear correlation ($p < 0.01$) was found between performance in 3000 m running (s) and Yo-Yo IR1 performance (m), $r = -0.724$ ($r^2 = 0.524$). A weak, not significant linear correlation ($p > 0.05$) was found between performance in 3000 m running (s) and predicted $\dot{V}O_{2\max}$ from submaximal treadmill test ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), $r = -0.309$ ($r^2 = 0.095$). **Conclusion:** According to this study the 3000 m running test could be replaced by the Yo-Yo IR1 test or vice versa in adolescent male handball players. The submaximal treadmill test used in this study had several potential errors in estimating $\dot{V}O_{2\max}$, this is probably the reason why only a weak correlation was found between the SMTJ and the 3000 m running test.

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Background

Introduction

Maximal oxygen uptake ($\dot{V}O_{2max}$) is according to Baechle and Earle (2008) one of the most popular ways of measuring cardiorespiratory fitness and are further explained as the amount of oxygen that can be used by each cell in our body. McArdle, Katch, and Katch (2010) additionally adds that $\dot{V}O_{2max}$ is “a fundamental measure of physiologic functional capacity for exercise” (p.234). Different testing procedures are used to be able to evaluate and assess athlete’s $\dot{V}O_{2max}$. Direct, indirect, maximal and submaximal measurements along with sport specific tests are used depending on the situation, accessibility and local routines. Different testing procedures also uses more or less of the aerobic and anaerobic energy metabolism which might influence the performance depending on the sport requirements. In this correlation study the relationship between 3000 meter (m) running, a test used in Swedish handball players to evaluate $\dot{V}O_{2max}$, are compared to a more sport specific Yo-Yo IR1 test. The 3000 m test are also compared to a Submaximal Treadmill Jogging Test (SMTJ) that are safer and require less effort and time and could potentially be as good indication of $\dot{V}O_{2max}$ as the 3000 m test in adolescent handball players.

Handball

Handball is an intermittent sport played over 2x30 minutes, qualities required from the players are mainly reported being endurance capacity, sprint performance, jumping ability and throwing velocity. Additionally, due to high intensity activities during the game, with short rest periods in between, anaerobic endurance capacity is also vital (Kruger, Pilat, Uckert, Frech & Mooren, 2013). In male adult handball players, $\dot{V}O_{2max}$ range between 50 – 60 ml · kg⁻¹ · min⁻¹ and on average 4000 m is covered during a game, ranging between 2000 – 5000 m (Ziv & Lidor, 2009). In adolescent handball players (age 15) distance covered during a game is somewhat shorter, on average (SD, standard deviation) 1777 ± 264 with a range between (1500-2611) m during 2x25 minute games where 4 % of the distance covered during the game is sprinting, 8% high intensity running, 59 % jogging and 29 % walking (Chelly, Hermassi, Aouadi, Khalifa, Van Den Tillaar, & Chamari, 2011). Although it’s hard to determine the time spent in different motions in handball due to inconsistencies between methods used in different studies (e.g. tracking systems, speed zones, consideration of players’ substitution) Karcher and Buchheit (2014) reported low intensity activities such as standing and walking as the most frequently occurring activities. For example, in elite male handball players (average age, 25) a total distance covered of 4370 ± 702 m was reported with 2 % of total distance

spent in sprinting, 12 % in fast running, 23 % jogging and 46 % walking. Although, in more than 50 % of the effective game time, a heart rate (HR) above 80 % of maximal HR has been observed (Póvoas, Seabra, Ascensa, Magalha, Soares & Rebelo, 2012).

High intensity actions, such as sprinting with or without the ball, jumps, stops, changes of direction and duels are less frequently occurring but crucial nonetheless because of the involvement of these movements during decisive parts of the game. High intensity runs can contribute to approximately 8 % of total playing time or 1.7 % of total distance covered (Karcher & Buchheit, 2014). Elevated blood lactate values have been observed in a gradually increased accumulation from prior match, after the first half and after the end of the match demonstrating the use of the anaerobic energy system during the game (Michalsik, Madsen & Aagaard, 2015). Although Chelly et al. (2011) observed a lower lactate accumulation after the game than after the first half, when comparing the second half to the first half. Shorter distance, less high speed running, fewer technical actions and lower mean HR was observed for the second half compared the first half. Also less time spent above 85 % of maximal HR in the second half was observed. Altogether this indicates that handball is a fatiguing sport in which lactic acid-tolerance and aerobic capacity are beneficial (Chelly et al., 2011).

Physiological Requirements

Looking at the physiological requirements needed to be able to perform sprints in handball, adenosinetriphosphate (ATP) is used to fuel the muscle contractions and creating sprint speed in a process also creating adenosine diphosphate (ADP) and inorganic phosphate (P_i). Although ATP never is completely worn out a 10-12 second sprint reduces the ATP stores by 14-32 % and a six seconds (s) sprint depletes ATP stores by 8-16 %. Phosphocreatine (PCr), anaerobic glycolysis and aerobic metabolism helps resynthesize ATP. During a three second sprint approximately 10% of the energy comes from stored ATP, 32 % from anaerobic glycolysis, 55 % from PCr and 3 % from aerobic metabolism. PCr creates ATP in a process with ADP and creatine kinase which results in ATP and free creatine. PCr creates 7-9 mmol ATP/kg dm (dry muscle)/sec. Anaerobic glycolysis creates approximately the same amount of ATP (5-9 mmol/kg dm/sec) but this process, using mainly muscle glycogen, also creates lactate. Up to 40 mmol lactate/kg dm during six-seconds maximal sprinting and 4 mmol lactate/kg dm after only 1.28 seconds has been demonstrated (Glaister, 2005; Spencer, Bishop, Dawson & Goodman, 2005).

In handball, sprinting is repeated several times during the game, repeated sprints reduce the contribution from anaerobic glycolysis compared to one single sprint bout but still creates greater levels of muscle lactate concentrations. The reduction in anaerobic glycolysis can be explained by increased aerobic metabolism (Spencer et al., 2005). According to Stølen, Chamari, Castagna and Wisløff (2005) lactate concentrations is lower in soccer players with a high $\dot{V}O_{2max}$, this is due to a better aerobic response but also a better PCr regeneration. On the other hand, Glaister (2005) reports conflicting evidence about endurance training and lactate clearance and concerning endurance training and multiple sprint performance. However, a better $\dot{V}O_{2max}$ most likely contributes to a better resistance to fatigue during repeated sprinting (Glaister, 2005; Bishop, Edge & Goodman, 2004). The duration of rest periods in between sprints is also highly influential, for example a six second sprint with 60 seconds recovery can be performed ten times but when reduced to 30 seconds recovery only five sprints can be performed (Spencer et al., 2005). In handball, recovery time between high intensity activities has been observed with an interval of > 90 s for 34 %, 61-90 s for 11 %, 31-60 s for 20 % and 0-30 s for 34 % of the high intensity activities (Póvoas et al., 2012). Handball thus requires both aerobic and anaerobic metabolism, handball is also a fatiguing sport creating lactate which highly influence the performance during the game. In the work of assessing handball players one can therefore use many different testing procedures depending on which energy system the coach wants to test. However, because a greater $\dot{V}O_{2max}$ can indicate better lactate clearance and better resistance to fatigue it might not make a big difference if the test used is more or less aerobic or anaerobic to measure the physiologic functional capacity for exercise. In this study three different tests are further studied.

$\dot{V}O_{2max}$ Prediction Test

There are several ways to determine the physiologic functional capacity for exercise in an individual, a direct laboratory measurement of $\dot{V}O_{2max}$ is the best way but also the hardest to conduct test. Therefore, numerous indirect tests exist, predicting the $\dot{V}O_{2max}$ ($P\dot{V}O_{2max}$). Although it's just a prediction, indirect tests do not need a laboratory and are relatively easy to conduct on-field (McArdle, Katch, & Katch, 2010). To determine aerobic capacity a reliable and valid on-field test is necessary to predict $\dot{V}O_{2max}$ for athletes. A commonly used test for $P\dot{V}O_{2max}$ is the Coopers 12 min run test. Validated against expired gas this test has a high validity in an aerobically fit population and is reliable in a population of 18-35 years (Penry, 2011). Two other frequently used test that can be performed on the field is the classical 20-m shuttle run test (Leger & Lambert, 1982) and the Yo-Yo intermittent recovery tests (IR) that

are considered more sport specific since it assesses the intermittent nature of sports such as soccer, basketball and handball. (IR) (Bangsbo, Iaia, & Krstrup, 2008). Also submaximal test can be conducted, even though these tests are not as accurate as a maximal test, these test require less effort, are safer, less time consuming and are not as sensitive to motivational factors (Cardinale, Newton & Nosaka, 2011).

3000 Meter Running Test

One of the most popular field test are the 12- minute Coopers test which was first introduced in 1968 by Kenneth H. Cooper who performed the endurance test on male US Air Force Officers and presented a correlation of $r = 0.897$ between maximal oxygen consumption and performance in miles after 12 minutes of running. In the original study, a table in which maximal oxygen consumption can be predicted based on the performance in miles after 12 minutes of running was presented (Cooper, 1968). More recent literature uses equations based on the Cooper (1968) study to calculate the same predictions based on either mile (Miller, 2012) or kilometres (Bandyopadhyay, 2015) performed.

The Swedish “Fysprofilen” used by the Swedish Olympic Committee is also used in handball players to identify individual abilities to better direct and optimize their training (Fysprofilen, 2013). Fysprofilen uses a test sometimes referred to as the “coopers 3000 meter”, this test is used in many different sports to assess athlete’s $\dot{V}O_{2max}$ and is conducted by running 3000 meter as fast as possible. The exact relation to the original Coopers test is somewhat unclear, although 3000 meter is a good result in the Coopers test, running 3000 m in 12 minutes results in a $\dot{V}O_{2max}$ of 56.0 which according to Cooper (1968) is above excellent for men aged 22 (range: 17-52). One study compared 3000 m running with 12-minute running ($r = -0.96$) and $\dot{V}O_{2max}$ ($r = -0.67$) which showed a strong correlation between all values, however the results from that study was very close to 12 minutes and 3000 m (mean distance 3075 m, mean time 702 s) (O’Gorman, Hunter, McDonnaacha & Kirwan, 2000) giving a quite expected correlation. If there is a correlation with a bigger spread from 12 minutes and 3000 m is unknown. Also in adolescent handball players whom on average only covers about 1777 – 1921 m during a game (Chelly et al., 2011; Souhail, Castagna, Mohamed, Younes & Chamari, 2010) it is unknown if a 3000 m running test is valid for both $\dot{V}O_{2max}$ and sport specificity. Further Miller (2012) presents three different distance filed tests that are somewhat similar to the 3000 m test in that a distance is ran instead running for a specific time. These tests are 1600, 2400 and 3200 m which represents 1, 1.5 and 2 miles accordingly and are proven to be

able to estimate $\dot{V}O_{2\max}$ but is to the authors knowledge not used in assessments of handball players.

Yo-Yo Intermittent Recovery

The intermittent recovery test (IR) tests has to levels, IR1 and IR2 which are both relevant and widely used in sports that require intermittent abilities such as soccer and handball since they are very sport specific. However, even though both tests significantly correlate with $\dot{V}O_{2\max}$, IR1 ($p < 0.05$, $r = 0.70$) and IR2 ($p < 0.05$, $r = 0.58$) Bangsbo et al. (2008) doesn't consider the IR tests as an accurately prediction of $\dot{V}O_{2\max}$ but more as an indication of the "*ability to perform repeated intense exercise*" (p. 48). The IR1 test is more suited to test the endurance capacity in an individual and has a slower start and an overall longer test time (about 5 min) then the IR2 test (Bangsbo et al., 2008; Souhail et al., 2010). The IR1 test is also reliable in soccer players aged 16 years (Deprez, Coutts, Lenoir, Franssen, Pion, Philippaerts & Vaeyens, 2014) Furthermore in soccer, sport specific test has become more popular since it can separate different levelled soccer players better then $\dot{V}O_{2\max}$ (Wells, Edwards, Winter, Fysh & Drust, 2012). Souhail et al. (2010) found a correlation of $r = 0.88$ between distance covered during a handball game and Yo-Yo IR1 performance in meter covered ($r^2 = 0.77$, $p < 0.01$) in adolescents (age 14) male handball players. In the study by Souhail et al. (2010) players covered 1921 ± 170 (1507-2478) m during math play and 1831 ± 373 (1440-2440) m during the IR1 test indicating the test could be used in adolescent handball players (Souhail et al., 2010). Due to the stronger correlation to $\dot{V}O_{2\max}$ for the IR1 than the IR2 test but still testing repeated intense exercise along with the proven correlation to distance covered during a handball game the IR1 test is used in this study.

Submaximal Treadmill Jogging Test

As mention before submaximal test are not as accurate as maximal test but they require less effort, are safer, less time consuming and are not as sensitive to motivational factors (Cardinale, Newton & Nosaka, 2011). For that reason, a submaximal test can be a good substitute if a direct measurement of $\dot{V}O_{2\max}$ is not accessible or if a maximal test is to straining, for example during competition season in handball. Miller (2012) presents three submaximal treadmill tests that predicts $\dot{V}O_{2\max}$ based on walking, jogging and walking/jog/run plus a questionnaire. The submaximal treadmill jogging (SMTJ) test by Vehrs, George, Fellingham, Plowman and Dustman-Allen (2007) is used in this study because of the high correlation ($r = 0.91$) and with $\dot{V}O_{2\max}$ measured by expired gas during a graded treadmill exercise test and low standard error of estimate (SEE) ($2.52 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). From the three tests that Miller (2012) presents it is also the least time consuming and best suited

for the study population (18-40 years). The prediction is based on an equation containing gender, weight, age, self-selected jogging speed and steady state HR. The test is performed in total 5 minutes plus warm up. The first two minutes is used to locate a self-selected jogging speed, the remaining three minutes is used to find a steady state heart rate not exceeding 85% of age predicted HR. With these values a $\dot{V}O_{2\max}$ can be calculated using a regression equation (1) (Vehrs et al. 2012).

Handball is a sport mainly requiring aerobic metabolism, however many decisive actions during the game requires anaerobic metabolism. Today a 3000 meter running test is used as a standard testing routine to test the physiologic functional capacity in handball players. This test doesn't consider the anaerobic requirements in handball, however aerobic capacity alone can be a good indication of repeated sprint capability and lactate clearance. Therefore, the aim of this study is to correlate performance on 3000 m running with IR1 performance to see if there is a difference between sport specific and non-sport specific test. The 3000 m running test will also be compared to the SMTJ test, investigating if the test could be exchanged to a less strenuous and demanding submaximal test.

Aim

The aim of this study were to compare performance on 3000- meter running with Yo-Yo Intermittent Recovery Test 1 and predicted $\dot{V}O_{2\max}$ from a submaximal treadmill jogging test.

Research questions:

- 1.) Which negative linear correlation have performance in meter in the Yo-Yo intermittent recovery test 1 (IR1) with performance in time for 3000- meter running?
- 2.) Which negative linear correlation have prediction of $\dot{V}O_{2\max}$ by submaximal treadmill jogging test with performance in time for 3000- meter running?

Methods

The study was a quantitative correlation study where all subjects (n=12 male) performed, in following order, one 3000 m run, one laboratory submaximal treadmill test and one Yo-Yo IR1 test.

Subjects

Students from a sports high school playing handball were invited to participate in the study voluntarily after interest. A total of 18 subjects signed the letter of consent (appendix 1) and performed at least one of the three tests. 13 subjects performed the 3000 m running, 17 subjects performed the laboratory treadmill test and 18 subjects performed the Yo-Yo IR1 test. In total 12 male subjects performed all three tests and was used in the statistical analysis. All 12 subjects met the inclusion criteria of being handball players, training at least three times a week and between 16-19 years old. Participants were excluded if showing signs of injury or illness at the time of study or if they missed one of the three tests.

3000 Meter Running Test

Equipment and location

The 3000 m running test were performed on a 400 meter, round outdoor running track between 9-10 a.m. The temperature were six degrees, windy and occasionally raining. Time was taken using a Polar M400 (Polar Electro Oy, Kempele, Finland).

Testing Procedures

The 3000 m test were conducted during two separate runs. In the first run nine subjects ran and in the second four subjects ran ($n = 13$). A warm-up of five min jogging in self-selected jogging speed was performed before the test started. All subjects had performed the test before as a standard testing routine for their sport. The subjects were instructed to run 3000 m as fast as possible, pacing themselves to manage 3000 m and not to compete with others. All subjects started at the same point and the test leader noted how many laps each participant completed. At every lap completed the test leader announced the time consumed (Penry, Wilcox & Yun, 2011). The end time in seconds at 3000 m was noted for each subject and was used in the statistical analysis (O’Gorman, Hunter, McDonnaacha & Kirwan, 2000).

Yo-yo IR1

Equipment and location

The “Team Beep Test software for PC, Version 4.0, Bitworks Design” was bought and downloaded from Topend Sports (2010) and were used to produce the audio signals during the IR1 test. The downloaded version included a standard IR1 test that did not exactly match the velocity at stage 2 used in previous studies by Souhail et al. (2010) and Castagna, Impellizzeri, Chamari, Carlomagno and Rampinini (2006). To match the velocity with previous studies velocity was changed according to Topend Sports (2010) from 11.5 to 12

km/h according to Souhail et al. (2010) and Castagna et al. (2006). The test took part between 9.00-10.30 a.m at the normal training ground for the subjects Sports High School.

Testing Procedures

N = 18 subjects performed the Yo-Yo IR1 test divided into two groups of nine subjects in each. Before the test started all subjects were verbally informed about the testing procedures of the test. Figure 1 shows how the test was set up. Two lines 20 m apart was marked by cones, 5 m behind one of the lines a third line was marked. Subjects started at line 1. When starting the Team Beep Test Software (Topend Sports, 2010) a beep indicated the start. The subjects then ran 20 m to line 2, and had to reach line 2 before the next beep. When the second beep was heard the subjects started to run from line two, 20 m, back to line 1, this 40 m stretch was referred to as one running bout. When one bout was complete the Team Beep Test Software played a voice saying “stop and rest”, this meant that the subject had a 10 sec active rest period in which they had to jog to line 3 and back to line 1. After approximately 8 sec a voice saying “get ready 3, 2, 1 run” followed by a beep was played indicating the start of a new bout after 10 second active rest. The test consisted of 15 stages, each stage consisting of 1-8 bouts of running. In stage 1-5 bouts increased from 1 to 4. In the remaining stages (6-15) 8 running bouts were performed in each stage. The speed in the three first stages was 10, 12 and 13 km/h respectively, then a 0.5 km/h increase in speed was made for the remaining stages. The test was ended when a subject could not reach a line twice in time of the beep (Krustrup et al., 2003). A 10-minute warm up routine (see appendix 2 for details) including the first 2:21 min (4 first stages) of the Yo-Yo IR1 test was performed before the test started to get used to the technique used in the IR1 track (Krustrup et al., 2003). The final stage and shuttle reached by each subject was collected and transferred into total meters achieved using table 1 which shows number of bouts, speed at each stage and total distance achieved after each stage (Souhail et al., 2010; Castagna et al., 2006). The total distance was used in the statistical analysis.

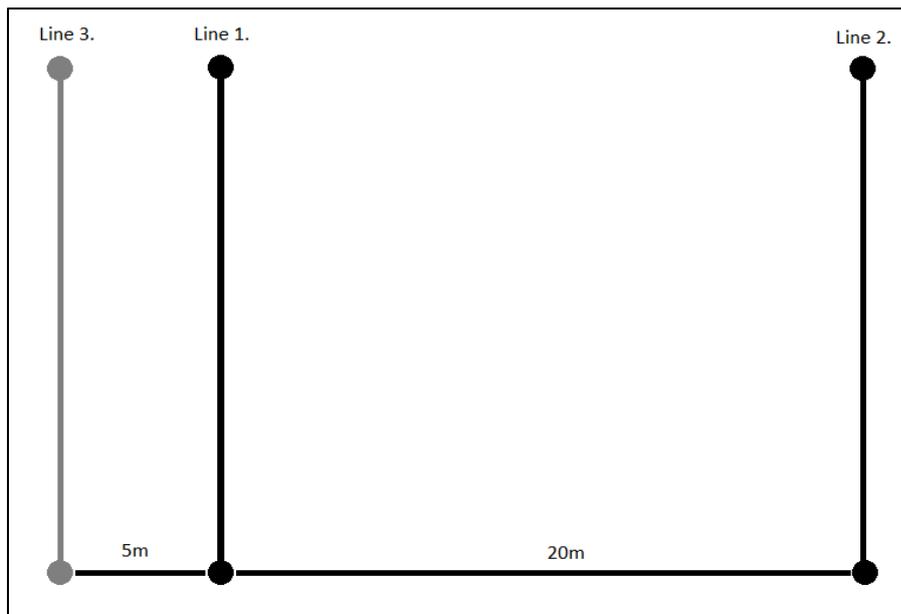


Figure 1. Yo-Yo Intermittent Recovery test 1 test track, 5+20 m. Participants starts at line 1, hearing the beep from the Team Beep test software participants started running to line 2. When hearing a beep again participants ran back to line 1, thereafter a 10 seconds active rest period was utilised jogging to line 3 and back to line 1. Then the beeps started over again.

Table 1. The 15 stages of the Yo-Yo Intermittent Recovery test 1. Each stage consisted of 1-8 shuttles with an increased speed after each stage. In the table total distance achieved after a completely finished stage are also presented.

Stage	Number of Shuttles (2x20m)	Speed (km/h)	Total distance
1	1	10	40
2	1	12	80
3	2	13	160
4	3	13.5	280
5	4	14	440
6	8	14.5	760
7	8	15	1080
8	8	15.5	1400
9	8	16	1720
10	8	16.5	2040
11	8	17	2360
12	8	17.5	2680
13	8	18	3000
14	8	5	3320
15	8	19	3640

Submaximal Treadmill Test

Equipment and location

The test was performed on a Rodby treadmill (RL 2500, No 112, Rodby innovation AB, Sweden) in a laboratory at Halmstad University between 8.30-11.00 a.m. during three separate days. A digital scale (Vågblock 200/ 0.05kg, VB2-200-50, Vetek AB, Väddö, Sweden) was used to collect weight. HR was collected using a Sigma Heart Rate Monitor (PC9 Woman/Man, Sigma-elektro GmbH, D-67433 Neustadt/WeinstraBe, Germany).

Testing Procedures

A total of 17 subjects (n = 17) performed the submaximal treadmill test. Age and weight of the subjects were collected before the test started (Miller, 2012). Exercise heart rate were collected every minute. A warm up of 3-minute walking on the treadmill were performed to get used to the treadmill, during the warmup the test procedures were explained to the subjects (Vehrs et al. 2007). Starting the test, in minute 0-2 the subject jogged at 0 % incline at a self-selected comfortable speed between 7 and 12 km/ hour (4.3-7.5 miles per hour). Between minute 2-5 the same speed and incline as in in the first 2 minutes were maintained. During these 3 minutes a steady state heart rate were achieved that did not exceed 85 % of the age predicted maximal heart rate ($220 - \text{age}$ (Cardinale, Newton & Nosaka, 2011)). Steady state HR was achieved when HR differed ≤ 3 beats per minute (bpm), if a steady state HR was not achieved within the 3 min of the test, the test continued until a steady state heart rate was achieved. (George, Vehrs, Allsen, Fellingham & Fisher, 1993). The steady state heart rate, self-selected jogging speed, body mass in kg, age and gender were used in the equation (1) by Vehrs et al. (2007) to calculate $\dot{V}O_{2\max}$.

Statistical analysis

Data collection

End time (s) for the 3000 m run and end distance of the Yo-Yo IR1 (m) was collected. Heart rate, age, weight, gender and velocity for the treadmill test was collected and used in the equation (1) by Vehrs et al. (2007). Data were presented as mean \pm SD (standard deviation).

$$\dot{V}O_{2\max} (\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = 58.687 + (7.520 \times \text{gender}) + (4.334 \times \text{mph}) - (0.211 \times \text{kg}) - (0.148 \times \text{HR}) - (0.107 \times \text{Age})$$

Gender: 0 = woman; 1 = man; Mph = self-elected jogging speed; HR = steady-state HR (bpm); Kg = body mass; Age = age in years.

Submaximal Treadmill calculations as proven by Vehrs et al. (2007). (1)

Data analysis

IBM SPSS Statistics Version 20 was used to analyse the data. A Shapiro -Wilk test was performed to check for normal distribution. Pearson r, interclass correlation was used to look for a negative linear correlation between Yo-Yo IR1 performance (m), 3000 m performance (s) and $\dot{V}O_{2\max}$. Statistical significance was set to $p \leq 0.05$ and a strong correlation was considered at $p \leq 0.01$ according to Souhail et al. (2010) whom presented a strong correlation of $r = 0.88$ in a population of $n = 18$. With decreased number of participants, the correlation needed for significance increases. In this study statistical significance was considered when $r \geq 0.5760$. A weak correlation was considered if $r \leq 0.5759$. A moderate correlation was considered between $0.5760 - 0.7078$ and a strong correlation was considered at $r \geq 0.7079$. (Thomas, Nelson & Silverman, 2011, p. 428).

Ethical and social considerations

The law, The Act concerning the Ethical Review of Research Involving Humans, clarifies what type of research needs to be reviewed. Inter alia if the research affects the subject physically or psychologically or if the research is using methods that can be a risk of harm to the subject and if sensitive personal data are conducted the research needs to be reviewed (Vetenskapsrådet, 2011, p.49). All participants in this study were informed of the procedures and risks of being part of the study. All subjects were also informed about the confidentiality in data processing, all data was stored on an external USB-drive belonging to Halmstad University. All participants agreed on a written conformed consent, confirming that they had been informed about and understood what the study involves, had been able to ask questions if needed, knew who the supervisor was, that he or she voluntarily participated in the study, knew why specifically he or she had been asked to participate and that he or she knew that the study whenever could be terminated at without needing to explain why. See appendix 1 for complete information letter and letter of consent.

This study could possibly lead to a better understanding for coaches and athletes when choosing a fitness test to evaluate athletes. Comparing the three tests in this study could potentially lead to an option of using a less strenuous test or a more sport specific test depending on which abilities the coach wants to test.

Results

Twelve males with a mean age of 17 (range:16-19) years and mean (SD) weight of 78.5 ± 8.8 (range: 59.8 – 90.0) kg participated in the study. A Shapiro -Wilks test showed that all data were normally distributed ($p > 0.05$). Mean values for all three tests, SD, range and Shapiro Wilks significance are presented in table 2.

Table 2. Mean values for all three tests along with SD, range and Shapiro- Wilks significance, n=12.

	Mean	SD	Range	Shapiro W. Sig
3000 m (s)	803	± 57	723 - 918	0.318
Yo-Yo IR1 (m)	1483	± 253	1160 - 1920	0.528
SMTJ $\dot{V}O_{2\max}$ ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	50.55	± 2.43	45.66 – 53.91	0.358

SD = standard deviation, m = meter, s = seconds, IR = intermittent recovery test 1, SMTJ submaximal treadmill jogging test, $\dot{V}O_{2\max}$ = predicted maximal oxygen uptake.

A strong, significant linear correlation ($r = - 0.724$, $r^2 = 0.524$, $p < 0.01$) was found between 3000 m running and Yo-Yo IR1 performance, correlation is presented in figure 2. A weak, not significant linear correlation ($r = - 0.309$, $r^2 = 0.095$, $p > 0.05$) was found between 3000 m running performance and $\dot{V}O_{2\max}$ from the submaximal treadmill test, correlation is presented in figure 3.

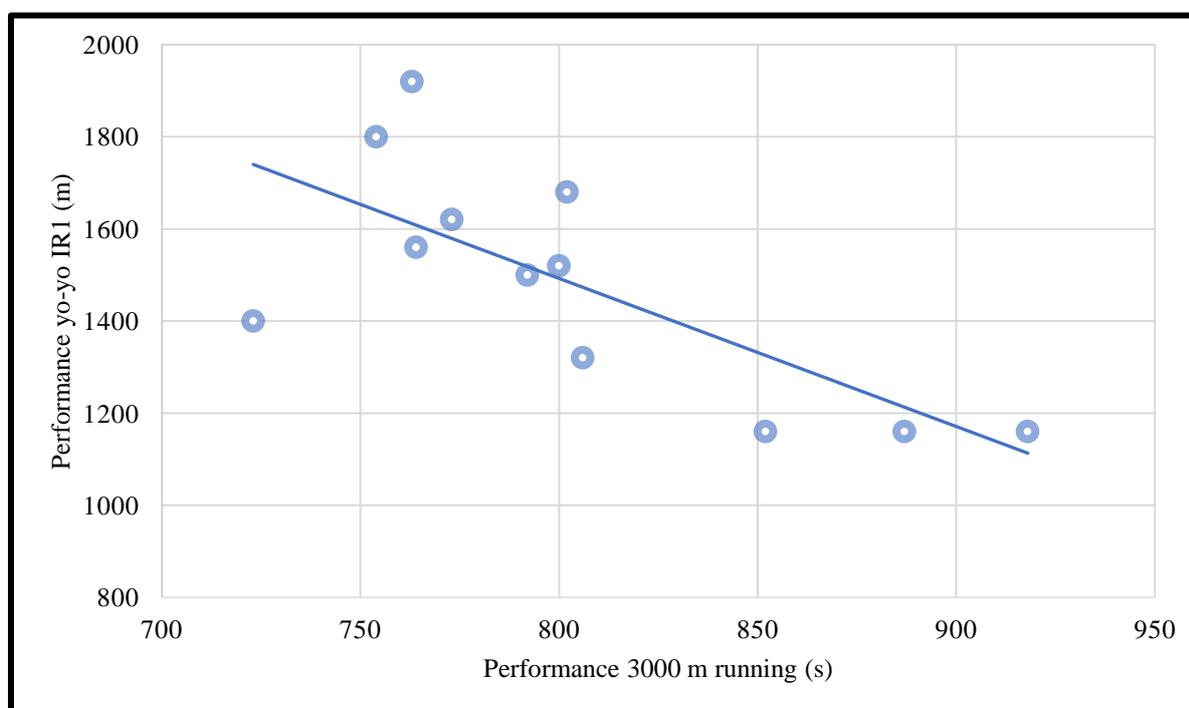


Figure 2. Correlation between performance in 3000 m running (seconds) and Yo-Yo intermittent recovery test 1 performance (meter), $r = - 0.724$ ($r^2 = 0.524$). Significance, $p < 0.01$, $n = 12$.

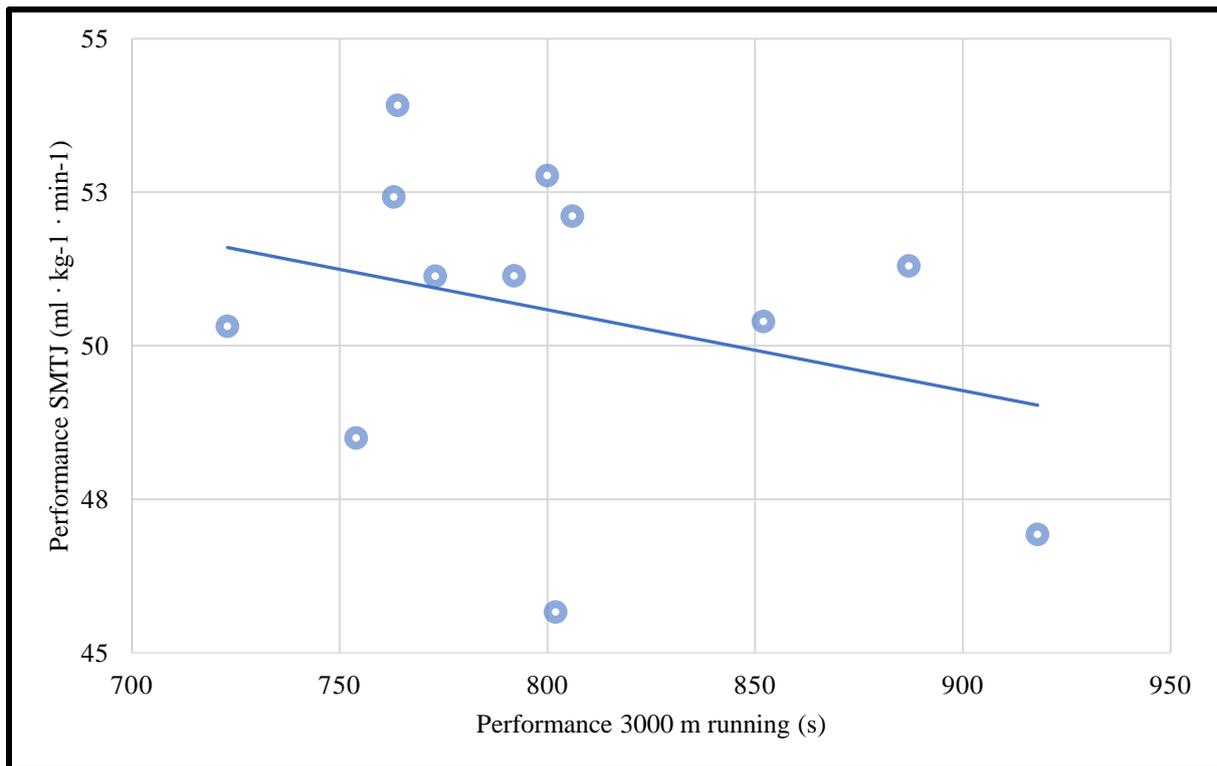


Figure 3. Correlation between performance in 3000 m running (seconds) and predicted $\dot{V}O_{2max}$ from submaximal treadmill jogging test (SMTJ) ($ml \cdot kg^{-1} \cdot min^{-1}$), $r = -0.309$ ($r^2 = 0.095$). Significance, $p > 0.05$, $n=12$.

Mean self-selected jogging speed during the SMTJ test was 9.4 ± 0.8 km/h and mean steady state heart rate achieved during the test was 153 ± 12 bpm. Mean 85 % of age predicted heart rate was 173 ± 1 and was not exceeded by any of the subjects.

Discussion

This study examined the linear correlation between 3000 m running and Yo-Yo IR1 and SMTJ test in male adolescent handball players. The results showed a significant strong correlation between 3000 m running and Yo-Yo IR1 performance and a weak, not significant, correlation between 3000 m running and SMTJ.

Result Discussion

The correlation found between 3000 m running and the Yo-Yo IR1 indicates that, although only 52.4 % of one variable can explain the other, the 3000 m running test could be replaced by the Yo-Yo IR 1 test or vice versa despite the differences in metabolic requirements in the two tests. As mentioned by both Stølen et al. (2005) and Glaister (2005) a greater $\dot{V}O_{2max}$,

which is well assessed during the 3000 m running, could be a good indication of the ability to clear lactate and resist fatigue during repeated sprinting. Therefore, a good result in the 3000 m running test could indicate a good performance in the Yo-Yo IR1 test which was showed in this study. Bishop et al. (2004) presented a significant, moderate correlation between repeated sprinting and $\dot{V}O_{2\max}$ in untrained to moderately trained females and further suggest that the ability to buffer hydrogen ions, which are a result from glycogen degradation, highly influence performance during repeated sprinting. However, one can discuss how strenuous and lactate creating the Yo-Yo IR1 test are. Compared to the IR2 test the IR1 creates lower levels of lactate, depletes less of the PCr and does not lower the muscle pH as much. The IR1 test is also further discussed as only testing the ability to perform high-intensity aerobic work (Bangsbo et al., 2008). Although, compared to 3000 m plain running the IR1 test definitely assesses the ability to perform repeated intense exercise to a greater extent and are further considered a valid test for handball players according to Souhail et al. (2010). So at least to some point the correlation between 3000 m and Yo-Yo IR1 found in this study is probably due to that a greater $\dot{V}O_{2\max}$ also indicates a better ability to clear lactate and resist fatigue during repeated sprinting.

The results from the 3000 m running test was on average 101s slower than the results reported by O'Gorman et al. (2000). Also the result from the Yo-Yo IR1 test 1483 m (1160-1920) was lower compared to the result in previous studies 1831 m (1440-2440) (Souhail et al., 2010). Compared to game distance covered in the studies by both Souhail et al. (2010) 1921 m (1507-2478) and Chelly et al. (2011) 1777 m (1500-2611) in young adolescent handball players the results from the Yo-Yo IR1 test was also lower. In this study no consideration to playing position was taken which is discussed by Ziv and Lidor (2009) to be the reason of the big range found in distance covered during games. Also Castagna et al. (2006) shows that explosive strength in the lower limbs can influence the performance in the Yo-Yo IR1 test in soccer players. No regards were neither taken for this or to relative body mass or to playing position, which if done, could have created a more homogeneously study group. However, lower limb explosive strength is probably not as determinant in the 3000 m running test or the SMTJ due to continuous running and no stopping and turning.

The $P\dot{V}O_{2\max}$ from the SMTJ test was 50.55 compared to 47 ml · kg⁻¹ · min⁻¹ in the original study by Vehrs et al. (2007). However, the speed chosen by the participants in this study 5.8 mph and steady state HR achieved 153 bpm was very similar to the data in Vehrs et al. (2007) study, 5.9 mph and 155 bpm respectively. There are many different factors that could have

influenced the non-correlation found between 3000 m and the Submaximal Treadmill Jogging Test. First of all, all four parameters of the SMTJ test; steady state HR, age, weight and mph could be a potential source of error. However, the SMTJ are validated according to Vehrs et al. (2007) and should yield a valid result. The biggest error was probably the age predicted HR used in the SMTJ, which can differ about ≥ 10 bpm and can produce a $\dot{V}O_{2\max}$ error of 10-15 %, sometimes even up to 25 % (Cardinale, Newton & Nosaka, 2011). Also the age-group used in this study could be a potential source of error for the SMTJ test and is further discussed under methods discussion. The major sources of error with the 3000 m run is discussed under method discussion. Overall, given that a submaximal test only is a prediction it is probably the result from the SMTJ test that creates the weak correlation found with 3000 m running. On the other hand, given that the SMTJ actually predicts a valid $\dot{V}O_{2\max}$, one could argue that the 3000 m running test is not a good indication of $\dot{V}O_{2\max}$. Even though the original study by Cooper (1968) is well researched in running 12 minutes as far as possible the 3000 m running test is not as researched. From this perspective and the result from this study one could draw the conclusion that the 3000 m running test should not be used to assess $\dot{V}O_{2\max}$. However, it is more likely that the prediction errors and errors in estimating HR yield a greater overall error for the SMTJ test than the errors that might have been with the 3000 m running test. Compared to the study by Ziv and Lidor (2009) the estimated $\dot{V}O_{2\max}$ from the SMTJ test was at the lower level of $\dot{V}O_{2\max}$ reported by Ziv and Lidor (2009) in adult handball players. This difference could be due to the adolescent subjects used in this study (Vehrs et al., 2007), but it could also be an indication of that the submaximal test used in this study was not the best choice for this particular age-group, this is further discussed under method discussion.

Method Discussion

This study was conducted a few weeks after the handball season ended. Bangsbo et al. (2008) reports varying results when the Yo-Yo IR1 is performed during the season and better performance when conducted pre-season. If the time of this study was pre-season or post-season can be discussed but however the tests were not disturbed by weekly high-intensity games that could have affected the result. The weather conditions during the 3000 m running test, which was the only test performed outdoors, was not ideal. It was cold and windy which might have influenced the physical performance but perhaps also the mental attitude to the test. The 3000 m test was also the test with the least number of participants. No explanations were given to the low attendance by the subjects opening for a discussion about if the bad

weather conditions could be an explanation of the low number of participants. For the 3000 m running test the subjects also had to travel to a different location than their normal training facilities which also might be an explanation of the low attendance and overall big drop-out of 33 % in this study. Different warm-up routines were used before each tests, this was because of the different nature of the tests. For the submaximal treadmill test and the 3000 m running test a shorter warm up of jogging was considered adequate as the test were continuous running. For the Yo-Yo IR1 test a more advanced warm-up were performed due to the high-intensity stopping, turning and acceleration during the tests.

The submaximal treadmill test protocol used was valued as the best suited for this study after evaluating three running test from Miller (2012) and one test from the review and meta-analysis of Ferrar, Evans, Smith, Parfitt & Eston (2014). The weak correlation found between 3000 m running and SMTJ could be explained by the HR variation as explained above but perhaps also by the age of the participants in this study. The test by Vehrs et al. (2007) used in this study is recommended for an 18-40-year-old population and although the age for the subjects in this study ranged above 18 the mean age was only 17 years. Since the test recommended by Ferrar et al. (2014) are considered a field test and requires one-mile jogging this was excluded primarily of practical reasons. This test is though better suited for a younger age-group (13-17 years) which might have been a better choice in this study group. However, using another Submaximal test would still give the possibility of heart rate variation and the test recommended by Ferrar et al. (2014) could possibly yield motivational problems, needing to running 1 mile, which was not a problem using the test by Vehrs et al. (2007). To eliminate the potential source of error with age predicted HR what could have been done is to first perform the Yo-Yo IR1 test, measuring maximal HR at the same time, and then use that maximal value for the SMTJ test. According to Krustup et al. (2003) 99 ± 1 % of maximal HR can be achieved during the Yo-Yo IR1 test.

As mentioned above weather conditions could have affected the result of the 3000 m running, however the test leader and the coach of the athletes put emphasis on explaining the reason and ideas behind the tests which motivated the players even more for all three tests. Some cheering did occur during the test, especially during the 3000 m running and Yo- Yo IR1. This is perhaps hard to avoid in a team sport when all, or at least half of the players, performs the test at the same time. But to better standardize the test, both the 3000 m and the IR1 test could have been performed one on one with no spectators. Also even though the subjects were

instructed not to compete with each other it is hard to avoid players not following a team mate or trying to beat someone else which could have affected the results.

For practical applications for a coach or trainer in handball one could, based on the result from this study, use the Yo-Yo IR1 instead of the 3000 m running. A coach however must take the practical implementations in consideration. The 3000 m running is very easy to conduct if one has access to a running track, then all you need is a stop-watch. The Yo-Yo IR1 test needs some sort of software that can play the audio signals and speakers. On the other hand, the test can be performed on a handball pith, which is a huge advantage. In this study the subjects were attracted and motivated by that they were promised to play a game of handball afterwards the Yo-Yo IR1 test, this could not be made for the 3000 m run and was perhaps also one of the reason for the low attendance in the 3000 m run and the high attendance for the Yo-Yo IR1. A submaximal test would be interesting for a coach from several different perspectives. First of all, a submaximal test could be conducted in-season, being able to test players during the season to see changes and possible decrements. The submaximal test can also be used to coach athletes into an appropriate intensity of exercise (Vehrs et al., 2007). And in an adolescent age-group it is not affected by motivational factors. The SMTJ, although the result in this study, could potentially still be used, but then instead looking at the changes in HR if one performs the test several times with the same relative speed. This should theoretically yield a difference in HR as a reaction to increased fitness.

Future Research

Future research should look into the relationship between 3000 m running and the Yo-Yo IR2 test to in a greater extent evaluate if the Yo-Yo test gives a good indication of maximal oxygen uptake ($\dot{V}O_{2max}$) in an even more strenuous and more lactate creating test. Also the 3000 m running test should be further validated as 3000 m running and not 12 min running and the test should also be **further** studied in direct relation to handball specificity as for example match performance. Very little literature has been found of the 3000 m running test, to make scientific research and writing easier all studies on this test is welcomed. Even though it feels like it is “common sense” that this test works, literature is missing. Future research should also evaluate the SMTJ test with measured maximal heart rate and with subjects that matches the age interval 18-40 years. Also replacing the SMTJ with a direct measurement of $\dot{V}O_{2max}$ will provide an interesting validation study of the 3000 m running test and the Yo-Yo IR1 test.

Conclusion

In handball today a strenuous 3000 m running test is used to evaluate $\dot{V}O_{2\max}$ in handball players. If this test could be replaced by either a more sport specific test or a less demanding submaximal treadmill test was evaluated in this correlation study. A strong and significant linear correlation was found between 3000 m running and the Yo-Yo IR1 test which is probably due to that a better $\dot{V}O_{2\max}$, which are well assessed during 3000 m running, also indicates a good ability to clear lactate and resist fatigue during repeated sprinting. The result from this study indicates that the Yo-Yo IR1 can replace the 3000 m running test used in handball today. This gives also coaches a chance to perform $\dot{V}O_{2\max}$ test on field which might be an advantage for some teams. No correlation was found between 3000 m and the submaximal treadmill jogging test, this was probably due to error sources such as age predicted heart rate used in this study and/ or the age mismatch of the test protocol and the subjects. This shows that when choosing a submaximal test one needs to be very accurate in which test to use and to use measurements that are carefully measured, as for example a real measurement of maximal HR in this study.

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Appendices

Appendix 1. Information letter and letter of consent.

Information om deltagande i forskning

Hej!

Jag heter Hampus och läser tredje året på kandidatprogrammet Biomedicin – Inriktning fysisk träning på Högskolan i Halmstad. Jag gör nu mitt examensarbete där jag ska undersöka hur tre olika test skiljer sig åt i att uppskatta den maximala syreupptagningen hos handbollsspelare och undrar om du är intresserad i att vara med i denna studie?

Maximal syreupptagning är ett mått på hur bra fysisk förmåga man har. Detta kan mätas på flera olika sätt, dels i laboratorium men också genom uppskattning efter att man till exempel har genomfört ett Cooper test och då man sedan räknar ut sin maximala syreupptagning. I denna studie jämförs ett 3000 meters test, ett Yo-yo test och ett löpbandstest. 3000 meter och Yo-Yo testet kräver maximal ansträngning medan testet på löpband görs i en egen vald, bekväm hastighet, i fem minuter.

Förfrågan om deltagande

Du tillfrågas att vara med i denna studie eftersom du är en aktiv handbollsspelare. För att delta i studien behöver du vara skade- och sjukdoms fri. Är du under 18 år så krävs godkännande av målsman/vårdnadshavare

Hur går studien till?

Studien kommer innehålla tre testtillfällen och göras i samband med handbollslektionerna. Det första testtillfället kommer ske i samband med det 3000 meter test ni gör i skolan och består av att man springer 3000 meter så fort man kan. Löpbandstestet kommer göras i labbet i N-byggnaden på Högskolan (lokal: N-129). Detta test kommer ta cirka 15 minuter och bestå av en uppvärmning och sedan 5 minuter jogging på en egen vald, bekväm hastighet. Yo-yo testet kommer göras i samband med en handbollsträning på skolan. Detta test kommer först innebära en uppvärmning och sedan att man springer fram och tillbaka 2x20 meter med 10 meters aktiv vila efter varje 40 meter. Ju längre testet pågår desto fortare ska man springa tills man inte längre orkar.

Vilka är riskerna?

Testerna innebär löpning och vändningar, detta medför inga andra risker än vad som förekommer under en normal handbollsträning eller match.

Finns det några fördelar?

Resultatet från testen innebär att vi uppskatta din maximala syreupptagning, detta värde kan du använda för att bättre anpassa din träning. Vid löpbandstestet kommer även din puls mätas vilket kan ge dig en inblick i hur pulsbaserad träning kan genomföras.

Hur får jag information om studiens resultat?

Du har möjlighet att få tillgång till resultatet om så önskas, kontakta i så fall Hampus Cato på kontaktuppgifterna nedan.

Hantering av data och sekretess

All information om deltagare kommer att hanteras konfidentiellt. I studien kommer inga personliga uppgifter redovisas enskilt utan allt resultat presenteras på gruppnivå. Detta betyder att inga namn eller personliga resultat kommer att kunna utläsas.

Frivillighet

Du som testperson har rätt att avbryta testet när som helst utan att ange orsak. Om så önskas kommer då redan insamlad data att förstöras.

Ansvariga för studien är:

Hampus Cato
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Högskolan i Halmstad

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Samtyckesformulär

Nedan ger du ditt samtycke att delta i den studien som jämför olika fysiska tester för att uppskatta den maximala syreupptagningen. Läs igenom informationen noga och ge ditt medgivande genom att signera ditt namn nederst på sidan.

Jag medgiver att jag:

- Har tagit del av informationen kring studien förstår vad den innebär.
- Har fått ställa de frågor jag önskar och vet vem som är ansvarig huvudman om jag har fler frågor.
- Deltar frivilligt i studien och förstår varför jag har blivit tillfrågad.
- Vet att jag när som helst kan avbryta mitt deltagande i studien utan att ange orsak.

Jag intygar att jag har läst det informerade samtycket och tagit del av informationen kring studien. Jag förstår vad deltagande i studien innebär och ställer upp frivilligt.

Ort och datum _____

Underskrift _____

Namnförtydligande _____

Ort och datum _____

Underskrift vårdnadshavare _____

Namnförtydligande _____

Appendix 2. Warm up Routine

Warm Up Routine Before Yo-Yo IR1	
Exercise	Time (min)
Easy Jogging	03:00
Forward Jumping Jacks	00:45
Jogging touching the ground with hands	00:45
Sideways Skipping	00:45
Stage 1-4 of the Yo-Yo IR1	03:00
Lunges	01:00
5 Fast maximal Sprinting	01:00

Hampus Cato



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