EFFECTS OF HIGH INTENSITY CYCLING INTERVAL TRAINING ON ENDURANCE PERFORMANCE IN ICE-HOCKEY PLAYERS

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SUMMARY

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Ice-hockey has changed considerably during the last few decades. Sport has become quicker, more physical and demanding for players. High levels of aerobic and anaerobic performance are crucial. Training programs and endurance training are expected to cause beneficial changes in aerobic performance which may ultimately lead to enhanced on-ice performance in ice-hockey players. Advanced and optimized training programs are developed to find optimal training intensity, load and recovery. The purpose of this study was to find out how effective a carefully planned high intensity cycling training program is for endurance performance in ice-hockey players. 24 competitive ice-hockey players trained for six weeks in three different groups. The cycling training group (n=8, 23.1 ± 1.2 yrs., 178.9 ± 4.9 cm, 78.9 ± 6.0 kg) trained endurance with high intensity cycling total of ten training sessions. The running group (n=8, 25.1 ± 1.2 yrs., 181.3 ± 6.4 cm, 83.2 ± 11.0 kg) trained endurance with high intensity running total of ten training sessions. The team training group (n=8, 19.8 ± 0.7 yrs., 182.3 ± 5.8 cm, 86.6 ± 8.9 kg) trained endurance according to the team training program. The cycling group resulted in significant changes in cycling time (5.9 %, $p<0.01$) and in maximal power output (5.8 %, $p<0.05$) in maximal cycle ergometer test. The running group did not result in significant changes in aerobic performance measured with maximal cycle ergometer test. The team training group resulted in a significant change in cycling time (2.8%, $p<0.05$). Differences in changes regarding cycling time were significant between the cycling and running groups ($p<0.05$) as well as between the team training and running groups ($p<0.05$). The cycling group improved performance in all strength tests. It is suggested that aerobic training in ice-hockey players can be optimized with a carefully planned high intensity cycling interval training program which is based on the individual training intensities determined from heart rate reserve without any concurrent strength interfering effects. Optimized individual training programs allow more time for high-quality training of the other important components in ice-hockey performance.

Key words: ice-hockey, interval training, endurance, cycle ergometer, heart rate reserve

CONTENTS

1 INTRODUCTION

Ice-hockey has become considerably quicker, more physical and demanding for players during last decades. Players must train hard to meet the requirements for playing in elite level. Advanced training programming and periodization are searched, developed and conducted in practice to find optimal training intensity, load and recovery.

Ice-hockey is multifaceted, challenging and unique sport in which many different aspects of elite sports are combined. Physical performance in endurance, strength and speed must be optimized in synergy to obtain highest possible total performance. And with exceptional physical appearance, the sport related skills must be trained to natural and smooth actions through thousands and thousands hours of skill training which then can be effectively executed during the game. Player, who can be skilled even in fatigued state, and shoot, skate and carry the puck most effectively in every situation of the game, will be successful. Player must be durable, strong and quick, have motoric skills, mental toughness, think fast, find the correct choices and react in blink of an eye.

During off season and in preparatory training phase much emphasis is dedicated to endurance training. Ice-hockey players train endurance with many different practices: for example with running, roller skating, uphill or stair intervals, playing ball games, wrestling and of course, when season starts, with skating on ice. Still, one of the most common training methods throughout the hockey world for improving endurance in ice-hockey players is cycling. Cycling is favored especially in off-ice training in summer and in rehabilitation programs with injured players.

Aerobic performance must be in optimal level when on-ice season starts and during competitive phase the qualities obtained in summer should be, at least, maintained. Different teams have different training protocols and coaches face challenges to find the optimal training programs for developing the endurance performance. All performance qualities (strength, endurance, speed, power, skill etc.) should be simultaneously improved, which causes high volume of training with several different training protocols, methods and regimens. Training programs in ice-hockey are sometimes complicated and disordered with mixed focus for one training method for a given period of time and then changing for another. This might cause problems such as loss of training program progressivity, continuance and individualism and even overreaching and overtraining which may deteriorate physical performance. Coaches need to consider how individual the training programs are and what are the most effective and useful training methods for achieving the purposes and goals that are ultimately reached for. This is very challenging task in a multifaceted sport, such as ice-hockey, with several different physical performance attributes.

The purpose of this study is to find out the effects of different type of six week training period on endurance performance in ice-hockey players. There is not much study data available from training studies conducted with ice-hockey players, an even less regarding individual high intensity interval training programs for ice-hockey players. This study aims to answer the question if endurance performance in ice-hockey player could be developed more with optimized individual high intensity cycle ergometer training program when compared to running and regular team training. The training period in this study takes place in the preparatory training phase between the end of previous competitive season and start of the on-ice training, which is critical phase in achieving improvements in endurance performance. Information that this study gives might be used for optimizing the off-ice training programs in ice-hockey players, especially for optimizing the endurance training and endurance performance development.

2 PHYSIOLOGICAL DEMANDS IN ICE-HOCKEY

2.1 Nature of the game

Ice-hockey is characterized by several high intensity game intervals (shifts) with recovery periods in between the intervals (Carey et al. 2007). One shift consists of skating with different intensity and speed, quick transitions and turns and repetitive body contacts (Montgomery 2000). In ice-hockey the intensity and duration of one single game shift (also called as work phase or interval) is unknown in advance. Total intensity is accumulated according to the demands of different circumstances and events on the ice. (Mero et al. 2007.)

One game includes three 20 minute periods with 15-18 minutes intermissions between the periods. Altogether the duration of one game event is from 120 to 170 minutes. Duration of one shift is typically 45 to 60 seconds and sometimes it can last up to 85-90 seconds. Recovery time between shifts changes from about two to five minutes. NHL-player play on average about 16 minutes in one game but some players may play as much as 35 minutes per game (Cox et al. 1995; Montgomery 1988; Montgomery 2000; Carey et al. 2007; Mero et al. 2007). Tables 1 and 2 show playing times and shift durations for elite ice-hockey players.

TABLE 1. Elite player average playing time in one game.

Ten players with most ice time	NHL defensemen 2009-2010	NHL forwards 2009-2010	Finnish Elite league defensemen 2012-2013	Finnish Elite league forwards 2012-2013	Swedish elite league defensemen 2012-2013	Swedish elite league forwards 2012-2013	Finnish 2nd elite league defensemen 2012-2013	Finnish 2nd elite league forwards 2012-2013
Time on ice/ game (min)	25:28–27:01	21:06–22:34	25:04–27.01	20:13–24:19	22:35-25:18	18:50-22:29	22:32–25:18	19:19–21:41

TABLE 2. Amount of shifts and duration of one shift in elite players.

Ten players with most ice time	NHL defensemen 2009-2010	NHL forwards 2009-2010
Shifts/ game	26.2–32.3	20.5–29.4
Shift duration (s)	50–60	43–64

2.2 Aerobic and anaerobic performance

The metabolic demands for body and energy production in ice-hockey are unique (Cox et al. 1995). Ice-hockey as a sport in physiological point of view is highly anaerobic, and that is why high states of fatigue accumulate and the execution of game skills become more difficult as game goes on. To cope with these circumstances and demands is challenging because the player should be able to maintain both the skill levels and energy levels throughout the game. (Montgomery 2000.)

Oxygen uptake during the whole game is on average at the level of 80% of maximal oxygen uptake (VO_2max). Maximal oxygen uptake of an ice-hockey player is typically 55-60 ml/kg/min. (Montgomery 1988.)

Heart rate during the game rises over the level of 90% of maximal heart rate (HRmax). Average heart rate during one shift is about 85% of maximal heart rate. Heart rate recovers to levels of 55-70% of maximal heart rate between the shifts at the bench. During the short game break (duration 20-30 seconds, players stay on ice for next shift) heart rate recovers only about 10 beats at maximum. (Montgomery 1988.)

The total required energy in ice-hockey is produced mainly **anaerobically (69%)** but the **aerobic energy system is also important (31%).** The intensity and duration of single shift determine whether energy is produced anaerobically or aerobically. Sprints and high-speed actions require anaerobic capacity and power whereas the duration of the whole game, recovery and replenishment of the energy supplies require aerobic endurance capacity. (Montgomery 1988.) Figure 1 explains the changes in sources for energy production during exercise (MacDougall et al. 1991).

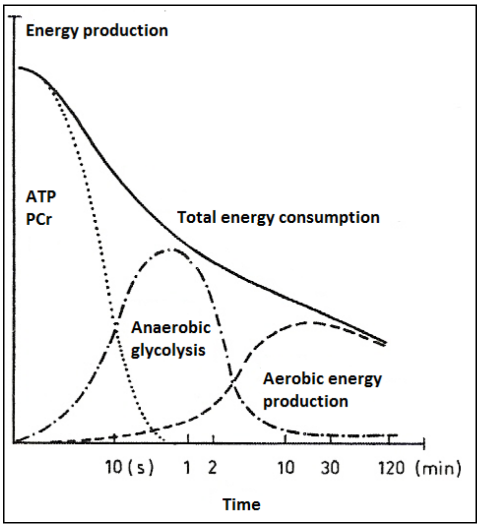

FIGURE 1. Energy production during exercise (modified from MacDougall et al. 1991).

During the game, player works with heart rates over the lactate threshold six minutes at maximum (Cox et al. 1995). When heart rates from game are examined, it is important to notice that psychical factors, static muscle contractions especially in upper-body, interval type of actions and rise in core temperature caused by hockey equipment may affect heart rates (Montgomery 1988).

Table 3 show how different energy systems function during hockey game. In short game actions anaerobic energy systems are dominating but as game (and season) goes on and more emphasis is placed on recovery, more demands are set for aerobic energy systems. (Tupamäki according to Bomba 1999.)

TABLE 3. Proportions of different energy systems to ice-hockey game actions (modified from Tupamäki according to Bomba 1999.)

Type of movement	Energy system:		
	Anaerobic non-lactic	Anaerobic lactic	Aerobic
5 sec sprint	**85 %**	**10 %**	5 %
10 sec fast skating	60 %	30 %	10 %
30 sec constant work	15 %	70 %	15 %
1 min game shift with sprints, stops, gliding	10%	**60 %**	**30 %**
Recovery between shifts and periods	5 %	5 %	**90 %**

Heart rate rises near maximum and lactate may even reach the level of 15 mmol/l at the end of the period. Figure 2 represents the changes in heart rate and lactate for one ice-hockey player during a game event. (Mero et al. 2007.)

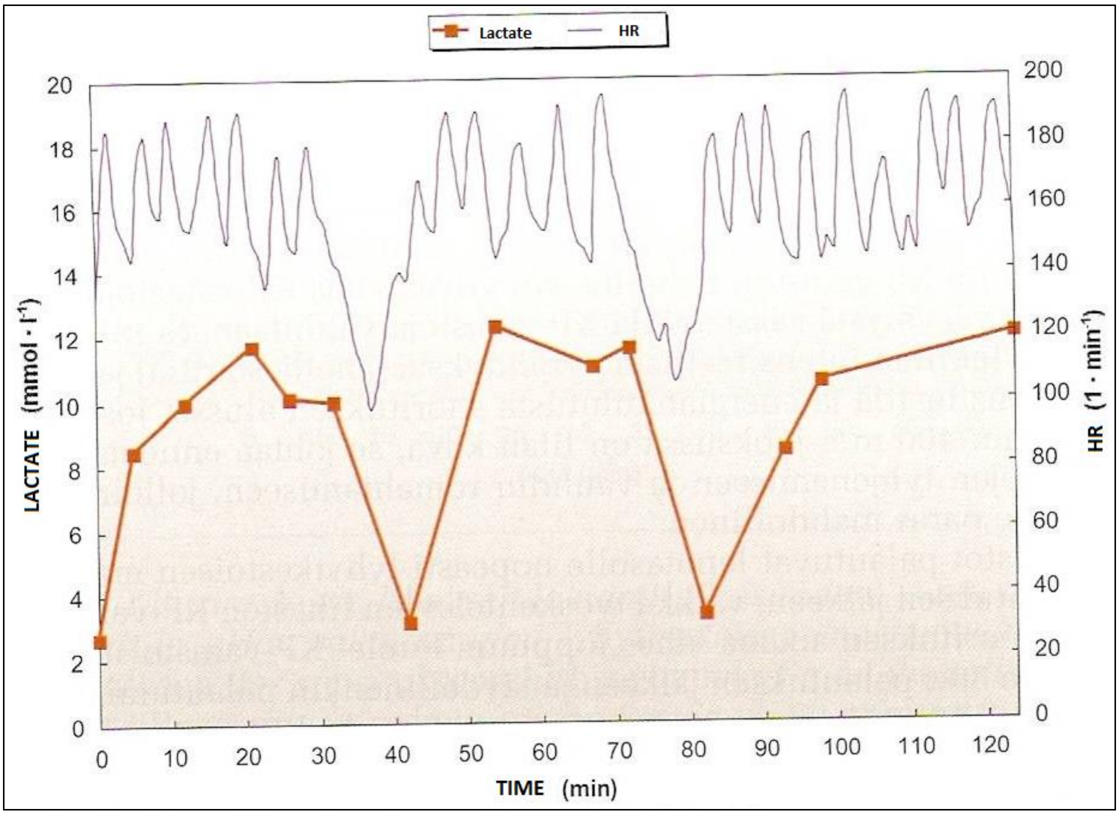

FIGURE 2. Lactate and heart rate during ice-hockey game (Modified from Mero et al. 2007).

Energy is produced mainly anaerobically for the high intensity actions on ice (Carey et al. 2007). For the explosive, repetitive and quick movements, muscles get the required energy from adenosine triphosphate (ATP) and phosphocreatine (PCr) stores (figure 3). Anaerobic glycolysis also contributes to the energy production. Side product lactic acid is also used for energy. These anaerobic mechanisms must work at adequate level, as rapidly and as effectively as possible. The restoration of these energy sources during recovery is crucial for the success in game. (Twist & Rhodes 1993.)

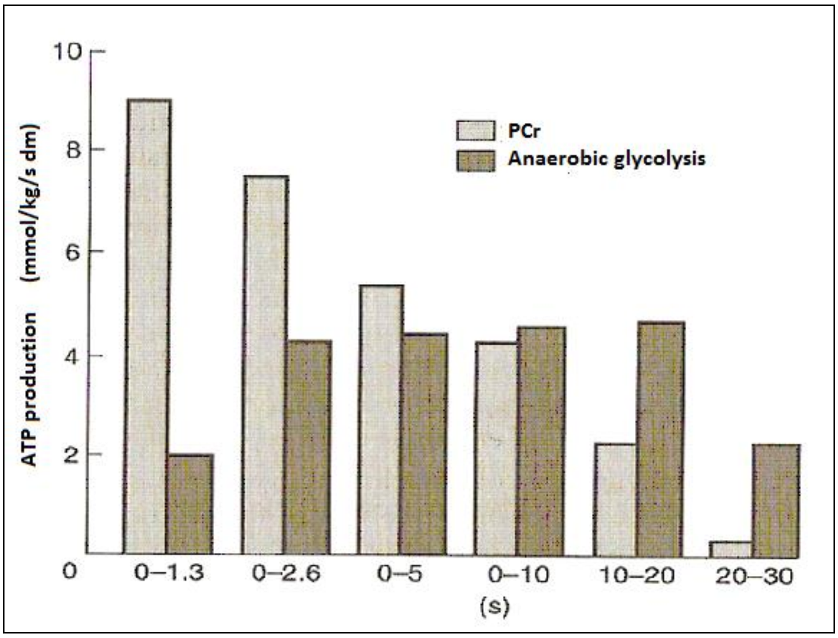

FIGURE 3. ATP production in short duration high intensity exercise bout (Modified from Maughan & Gleeson 2004).

Body can additionally use free fatty acids for energy because of the interval type nature of ice-hockey. However, this requires efficient recovery leading to low lactate levels. Efficient recovery is obviously reached with good aerobic capacity. Free fatty acids in blood may double during ice-hockey game, and this certainly has some muscle glycogen sparing effect. (Montgomery 1988.)

Depletion of adenosine triphosphate and phosphocreatine (PCr) stores, accumulation of hydrogen ions, lactate formation and decline in body acidity (pH) lead to fatigue and impaired performance (Carey et al. 2007). Additionally, glycogen stores are depleted during game, which affects performance (Montgomery 1988). Newer research information also states that accumulation of inorganic phosphate and impairment in calcium transport cause muscular fatigue also in ice-hockey which is a sport characterized with repetitive high intensity intervals (Maughan & Gleeson 2004). In order to maintain high and explosive performance during game, it would be most advantageous, if high intensity intervals are performed mostly with PCr stores and recovery periods are adequate for replenishing the PCr stores (Mero et al. 2007). Phosphocreatine stores are almost fully restored in about four minutes and 50% of the stores are filled in about 30 seconds (Maughan & Gleeson 2004).

It is clear that coach should find optimal playing tempo, so that shifts are short enough and energy stores are filled adequately during the recovery for the next high intensity interval. If shift is too long, the high total intensity of the interval causes the accumulation of lactate and insufficient recovery is not enough for the restoration of the important quick energy sources. Lactate elimination during recovery is slower than restoration of PCr and ATP stores. Adequate recovery between shifts also promotes the muscle oxygen store (myoglobin) restoration and ATP formation with oxygen. This obviously has also some muscle glycogen sparing effect. (Montgomery 1988.)

Spiering et al. (2003) found out that eleven elite female ice-hockey players from United States National hockey team experienced significantly greater cardiovascular stress during games than in practice. Heart rate analysis revealed that mean working heart rate was significantly higher during game play than in practice ($p<0.05$). Also the average amount of time worked over the 90% of maximal heart rate was significantly greater ($p<0.05$) in game (10.5%) than in practice (5.6%). Researchers highlight that this difference between training and actual game play may impair the cardiovascular fitness level and further affect the competition performance. Researchers also state that supplemental in-season high intensity cycling is recommended to maintain or improve cardiovascular fitness. (Spiering et al. 2003.)

2.3 Strength and power

Ice-hockey is fast contact sport, which requires strength and power from upper and lower body (Montgomery 1988). Leg strength and power are essential for effective skating, repetitive accelerations, agility and balance in body contacts. Upper body strength support execution of puck handling, shooting, body contacts and battles. Upper and lower body must function strongly together for winning the battles for puck and positioning on the ice. Explosive strength (power) is one of the most important physical components of the performance in ice-hockey. Optimal game performance requires quick movements, fast reactions and effective force production from whole body. (Twist & Rhodes 1993.)

The ability of lower body to produce force effectively and repetitively is especially essential for skating. Muscles that execute the hip flexion must be adapted for force production needed for effective skating stride. (Montgomery 1988.)

It is important to maintain skill related strength features for whole season. Purpose of strength training in ice-hockey is to increase muscle mass, develop force levels and eventually build up foundation for power training. Importance is pointed for both relative strength and also for absolute strength (muscle mass and force production). Absolute strength is also needed simply for toleration of body contacts. Lower position of center of mass and increase in inertia contributes for more effective skating performance (dynamic balance and overcome of external resistance). Muscle mass and strength also prevent from occurrence of injuries. It must be highlighted that power training in ice-hockey require sufficient base from aerobic, anaerobic and general strength qualities. (Twist & Rhodes 1993.)

3 AEROBIC PERFORMANCE IN ICE-HOCKEY

3.1 Maximal oxygen consumption

Maximal oxygen consumption (VO_2max) is the peak value of oxygen consumption measured during exercise test. It is regarded as the maximal aerobic capacity, which indicates that the subject has reached the maximal limit of oxygen consumption. Most physiology professionals regard VO_2max as the best measure for cardiorespiratory endurance and aerobic fitness. (Wilmore & Costill 2004.) We must remember that VO_2max actually expresses (in terms of oxygen) the maximal rate at which energy (ATP) is produced from aerobic metabolism. The maximal amount of oxygen that can be extracted from atmosphere and delivered to tissues for energy production is dependent on: a) the transport of oxygen by pulmonary, cardiac, blood, vascular and cellular mechanisms and b) the chemical ability of tissues to use oxygen for break down fuels and produce ATP. (MacDougall et al. 1991.) VO_2max is reproducible characteristic of performance with insignificant day-to-day variation (Rowell 1986).

3.2 Aerobic performance exercise testing

Most of the elite ice-hockey players are tested in laboratory conditions to measure their aerobic capacity and performance. Laboratory tests provide accurate information about the endurance performance of an ice-hockey player. Player must meet the certain level of performance in order to be successful at elite level.

Assessing different physical characteristics of an ice-hockey player by different test methods provide many important functions and useful information both for a coach and for a player. Test methods should be specific and relevant to ice-hockey, applicable for training, use measures that are valid and reproducible and conducted on a regular planned schedule in order to provide useful practical benefits. (Cox et al.1995.)

Today the best and most reliable method for testing the aerobic performance in ice-hockey players is under debate. Some coaches favor cycle ergometer tests, some highlight running and some has started to use skating tests every now and then. Whatever the method chosen, aerobic cardiovascular exercise testing is an important tool for optimizing training and monitoring the performance of hockey player during whole hockey season. Montgomery (1988) suggested already back in late 1980`s that on-ice skating tests should be used to measure maximal aerobic performance (VO_2max) for hockey players (Montgomery 1988). However, only one NHL coach reported using oxygen uptake test on ice and two coaches reported using other on ice skating endurance tests. Altogether 18 out of 23 survey answered NHL coaches reported measuring aerobic endurance. Also only a few coaches reported using other skating tests on ice for evaluating agility, acceleration, sport specific muscular endurance or anaerobic endurance. (Ebben et al. 2004.) If there is no possibility for skating tests, cycle ergometer testing might be the most task specific laboratory test method related to skating (Cox et al. 1995).

Aerobic exercise testing is considered to be relevant in team sports for performance monitoring. It is logical to assume that an athlete with high aerobic capacity will tax anaerobic energy sources less and recover at more rapidly than less aerobically trained individual. This is why aerobic performance is important also in team sports with repetitive anaerobic actions. (MacDougall et al. 1991).

Maximal cycle ergometer test has been commonly used test method for determination of the endurance performance in elite athletes within many different sports (Häkkinen et al. 1984; Coyle et al. 1988; Rundell & Pripstein 1995). In ice-hockey the maximal cycle ergometer test has been also widely used for decades (Seliger et al. 1972; Vescovi et al. 2006; Burr et al. 2008; Durocher et al.2010 & Roczniok et al. 2012).

In most cycle ergometer test protocols cadence of 60-90 revolutions per minute (RPM) are used. The cycling power (resistance) is increased constantly with 20 to 50 Watts every two or three minutes and athlete cycles as long as he or she can keep up the minimum required revolutions per minute. Starting power depends on the athletes that are tested. The maximal aerobic performance is determined either through direct oxygen consumption measurement with ventilation gas analyzer or estimated indirectly with equations based on maximal power and time cycled. (MacDougall et al. 1991 & Mero et al. 2007.) The indirect estimations of VO_2max are based on the quite reproducible relationship between heart rate and oxygen uptake in any individual under properly standardized conditions (Rowell 1986). With maximal oxygen uptake (either measured or estimated) and maximal cycling power, also heart rate, rating of perceived exertion (RPE) and often also lactate from fingertip blood sample are used as test variables. Because changes in endurance capacity might be relatively small in elite athletes, the direct measurements give more accurate results. Though, indirect measurements require less device and time, which is why indirect tests are also widely used. Whether the direct or indirect method selected, maximal all-out effort is needed. Submaximal tests are not relevant for elite athletes. (Mero et al.2007.) Average maximal cycling power of 380 Watts was achieved by elite Finnish ice-hockey players in maximal cycle ergometer test (Tiikkaja 2002).

If indirect test method is chosen, the power output is in great importance. Electrically braked cycle ergometer is needed, because of adjusting the cycling power independently of the pedaling cadence. This makes reliable measurement of cycling power possible. Also the test time (how long high levels of oxygen uptake are expressed) can be considered as important measurable characteristic of aerobic capacity in indirect test protocol. (MacDougall et al. 1991.)

Durocher et al. (2010) used the same protocol as have been used for testing NHL-prospects (Burr et al. 2008). Subjects cycle with 80 RPM. Start workload is 80 W and increments are 40 W. Each stage consists of 80 seconds of cycling and, if needed, 40 seconds of rest. Players continue cycling until maximal exhaustion. (Durocher et al. 2010.)

Montgomery (2006) reported continuous cycle ergometer protocol which was used for NHL-players already in early 1980’s. Initial power is 120 Watts and increments are 30 Watts every two minutes. Test subject should remain seated throughout the test. Expired air was analyzed for determination of maximal oxygen uptake. (Montgomery 2006.)

VO_2max predictions based on maximal performance test without ventilation gas measurements rely on assumption of linear oxygen-cost/power-output relationship (mechanical efficiency). In indirect test the repeated high level of motivation from subjects is important to really bring forth the all-out maximal effort. (MacDougall et al. 1991.)

3.3 Adaptations to high intensity interval training

High intensity interval training (HIIT) programs can lead to increases in aerobic as well as in anaerobic performance. There are some data from studies with ice-hockey players but more data are available for other subject populations. Surprisingly, training studies with ice-hockey players are very unusual and that is why there is not much data available regarding ice-hockey players. Most of the studies regarding interval training have used short sprint intervals (less than minute) and studies with longer aerobic intervals are rarer.

Several physiologic factors limit VO_2max and aerobic exercise performance in ventilation, muscle metabolism, central blood flow and peripheral blood flow. Aerobic exercise training will lead to adaptations in cardiovascular system, pulmonary function, lactate concentration, body composition and thermoregulation. Enhancement of these factors will lead to increases in VO_2max and in aerobic performance. In general, higher training intensity leads to greater improvement, especially in populations with high initial fitness level. Still, high and abrupt increases in training volume may increase the risk for injuries. Higher volume does not always necessary mean greater improvements. (McArdle et al. 2007.)

High-intensity interval training is recently suggested as a primary endurance training method for ice-hockey players according to Carey et al. (2007). High intensity training clearly simulates game performance and also leads to improvements in aerobic capacity. (Carey et al. 2007). Studies from Gormley et al. (2008) and Helgerud et al. (2007) clearly show that high intensity interval training may be more effective for improving aerobic capacity when compared to lower intensity training. These studies observed significant improvements in VO_2max after different kind of interval training program in non-athlete subjects. (Helgerud et al. 2007 and Gormley et al. 2008.)

In the study of Helgerud et al. (2007) the VO_2max measured with running treadmill increased after eight weeks of training three times per week by 7.2 % in 4*4 minute training group and by 5.5 % in 15/15 training group. Program with 4*4 minute training included interval running 4*4 minutes with intensity of 90-95% HRmax with three minutes of active rest at 70% HRmax. Program with 15/15 interval running included 47 repetitions of 15 seconds running followed by 15 seconds rest with intensity of 90 to

95 % of HRmax with active recovery of 70 % HRmax. Subjects were in relatively good shape, with the high average initial VO_2max values of 60.5 ml/kg/min and 55.5 ml/kg/min. (Helgerud et al. 2007.)

Gormley et al. (2007) demonstrated that near-maximal intensity interval training (95 % of VO_2reserve) resulted in 20.6 % increase in maximal oxygen uptake. Subjects were ordinary, active, non-athlete people. Subjects were tested with cycle ergometer protocol. Training program was progressive, including five minute intervals with high intensity, followed by active recovery periods of five minutes with lower intensities. Training was done for six weeks, three to four sessions per week. (Gormley et al. 2007.)

Study from MacDougall et al. (1998) observed beneficial adaptations from high intensity (maximal effort) interval training with cycle ergometer. The 7-week training program with three sessions per week consisted of 4-10 * 30 second sprint intervals with 4 to 2.5 minute recovery between intervals. Training program resulted in significant increases in activity levels in several aerobic and aerobic enzymes, power output, total work and VO_2max. (MacDougall et al. 1998.)

Edge and colleagues (2005) demonstrated that high intensity interval training resulted in significant improvement in repeated sprint ability when compared to medium intensity training (total work was matched between groups). High intensity interval training included 4 to 10 intervals of two minute cycling with individually determined power at over the lactate threshold. One minute recovery period followed each interval. (Edge et al. 2005.)

Gaiga & Docherty (1995) found out that nine week aerobic interval training program significantly enhanced the intermittent work test capacity (four times 30 second Wingate-test with three minutes of rest between) in 13 men (primarily field hockey players, average age 20.7 years). Study data states that this nine week training program (three times per week) consisting of five to ten repetitions of three minute intervals with cycle ergometer led to increase in aerobic power and also enhanced ability to repeat high intensity short duration work. (Gaiga & Docherty 1995.)

Study from Gibala et al. (2006) states that low volume high intensity sprint-interval training (SIT) with cycle ergometer led to similar improvements in aerobic exercise test as traditional high volume endurance training with 90 to 120 minutes of continuous cycling. Subjects (active men, average age 21 years) did six training sessions during two week training program. Researchers suggest that SIT is an efficient and time-sparing training strategy for rapid adaptations in exercise performance. Biopsy samples revealed increases in muscle oxidative capacity, muscle buffering capacity and muscle glycogen content. (Gibala et al. 2006.)

McMillan and colleagues (2005) found out clear benefits from sport specific high intensity interval training in soccer players. A ten week training program with two sessions per week resulted to significant improvement in VO_2max with no negative effects on strength, jumps or sprinting performance. Players did 4*4minute intervals with 90 to 95 % of HRmax. Recovery between intervals was jogging for three minutes with intensity of 70% of HRmax. (McMillan et al. 2005.)

Spiering et al. (2003) refer to unpublished data from Rundell, which indicate that in-season high intensity cycle ergometer training improved significantly VO_2max in elite female ice-hockey players. Training protocol included six intervals of five minutes of cycling at 90-93 % of HRmax with three minutes active recovery periods. In their study Spiering et al. (2003) found out that cardiovascular stress differed significantly between practice and actual games. Researchers explain that high-intensity interval training is recommended for ice-hockey players, because it stresses the same energy systems as body uses in ice-hockey. This might ultimately improve competition and game performance. (Spiering et al. 2003.)

3.4 Importance of aerobic capacity in ice-hockey

Every now and then the importance of aerobic endurance is questioned in interval-type of sports. Research results are interestingly somewhat conflicting and some coaches may lead into making blind assumptions. Need for training studies is highlighted in previous research (Abdelkrim et al. 2010). It is amusingly interesting to see, that some of the previous studies have not been able to find significant correlations between for example VO2max and game related performance. Still, when connections between changes in aerobic performance resulted from aerobic training and sport related performance has been investigated, clear beneficial evidence is found. Aerobic performance has evident importance in interval-type of team sports such as in ice-hockey and for example in basketball (Abdelkrim et al. 2010 & Balciunas et al. 2006), field hockey (Gaiga & Docherty 1995) and soccer (McMillan et al. 2005).

Tomlin & Wenger (2001) summarize that aerobic fitness improves ability to recover from high intensity intermittent exercise through increased aerobic response, improved lactate removal and enhanced PCr regeneration (Tomlin & Wenger 2001). Increased aerobic response is seen in study from Hamilton et al. (1991), where games player with lower VO_2max had greater decrement in mean power output in multiple sprint test when compared to subjects with higher VO_2max. Also blood lactate concentrations were significantly higher for games players after the test. (Hamilton et al. 1991.) Study from Yoshida & Watari (1993) revealed that subjects with higher VO_2max showed faster phosphocreatine and inorganic phosphate kinetics after repeated exercise when compared to subjects with lower VO2max (Yoshida & Watari 1993). Study from Forbes et al. (2008) showed similar findings and suggested that high-intensity interval training is effective for enhancing the oxidative capacity in muscles (Forbes et al. 2008).

Although many of the actual game-related actions are mostly anaerobic also in ice-hockey, aerobic performance has still notable importance in game performance as following studies indicate some advantages from good aerobic capacity in ice-hockey. Green et al. (2006) found out that maximal oxygen uptake related significantly to ice-hockey game performance and playing time. Maximal oxygen uptake also predicted scoring opportunities in ice-hockey players. Players (n=29) who had lower lactate concentration with certain oxygen uptake level on treadmill running (speed 12.9 km/h with seven degree elevation) played more during season. It is obviously advantageous for the total team performance that player who can maintain high playing intensity throughout the game will also play more. Correct positioning on the ice, one on one situations, checking and sudden changes in game play (power play, penalty killing, two minute shifts) require effective function from both aerobic and anaerobic performance. This study showed that maximal oxygen uptake significantly correlated to amount of net scoring chances (created scoring chances minus allowed scoring chances). High level aerobic performance delays the onset of fatigue and enhances the recovery during breaks. Thus, player is able to involve more effectively to both offensive and defensive game situations. (Green et al. 2006).

Bracko et al. (1998) study showed that successful players played on average 19.9 seconds longer shifts compared to regular players. Researchers suggested that successful players do not become as quickly as fatigued as regular players while involving game related actions. Interestingly, players were mostly gliding with low intensity with both skates on ice. (Bracko et al. 1998.) In addition, Durocher et al. (2008) stated that skating velocity in lactate threshold (<4 mmol/l) improved from start of the season (15.9 km/h) to the middle of the season (16.9 km/h) but dropped to near the initial level (16.3 km/h) in 16 male ice-hockey players (21.1 years, 86.9 kg, 183.2 cm). Researchers suggested that it is important to maintain the aerobic performance throughout the whole season. (Durocher et al. 2008.) These findings are in close relation to the study of Upjohn et al. (2008) in which skating analysis indicated that more successful players (experience and playing level in their playing career) were more effective skaters, especially in the propulsion phase of the skating stride. Push and propulsion were more effective, because ankle and knee extension occurred more quickly. The extensive range of motion also made the longer stride length possible. Better skaters reached higher skating velocity and stride frequency. These features clearly allow players to execute more superior game performance when compared to less successful players. (Upjohn et al. 2008.)

Quinney et al. (2008) found out that physical performance of elite ice-hockey players has improved considerably during previous 26 years. Clear development is seen also in maximal oxygen uptake. It was also stated, that no significant differences was found between the physical performance in successful and non-successful seasons. (Quinney et al. 2008.)

It is worth of highlighting that each performance quality is limited in the ability to improve with training. When no change in performance in primary quality is seen, maybe the useful way to improve performance is to concentrate on secondary qualities. A 20 % improve in maximal aerobic capacity in sport with “only” 30 % aerobic proportion for total energy production will result into a 6 % increase in total energy production. If for example anaerobic qualities have plateaued, this 6 % will still significantly improve overall athletic performance. (MacDougall et al. 1991.)

4 PURPOSE OF THE STUDY AND RESEARCH QUESTIONS

Ice-hockey is highly competitive professional sport and a large number of talented athletes and coaches are involved in elite level and at the edge of elite level. In elite level even small changes in player's performance might make the difference between winning and losing. Optimal training modes and programs are searched and developed in order to enhance individual performance of an ice-hockey player and further optimize the team performance.

Only a limited number of studies have investigated the effectiveness of a similar type of interval training programs for ice-hockey players as used in this study. Data with other subject populations show that high intensity interval training may lead to significant improvements in aerobic performance. It is clear that these improvements might be smaller, or even undetectable in ice-hockey players with more intense training background and with higher initial aerobic capacity.

The hypothesis of the present study was that endurance performance is enhanced after a six-week period of intense training. It is clear that training should result in improvements in all training groups with different kind of training, but in a special interest was that what kind of an effect an individual high intensity cycle training program will have on aerobic performance when compared to training by running and regular team training. Answers were looked for questions: Is the aerobic performance improved after high intensity cycling training program? Could an enhancement in aerobic performance be optimized with carefully planned individual high intensity cycle ergometer interval training? What is the optimal amount of aerobic training in preparatory phase of the ice-hockey season? Can aerobic performance be improved even with lower training volume when compared to training volumes with regular team training? Is the strength performance interfered by aerobic high intensity interval training?

5 METHODS

5.1 Subjects

Competitive ice-hockey players from Middle-Finland volunteered for the study (n=24, 18-26 yrs.). Playing level ranged from the Finnish 2nd highest elite level to the highest junior elite level. Players were training in three different groups: cycling only (cycling), running only (running) and team training (team). The running and team training groups served as control groups for the cycling group for the comparisons between different training regimens. Table 4 presents subjects' descriptives.

TABLE 4. Descriptives of the subjects.

Group	Age (years)	Height (cm)	BW_PRE (kg)	FAT_PRE (%)	Competitive hockey years	Playing level
Cycling, n=8	23.1 ± 1.2	178.9 ± 4.9	78.9 ± 6.0	17.3 ± 4.0	10.8 ± 1.0	3.0 ± 0.0
Running, n=8	25.1 ± 1.2	181.3 ± 6.4	83.2 ± 11.0	14.5 ± 3.1	12 ± 2.0	2.6 ± 0.5
Team, n=8	19.8 ± 0.7	182.3 ± 5.8	86.6 ± 8.9	19.5 ± 2.5	8.8 ± 0.7	2.4 ± 0.5

Competitive hockey years were calculated from the start of peewee junior age (11 to 12 year old juniors), and years without competitive hockey were also taken into account. Playing level was determined with simply scoring the level in which a player was currently playing with a number from the following criteria (The lower the number the higher the playing level):

1= Finnish elite league ("SM-Liiga")

2= Finnish first division ("Mestis")

3= Finnish second division ("Suomi-Sarja") and

Finnish elite Junior level ("Nuorten SM-Liiga")

Permission for this study was obtained from the ethical committee of University of Jyväskylä. All players were asked for written consent for the participation to the study (Appendix 1).

5.2 Study design

Figure 4 illustrates the study design. The study was conducted during the summer and autumn 2012 (off-ice training phase). PRE measurements were done just at the start of the preparatory training period before the start of the season 2012-2013. A training period of five to six weeks (some players did the total of 10 training sessions in six weeks) was conducted during this off-ice training period. POST measurements were done just before players started on-ice training.

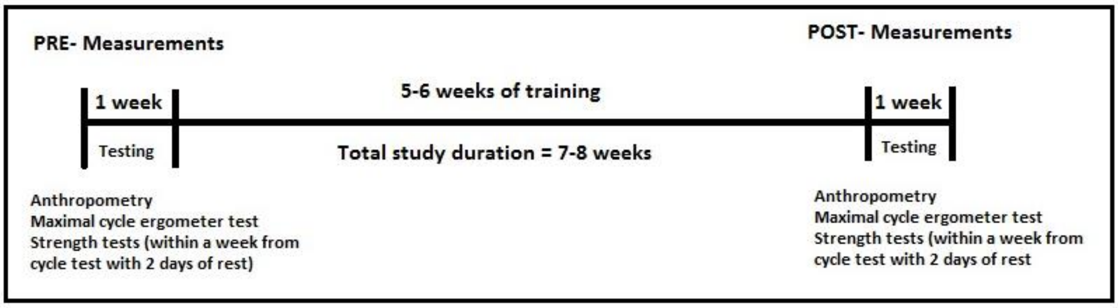

FIGURE 4. Study design.

5.3 Training protocols

5.3.1 Cycling training

The study was performed with three training groups. The cycling group trained endurance only with a specific individual high intensity interval training program (CorusCardio Sport). The training program was progressive, starting with lower intensities and shorter intervals. Table 5 illustrates an example of a cycle ergometer training session. Training was done with Star Trac Spinner Elite- cycling bike (Irvine, USA) twice a week for a total of ten training sessions. Training sessions were conducted in CorusFit Inc. training facilities and physical therapists instructed and supervised every training session.

TABLE 5. Example of cycle training session (with a permission of CorusFit Inc.)

Example of one cycle training session

”long intervals” BASED ON HR Reserve zones

1. 7 min WARM UP HR65% + STRETCHING
2. 3 min HR70%
3. **3 min HR75%**
4. 4 min HR70%
5. **6 min HR80%**
6. 4 min HR75%
7. 3 min HR80%
8. **5 min HR85%**
9. 7 min COOL DOWN 70 % + STRETCHING

→ If MAXHR 190 and RESTHR 42 → HR85%= 169 to 175

→ EKG recorded + monitored all the time during training

Heart rates and ECG (electrocardiograph) were monitored for all players in every training session with a wireless real time ECG monitoring technology (Figure 5) that includes Corus Exercise Assistant V 2.0.16- software, CorusFit WiECG wireless ECG-technology and Sensorwear ECG- shirt (CorusFit Inc. Jyväskylä, Finland).

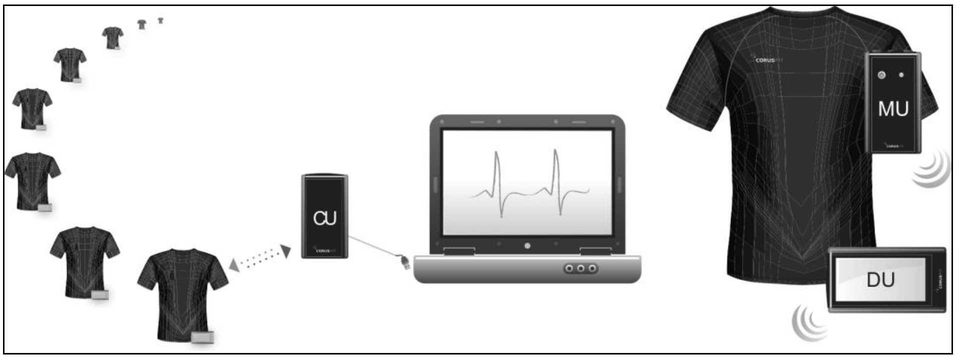

FIGURE 5. Set up for HR and ECG monitoring. CU=collection unit, DU= display unit, MU=Measurement unit (with a permission of CorusFit Inc.)

Players trained together in a group of eight players (Figures 6, 7 and 8) according to the heart rate level intensities calculated from heart rate reserve (HRR). HRR is calculated with the traditional Karvonen equation (Karvonen et al. 1957 according to Swain & Leutholz 1997 and Neumayr et al. 2003), which includes maximal heart rate and resting heart rate determined in maximal cycle ergometer test.

FIGURE 6. Players training with high intensity cycling.

FIGURE 7. Individual heart rate zones for training.

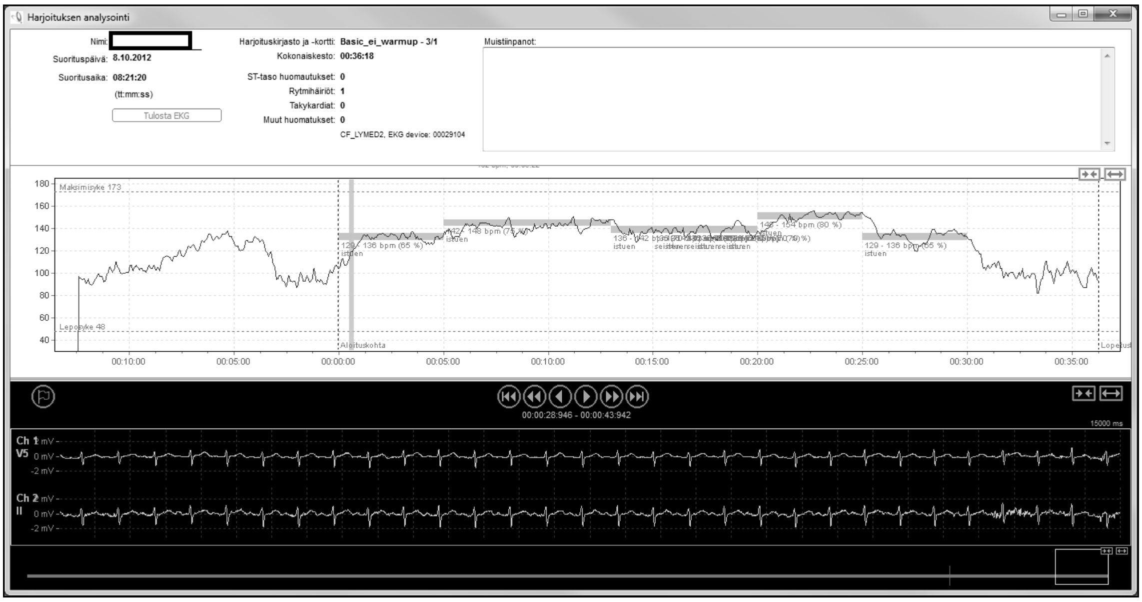

FIGURE 8. Example of a view from a cycling exercise session monitoring (with a permission of CorusFit Inc.)

Training intensities ranged from 65 to 85 % of HRR. For example, calculation for 85 % intensity is: ((HRmax-HRrest)*0.85) + HRrest. Table 6 shows the difference between intensities calculated from maximal heart rate and heart rate reserve. HRR takes into account the individual level of resting heart rate. This approach gives higher intensities for training when compared to calculations simply from HRmax (McArdle et al. 2007). Intensity for 80 % level is heart rates between 80 % and 85 %. A total duration for each cycle ergometer training session was between 35 to 45 minutes.

TABLE 6. Comparison between intensities calculated from HRmax and HRR

	MAX HR	193	
Beats/min	REST HR	44	
Intensity	80 %	85 %	90 %
HRR	163	171	178
HRmax	154	164	174

Players were instructed not to train endurance with any other specific endurance training methods in addition to this cycle training program. One training session per week was allowed for tennis, soccer, indoor bandy and other preferred sports which are regarded here as other endurance. Training diaries were collected from all players in the cycling group. All cycle training sessions were conducted from Monday to Friday (in late after-noon) but players did other training also on weekends. Between two consecutive cycle training sessions there was at least one day rest in between.

5.3.2 Running training

The running group trained endurance only with a specific interval training program with running two times per week for a total of ten training sessions. Running training pro-gram was designed specifically for the purposes of this study to match the volume and intensities of endurance training with the cycling group. All training sessions were con-trolled and recorded with Suunto T6c heart rate monitors (Suunto Inc. Vantaa, Finland) to track and monitor the training. Some of the running sessions were also supervised. Players in the running group got comprehensive instructions for heart rate monitor us-age before starting the training. Players were allowed to train either in groups or individually. Players were suggested to train on track or on flat terrain to be able to more easily control the running velocity and intensity. The running training program was also progressive. Players ran with near same kind of program with a same relative heart rate intensities as the cycling group cycled. Table 7 illustrates one example of running session.

TABLE 7. Example of running session.

Example of one running training session

”long intervals” BASED ON HR Reserve zones

1. 5 min WARM UP HR65%
2. 5 min HR75%
3. **5 min HR80%**
4. 5 min HR85%
5. **5 min HR75%**
6. 5 min HR80%
7. 5 min HR85%
8. **5 min** COOL DOWN **HR65%**

Training diaries were collected from all players in the running group. Players chose the days for training themselves, but two running sessions in consecutive days were not allowed in order to provide adequate recovery.

5.3.3 Team training

The third group trained according to the regular team training program. Coaches determined the training practices, frequency and intensities for the third group. Training for the team training group took mostly place from Monday to Friday. Weekends were mostly devoted for recovery and for one unsupervised light training session.

5.3.4 Training amounts

Training amounts (Table 8) were calculated from individual training diaries collected from the cycling and running groups and from the training program provided by coaches for the team training group.

TABLE 8. Average amounts of training (times/week) for each training group.

TRAINING/ GROUP	Cycling	Running	**Cycling + Running**	Other endurance	**Total endurance**	Upper body strength	Lower body strength	Speed	Flexibility	**Total training**
Cycling	2 ± 0	0 ± 0	**2 ± 0**	1 ± 0.2	**3 ± 0.2**	1.2 ± 0.3	0.8 ± 0.2	0.4 ± 0.2	0.9 ± 0.5	**5.5 ± 0.9**
Running	0 ± 0	2 ± 0	**2 ± 0**	1.1 ± 0.4	**3.1 ± 0.4**	0.9 ± 0.6	0.7 ± 0.4	0.3 ± 0.1	0.3 ± 0.2	**4.7 ± 0.9**
Team	1.7 ± 0.5	1.4 ± 0.2	**3.1 ± 0.7**	1.8 ± 0.4	**4.8 ± 1.1**	1.6 ± 0.2	1.4 ± 0.1	1 ± 0.1	1 ± 0.1	**9.7 ± 1.4**

5.4 Measurements

5.4.1 Anthropometry

Anthropometric variables were measured before the maximal cycle ergometer test in the CorusFit Inc. test laboratory. With the instructions given for players for cycle ergometer test, the circumstances for anthropometric measurements were standardized. Weight was determined with a weight scale (CLAtronic international Gmbh, Kempen, Germany) and height with a tape measure at the laboratory before the maximal cycle ergometer test. Fat percentage was estimated from skinfolds measured from subscapula, supra-iliac, triceps and biceps with skinfold caliper (British Indicators Ltd. Burgess Hill, UK). Fat% was determined for a given sum of four skinfolds according to the table provided by Mero et al. (2007) which is based on the equations of body density by Durnin & Rahaman (1967) and fat% by Siri 1956. The same fitness tester performed all skinfold measurements.

5.4.2 Cycle ergometer measurements

The PRE measurements started with the indirect (without the ventilation gas measurements) maximal cycle ergometer test with an electrically braked cycle ergometer (Lode

B.V. Technology, Groningen Netherlands). The cycle ergometer tests were performed in the CorusFit Inc. testing laboratory (Figure 9).

FIGURE 9. Maximal cycle ergometer test.

At first, players were informed about the study design and details upon the arrival to the test laboratory. Players were instructed to have at least 24 hour rest before the cycling test. Alcohol consumption was not allowed 48 h prior to the test. Players were asked to refrain from caffeine and heavy meal three hours before testing. In the case of sickness or inadequate rest before the test a new testing date was arranged.

Players changed sport clothing on and had about three minutes for warm-up, and after that three to five trials of countermovement jumps were performed. After the measurement of countermovement jumps, body weight, height and skinfolds were measured (described in detail below). Then, player lay down for preparation and installation of electrocardiograph electrodes, Ambu Blue Sensor (Ambu A/S, Ballerup, Denmark) and GE CardioSoft V6.01 (GE medical systems Inc. Milwaukee, USA) ECG measurement device. Electrodes were attached to skin after proper skin preparation according to the standard 12-lead electrode placement instructions. After five minutes of supine rest, resting heart rate was determined (heart rate value maintained constant for a period of 15 seconds) and resting blood pressure was measured twice with Welch Allyn mobile aneroid sphygmomanometer (WelchAllyn Inc. Skaneateles Falls, USA). Resting ECG was also recorded. Physician analyzed the resting ECG data for each player for possible abnormalities. After that, the cycle ergometer and test protocol was set up and player sat on the ergometer for measurement of resting blood pressure in a sitting position. Blood pressures were monitored also through the test with at least in the four initial stages of the test to examine the behavior for the normal blood pressure during exercise. Also heart rate was recorded in a sitting position before the start of the test.

A fitness tester reviewed all the test instructions carefully with the player. Player was allowed to drink water during the test, cycling in the standing position was not allowed. Player was asked to report any discomfort feelings, chest pain, and dizziness if occurred during the test. Player had to cycle with 60 to 70 revolutions per minute (RPM) as long as he could keep at least the pace of 60 RPM. The maximal cycle ergometer test was done in this study with WHO 80+40 protocol. The test started with a two-minute warm-up with 50 Watts (not included in official test time) and then the resistance was increased to 80 Watts, which was the first stage for actual test. Then, resistance was increased every two minutes with 40 W until volitional exhaustion.

RPE was asked 20 to 15 seconds before the increase in Watts (1:40 to 1:45 time point) at the end of each stage. Blood pressure was measured in the middle of each stage (1:00 time point) as long as the sound for auscultation could be heard (at least for four stages in each subject). Heart rate was recorded for each stage ten seconds before the start of the next stage (1:50 time point). Player completed as many stages as possible until volitional exhaustion. The test was terminated when player could not keep up the pace of 60 RPM. ECG was monitored and recorded throughout the whole test. Strong verbal encouragement was provided from the fitness tester in every test. Maximal heart rate was considered as the highest heart rate recorded during final stages in the test.

As the exhaustion occurred, monitoring of recovery heart rates started. Player was provided an opportunity to lie down after the test in the case of feeling of vomiting or if he felt too dizzy to be able to sit on the cycle ergometer and start the cool down with 25 W and 20 to 30 RPM immediately after the test. Recovery heart rates were recorded during active cool down 1, 3 and 5 minutes after the end of the test. Recovery blood pressures were also measured to monitor the normal recovery from all-out exercise. A player who had to lie down for a while in the PRE test was asked to lie down also in POST test to record the heart rates in the similar body position. These players were also provided active recovery after they felt their condition was getting better. In this study protocol, fingertip blood samples for lactate determination or ventilation gases were not collected. After the recovery period (altogether seven to eight minutes) was completed, player was provided spoken and written feedback from the test. The cycle ergometer testing session took altogether 1.5 hours for each subject. ECG and blood pressure responses were normal for every player. Subjective feedback was also collected after the POST testing about feelings and opinions on the training program, load, physical and psychical performance.

5.4.3 Strength measurements

Strength measurements were done with at least two day rest after the cycle ergometer test but not more than a week apart from the cycling test. Strength testing was done only for the cycling and running groups. The team training group could not perform the strength tests. The strength tests were done at the test laboratory in the department of Biology of Physical Activity. The strength measurements included following in this certain order:

1. 10 min warm up with preferred actions (cycling, squats, running, stretching)
2. Countermovement jump (3-5 trials)
   3 MIN REST
3. Isometric bilateral leg press with 107 degree knee angle (3-5 trials)
   3 MIN REST
4. Dynamic bilateral leg press repetition maximum in a horizontal leg press bench with resistance of 2.5*bodyweight (maximum number of repetitions performed correctly with safe technique)
   5 MIN REST
5. Isometric bench press (3-5 trials)
   3 MIN REST
6. Dynamic bilateral knee flexion in the knee flexion bench with the resistance of 1*bodyweight (maximum number of repetitions performed correctly with safe technique)

Players performed three to five trials (at least 3 or maximum of 5 until improvement of more than 5% from previous trial was not reached in the test) in all tests, except in dynamic tests (only one trial), with two minute rest between trials. Dynamic strength tests (horizontal leg press and knee flexion) were done with the same resistance in POST test as in PRE test. Altogether the strength test session took about 45 minutes for each subject.

One running group subject could not perform strength tests due to injuries. For one running group subject, results from isometric bilateral leg press had to be excluded from final data because of measurement error. In the team training group one countermovement jump result was missing due to a problem with measurement device.

Countermovement jump. Countermovement jumps were performed on a jump mat (Department of Biology of Physical Activity, Jyväskylä, Finland). An electronic clock (Department of Biology of Physical Activity, Jyväskylä, Finland) attached to the mat calculated the time on air. Jumping height was calculated with the equation h = (g*t^2)/8 from the time on air. Jumps were performed two times in a rested state for the cycling and running groups before cycle ergometer test and before strength tests. The better result was taken into account. The team training group players performed jumping tests only once, before the cycle ergometer tests. In countermovement jump, subject is standing on jump mat, feet shoulder wide apart. Subject squats down to a position of 90 degree knee angle and immediately jumps as explosively and as high in the air as possible. Landing is controlled, subject can`t squat into a too deep position on landing, slight flexion in knees is allowed.

Isometric bilateral leg press. Isometric bilateral leg press force was measured on an isometric leg dynamometer (Department of Biology of Physical Activity, Jyväskylä, Finland). A force plate measures the force that subject produce to the force plate. Results for every trial were recorded from the force amplifier display (Department of Biology of Physical Activity, Jyväskylä, Finland) connected to the force plate. Results of force are expressed as kilograms. In isometric bilateral leg press, subject is sitting steady on the bench, with knee angle of 107 degrees, determined with a goniometer (Häkkinen & Komi 1986). Subject pushes the force plate as hard as possible keeping up the tension for two to three seconds. Strong verbal encouragement was given from the test instructor to motivate subject for maximal effort.

Dynamic bilateral leg press. Dynamic bilateral leg press repetition maximum was tested with DAVID 210 dynamic horizontal leg press bench (DAVID international Ltd. Helsinki, Finland) with the resistance of 2.5 times subject bodyweight. Subject performed as many repetitions as possible. Subject had to keep the lower back and buttocks in contact with the bench throughout the test. Each repetition from 90 degree knee angle to

180 degree knee angle was considered as complete repetition. Slight flexion in knees was allowed to keep the test safe. Test instructor controlled the knee angle. Subject performs repetitions until exhaustion or until the instructor terminates the test, in the case of inappropriate control of technique or more than three uncompleted repetitions in a row. Uncompleted repetitions were not taken into account in the total result. Subject had to keep up constant pace and too long rest between the repetitions was not allowed. The test duration for maximum repetition in dynamic leg press was from 1.5 to 3.5 minutes.

Isometric bench press. Isometric bench press was tested with isometric bench press dynamometer device (Department of Biology of Physical Activity, Jyväskylä, Finland). Force sensors measured the force that subject produced to the bar. Results for every trial were recorded from the force amplifier display connected to the force plates. Subject is lying on the bench in a bench press position (upper arm horizontally and elbow in 90 degree angle) and pushes the bar as hard as possible keeping up the tension for two to three seconds. Strong verbal encouragement is given from test instructor to motivate subject for maximal effort.

Dynamic bilateral knee flexion. Dynamic bilateral knee flexion repetition maximum was tested with DAVID F300 knee flexion bench (DAVID sport Ltd. Helsinki, Finland) with a resistance of 1*bodyweight. Subject performed as many repetitions as possible (Figure 10).

FIGURE 10. Strength testing at the laboratory of Department of Biology of Physical Activity.

Subject had to keep his lower back and buttocks in contact with the bench throughout the test. Repetition from 180 degree knee angle to 90 degree knee angle was considered as a complete repetition. Slight flexion in knees was allowed in the starting position of the repetition to keep the test safe. The bar placed over the thighs supported the position and kept knees steady. The test instructor controlled the knee angle. Subject performed repetitions until exhaustion or until the instructor terminated the test, in the case of inappropriate control of technique or more than three uncompleted repetitions in a row. Uncompleted repetitions were not taken into account in the total result. Subject had to keep up constant pace and too long rest between repetitions was not allowed. The test duration for maximum repetition in knee flexion was from one to 2.5 minutes.

5.5 Statistical analysis

Statistical analyses were done with IBM SPSS Statistics 20- software (International Business Machines Corp. New York. USA) for Windows 7 V6.1 (Microsoft Corp. Redmond, USA). Also Excel 2010 (Microsoft Corp. Redmond, USA) for Windows 7 was used for basic calculations, tables and figures. Differences between groups in PRE and POST measurements were determined with one way analysis of variance. Changes within one group in PRE and POST measurements were analyzed with paired samples t-test. Differences in changes between groups were investigated with multivariate analysis of variance. Levels of significance are $p<0.05$*, $p<0.01$** and $p<0.001$***.

6 RESULTS

6.1 Anthropometry

For all results the levels of significance are presented as p<0.05*, p<0.01** and p<0.001*** for changes within a group. The levels of significance for differences between groups are presented as p<0.05#, p<0.01## and p<0.001###.

The cycling group gained body mass significantly (p<0.01). The differences in values between groups or differences in changes between groups were not observed (Table 9).

TABLE 9. Values for body weight.

Group	Body weight PRE (kg)	Body weight POST (kg)	Change (%)
Cycling	78.9 ± 6.0	80.6 ± 6.5 **	2.1
Running	83.2 ± 11.0	83.6 ± 9.2	0.5
Team	86.6 ± 8.9	86.4 ± 8.4	-0.2

All groups decreased body fat% (Table 10), but the only statistically significant decrease was observed in team training group (p<0.01). The values for PRE body fat % were significantly different between running and team training groups (p<0.05). The change in body fat % between the running and team training groups was significantly different (p<0.05).

TABLE 10. Values for fat%.

Group	Fat % PRE	Fat % POST	Change (%)
Cycling	17.3 ± 4.0	16.1 ± 2.5	-7.0
Running	14.5 ± 3.1	13.7 ± 2.3	-5.7
Team	19.5 ± 2.5	16.7 ± 2.7 **	-14.3
# = Statistical difference between groups	Running-Team #	no	Running – Team #

Changes in body fat mass and lean tissue mass are shown through simple calculations in table 11. These values give some detailed info for possible changes in body composition.

TABLE 11. Calculations for fat mass and lean tissue mass from estimated body fat %

	BW	Fat %	Fat mass (kg)	Lean tissue mass (kg)	Change from pre to post	
					In fat	In lean tissue
Cycle Pre	78.9	17.3	13.6	65.3	-4.9 %	3.6 %
Cycle Post	80.6	16.1	13.0	67.6	-0.6 kg	2.4 kg
Run Pre	83.2	14.5	12.1	71.1	-5.1 %	1.4 %
Run Post	83.6	13.7	11.5	72.1	-0.6 kg	1.0 kg
Team Pre	86.6	19.5	16.9	69.7	-14.6 %	3.2 %
Team Post	86.4	16.7	14.4	72.0	-2.5 kg	2.3 kg

6.2 Cycle ergometer test

6.2.1 Heart rate levels

Resting heart rate in the cycling group was 7.3% higher before POST test than in PRE test (difference was not statistically significant, Table 12). In the running and team training groups resting heart rate was maintained about at the same level. A significant difference was observed between running and team training groups in POST test ($p<0.05$).

TABLE 12. Values for resting heart rate

Group	REST_HR_PRE	REST_HR_POST	Change (%)
Cycling	51.6 ± 4.7	55.4 ± 7.8	7.3
Running	52.0 ± 8.6	51.8 ± 4.9	-0.5
Team	61.3 ± 9.2	61.4 ± 9.2	0.2
# = Statistical difference between groups	no	Running-Team #	no

No statistical significant differences or changes between the groups were observed in maximal heart rate (Table 13). However, all groups slightly decreased maximal heart rate in maximal cycle ergometer test.

TABLE 13. Values for maximal heart rate

Group	MAX_HR_PRE	MAX_HR_POST	Change (%)
Cycling	190.6 ± 9.0	187.5 ± 5.4	-1.6
Running	192.9 ± 8.1	191.3 ± 5.0	-0.8
Team	192.9 ± 6.2	188.6 ± 10.1	-2.2

Changes in recovery heart rates after the maximal cycle ergometer test are shown in tables 14, 15 and 16. Recovery of heart rate after one minute following the maximal test was lower for the cycling and running group when POST test value is compared to PRE test value (Table 14). Heart rate was higher in POST test for the team training group, although no statistical significant differences or changes were observed. No statistically significant differences or changes were observed in recovery of heart rate after three minutes. Still, recovery heart rates were lower in POST test for the cycling and running groups. For the team training group recovery heart rate remained higher. There were no statistically significant differences or changes in the recovery heart rate after five minutes. For every group, recovery heart rate after five minutes was lower in POST test. For running group, decrease is 7.1%.

TABLE 14. Recovery of heart rate after 1 minute

Group	REC_HR_1MIN_PRE	REC_HR_1MIN_POST	Change (%)
Cycling	154.8 ± 20.6	149.8 ± 11.7	-3.2
Running	148.9 ± 18.9	143.6 ± 18.7	-3.5
Team	147.0 ± 11.2	150.0 ± 10.1	2.0

TABLE 15. Values for recovery heart rate after 3 minutes

Group	REC_HR_3MIN_PRE	REC_HR_3MIN_POST	Change (%)
Cycling	126.5 ± 9.0	121.8 ± 6.0	-3.8
Running	122.1 ± 11.0	116.1 ± 12.8	-4.9
Team	118.9 ± 8.7	122.8 ± 11.8	3.3

TABLE 16. Values for recovery heart rate after 5 minutes

Group	REC_HR_5MIN_PRE	REC_HR_5MIN_POST	Change (%)
Cycling	112.9 ± 7.1	109.5 ± 7.8	-3.0
Running	111.3 ± 13.2	103.4 ± 12.9	-7.1
Team	112.6 ± 7.9	111.1 ± 8.3	-1.3

6.2.2 Maximal oxygen uptake

No statistically significant differences or changes were observed in maximal oxygen uptake (Table 17). The cycling and team training groups showed slight increases in VO2max.

TABLE 17. Values for maximal oxygen uptake

Group	VO2 MAX_PRE (ml/kg/min)	VO2MAX_POST (ml/kg/min)	Change (%)
Cycling	56.7 ± 5.8	58.4 ± 6.2	3.1
Running	58.5 ± 3.3	58.1 ± 2.8	-0.5
Team	52.5 ± 5.0	53.9 ± 4.8	2.7

6.2.3 Maximal power output

Maximal power output (watts) increased significantly (Figure 11) in the cycling group ($p<0.05$). Statistically significant differences were not observed between groups (Table 18).

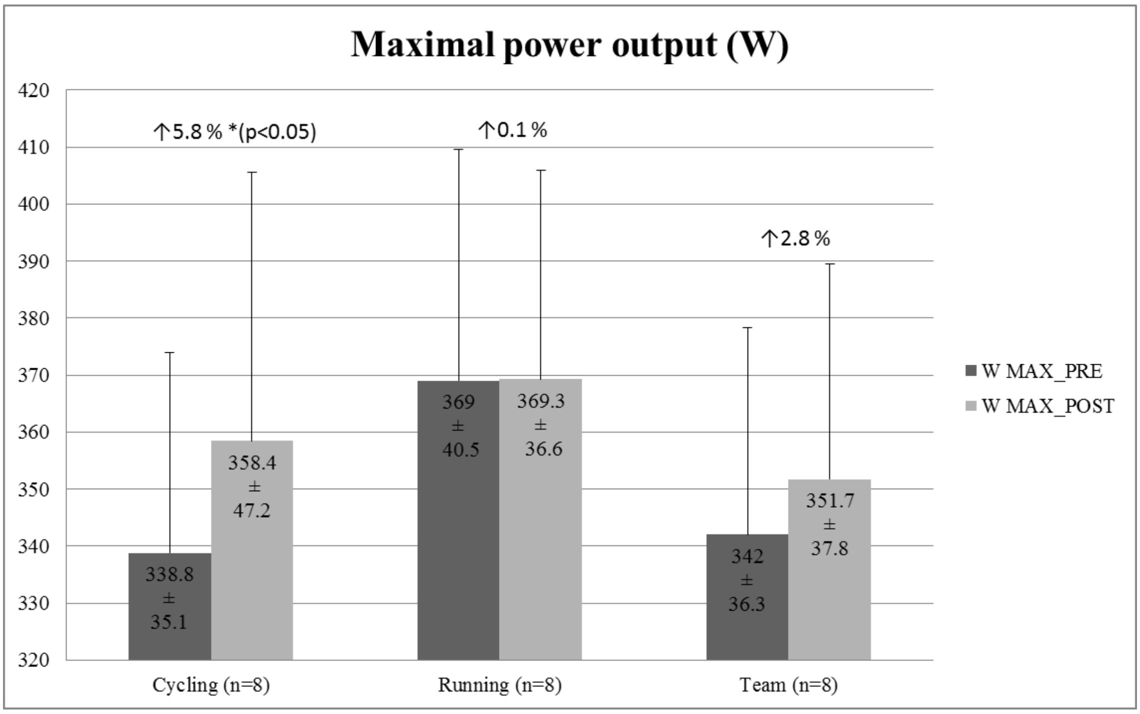

FIGURE 11. Changes in maximal power output.

TABLE 18. Values for maximal cycling power

Group	W MAX_PRE	W MAX_POST	Change (%)
Cycling	338.8 ± 35.1	358.4 ± 47.2 *	5.8
Running	369.0 ± 40.5	369.3 ± 36.6	0.1
Team	342.0 ± 36.3	351.7 ± 37.8	2.8

6.2.4 Cycling time

The cycling and team training groups showed significant improvements in cycling time ($p<0.01$ and $p<0.05$, Figure 12). Changes observed were statistically significant ($p<0.05$) when compared to the running group (Table 19). The cycling group cycled on average 54 seconds longer in POST test, the team training group 42 seconds longer and the running group 10 seconds longer when compared to PRE test.

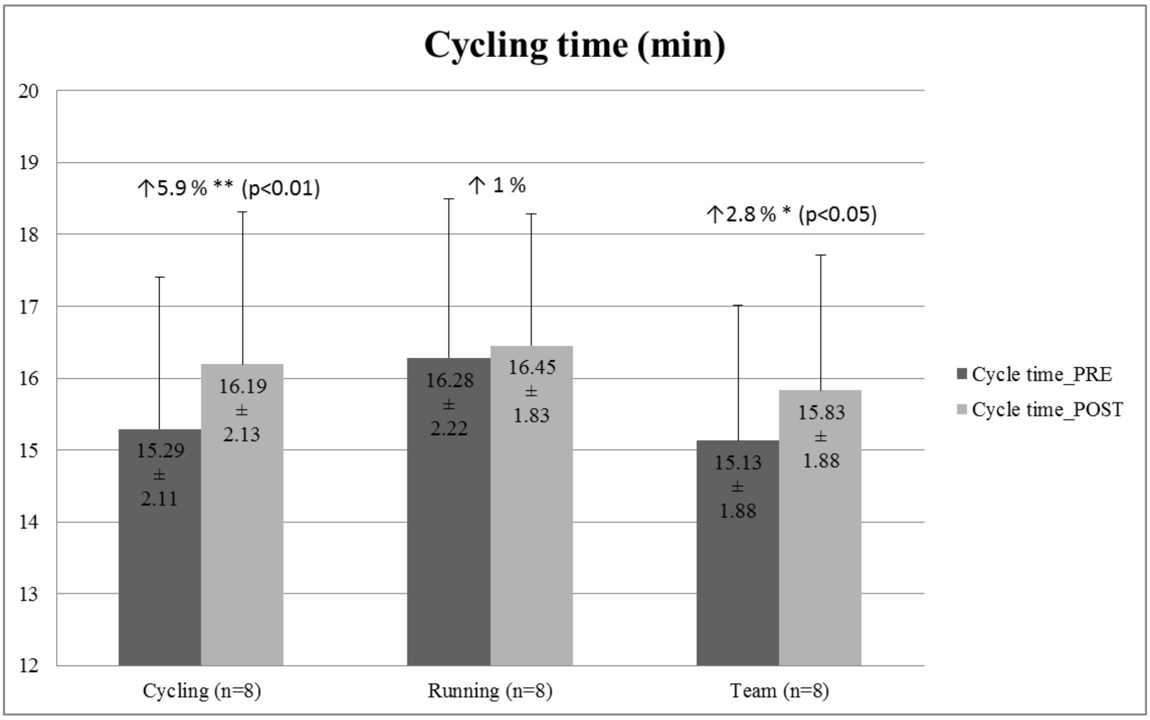

FIGURE 12. Changes in cycling time.

TABLE 19. Values for cycling time

Group	Cycle time_PRE (min)	Cycle time_POST (min)	Change (%)	Change (seconds)
Cycling	15.29 ± 2.11	16.19 ± 2.13 **	5.9	54
Running	16.28 ± 2.22	16.45 ± 1.83	1	10
Team	15.13 ± 1.88	15.83 ± 1.88 *	2.8	42
# = Statistical difference between groups	no	no	Cycling-Running # Team- Running #	

6.3 Strength

6.3.1 Explosive lower body strength

No statistical significant changes or differences were observed in countermovement jump height (Table 20). The cycling group was only group to slightly improve their explosive jumping ability (3.2 %).

TABLE 20. Countermovement jump height values

Group	CMJ_PRE (cm)	CMJ_POST (cm)	Change (%)
Cycling	39.6 ± 4.7	40.8 ± 6.1	3.2
Running	41.0 ± 3.1	39.8 ± 4.1	-2.9
Team (n=7)	41.0 ± 4.5	39.7 ± 5.7	-3.2

6.3.2 Lower body isometric and dynamic strength

Only minor changes were observed in isometric bilateral leg press (Table 21). No statistical significant changes within groups or differences between groups were detected.

TABLE 21. Values in isometric bilateral leg press

Group	Isometric leg press PRE (kg)	Isometric leg press POST (kg)	Change (%)
Cycling	453.5 ± 131.8	463.6 ± 124.0	2.2
Running (n=6)	416.3 ± 65.3	407 ± 47.8	-2.2

The cycling and running groups increased the amount of repetitions significantly ($p<0.001$) in dynamic bilateral leg press (Figure 13). No statistically significant differences were observed between groups (Table 22).

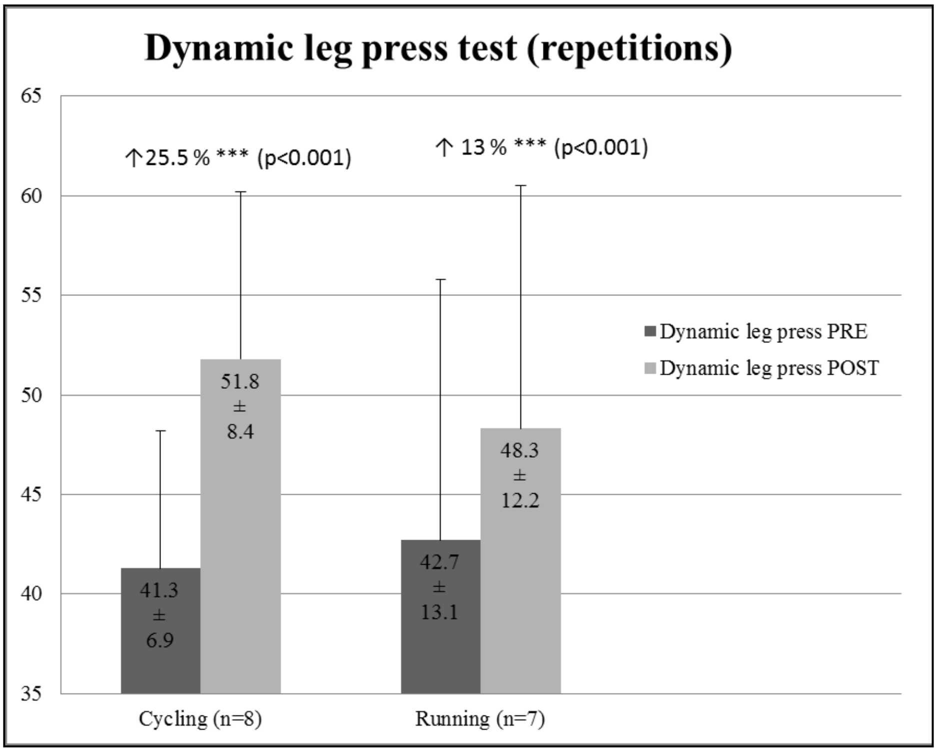

FIGURE 13. Changes in maximal power output.

TABLE 22. Values for dynamic bilateral horizontal leg press with 2.5 * bodyweight

Group	Dynamic leg press PRE (repetitions)	Dynamic leg press POST (repetitions)	Change (%)
Cycling	41.3 ± 6.9	51.8 ± 8.4 ***	25.5
Running (n=7)	42.7 ± 13.1	48.3 ± 12.2 ***	13

The cycling and running groups increased the amount of repetitions significantly ($p<0.05$) in dynamic knee flexion (Table 23). No statistically significant differences were observed between groups.

TABLE 23. Values for dynamic knee flexion with 1 * bodyweight

Group	Dynamic knee flexion PRE (repetitions)	Dynamic knee flexion POST (repetitions)	Change (%)
Cycling	18.1 ± 7.2	20.6 ± 5.3 *	13.8
Running (n=7)	17.3 ± 5.4	21.7 ± 5.6 *	25.6

6.3.3 Upper body strength

The cycling and running groups developed the measured force in kilograms significantly ($p<0.05$ for running and $p<0.01$ for cycling) in bench press (Table 24). A statistically significant difference was observed for PRE values between groups ($p<0.05$) and for the change observed between groups ($p<0.01$).

TABLE 24. Values for isometric bench press.

Group	Isometric bench press (kg)	Isometric bench press (kg)	Change (%)
Cycling	87.6 ± 10.4	97.4 ± 12.0 **	11.1
Running (n=7)	100.9 ± 11.4	104.1 ± 12.6 *	3.3
# =Significant difference between groups	Cycling- running #	no	Cycling- running ##

7 DISCUSSION

7.1 Aerobic performance

7.1.1 VO_2max, power output and cycling time

Estimated maximal oxygen uptake improved slightly in the cycling and team training groups (changes were not statistically significant). VO_2max in the running group did not change. It seems that cycling and team training may have resulted in slight improvements in endurance capacity, as expressed in the values of maximal oxygen uptake. Body weight affects the value of VO_2max when expressed as relative terms (ml/min/kg). This might lower the values for the team training group players, because of their higher body weight. Still, the relative change was same as for the cycling group, in which players have actually gained weight. Gained body mass slightly compensates the improvement in the value of VO_2max when expressed in relative terms which takes into account the body weight. Also, the lower initial aerobic capacity of the team training players (but not statistically different when compared to the other groups) might have given stronger potential for improvements in VO_2max.

Maximal power output expressed as Watts (calculated from maximal cycle ergometer test) increased significantly only in the cycling group ($p<0.05$). Thus, high intensity cycling training was clearly effective to improve power output in the maximal cycling ergometer test. When taking into account the improvements in lower body strength (discussed later) with a relatively low volume of strength training in the cycling group, it is obvious that high intensity cycle training as such may also improve leg strength. These effects are not seen as clearly in the team training group in maximal power output (no information available from strength tests). Even though the running group improved leg strength, this effect was not observed in maximal power output in cycling test. The important factor of training specificity must still be highlighted.

The major finding in this study was that improvement in the cycling time is the greatest in the cycling group. Cycling time can be considered here as the most objective variable for aerobic performance. Individual high intensity interval training with the cycle ergometer was significantly more effective in improving aerobic performance measured with cycle ergometer when compared to training with running ($p<0.05$). The improvement in cycling time in six weeks was statistically significant ($p<0.01$) for the cycling group.

It seems that the present individual high intensity training program with the cycle ergometer resulted to even slightly better improvement than in the team training group (although the difference was not statistically significant). Training done in the team training group was also effective for improving cycling time ($p<0.05$) and the change compared to the running group was significant ($p<0.05$). Still, improvements were greatest in the cycling group. Higher total training volume and endurance training volume in team training group did not lead to the improvements in same extent as with individual high intensity cycling.

The present results are somewhat similar when compared results obtained for elite ice hockey players in studies by Tikka (2000) and Tiikkaja (2002). This indicates the importance of aerobic conditioning throughout the season and potential for playing in elite level. Players in studies from Tikka (2000) and Tiikkaja (2002) were also tested with indirect maximal cycle ergometer test, with a slightly different protocol. The research data for comparison the cycling time for WHO 80+40 protocol is not available from recent research.

It seems that the present high intensity interval training with cycling has been most effective for improving all the measured variables regarding aerobic endurance in this study. Training of ice-hockey players with cycling is clearly more superior when compared to training with running. Improvements in the cycling group were also even more notable when compared to the team training group with almost a similar amount of cycling training with different cycle training protocol (averages of 1.7 times per week for the team training group and 2.0 times per week for the cycling training group with CorusCardioSport cycle training) and a clearly higher total training volume of training (endurance training of 4.8 times per week compared to 3.0 times per week). As stated previously, clear evidence from benefits of aerobic performance on ice-hockey performance is observed in several recent studies (Green et al. 2006; Quinney et al. 2008; Durocher et al. 2008. Roczniok 2012).

7.1.2 Recovery heart rates

No statistically significant changes or differences between groups were observed in heart rates during recovery. However, it seems that players in the cycling and running groups have been able to recover more quickly from maximal cycle ergometer test at 1 minute, 3 minute and 5 minute time points. For the team training group, recovery has been slower after 1 minute and 3 minutes, but after 5 minutes there is a slight decrease when compared to the PRE and POST measurements. The recovery heart rates were highest for the cycling group in the PRE test which indicates the effect of cycle training for recovery, while HRmax has maintained the same level. Interestingly, the running training group had obtained the relatively most notable effect for recovery heart rates. Still, the slight decreases in HRmax might influence the recovery heart rates. It is worth of noting from the results that the cycling group was able to increase cycling time significantly, as overall exertion is higher and still players in the cycling group had recovered for some extent. Maybe running training has affected more on recovery than on maximal capacity. Despite some earlier criticism on widely used recovery heart rate as a measure of aerobic performance (MacDougall et al. 1991), recent research has found evidence that recovery heart rate is accelerated immediately after exercise in both endurance-trained and strength-trained athletes (Otsuki et al. 2007).

These possible markers of enhanced recovery seen in the cycling and running groups are essential for ice-hockey players. It is very beneficial if the ice-hockey player is able to recover more effectively after high intensity exercise. Recovery occurring during 1 minute, 3 minute or 5 minute break in a game play is crucial for game performance. Player, who is capable for quick recovery, is also able to perform and repeat high intensity game actions more effectively.

7.1.3 Resting heart rate and maximal heart rate

Resting heart rate did not change significantly in the running group or in the team training group. The clearest finding was the increase of a 7.3% in the cycling group (not statistically significant). The reason for this is unknown. A relatively short period of training (six weeks) should not increase resting heart rate. Maybe the slight day-to-day variation (because of either from physical or psychical stress) might increase resting heart rate for some subjects in the cycling group (more extensive standard deviation is observed in the group values). The players in the cycling group might have been nervous or excited about POST testing and this may put psychical stress upon the resting heart rate (increase sympathetic activity in the nervous system). This same effect was seen in the running group, but in opposite direction: more extensive standard deviation observed in the PRE measurements, but changes did not affect the POST averages. No other differences between the cycling group and running group were observed. The significant difference in the POST measurements was observed between the running and team training group. This does not give much information about possible mechanisms behind resting heart rate changes. It might just highlight the differences in individual resting heart rates. Players in the team training group just tend to have slightly higher resting heart rates. It is stated that resting heart rate may not respond significantly to aerobic training, especially in short duration training interventions (MacDougall et al. 1991).

From the resting heart rate data we can`t assume the possible occurrence of overreaching or overtraining syndrome. The increases in heart rates were not high enough to be considered as possible indications of overtraining symptoms. This is of course desirable information for players and coaches, especially in the team training group with a high volume of training. Increased heart rate is stated as one common marker of parasympathetic form of overtraining (McArdle et al. 2007).

No statistically significant changes or differences between groups were observed in maximal heart rate. The tendency for a slight decrease in maximal heart rate was however seen. This decrease (or unchanged HRmax) with improved performance (or at least maintained) might represent the strengthened pumping actions of cardiac muscle. We must recall the basis for maximal oxygen uptake: VO_2max is the product from heart rate * Stroke volume * Arteriovenous oxygen difference. Studies indicate that an increase in stroke volume has great contribution to enhanced VO_2max. Adaptations in stroke volume strongly correspond with changes in VO_2max as stated by Rowell (1986), McArdle et al. (2007) & Helgerud et al. (2007). Heart does not have to pump with the same rate in maximal effort because stroke volume might have been increased after endurance training. Simultaneous slight improvements in VO_2max in the cycling and team training groups may indicate these adaptations in cardiac muscle, and especially greater stroke volume. These are clearly desired outcomes from effective endurance training, but need more studies in the future.

7.2 Strength

It can be seen from the present study data that only the cycling group resulted in a slight increase in countermovement jumping height (without arm swing). Although it is impossible to say how much the cycling training contributed to jumping ability, at least this training program in all resulted in an improvement in vertical explosive leg power, which is important for ice-hockey players. Farlinger et al. (2007) found a strong correlation between vertical jump (with arm swing) and 35 meter on-ice skating sprint. Vertical jump is shown to predict on-ice skating performance and indicate vertical leg power in general. (Farlinger et al. 2007). As discussed previously with cycling power, it is clear that cycling training has contributed for leg strength at least for some extent, because of more marked improvements in isometric and dynamic leg press leg strength when small difference in lower body strength training volume is taken into account. Interestingly, the greater improvement in dynamic knee flexion was seen for the running group. Although the change was significant for both groups, the running group performed 25% more repetitions in POST test, whereas the cycling group increased the amount of repetitions only 13%. Still, no statistical significant difference between changes were observed, which lead to an assumption that both training programs were as effective in improving dynamic knee flexion repetition strength.

It also seems that players in the cycling group have maintained relative strength level in isometric leg press, whereas relative strength for the running group has decreased. When considering low volumes of strength training in the cycling and running groups, it seems that cycling training has helped in maintaining the relative strength, even with slight gain in body mass. Relative strength for total weight lifted in repetition maximum test has improved for both groups. Several studies highlight the importance of strength to ice-hockey performance (Burr et al. 2008; Farlinger et al. 2007; Montgomery 2006; Peyer et al. 2011). It seems that high intensity cycling training done in this study did not have any interfering effects on strength performance qualities, rather strength levels improved together with improvements in aerobic performance.

For the team training group changes in strength are unknown. It could be assumed that players in the team training group have improved strength qualities with a higher volume of strength training. The team training group could have a high probability to improve more than cycling and running groups in these strength tests. Improvements in maximal power output in cycle ergometer test might be one indication for improved leg strength. A high total volume of training may have impaired the ability for explosive force production in POST testing. This is seen in countermovement jump results for the team training group. A slight decrease in jumping height may indicate the state of fatigue in leg muscles.

7.3 Anthropometry

The players in the cycling group gained body weight significantly ($p<0.005$) by 2.1%. At the same time, players in the cycling group decreased body fat percentage. The decrease in body fat-% was 7.0 %. However, a more detailed measurement of body composition is needed to obtain more reliable changes in fat and lean tissue mass. Simple calculations (table 11) from the present result averages give some detailed estimations about the changes in body composition. Body fat mass calculated from total body mass is a quite reliable estimation, but lean tissue includes all other tissues: muscle, tendons, connective tissues, bones and body water content, which might be different even when measurement circumstances are standardized. Fat-% calculations from skinfold thickness measurements are always estimations. With same experienced measurer the repeated test results are comparable, but with ice-hockey players, the measurements from upper body parts: subscapula, supra-iliac, triceps and biceps, overestimations of fat% may occur. The PRE measurements were done at the start of the training season, when ice-hockey players might not usually be at the peak condition.

Calculations in table 11 give some detailed info from possible changes that have occurred regarding the body composition. Even though the decrease in body fat-% for the cycling group was not significant, it seems that the training program in the cycling group resulted in a slight loss of fat mass (0.6 kg) and 2.4 kg increase in lean tissue mass. Despite the gain in body mass, fat mass was lost for the cycling group. The comparisons between the cycling and team training groups did not reveal any statistically significant differences. Still, the cycling group seems to result in more beneficial adaptations to training, with the greater lean tissue mass gain with a slight decrease in body fat and respectively to a greater body fat% decrease (7.0 %). For the running group, body mass did not change. Fat% decreased, which was observed as 0.6 kilograms of loss in fat mass. At the same time, mass of lean tissue increased slightly in the running group, 1.0 kg respectively. For the team training group, a significant decrease in body fat % was observed ($p<0.01$), while body mass did not change. These changes were observed as 2.5 kg loss in fat mass and 2.4 kg gain in lean tissue mass. The team training group decreased fat% significantly more when compared to the decrease in the running group ($p<0.05$), even when the significant difference ($p<0.05$) in initial fat% was taken into account. The higher training volume in the team training group may have contributed to this significant change.

In the preparatory training phase during the summer, gains in lean tissue mass with a simultaneous decrease in body fat mass are desirable outcomes for off-ice training with proper nutrition in ice-hockey players. These effects were observed in all groups. Gains in lean tissue mass may be adaptations to strength training as cycling and especially the team training groups did train more strength than the running group. Unfortunately, from this data we can`t know the exact amount of gained muscle mass. The decrease in body fat % may have been occurred because of engaging the endurance training program after the transition phase and especially with a high total volume of training in the team training group, which clearly resulted in the significant decrease in body fat.

With the similar skinfold measurement method, Tikka (2000) and Tiikkaja (2002) obtained almost similar values for body composition (fat %) for elite Finnish ice-hockey players as observed in this study. Players in the Finnish U-20 National team tended to have slightly lower body fat percentage, which is expected for international level players. Still, the differences which might originate from different skinfold measurers must be taken into account. Interestingly, Tiikkaja (2002) found out that body fat % increased during the first half of the season. (Tikka 2000 & Tiikkaja 2002.)

7.4 Factors affecting study results

Subject background, training, individual differences and factors relating to the test methods and test situation may affect the study results. A high volume of training may influence results especially in the team training group and training prior to the performance testing may impair the ability to execute maximal effort in maximal cycle ergometer test. When considering the training amounts, subjects and coaches are mostly responsible for reporting the training data themselves, which highlights the problems and possible errors that may occur when reporting the training amounts with training diaries and pre-planned programs. These are challenging factors to control in scientific studies with elite team sport athletes and these aspects must be taken into account when interpreting the results.

Learning may influence the test results in the strength tests. Players do not have to perform tests chosen for this study very often and already learning and familiarizing the correct techniques and increased motivation for testing might give better results in POST testing. Isometric strength tests are not usually included in test methods for ice-hockey players. Dynamic tests are more relevant but isometric tests are easier to control and reproduce reliably.

A running performance test could have given more information about training adaptations in the running group. This might also give more insight into training specificity phenomenon. Still, when ice-hockey players are considered, maybe the most reliable aerobic performance test should be performed with skating, either on ice or on skating treadmill, to get more sport-specific information of aerobic performance whether it is more beneficial if the aerobic training is done with cycling or either with running. On-ice performance test or game analysis is also needed to find out the most important effects of different ice-hockey training protocols. Data from this study can`t indicate how much the improved aerobic performance from different training programs contribute to actual game performance.

7.5 Conclusions

The main finding in this study was that the cycle training group and team training group improved aerobic performance significantly when measured with maximal cycle ergometer test. The cycle training resulted in most prominent changes in cycling time and maximal power output. When considering the increase in body mass in the cycle training group, the change in VO_2max is also worth of noting. Running training did not have an effect on endurance performance when measured with maximal cycle ergometer test. Simultaneously, players in cycling group improved in all strength tests. Results from anthropometric measurements state that players in the cycling group gained body mass significantly. The team training resulted to a significant decrease in body fat%. The higher training volume had a greater impact on body composition, especially in body fat content.

It can be concluded that high intensity cycling training done in this study did not interfere strength performance. Training resulted in beneficial improvements in strength levels together with improvements in aerobic performance. Players in the cycling and running groups improved dynamic leg press strength and knee flexion strength. It seems that the difference in the training program did not lead to different adaptations in terms of isometric or dynamic leg strength. Players in the cycling group did improve isometric upper body strength more than players in the running group mainly due to a higher volume of upper body strength training. Only the players in the cycling group resulted in slight positive change in countermovement jump.

7.6 Practical applications

The importance of improvements in aerobic capacity for overall physical performance is highlighted by MacDougall et al. (1991) and beneficial adaptations can be achieved by high intensity interval training (Spiering et al. 2003; Edge et al. 2005; McMillan et al. 2005; Helgerud et al. 2007). That is unquestionably clear why in today`s competitive sport, such as in ice-hockey, all energy production systems should be optimized for superior athletic performance and the rigid underestimations of importance of aerobic training made within ice-hockey every now and then should be reconsidered.

Different ice-hockey training procedures may lead to different kind of adaptations in physiological variables and especially in aerobic performance as were investigated in this study. That is why individual programs should be planned for players with different needs and qualities. Coaches must evaluate the benefits and costs carefully when planning training programs for ice-hockey players.

Improvements in aerobic performance can be optimized with individualized high intensity training. High volume might not always be the best method for improving aerobic performance in ice-hockey players. With good planning in aerobic training, more time could be devoted for training the other performance features such as strength, speed, power and coordination. This is how more recovery may be possible to allow for ice-hockey players with high training volumes. Overreaching and overtraining syndromes could be avoided easier and the occurrence of overuse injuries could be minimized. This study gave also useful information about strength interfering effects of endurance training. Carefully planned and implemented cycling endurance training program didn`t interfere the strength performance or impair the effects of strength training. Training with high intensity cycling seems to have rather resulted in improvements in leg strength.

High intensity interval cycling training may also be useful for rehabilitation procedures as adaptations might be expected during a relatively short training period. In the case of injuries that still allow cycling, planned and individual cycle training is an effective method for enhancing and maintaining the aerobic performance in ice-hockey players. This ensures the capacity for returning to the on-ice training.

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9 APPENDIX 1 Consent form for study participation

Suostumus

Olen perehtynyt tämän tutkimuksen tarkoitukseen ja sisältöön, tutkittaville aiheutuviin mahdollisiin haittoihin sekä tutkittavien oikeuksiin ja vakuutusturvaan. Suostun osallistumaan mittauksiin ja toimenpiteisiin annettujen ohjeiden mukaisesti. En osallistu mittauksiin flunssaisena, kuumeisena, toipilaana tai muuten huonovointisena. Minulla ei ole kroonista sydämen tai hengitys- ja verenkiertoelimistön sairautta. Voin halutessani peruuttaa tai keskeyttää osallistumiseni tai kieltäytyä mittauksista missä vaiheessa tahansa. Tutkimustuloksiani saa käyttää tieteelliseen raportointiin (esim. julkaisuihin) sellaisessa muodossa, jossa yksittäistä tutkittavaa ei voi tunnistaa.

	Kyllä	Ei
Suostun yllämainitun tutkimusprojektin mittauksiin annettujen ohjeiden mukaisesti		
Annan luvan tulosteni käyttöön tutkimuksen raportoinnissa		
Anna luvan tulosteni käyttöön tuotekehitystoiminnassa		
Annan luvan tulosteni säilyttämiseen liikuntabiologian laitoksen ja CorusFit Oy:n tutkimusrekisterissä		
Annan luvan mittausten yhteydessä otetun video/valokuvani käyttöön tutkimustulosten kirjallisessa ja suullisessa raportoinnissa.		
Yhteystietoni saa sisällyttää liikuntabiologian laitoksen henkilörekisteriin ja minuun saa olla myöhemmin yhteydessä haettaessa tutkittavia liikuntabiologian laitoksen tai CorusFit Oy:n tutkimuksiin		
Tunnen itseni terveeksi		
Olen tutustunut suoritettaviin testeihin ja mittauksiin, ja olen ymmärtänyt mittausten tarkoituksen ja niihin liittyvät riski- ja hyötynäkökohdat.		

Jyväskylässä___________2012 ______________________________________

Tutkittavan allekirjoitus

Puh nro:_______________________ email:_________________________________

Jyväskylässä___________2012 ______________________________________

Tutkijan allekirjoitus

Puh nro:_______________________ email:_________________________________