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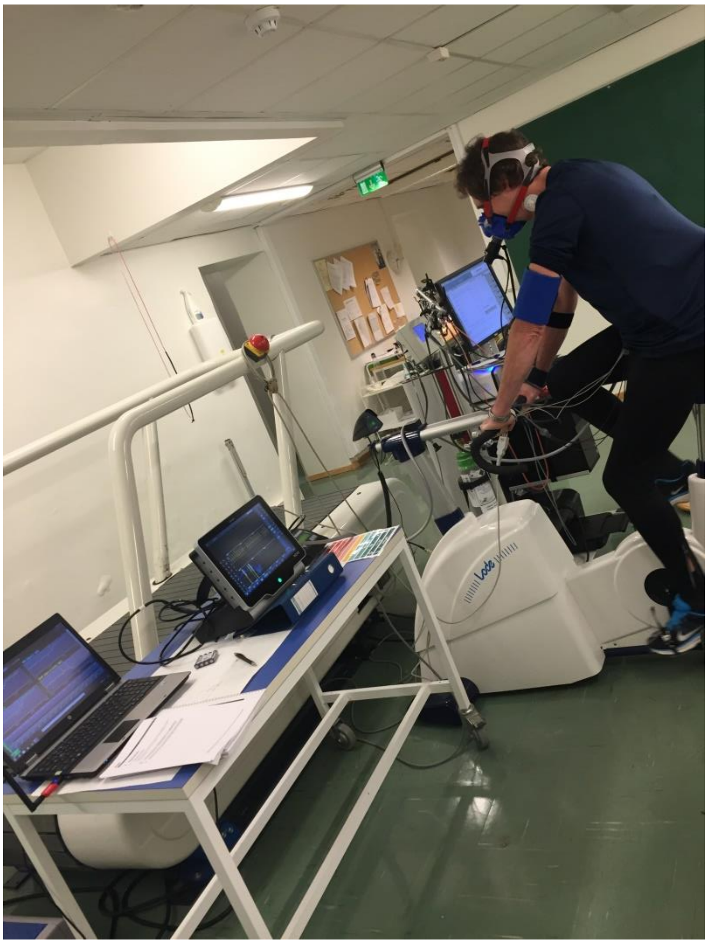

SAMTYKKE TIL HØGSKOLENS BRUK AV MASTEROPPGAVER

Forfatter: Marianne Olsrud

Norsk tittel: Akutte effekter av intervall og kontinuerlig trening på post-exercise hypotensjon hos inaktive menn.

Engelsk tittel: Acute effects of interval and continues training on post-exercise hypotension in inactive men.

Studieprogram: Master i Kroppsøvings- og idrettsvitenskap.

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Dato: 01.06.2016

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underskrift

Abstract

Purpose: This study investigated the effects of isocaloric high-intensity interval training and moderate intensive continuous training on post-exercise hypotension (PEH) in inactive men, hence it is possible to be specific to the effect of intensity on the PEH response. It is hypothesized that high-intensity interval training would give a greater extent and duration than moderate intensity endurance training on the PEH response and that total peripheral resistance (TPR) and stroke volume (SV) is lower after training with high-intensity than training with moderate intensity.

Method: Six physically inactive men (age: 52.0 ± 7.8 year; maximal oxygen uptake (VO_{2max}): 35.6 ± 7.3 ml kg^{-1} min^{-1}) volunteered to participate in this study. A controlled cross-over design was used in this study, meaning that all test subjects get all types of treatment, but in different time periods. Three different cycle ergometer endurance tests was performed on three different days, respectively VO_{2max}, high-intensity (87% HF_{max}.) 4x4min interval training and moderate-intensity (77% HF_{max}) continuous training. High-intensity session was performed as the first test and then continuous training, because the duration of the continuous training had to be adapted so the energy consumption was similar between both sessions. Before the VO_{2max} session, the subjects had to relax in a chair and rest blood pressure (BP) and blood lactate concentration (Lac) was measured. When they sat quietly on the bike with all the electrodes, Lac, BP, rating of perceived exertion (RPE), heartrate (HR), SV, cardiac output (CO), TPR, oxygen uptake (VO_2), left ventricular end-diastolic volume (EDV) and ejection fraction (EF) was measured in rest. During the two test protocols BP, RPE, HR, SV, CO, TPR, VO_2, EDV and EF was measured. Mean arterial pressure (MAP) was calculated from systolic blood pressure (SBP) and diastolic blood pressure (DBP). After interval – and continuous training, participants were resting in a chair for 30 min post-exercise (PE), where the same variables was measured after 5-10-30 min, and Lac after 0 and 30 min post-exercise.

Results: The main findings showed that SBP and MAP changed significantly over time (independent of type of training) ($p<0.001$), but DBP showed no significant differences. TPR, CO, HR and SV changed significantly over time ($p<0.001$) and HR was the only one who showed significantly differences between interval and continuous training, where interval training had greater HR after 10 min PE. The present study did not find any significant different between interval and continuous training on SBP, DBP and MAP in the PE period.

Conclusion: This study indicates that high-intensity interval training and moderate intensive continuous training at same calorie consumption had similar PEH responses. Individuals with mild hypertension can use both training types to get a PEH response and prevent higher BP.

Key words: Diastolic blood pressure, endurance training, heartrate, blood lactate concentration, systolic blood pressure and total peripheral resistance.

Sammendrag

Formål: Denne studien undersøkte effekten av likt kalori forbruk ved høy-intensitets intervall-trening og moderat intensitet kontinuerlig trening på post-exercise hypotensjon hos inaktive menn, her er det derfor mulig å være spesifikke på effekten av intensiteten på PEH responsen. Hypotesene for studien sier at høy-intensitets intervalltrening vil føre til en bedre størrelse og varighet på post-exercise hypotensjon enn moderat intensitets trening, og total perifer motstand og slagvolum er lavere etter trening med høy-intensitet enn ved trening med moderat intensitet. **Metode:** Seks fysisk inaktive menn (alder: 52.0 ± 7.8 år; maksimalt oksygenopptak (VO_{2max}): 35.6 ± 7.3 ml kg^{-1} min^{-1}) var frivillig med i denne studien. Et kontrollert cross-over design ble brukt i denne studien, det betyr at alle testpersonene gjennomfører alle treningene, men på forskjellige dager. Tre forskjellige utholdenhetstester på sykkel ble gjennomført på tre forskjellige dager, henholdsvis maksimal oksygen opptakstest, høy intensitet (87 % HR_{maks}) 4x4 min intervall trening og moderat intensitet (77 % HR_{maks}) kontinuerlig trening. Høy-intensitetsøkten ble gjennomført som første test og deretter kontinuerlig trening, pga. varigheten av den kontinuerlige treningen måtte tilpasses slik at energiforbruket var likt for begge testene. Før VO_{2max} økten, satt de i en stol og slappet av mens det ble målt hvileblodtrykk og laktat konsentrasjonen i blodet. Når de satt stille på sykkelen med alle elektrodene fastmontert, målte vi Lac, blodtrykk, vurdering av opplevd anstrengelse, hjertefrekvensen, slagvolum, minuttvolum, total perifer motstand, oksygenopptak, ende-diastolisk volum og ejeksjonsfraksjon. Under de to testprotokollene målte vi blodtrykk, vurdering av opplevd anstrengelse, hjertefrekvensen, slagvolum, minuttvolum, total perifer motstand, ende-diastolisk volum og ejeksjons friksjon. Gjennomsnittlig arteriell blodtrykk ble kalkulert ut ifra systolisk- og diastolisk blodtrykk. Etter intervall og kontinuerlig trening satte testpersonen seg i en stol for å hvile i 30 min, hvor de samme variablene ble målt etter 5-10-30 min og Lac etter 0 og 30 min etter trening.

Resultat: Hovedfunnene viste at systolisk blodtrykk og det gjennomsnittlige arterielle blodtrykket endret seg signifikant over tid (uavhengig av type trening) ($p<0.001$), men diastolisk blodtrykk viste ingen signifikante forskjeller. Total perifer motstand, minuttvolum, hjertefrekvens og slagvolum endret seg signifikant over tid ($p<0.001$), hjertefrekvensen var den eneste variabelen som viste signifikante endringer mellom intervall og kontinuerlig trening, hvor intervall var bedre 10 min etter trening. Studien fant ingen signifikante forskjeller mellom intervall og kontinuerlig trening ved systolisk-, diastolisk- og gjennomsnittlige arterielt blodtrykk i perioden etter trening. **Konklusjon:** Denne studien viser at utholdenhetstrening på høy-intensitet intervall trening og moderat intensiv kontinuerlig trening med samme kaloriforbruk hadde lik post-exercise hypotensive respons. Personer med mild hypertensjon kan benytte seg av begge treningstypene for å få en post-exercise hypotensive respons og forhindre høyere blodtrykk. **Nøkkelord:** Diastolisk blodtrykk, hjertefrekvens, laktat, systolisk blodtrykk og utholdenhetstrening.

Preface

A special thanks to my knowledgeable supervisor Terje Gjøvaag, for a very good teamwork and implementation of this project. He has been very helpful all the time, special during the test period and writing process.
Thank you to my supervisor Boye Welde, for good feedback and help during the writing process. And a great thanks to my good student co-worker Hanna Berge, for good cooperation in the planning and execution of all tests.

I also want to thank all the test subjects who participated in this project and good luck with the training.

Contents

Glossary

BP – blood pressure

CO – cardiac output

DBP – diastolic blood pressure

EDV – end-diastolic volume

EE – energy expenditure

ECG – electrocardiogram

EF – ejection fraction

HR – heart rate

HRV – heart rate variability

HT – hypertension

MAP – mean arterial pressure

Min – minutes

PE – post-exercise

PEH – post-exercise hypotension

PWV – pulse wave velocity

RER – respiratory exchange ratio

RPM – rate per minutes

SBP – systolic blood pressure

SV – stroke volume

TPR – total peripheral resistance

VO_{2max} – maximal oxygen consumption

W - Watt

1.0 Introduction

Hypertension or high blood pressure is a major risk factor for cardiovascular disease and mortality (Börjesson, Kjeldsen & Dahlöf, 2008). Hypertension defines a blood pressure (BP) ≥140mmHg systolic, and/or ≥90mmHg diastolic (Börjesson et al., 2008). It is believed that at least 25% of the population in the Nordic countries are suffering from hypertension (HT) or/are using antihypertensive medicine (Börjesson et al., 2008). This study wants to look at how intensive- and moderate endurance training can reduce the BP after training in inactive men.

The Norwegian Directorate of Health recommends all peoples to have minimum 30 min of moderate physical activity every day. They recommend endurance training 5-7 days a week, with an intensity of 40-70% maximum oxygen consumption (VO_{2max}) in 30 min for prevention and treatment of hypertension (Börjesson et al., 2008). These recommendations are based on previous research of what intensity that is sufficient to induce post-exercise hypotension (PEH). But still, it is believed that 30-50% of the Norwegian population are less physically active than current guidelines recommend (Börjesson et al., 2008). Changes of lifestyle habits such as physical activity and diet can be effective to prevent HT. BP increases with increasing age and many men are affected of high BP because of too little exercise and too much good food (Börjesson et al., 2008).

Previous research has shown that the BP is reduced acute after a single session of endurance training and BP values may fall lower than resting values measured before the training, a phenomenon called post-exercise hypotension (Forjaz et al., 2000; Halliwill, 2001; Kenney & Seals, 1993).

In the present study, the PEH response was investigated in a population of untrained men, performing both intensive interval training and moderate intensity continuous exercise. The exercise is based on continuous control of the exercise intensity, and the men have similar calorie consumption following both test protocols. This study is not aware of other studies which are similar in design.

2.0 Theory

2.1 Endurance training

Endurance training can be divided into two main modes: interval- and continuous training. Interval training is defined as: "Training where changing between periods of work and breaks, and work changing between higher and lower intensity" (Gjerset, Haugen & Holmstad, 2006. S.73). Continuous work is defined as: "Training performed as one work period of fairly steady load" (Gjerset et al., 2006. S.72). The advantage of interval training is that you can work at a higher intensity than continuous training, and the hemodynamic load is therefore greater (Smith & Fernhall, 2011). According to Helgerud et al. (2007) is endurance training with high-intensity (90-95% max heartrate (HR_{max}) with 4x4 interval training significant more effective than other endurance training regiments to improve the exercise capacity (VO_{2max}). These types of interval 4x4 min (i.e. 4 intervals, each lasting 4 min) have been a popular training method because of its exercise benefits and the time spent (only 32 min).

It is good documented that moderate intensity endurance training contribute quickly in the reductions in BP that may persist for several hours after training (Taylor et al., 2010). Endurance training can reduce the systolic blood pressure (SBP) and diastolic blood pressure (DBP) with 20mmHg in subjects with mild to moderate HT, and the BP lowering effects are greater in subjects with HT than normotensive subjects (5-10 mmHg) (Jones, George, Edwards & Atkinson, 2007). The BP lowering of endurance training is not permanent; the subjects have to exercise regularly to maintain this response. Forjaz et al., (2000) indicate that PEH are more pronounced in subjects with a higher initial BP level and means that an acute exercise is an important non-pharmacological treatment to hypertension. Aerobic exercise at mild, moderate and high- intensity exercise can be used in the control of hypertension as long as the duration is regulated after the intensity degree.

Forjaz et al. (2004) and Jones et al. (2007) refer to results of PEH after training with low to moderate intensity exercise at 30-40% of VO_{2max}. In their results one can see that the duration of the endurance session to Forjaz et al. (2004) is 45 min, the study concluded that PEH is greater and longer after more intense exercise. Jones et al. (2007) on the other hand found that the acute hypotensive response during the 20 min post-exercise (PE) period is similar for SBP and mean arterial pressure (MAP) between interval and moderate training. The major finding from the study was that the acute hypotensive responses during the 20 min PE period is different for sessions that differ in terms of intensity and duration, but not in terms of total work done. These findings suggest that total work done is the most important factor in determining the degree of acute PEH for normotensive individuals. The BP response was apparent despite other cardiovascular adjustments, including cardiac output (CO) and total peripheral resistance (TPR), being greater after the bout of higher intensity, shorter duration exercise (interval) compared to moderate exercise. Jones et al. (2007) have controlled the training intensity based on constant Watt (W), where the subjects were training (bike ergometry) on the same W during the session.

Cote (2015) means that the magnitude of PEH has been reported to be intensity dependent, but similar when total work is controlled for and comparisons of PEH following high-intensity interval exercise are reported to be similar to PEH following a bout of continues exercise. Pescatello, Fargo, Leach and Scherzer (1991) have also looked at the intensity, and studied men for 30 min at mild to moderate intensity and reported no intensity effect on the PE reduction in BP and they measured the BP for 24 h. This study concludes that dynamic exercise may be important in the treatment of mild HT.

The exercise intensity and duration which is most used with normotensive and hypertensive subjects (with PEH as a result) are between 60-75% of the VO_{2max} with an exercise duration of 30 min (Forjaz et al. 2004; Jones et al. 2007; MacDonald, MacDougall and Hogben. 1999).

PEH is a key factor in the cardiovascular benefits associated with regular endurance training (Thompson, 2001). Halliwill (2001) states that PEH has been characterized by a persistent drop in MAP and TPR, but that is not completely offset by an increase in CO.

According to Halliwill (2001) is PEH caused by a reduced CO and a persistent reduced TPR after training. It is though that when the training session has ended, CO will reduce faster than TPR increase, and this imbalance results in PEH.

2.2.1 Mechanisms in post-exercise hypotension

Several articles and reviews have looked into the potential causes and mechanisms behind PEH (Halliwill, 2001; Kenney & Seals, 1993; MacDonald, 2002). Knowledge of PEH can be useful in the work of designing strategies for prevention and treatment of hypertension, but the mechanisms behind PEH are not fully identified yet.

During endurance training, the VO_2 increases and to fulfil the VO_2 requirements during exercise, more blood must be delivered to working muscles and CO will therefore increase. CO increases linearly with the exercise intensity, since VO_2 consumption increases with increasing intensity (Smith & Fernhall, 2011). Since training with high-intensity give a higher acute hemodynamic load than moderate training intensity, it is conceivable that the hemodynamic responses are also larger after thus type of training (Smith & Fernhall, 2011). It is several advantages of high-intensity training, since high-intensity training activates a greater percentage of muscle mass than moderate exercise intensities, which can lead to a more pronounced reduction in TPR. It may be that TPR will be more reduced after the high-intensity exercise than after exercise with moderate intensity. This may affect the magnitude of PEH, since MAP is the product of CO and TPR (Smith & Fernhall, 2011). Since arterial BP is a function of the product of CO and TPR, reductions in arterial BP observed after exercise and electrical stimulation of somatic and muscle afferent must result from decreases in CO, TPR, or both (Kenney & Seals, 1993).
During endurance training, is the increase in CO greater than the reduction in TPR, and the MAP will therefor increase. The increase in MAP during training is mainly due to increases in SBP, which increases with increasing CO. DBP remains mostly unchanged because of the opposite vasoactive signals (systemic vasoconstriction and local vasodilation). The increase in MAP is proportional to the exercise intensity at continuous workloads (Smith & Fernhall, 2011).

Several studies have also shown reduced TPR in areas that have not been working, and this indicates that PEH is a "whole body phenomenon" The mechanism behind PEH is not completely understood, but factors such as reduced stroke volume (SV) and reduced TPR is believed to be most important (Halliwill, 2001; MacDonald, 2002).

Other factors that can affect PEH are the body position when the subjects resting in the PE period, since this can affect the PEH results (Halliwill, 2001). According to Halliwill (2001) the extent of PEH is greater in standing and sitting position than in the supine position. If the subjects have high BP values before training and low VO_{2max} (i.e. being untrained), it can cause a greater extent of PEH (Taylor et al., 2012). The time of the day was also found to be predictor for changes in BP, because it was a greater extent of PEH when the measure was taken in the afternoon than in the morning (Taylor et al., 2012).

Circulating hormones, local metabolic factors or both may play a role in mediating PEH, but it is not provided information of the influence of these mechanisms on PEH. Another mechanism that can affect the PEH is baroreflex (MacDonald et al., 2002). PEH is associated with changed baroreceptor reflex control of the circulation, it is reported that baroreceptor reflex control of heart rate have been enhanced after a short training session with maximal exercise in normo- and hypertensive subjects (Kenney and Seals, 1993).
A different mechanism that may affect the PEH response is the renin angiotensin system, this process takes place in the kidneys and it is found increased renin and angiotensin concentrations during PEH, but not a significant role in PEH (MacDonald et al. 2002).

Some studies have examined the influence of sympathetic nerve activity on PEH and a study reported a reduced muscle sympathetic nerve activity following exercise in borderline HT individuals. Heart rate variability (HRV) has been used as an indication of the autonomic nervous system control, and these indices suggest that sympathetic outflow is increased over the same interval in which PEH is observed. It is some indication that afferent nerve activity to cardiovascular control centres may be involved in the PEH response (MacDonald et al., 2002).

Possible mechanisms behind PEH are still unclear and needs more research. What we know is that the PEH effect is more pronounced in subjects having higher initial BP values.
It is important to know which methods that can reduce BP, increased knowledge of the various forms of endurance training who reduce BP are important to develop better strategies for safer training, both in normo- and hypertensive individuals.

3.0 Aims of the study

The research question for the study is: “Can endurance training with high-intensity in terms of 4x4 interval training give a greater extent and/or duration of PEH than endurance training with moderate intensity in terms of continuous work in inactive men?”

The participants in the study are middle-aged men who exercise max. 1-2 times a week. All the tests in this study are performed on a bike and both training sessions have the same caloric consumption. The endurance session with high-intensity is in the form of 4x4 interval training, with intensity around 90% of HR_{max} during each interval and around 75% of HR_{max} during each recovery period. The endurance session with moderate intensity is in the form of continuous work and intensity around 75% of HR_{max}. Since MAP is a product of CO and TPR, we will consider PEH by measuring BP, CO, HR, SV and TPR.

The hypothesis for the study is: a) High-intensity interval training would give a greater extent and duration than moderate intensive endurance training on the PEH response. b) TPR and SV are lower after training with high-intensity than training with moderate intensity.

4.0 Method

4.1 Experimental approach to the research question

Six physically inactive men carried out high-intensity interval training and moderate continuous endurance training. All tests were performed by using a cycle ergometer. The subjects were tested for VO_{2max} on separate day, before they carried out the two experimental protocols, high-intensity interval training (4x4) and moderate intensity continuous training (independent variables). Resting SBP, DBP, HR, CO, TPR, RPE, SV (dependent variables) were measured before and during each exercise session, as well as for 30 min after completing the exercise. MAP was calculated from SBP and DBP.

HR and VO_2 consumption were measured continuously during the exercise sessions, while Lac was measured before exercise, immediately after exercise and 30 min PE. All testing procedures were completed between a period from February to April and all tests were completed with minimum 48 h recovery between tests.

It is conducted an ideal resting measurement, which is used as a reference for both training methods, because of practical reasons since it was not possible to implement the rest measurement before every workout.

When the interval session was conducted, the computer (Jaeger Vyntus CPX) showed us the calorie consumption. The calorie consumption was writing down and when they conducted the continuous session, they had to consume the same calorie consumption. We had to look at the computer display and stopped the continuous training when they reach the same calorie consumption. The duration of the continuous session was different, but they used around 30-40 minutes to reach similar calorie consumption.

4.2 Participants

Twenty inactive, middle-aged men and women were voluntarily enrolled in the study, two of them resigned, two of them had too low BP and four were too well-trained. A total of twelve participants conducted the study, six men and six women. All participants were non-smokers, had no history of cardiovascular disease, were not taking any medication and engaged in regular physical activity not more than 1-2 days per week. The participants were recruited mainly by a local advertising to the college staff at HIOA.

This study is a part of a larger project and the dataset is split in two, since my student co-worker writes about PEH and women and this study writes about PEH and men. The subjects characteristics are given in Table 1.

Table 1. Subjects characteristics at study commencement in inactive men (N=6).

Variable	Mean	SD
Age (year):	52.0	7.8
Height (cm):	185.7	7.8
Weight (kg):	88.9	17.4
BMI:	25.8	4.1
HR max (beats min^{-1}:	174	14.3
Lactate, rest (mmol L^{-1}):	1.2	0.4
SBP, rest (mmHg):	131	5.6
DBP, rest (mmHg):	87	7.2
PWV (m s^{-1})	7.3	0.9

BMI= body mass index. DBP= diastolic blood pressure. HR= heart rate.
mmHg=millimetres of mercury. PWV= Pulse wave velocity.
SBP= systolic blood pressure. SD= standard deviation.

The inclusion criteria for the study were men older than 40 years, with slightly elevated normal BP (<120-139 mmHg SBP and 80-89 mmHg DBP). The exclusion criteria were no alcohol, chewing tobacco and smoke 24 hours before intervention. Individuals with diseases (diabetes, heart problems) and blood pressure lowering medicines were excluded.

This study was approved by Regional ethical committee (REK South-East) before participants were recruited and study initiated (appendix.5). The participants signed a written consent form for participation in the study. They were informed both orally and in writing about any advantages and risks associated with the study, the same for the study purpose and the procedure (appendix.3). It was possible to ask question about the research project all the time. The participants were aware that they could at any time withdraw from the study without giving any justification and that it would not cause any negative consequences for them. Before the testing, they had to answer a IPAQ questionnaire about physical activity and sedentary work (appendix.4), this results are not presented in this master thesis.

4.3 Testing and training procedures

All testing and measurement was performed at the Physiology Laboratory (FysLab), Faculty of Health Sciences, University college of Oslo and Akershus. Before they arrived at the laboratory, the participants were instructed to refrain from exercise for 24h, as well as intake of food (including any caffeine) for 2h before each session. Participants attended on three separate exercise session, with the first visit for signing a consent form in accordance with Helsinki Declaration, answer a questionnaire about physical activity and conduct a VO_{2max} test.

The participants completed total three tests on an ergometer cycle in the laboratory. One VO_{2max} session to test the participant's maximal aerobic capacity and two endurance tests (high-intensity and moderate training). The order between high-intensity and continuous training was not randomised. The high-intensity session was chosen as the first test, because this is the training session with highest calorie consumption per unit time.

On day one of the tests, resting BP was measured with the participant sitting and relaxing for five min in a chair. Body composition was also analysed, and a measurement of the pulse wave velocity for evaluation of the participant arterial stiffness was performed.

Before testing the riding position of each participant on the ergometer bike (Lode Excalibur Sport, Lode BV, Groningen, The Netherlands) was registered, and this position was repeated for all tests.

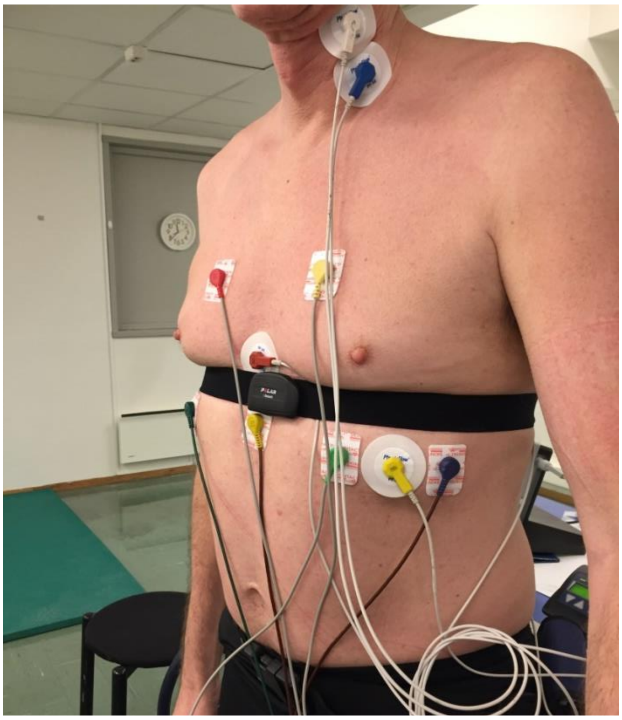
In every test the participants VO_2 consumption was measured continuously, and the participants were fitted with electrodes, a cuff to measure BP during exercise and a belt to measure HF.

Initial test (VO_{2max})

Before the test the participants were fitted with three electrodes to measure electrocardiogram (ECG) signals, which need to trigger the start of the BP measurements. The subjects were instructed to keep a constant pedal cadence between 60-100 rates per min (RPM). The warm-up was similar for all tests and consisted of 10 min cycling with light resistance (75 W). During the VO_{2max} test the resistance increased 10 W each ½ min. It was measured HR, BP and RPE during the test and measured Lac before and immediately after the test. The participants were exhausted after about 5 minutes.

Interval and continuous training

In the high-intensity and continuous session the participants were fitted with a total of 12 electrodes to measure ECG for triggering of BP measurements (three electrodes), HR, SV, CO, TPR, EDV and EF (six electrodes) and three electrodes for measuring heart rate variability (HRV). HRV, EDV and EF data will not be reported in this master thesis. Preparation of the electrodes involved scrubbing and disinfecting the skin areas where electrodes were fastened, the placements of the electrodes is standardized and was mounted in relation to vendor`s descriptions (see picture 1).



Picture.1 The placement of the electrodes + two electrodes on his back.

Before both exercise sessions, the participants were sitting quiet on the cycle and we synchronized the equipment and recorded values for HF, RPE, CO, TPR, SV, Lac and BP at rest. During the interval and continuous sessions HF, BP, SV, TPM, CO and RPE was measured. The participant was instructed to keep a constant cadence on 60-100 rpm.

The warm-up was 10 min at 75 W. After the test, they had to sit and relax in a chair and watch a nature movie for 30 min. It was measured BP, HR, CO, TPR, SV and RPE immediately after exercise, and 5, 10, 20 and 30 min. Statistical analysis will only be performed for values obtained at rest, during exercise and at 5, 10 and 30 min PE. Lac was measured immediately after exercise and after 30 min.

Interval training

The test consisted of 10 min general warm-up and 4 min of more intensive warm-up to reach a greater target HR. The interval session consisted of 4 intervals of 4 min. with 4 min. active recovery between the intervals. The intensity on the intervals was equivalent to about 90% of HR_{max} and the intensity during recovery was about 75% of HR_{max}. Immediately after the last interval, the participants went of the bike and sat down in the chair next to the bike and rest for 30 min.

Continuous training

The test consisted of 10 min general warm up (75 W) and then continuous cycling at a constant HR until the same calorie consumption as interval session was reached. The watt-monitor was controlled manually to keep the HR at the chosen intensity and the subjects were cycling for 30-60 minutes dependent on the calorie consumption at about 75% of HR_{max}. Immediately after the continuous session, the participant went of the bike and sat down in the chair next to the bike and rest for 30 min.

4.4 Collecting data

The BP was measured while the participants resting in a chair for 5 min (Omron M10, Omron Healthcare, Hoofddorp, The Netherlands). Body composition was analysed by an InBody 720 bioimpedance instrument (InBody CO, Seol, Korea). Pulse wave velocity (PWV) was measured by a Boso ABI-system 100 PWV (Bosch and Sohn GmBH, Jungingen, Germany).

During the VO_{2max} test oxygen uptake was measured (VO_2 mL kg^{-1} min^{-1}) breath-by-breath with a Jaeger Vyntus CPX apparatus, (CareFusion/BD, New Jersey, USA). The Jaeger was calibrated for volume, temperature, barometric pressure and gas concentration (CO_2 and VO_2) before each test.

In all tests we measured HR and BP before, during and after exercise. HR (for use of the Vyntus apparatus) was recorded by a Polar H7 heartrate monitor, interfaced with the Jaeger Vyntus CPX. SBP and DBP was measured with a Tango + BP monitor (SunTech Medical, North Carolina, USA). Measurements of HR (beats min^{-1}), SV (mL), CO (L min^{-1}), TPR (dyn s cm^{5}) was assessed non-invasively by impedance cardiography (PhysioFlow Enduro, Manatec Biomedical, Fochsvillier, France). Before and after each test we measured lactate by Arkray Lactat Pro2 1730 (Arkray Inc. Kyoto, Japan).

4.4.1 Measuring instruments

Omron M10-IT (Hoofddorp, The Netherlands) is a small fully automatic BP monitor with advanced ocillometric measuring method with high accuracy.

InBody 720 Body composition analyzer (Seoul, Korea) is a precise measuring device for body composition and using a bioelectric resistance analysis to quantify muscle mass, body fat percentage (Ling et al. 2011). Most of the participants had normal findings.

Boso ABI-system 100 PWV (Jungingen, Germany) calculates the ankle brachial index (ABI) both on the left and on the right side and also measure important cardiovascular parameters as individual BP readings in arms and legs, differences in BP on different sides of the body, pulse, pulse pressure, oscillation profile and pointers to possible cardiac dysrhythmia disorders. PWV is an additional tool to measure arterial stiffness, and it allows PWV to be measured on both sides of the body. PWV is then calculated from that result. Arterial stiffness readings provide useful information about the existence of functional arterial changes. Arterial stiffness increases with age and in response to other risk factors (cardiovascular risk). PWV is a good predictor of the onset of cardiovascular disease. It is more accurate than classical risk parameters such as BP and age (Diehm et al., 2009). Only PWV recordings will be reported in this master thesis.

Jaeger Vyntus CPX, CareFusion/BD (New Jersey, USA) is an automated apparatus for measuring oxygen uptake, breath-by-breath, and provides stable and reliable results (Macfarlane & Wong, 2012).

Tango + blood pressures monitor (North Carolina, USA) is an automated, non-invasive blood pressure monitor designed specifically for use on the treadmill, stationary bicycle and during stress testing. The participant gets three electrodes on a prepared skin surface for ECG signal and a cuff designed specifically for stress testing on the left arm (Orbit-K ™ cuff, SunTech Medical, Morissville, North Carolina, USA). Tango+ has been shown to give at least as accurate and reliable blood pressure measurements as under stress testing and rest, as manual BP measurement (Cameron et al., 2004).

By using the PhysioFlow Enduro, Manatec, (Fochsvillier, France) a non-invasive estimation of the hemodynamic response was obtained. The participant got six electrodes on a prepared skin surface. PhysioFlow calculates SV, CO, TPR, EDV and EF and is a good alternative for invasive methods that are performed at the hospital. In a comparison of the PhysioFlow with the "direct Fick" method, concludes Charloux et al. (2000) that PhysioFlow is a clinically acceptable and reliable method for determination of the different variables during exercise.

Lactate levels (Lac, mmol L^{-1}) in capillary whole blood were measured by a Lactate Pro 2 LT-apparatus (Kyoto, Japan). Lactat Pro2 measures lactate with only a small sample of blood, only 0.3µl blood sample is required to test and the measurement takes 15 sec.

Finapres NOVA (Finapres Medical Systems, Amsterdam, The Netherlands) is a hemodynamic monitoring system and a non-invasive continuous BP monitor. In the present study it was used to monitor HRV during exercise testing and during the PEH measurement sequence. These data will not be reported in this master thesis.

4.5 Calculations

In this study it is calculated MAP and target HR zones for each subjects. In addition energy expenditure was calculated by the Jaeger machine.

MAP describes an average blood pressure in an individual. MAP during rest is calculated as: 2/3 DBP + 1/3 SBP. MAP during exercise is calculated as: ½ DBP + ½ SBP.

Respiratory exchange ratio (RER) is a number that varies between 0.7 or 1.0 depending on the nutrient that is combusted. RER value varies with the work intensity (% of VO_{2max}). In appendix.1 one can see that the combustion of carbohydrates releases 5.05 kcal per liter oxygen. Pure fat burning releases slightly less energy per liter of oxygen (4.69 kcal), i.e. the caloric value of oxygen.

The Jaeger machine calculates the calorie consumption for each subjects during the exercise based on measurements of RER values and oxygen uptake during testing and the value of oxygen at the specific intensity (Frayn, 1983). These measurements are then integrated over time, and energy expenditure is given in kcal min^{-1}.

It is calculated HR zones for every subject in interval- and continuous training. The formula for calculation target pulse zone is (an example):

Interval: 0.85 x 170 = 145 beats min^{-1}

Continuous: 0.70 x 170 = 119 beats min^{-1}

Where 0.85 is 85% of HR_{max} and 0.70 is 70% of HR_{max} and 170 is HRmax for one of the subjects.

Table 2. An overview of the Norwegian Olympic intensity scale of standard pulse values and lactate values for each intensity zone.

Intensitetssone	% av VO_{2maks}	% av HF_{maks}	Laktat (KDK)	Total varighet
I-sone 8	---	---	---	1 – 3 min
I-sone 7	---	---	---	3 – 6 min
I-sone 6	---	---	---	6 – 15 min
I-sone 5	94 – 100	92 - 97	6,0 – 10,0	15 – 30 min
I-sone 4	87 – 94	87 – 92	4,0 – 6,0	30 – 50 min
I-sone 3	80 – 87	82 – 87	2,5 – 4,0	50 – 90 min
I-sone 2	65 – 80	72 – 82	1,5 – 2,5	1 – 3 timer
I-sone 1	45 – 65	60 – 72	0,8 – 1,5	1 – 6 timer

4.6 Design and statistical analysis

In this study it is used a controlled cross-over design; it means that all test persons get both types of treatment, but in different time periods. Cross-over designs need therefore fewer subjects than parallel design. Each test person is its own control and that will reduce the random variation. A cross-over study will compare the effects within each individual and the advantage of this is that the variation in each individual over time will often be less than the variation between individuals (Thomas et al., 2011).

Data were checked for normality by visual inspection of quantile–quantile (Q-Q) plot. When only two averages were involved in the analyses, the paired samples *t*-test procedures were applied. A 2 (high-intensity interval vs. continuous training) x 5 (rest before exercise, mean during exercise, 5 min, 10 min, 30 min PE). ANOVA with repeated measures on both variables was used to test for differences in SBP, DBP, MAP, TPR, HR, SV and CO between the two training regimens before, during, and after the exercise period. Post Hoc comparisons with Bonferroni corrections were conducted to locate differences. All results are presented as mean ± SD. The criterion level for significance was set at $p<0.05$. Statistical analyses were performed in SPSS, version 23.0 (SPSS, Inc., Chicago, IL)

5.0 Results

5.1 Maximum responses and exercise

Mean VO_{2max} for the subjects was 35.6 ± 7.3 ml kg^{-1} min^{-1}. Corresponding values for RER and ventilation was respectively 1.20 ± 0.08 and 129.5 ± 27.2 L min^{-1}. Maximum HR and W generated during VO_{2max} test was 173.8 ± 14.3 beats min^{-1} and 309.2 ± 40.8 W.

After completion of the VO_{2max} test the subjects Lac was 13.3 ± 1.6 mmol L^{-1} and they reported 9.3 ± 0.5 on Borg-scale (0-10) (appendix nr.2). The responses from interval- and continuous training are shown in table 3.

The interval exercise values are based on mean values during the four intervals and recovery periods between the intervals are not included. During the interval exercise the resistance dropped from 200 ± 48 W at the first interval and 161 ± 30 watt on the last interval, while corresponding values for the continuous exercise was 163 ± 40 W (first 7 min) and 130 ± 30 watts (last seven min) (P= 0.01 for both training forms).

Table.3 Physiological responses, energy expenditure (EE), watt and self-reported level of exertion during interval- and continuous training for six men who participated in this study (mean ± SD).

Variables	Interval [a]	Continuous
Duration of exercise (min)	28 ± 0	34.7 ± 4.5
VO2-uptake (ml kg^{-1} min^{-1})	29 ± 4.7 **	24 ± 3.7
VO2-uptake (% VO_{2max})	82.4	68.3
Heartrate exercise (beat/min)	152.3 ± 10.1	134.8 ± 8.7
Heartrate exercise (% HF max)	87.6	77.6
Watt exercise	176.2 ± 35.1*	145.8 ± 32.3
Watt exercise (% watt max)	57	47.2
EE exercise	412.5 ± 57.7	413.3 ± 57.2
Blood lactate concentration, post-exercise,0 min(mmol L^{-1})	3.4 ± 1.7	2.7 ± 0.7
RPE, post-exercise 0 min. (scale 0-10)	5.2 ± 1.3	4.7 ± 1.6

[a]= The interval exercise values are based on mean values of the four intervals; the recovery periods are not included. *=Significant differences between interval- and continuous training; *P<0.05; **P<0.01.

5.2 Systolic blood pressure

The BP response following interval and continuous training is illustrated in Fig.1. The results show us that SBP change significantly over time ($F_{4/20} = 138.20$, $p < 0.001$), but no SBP differences between interval- and continuous exercise ($F_{1/5} = 0.51$, $p = 0.51$). It is no significant interaction between time and type of exercise. ($F_{4/20} = 0.62$, $p = 0.65$). Pairwise post-hoc comparisons showed that SBP was 14.25 mmHg lower 30 min PE than at rest (95 % CI: 0.43 – 28.07; p = 0.04). Fig.1 shows the changes in SBP of the two exercise types over time and which measuring time that differ from each other.

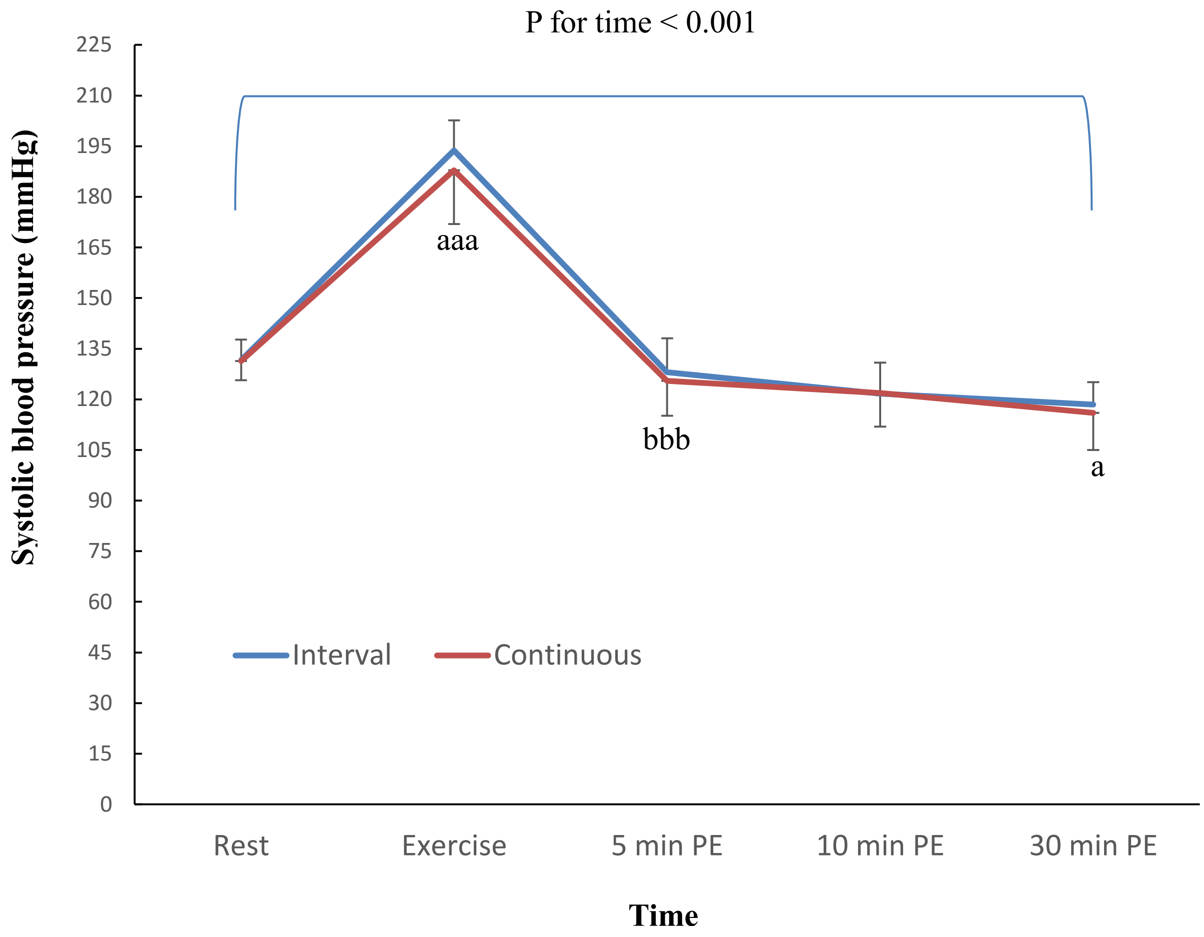


Figure 1. Systolic blood pressure (SBP) in rest, during exercise and 5-10-30 min post-exercise (PE) on interval- and continuous exercise (mean and SD). N=6

[a] =Significant different from first measure, a P<0.05; aaa P<0.001

[b] =Significant different from previous measure, b P<0.05; bbb P<0.001.

5.3 Diastolic blood pressure

The BP response following interval and continuous training is illustrated in Fig.2. The results shows us that DBP did not changed significantly of the five measurement periods ($F4/20 = 2.52$, $p= 0.073$). It was no main effects of the exercise types ($F1/5 = 0.016$, $p = 0.905$) and no significant interaction between time and type of exercise ($F4/20 = 1.490$, $p = 0.243$). Figure 2 shows the changes in DBP of the two exercise types over time and which measuring time that differ from each other.

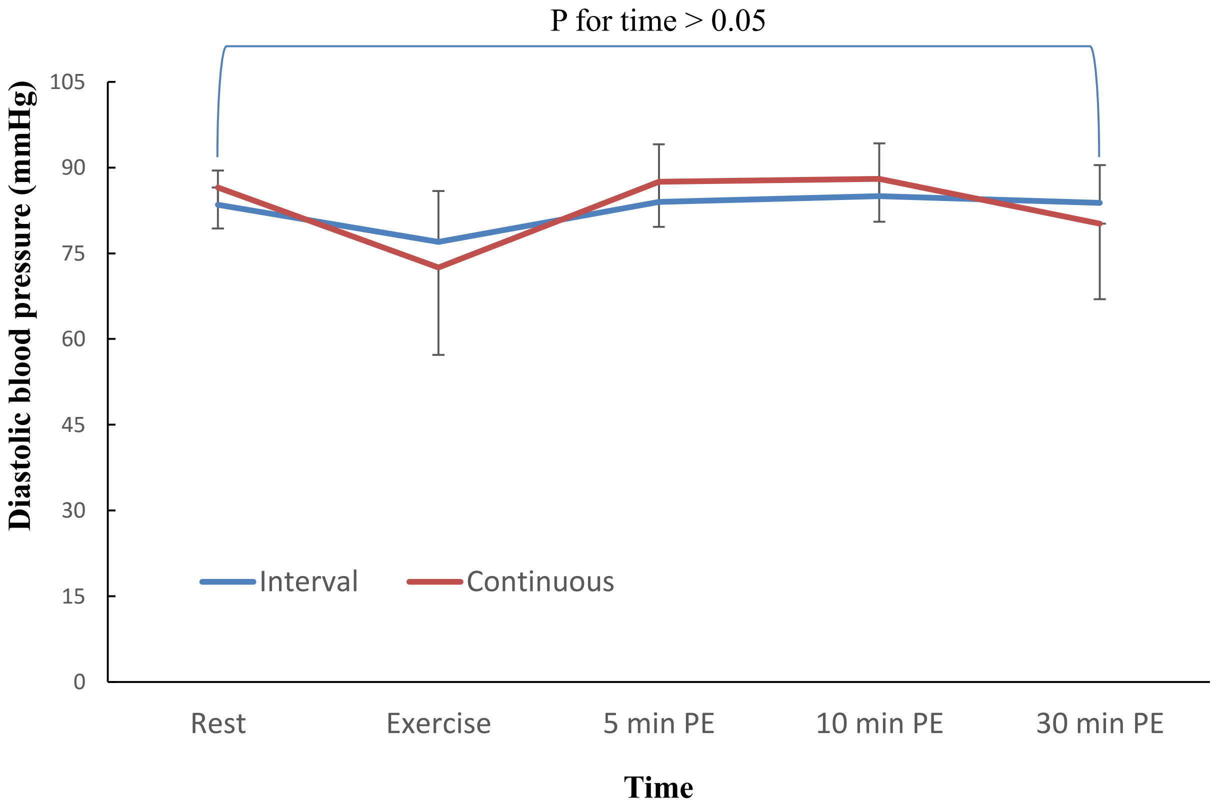


Figure 2. Diastolic blood pressure (DBP) in rest, during exercise and 5-10-30 min post-exercise (PE) on interval- and continuous exercise (mean and SD). N=6

5.4 Mean arterial pressure

The BP response following interval and continuous training is illustrated in Fig.3. MAP changed significantly of the five measurement periods ($F4/20 = 42.66$, $p < 0.001$), but it was no main effects of the exercise types ($F1/5 = 0.03$, $p = 0.86$) and no significant interaction between time and type of exercise ($F4/20 = 1.66$, $p = 0.20$). Figure 3 shows the changes in MAP of the two exercise types over time and which measuring time that differ from each other.

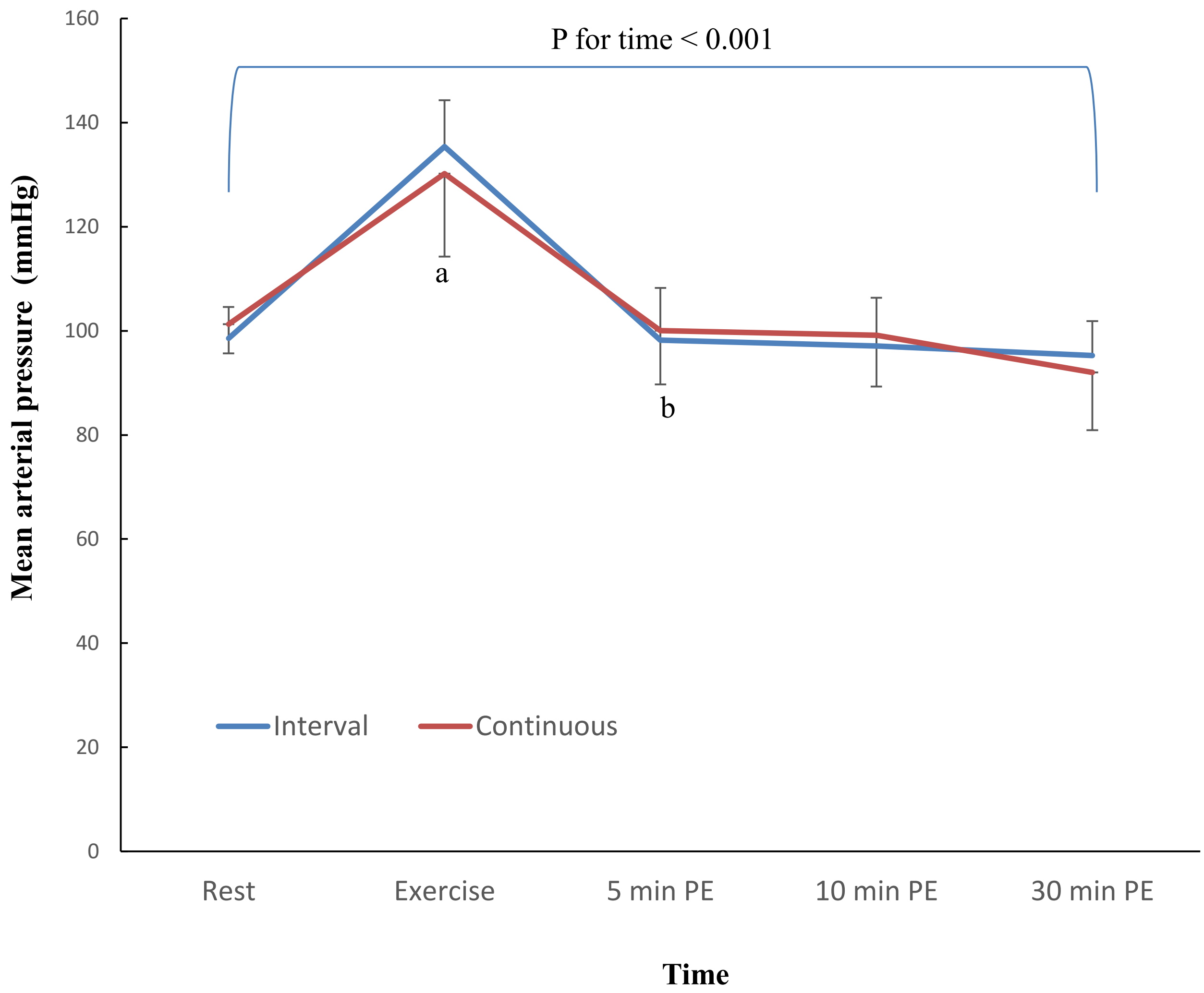


Figure 3. Mean arterial pressure (MAP) in rest, during exercise and 5-10-30 min post-exercise (PE) on interval- and continuous exercise (mean and SD). N=6

[a] =Significant different from first measure, a P<0.05.

[b] =Significant different from previous measure, b P<0.05.

5.5 Cardiac output

The response following interval and continuous training is illustrated in Fig.4. The results shows that CO changed significantly of the five measurement periods ($F4/20 = 324.47$, $p < 0.001$). It was not a main effects of the exercise types ($F1/5 = 1.09$, $p= 0.345$ and no significant interaction between time and type of exercise ($F4/20 = 1.78$, $p=0.173$). Fig.4 shows the changes in CO of the two exercise types over time and which measuring time that differ from each other.

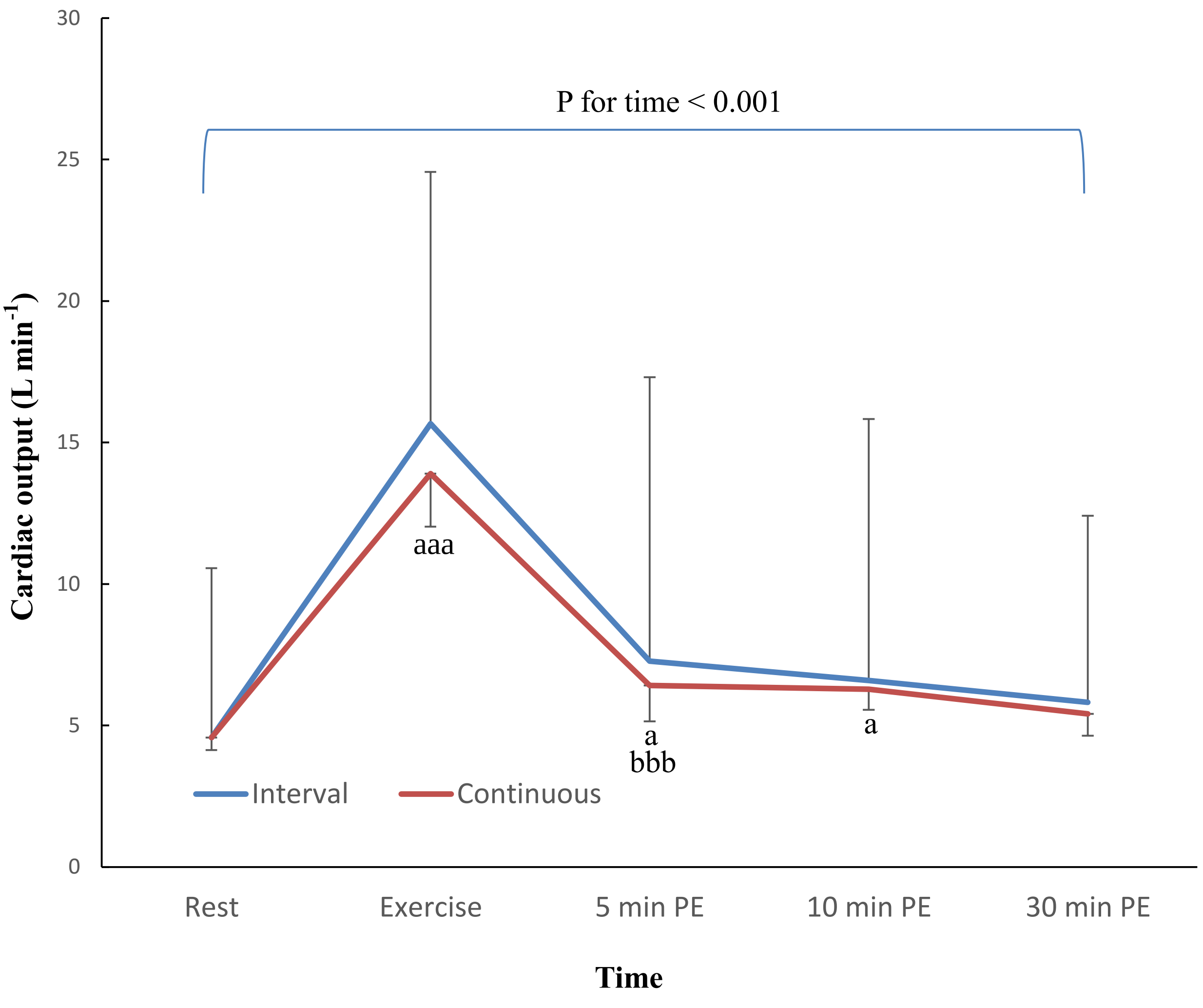


Figure 4. Cardiac output (CO) in rest, during exercise and 5-10-30 min post-exercise (PE) on interval- and continuous exercise (mean and SD). N=6

[a] =Significant different from first measure, a P<0.05; aaa P<0.001

[b] =Significant different from previous measure, b P<0.05; bbb P<0.001.

5.6 Stroke volume

The response following interval and continuous training is illustrated in Fig.5. SV changed significantly of the five measurement periods ($F4/20 = 12.576$, $p < 0.001$). It was not a main effects of the exercise types ($F1/5 = 0.006$, $p=0.943$ and not a significant interaction between time and type of exercise ($F4/20 = 0.013$, $p=1.0$). Fig.5 shows the changes in SV of the two exercise types over time and which measuring time that differ from each other.

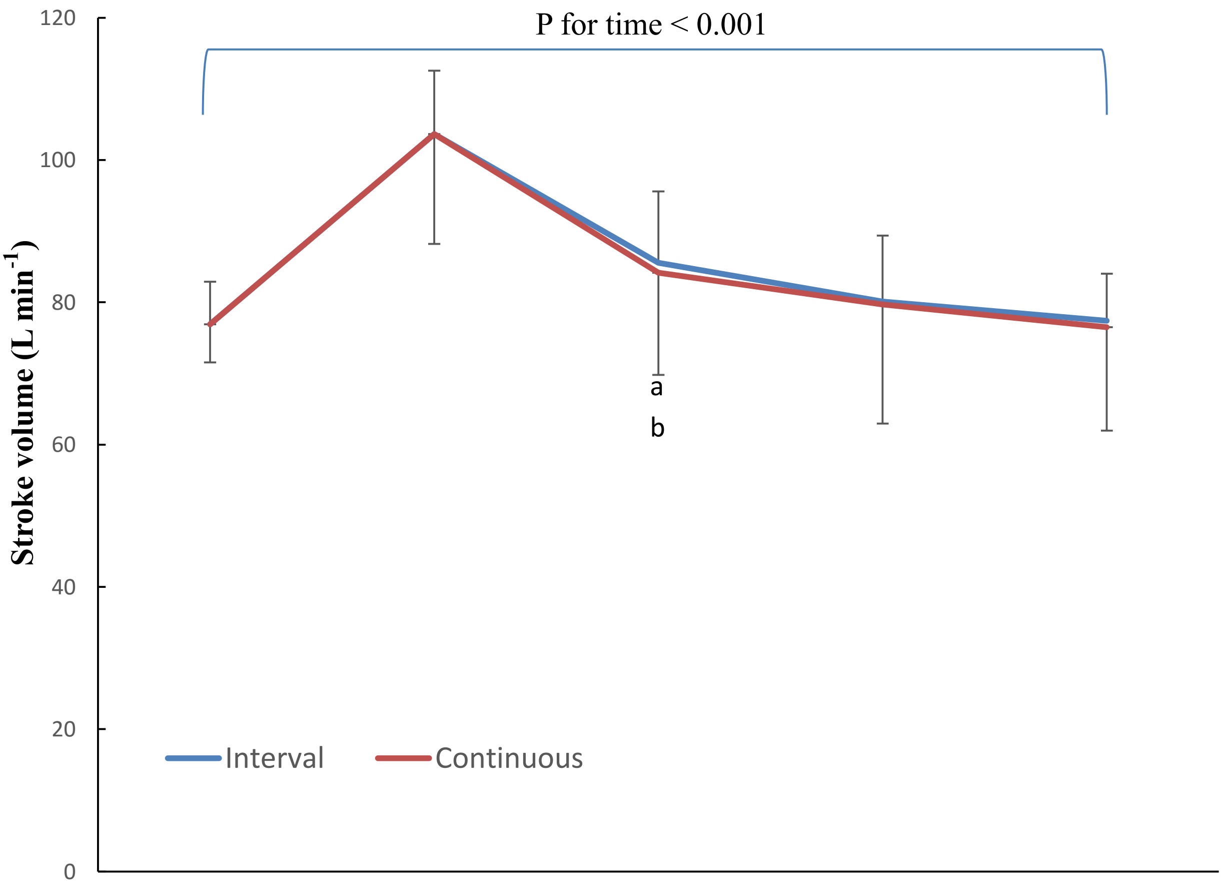


Figure 5. Stroke volume (SV) in rest, during exercise and 5-10-30 min post-exercise (PE) on interval- and continuous exercise (mean and SD). N=6

[a] =Significant different from first measure, a P<0.05.

[b] =Significant different from previous measure, b P<0.05.

5.7 Heartrate

The response following interval and continuous training is illustrated in Fig.6. The results from HR show us that the changed significantly of the five measurement periods ($F4/20 = 176.46$, $p < 0.001$). HR showed a main effects of the exercise types ($F1/5 = 16.71$, $p < 0.01$ and a significant interaction between time and type of exercise ($F4/20 = 7.68$, $p < 0.001$). Pairwise post-hoc comparisons showed that HR was higher for interval training than in continuous training at 10 min. PE (mean diff. = 6.5 beats min^{-1}; 95% CI: 0.54 – 12.46 beats min^{-1}; $p = 0.04$). Fig. 6 shows the changes in HR of the two exercise types over time and which measuring time that differ from each other.

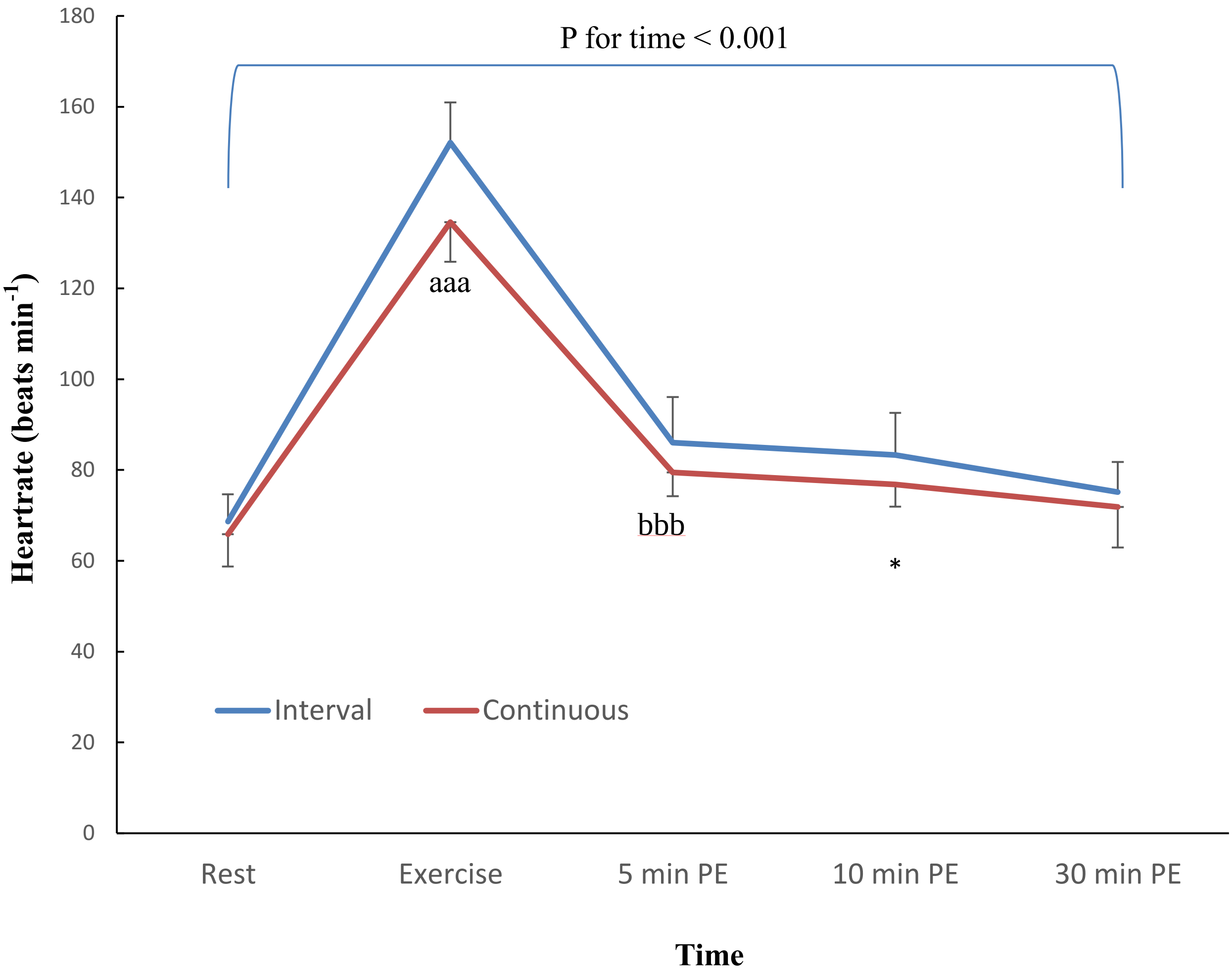


Figure 6. Heartrate (HR) in rest, during exercise and 5-10-30 min post-exercise (PE) on interval- and continuous exercise (mean and SD). N=6

[a] =Significant different from first measure, a P<0.05; aaa P<0.001

[b] =Significant different from previous measure, b P<0.05; bbb P<0.001.

*= Significant different between interval and continuous exercise.

5.8 Total peripheral resistance

The response following interval and continuous training are illustrated in Fig.7. The results of TPR changed significantly of the five measurement periods ($F4/20 = 39.97$, $p < 0.001$). It was no main effects of the exercise types ($F1/5 = 0.27$, $p = 0.62$) and no significant interaction between time and type of exercise ($F4/20 = 0.63$, $p = 0.65$). Fig. 7 shows the changes in TPR of the two exercise types over time and which measuring time that differ from each other.

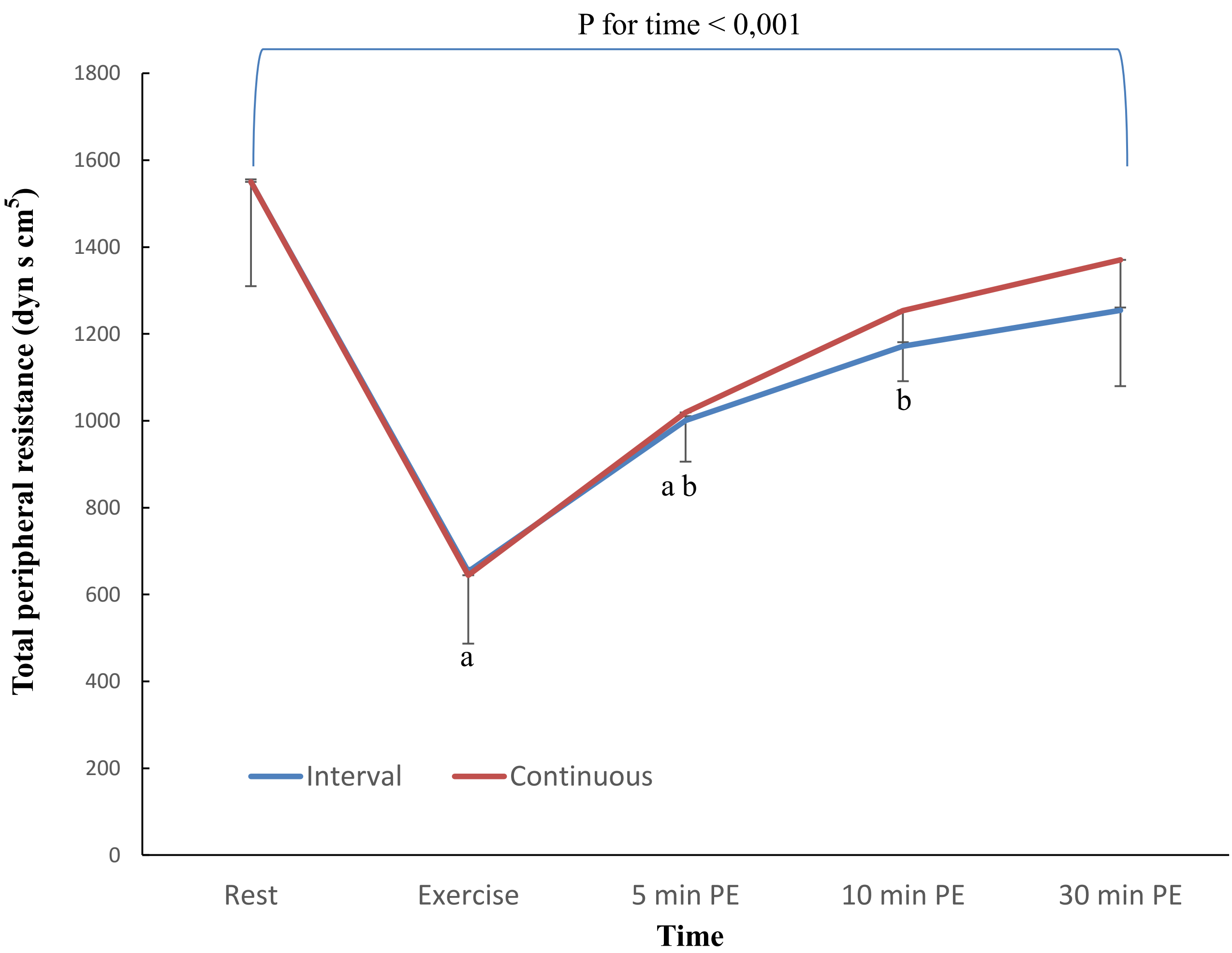


Figure 7. Total peripheral resistance (TPR) in rest, during exercise and 5-10-30 min post-exercise (PE) on interval- and continuous exercise (mean and SD). N=6

[a] =Significant different from first measure, a P<0.05

[b] =Significant different from previous measure, b P<0.05.

6.0 Discussion

In the present study, six men with normal to slightly elevated normal BP performed isocaloric high-intensity interval training and moderate intensity continuous training in order to investigate the effect of different intensities on the extent and duration of PEH. The main finding was that interval and continuous training was quite similar in the PEH response. Only SBP was significant lower 30 min PE compared to rest values for interval and continuous training and the other variables showed no significant changes in the PE period compared to rest values, only HR was significant different between interval and continuous training 10 min PE.

As mentioned before, this present study have conducted an ideal resting measurement which is used as a reference for both training methods, because of practical reasons since it was not possible to implement the rest measurement before every workout. I know that it is not an optimal method, since in statistically it is not great because it violated the assumption of independent measurements. Methodically could it have been better if it was carried out a resting measurement before each workout, so we got a unique time series from rest through exercise and even 30 min after exercise for each exercise. For practical reasons, this was not possible and the alternative was to use values from warm-up, but we considered that the best was to compare with an ideal resting measurement.

In this study the PE response was measured for only 30 min. Ideally, a period of 60-90 min would have been better. The participants in the present study had to use their lunch break on the work to test in the laboratory, hence two hours (1.5 h for preparations and exercising and ½ h to PE) per test day was a necessary compromise.

6.1 Systolic blood pressure

In the present study one can see that SBP raises significantly during exercise (Fig.1) compared to resting values (baseline) at both interval- and continuous training. This is related to changes in CO and TPR during exercise (Smith & Fernhall, 2011). One can see that CO (Fig.4) during exercise was significantly higher and that TPR (Fig.7) during exercise was significantly lower than in rest of both exercise types. Because SBP increased significantly during exercise, the increase of CO may have been greater than the reduction in TPR (Smith & Fernhall, 2011).

Based on the results, it appears that the increase in CO during interval exercise is mainly due to an increased HR, while during continuous exercise it is attributed to a combination of both increased HR and increased SV. As expected, SBP reach higher values during exercise and 5 min PE during interval training than during continuous training, as CO increases linearly with increasing exercise intensity (Smith & Fernhall, 2011).

On 5 min PE one can see that SBP are lower than baseline (rest), the results show that SBP was reduced in relation to rest in the time we have measured for both exercise types, but the reduction was only significant at 30 min PE (14.25 mmHg) after interval- and continuous exercise. The reduction of SBP may be due to a reduction in TPR, CO or both (Smith & Fernhall, 2011).

This study could not find any significant differences between SBP at the two different training types after 30 min PE. It looks like that SBP responds quite similar in the two training types, but the underlying mechanisms that determine SBP may be different.

The SBP finding corresponds with Cote et al. (2015) findings, where they just find significant reduction in SBP in the PE period and MAP was similarly reduced in both groups, like the present study.

6.2 Diastolic blood pressure

During both interval- and continuous exercise the results shows no significant differences between DBP during exercise and PE compared to rest values. Almost unchanged DBP during exercise may be due to a concomitant systemic vasoconstriction and a local vasodilation (Smith & Fernhall, 2011). According to results in the present study, it seems that endurance training has a small effect on the reduction of DBP, and that DBP responds quite similar during two different training types. A small reduction in DBP at PE relative to the rest, may be due that DBP was virtually unchanged during exercise.

6.3 Mean arterial pressure

MAP show no significant PEH reduction, just a significant different during exercise compared to rest. The PE responses are quite similar, just a small reduction for both training types and it can be seen in Fig. 1 and Fig. 3 that the PE responses of SBP and MAP were similar between the interval and continuous exercise.

6.4 Cardiac output, stroke volume, heartrate and total peripheral resistance.

There are no significant differences between the training types as regards CO in PE and TPR in PE, but we can see a tendency that CO is greater (Fig.4) and TPR is lower (Fig.7) at all measurement times for interval training compared to continuous training.

The PE responses of HR and CO decreased in parallel and SV were quite similar PE following high-intensity interval training and moderate intensive training. The decreases in HR and CO was very small PE, but they showed significant reduction on the PE period compared to rest values (HR 10 min PE and CO 5 and 10 min PE).

The PE responses of TPR show significant differences of the five measurement periods, but no significant effects of the exercise type and no interaction between time and type of exercise. As mentioned before, that TPR will be more reduced after high-intensity training than continuous training, since high-intensity activates a better percentage of muscle mass (Smith & Fernhall, 2011). The present study doesn't see that TPR different and the results are quite similar for both training types.

One can see that TPR represented the lowest values initially in the PE period and then increased gradually towards baseline with increasing time for both training types (Fig.7). On the other side one see that CO represented the highest values at the start of the PE period for both training types and declined with increasing time (Fig.4).

6.5 The extent and duration of post-exercise hypotension

It is evidence that the longer the duration of the exercise sessions, the greater the reduction in pressure values, the present study don't find this evidence in the present study from continuous training where the duration of exercise was 30-60 min. The present study findings suggest MacDonald et al. (2000) findings, were they showed no differences in PEH following shorter exercise sessions or ones of longer duration. It seems to be no relationship between exercise duration and PEH.

A previous study by Jones et al. (2007) have made a similar approach where they tested the effects of intensity on the magnitude of acute PEH and controlling for total work done. The findings of this study show that acute PE reduction in BP was similar following high-intensity with short duration and moderate intensity with longer duration that was matched for total work done. This result harmonises with findings made in this study, but in the present study HR was used to control for intensity and Jones et al. (2007) have used W to control for intensity. The participants in the Jones et al. (2007) study exercised at the same resistance during the whole exercise period, which would mean that the training would get more and more strenuous as the training progressed. Hence, as the participants developed fatigue, their HR, VO_2 etc, would increase, and in consequence, physiological responses to prolonged are not stable over time, but variable. In the present study, HR was monitored continuously to keep the exercise intensity within the predetermined limits, and the physiological responses this remains more stable during the test sequence.

As mentioned before, the magnitude of PEH has been reported to be intensity dependent, but similar when total work is controlled for, comparisons of PEH following high-intensity interval exercise are reported to be similar to PEH following a bout of continues exercise (Cote, 2015). We can see the same response in the present study were the PEH response are similar following interval and continuous training.

In the present study it is observed that a small PEH response occurs after endurance training in inactive middle aged subjects (men). As mentioned previously could this study only see one significant reduction in SBP after exercise (30 min PE), but no changes during DBP and MAP. It is possible that the BP reductions had occurred on several measurement times if the study had been conducted with more hypertensive individuals, as it is known that the hypertensive effect after training is less on normotensive than in hypertensive individuals (Halliwill, 2001; MacDonald et al. 2000).

As mentioned before, Halliwill (2001) means that CO will reduce faster than TPR increase after a training session and this imbalance results in PEH. In our study we can see a very small reduction in CO and a great increase in TPR, so it is not a good imbalance between them and not a good PEH response.

According to Taylor et al. (2012), it seems that high BP values before exercise and low VO_{2max} values, is stimulating to the greatest extent of PEH. Since this study subjects had SBP rest 131.3 ± 5.6 mmHg, DBP rest 86.5 ± 7.2 mmHg and VO_{2max} 35.6 ± 7.3 ml kg^{-1} min^{-1}, this may have been contributory factors to the missing effects on PEH.

Another influencing factor that can reduce the extent of PEH is water, because Halliwill (2001) means that water can affect the PEH response. The subjects in the present study got water during the PE period and that may have affected the PEH response. The subjects were informed to rest in the chair with both legs on the floor, and not have their feet crossed since it may affect the PEH response (Halliwill, 2001).

In the present study, the hemodynamic response was measured for 30 min PE. Several previous studies have a more longitudinal approach to the study of PEH, where BP responses were measured up to 24 h PE (Pescatello et al. 2004; Quinn et al. 2000). Since PEH have been observed in 2 h and after 12 h PE in normo- and hypertensive individuals (Halliwill, 2001), it is possible that measuring of hemodynamic responses for a total of 30 min PE is not sufficient to get an impression in the duration of PEH. In the results one can see that PEH occur at the end of the measure period (30 min PE). It would have been interesting to measure PEH for 60-90 min, given the opportunity. Pilottesting in the FysLab has shown similar exercise as performed in the present study, and resulted in a very small decrease in MAP after moderate and high-intensity training, and there was no PE differences in MAP, CO and TPR values between moderate and high-intensity training (Gjovaag, Øygarden, Wold and Mirtaheri. 2015)

Even though this study did not find many significant differences in BP values after exercise between interval- and continuous training, the study cannot exclude that there is a real difference between them. The reason may be that we had few subjects and a spread of data, which increases the risk of type 2 errors. It is also conceivable that the contrast between the intensity in interval- and continuous training were not big enough to produce a significant different in the PEH response.

The subjects in the present study seem that interval training was a more fun training method than continuous training, because of the variation between the intervals and active recovery periods.

6.6 Method criticism and limitation

In this study have six participants fulfilled the inclusion criteria, that number of persons may be a weakness since few test subjects increases the risk of type two errors (Thomas et al., 2011).

The cessation of data collection at 30 min PE is a limitation, but in our study the subjects arrived the laboratory in their working time, since we had only 2 hours to complete each test. Further assessment at 60-90 min PE might have provided insight into the sustained PEH response.

Several exercise endurance tests require that the participants are motivated and able to exert themselves, and lack of motivation could possibly affect the results. The blood pressure measure before, during and after tests can also have been affected because of the unfamiliar situation for the participants.

7.0 Conclusion

This study wanted to find out about endurance training with high-intensity like 4x4 interval training, gave a greater extent and a longer duration of PEH in inactive middle-aged men, compared to continuous training. The present study did not find any significant differences in extent and duration of PEH in high-intensity and moderate training. TPR and SV were quite similar during exercise and in the PE period with high-intensity (interval training) compared to training with moderate intensity (continues work) with same calorie consumption.

As mentioned previously, recommendations from The Norwegian Directorate of Health are endurance training 5-7 days a week at an intensity of 40-70% of VO_{2max} for 30 min for prevention and treatment of hypertension. These recommendations are based on previous research on the exercise intensity and duration that are sufficient to induce PEH. In the present study we found that SBP occurred in physically inactive men after 30 min PE in endurance training. This is the first study to my knowledge, investigating the effects of 4x4 min interval training with high-intensity and moderate continuous training with similar calorie consumption and controlled for intensity.

The present results did not show a significant advantage of interval and continuous training on the PEH. Based on the findings from this study, there is no reason why endurance training with high-intensity and moderate intensity cannot be included in the recommendations for prevention of hypertension. I therefore believe that our results have a clinical value and the results can be generalized for hypertensive individuals. But this study cannot conclude which exercise intensity is better for the treatment and control of hypertension and further research is there for necessary to examine PEH in this population.

Future studies should test high-intensity training with 4x4 intervals and moderate intensity continuous training on more hypertensive individuals with a PE period on 60-90 minutes.

8.0 Appendix

Appendix 1. “Non-protein” respiratory quotient (RQ), caloric value and percentage contribution of carbohydrate and fat to energy metabolism.

Respiratorisk kvotient	Kcal per liter oksygen	Prosent kalorier fra	
		Karbohydrat	Fett
0.70	4.851	0	100.0
0.71	4.858	2.3	97.7
0.72	4.870	6.0	94.0
0.73	4.881	9.6	90.4
0.74	4.893	13.2	86.8
0.75	4.904	16.8	83.2
0.76	4.916	20.4	79.6
0.77	4.927	23.9	76.1
0.78	4.939	27.4	72.6
0.79	4.951	31.0	69.0
0.80	4.962	34.5	65.5
0.81	4.974	38.0	62.0
0.82	4.985	41.4	58.6
0.83	4.997	44.9	55.1
0.84	5.008	48.3	51.7
0.85	5.020	51.7	48.3
0.86	5.032	55.1	44.9
0.87	5.043	58.5	41.5
0.88	5.055	61.9	38.1
0.89	5.066	65.3	34.7
0.90	5.078	68.6	31.4
0.91	5.089	71.9	28.1
0.92	5.101	75.3	24.7
0.93	5.112	78.6	21.4
0.94	5.124	81.8	18.2
0.95	5.136	85.1	14.9
0.96	5.147	88.4	11.6
0.97	5.159	91.6	8.4
0.98	5.170	94.8	5.2
0.99	5.182	98.0	2.0
1.00	5.189	100.0	0

Appendix 2. Borg RPE (Ratings of Percieved Exertion) used to get the subjective experience of effort by different degrees of physical activity.

Borg Scale

RPE Method

0	No exertion at all
0.5	Very, very weak
1	Very weak
2	Weak
3	Moderate
4	Somewhat strong
5	Strong
6	
7	Very Strong
8	
9	
10	Extremely strong
*	Maximal

Appendix.3 Requests to participate in the research project

Effekt av aerob utholdenhetstrening på akutt blodtrykksreduksjon etter trening

Vi er ute etter deg som:

- Har normalt til lett forhøyet normalblodtrykk
- Over 40 år
- Mosjonerer maksimalt 1-2 gang i uken.
- Ikke bruker blodtrykksmedisiner

Forespørsel om deltakelse i forskningsprosjektet

Effekt av aerob utholdenhetstrening på akutt blodtrykksreduksjon etter trening

Dette er et spørsmål til deg om å delta i et forskningsprosjekt med formål å undersøke hvordan utholdenhetstrening med forskjellig intensitet påvirker blodtrykk etter avsluttet trening. Vi vet at moderat utholdenhetstrening reduserer blodtrykket etter en avsluttet treningsøkt til nivåer som er lavere enn det normale hvile-blodtrykket (såkalt *post-exercise hypotension; PEH*). Regelmessig trening og fysisk aktivitet kan derfor være et fullgodt alternativ til medikamentell behandling av forhøyet blodtrykk, men man trenger økt kunnskap om hvordan PEH påvirkes av henholdsvis intensiv og moderat.

Som deltagere i denne studien rekrutter vi personer som har 120-139 mmHg systolisk trykk og 80-89 mmHg diastolisk trykk. Hvis du ikke vet hvilket blodtrykk du har, så vil vi måle det ved første oppmøte til laboratoriet.

Du kan ikke delta i studien hvis du bruker snus, røyker, har diabetes, nyresykdom, hjertelidelse eller en stoffskiftelidelse.

Det er Høgskolen i Oslo og Akershus (HiOA) som er ansvarlig institusjon for denne studien, og studien er godkjent av REK (2015/1866). Både testing og trening foregår på ergometersykkel i Fysiologilaboratoriet på HiOA (Pilestredet 50).

Hva innebærer prosjektet?

Prosjektet innebærer en test av ditt maksimale oksygenopptak (VO2max), og to økter med utholdenhetstrening (én intervall økt og én økt med moderat treningsintensitet). Både testing og trening foregår på ergometersykkel i Fysiologilaboratoriet på HiOA.

VO2max test og utholdenhetstreningen skal gjennomføres i løpet av 2 uker. Hver test/treningsøkt vil ta ca.60 minutter i laboratoriet (+30 min hvile). Ut ifra dataene som blir samlet inn før, under og etter testene, kan man se på effekten av utholdenhetstrening med ulik intensitet på reduksjon i blodtrykk etter avsluttet trening. Under de to øktene med utholdenhetstrening vil vi måle blodtrykk, hjertefrekvens, hjertets minuttvolum samt ta noen få fingerstikks-prøver for å måle melkesyre/laktat. Etter avsluttet trening skal du slappe av og hvile i en stol i ca. 30 minutter. I denne hvileperioden fortsetter vi å måle blodtrykk, hjertefrekvens og minuttvolum med regelmessige mellomrom.

I prosjektet vil vi også be deg om fylle ut et spørreskjema om din fysiske aktivitet, og i forkant av første test vil vi be deg om å gjennomføre en måling av din kroppssammensetning (InBody720). Denne målingen tar to minutter og krever kun at du står stille på en plattform.

Vi ønsker også å sammenligne spørreskjema opplysninger og fysiologiske test-data (blodtrykk og minuttvolum). De opplysningene vi registrerer om deg vil anonymiseres, slik at det vil ikke være mulig å koble enkeltopplysninger tilbake til deg som person.

Mulige fordeler og ulemper

Fordelene ved å delta i dette prosjektet er at man får nyttige informasjon som hvordan blodtrykket påvirkes av forskjellig type utholdenhetstrening samt at man får testet sitt kondisjonsnivå. Erfarne fagpersoner vil bistå med treningsråd og oppfølging av testresultatene.

Ulempene ved dette prosjektet er at utholdenhetstestene kan være slitsomme, men ikke slik at dette krever langvarig restitusjon. Selve treningen har en varighet på 30-45 minutter, med forberedelser ca.60min. Alle testene overvåkes kontinuerlig av erfarne testledere. Testingen/treningen kan avbrytes når som helst etter eget ønske.

Frivillig deltakelse og mulighet for å trekke sitt samtykke

Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Dersom du trekker deg fra prosjektet, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner. Dersom du senere ønsker å trekke deg eller har spørsmål til prosjektet, kan du kontakte førsteamanuensis Terje Gjøvaag, tlf. 95866979 eller mail: terje.gjovaag@hioa.no

Hva skjer med informasjonen om deg?

Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert.

Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kode knytter deg til dine opplysninger gjennom en navneliste. Denne koden oppbevares adskilt fra datamaterialet og innelåst i et arkivskap.

Prosjektlederne har ansvar for den daglige driften av forskningsprosjektet og at opplysninger om deg blir behandlet på en sikker måte. Informasjon om deg vil bli anonymisert eller slettet senest fem år etter prosjektslutt.

Godkjenning

Prosjektet er godkjent av Regional komite for medisinsk og helsefaglig forskningsetikk, 2015/1866 hos REK (22.09.2015).

Jeg er villig til å delta i prosjektet

Sted og dato

Deltakers signatur

Deltakers navn med trykte bokstaver

Jeg bekrefter å ha gitt informasjon om prosjektet

Sted og dato

Signatur

Rolle i prosjektet

Appendix.4 IPAQ questionnaire

DEL 1 – Fysisk aktivitet

Vi er interessert i informasjon om ulike former for fysisk aktivitet som folk driver med i dagliglivet. Spørsmålene gjelder tiden du har brukt på fysisk aktivitet de **siste 7 dagene**. Vennligst svar på alle spørsmålene uansett hvor fysisk aktiv du selv synes du er. Tenk på aktiviteter du gjør på jobb, som en del av hus- og hagearbeid, for å komme deg fra et sted til et annet, og aktiviteter på fritiden (rekreasjon, mosjon og sport).

Tenk på all **meget anstrengende** aktivitet du har drevet med de **siste 7 dagene**. **Meget anstrengende** aktivitet er aktivitet som krever hard innsats og får deg til å puste mye mer enn vanlig. Ta bare med aktiviteter som varer minst 10 minutter i strekk.

1. Hvor mange dager i løpet av de **siste 7 dagene** har du drevet med **meget anstrengende** fysisk aktivitet som tunge løft, gravearbeid, aerobics, løp eller rask sykling?

   ____**dager**

   ☐ Ingen meget anstrengende aktivitet ⟶ *Gå til spørsmål 3*

2. Hvor lang tid brukte du vanligvis på **meget anstrengende** fysisk aktivitet på en av disse dagene?

   ____**timer per dag**

   ____**minutter per dag**

   ☐ Vet ikke/usikker

Tenk på all **middels anstrengende** aktivitet du har drevet med de **siste 7 dagene**. **Middels anstrengende** aktivitet er aktivitet som krever moderat innsats og får deg til å puste litt mer enn vanlig. Ta bare med aktiviteter som varer minst 10 minutter i strekk.

3. Hvor mange dager i løpet av de **siste 7 dagene** har du drevet med **middels** anstrengende fysisk aktivitet som å bære lette ting, jogge eller sykle i moderat tempo? Ikke ta med gange.

   ____**dager**

   ☐ Ingen middels anstrengende aktivitet ⟶ *Gå til spørsmål 5*

4. Hvor lang tid brukte du vanligvis på **middels anstrengende** fysisk aktivitet på en av disse dagene?

____**timer per dag**

____**minutter per dag**

☐ Vet ikke/usikker

Tenk på tiden du har brukt på å **gå** de **siste 7 dagene**. Dette inkluderer gange på jobb og hjemme, gange fra et sted til et annet eller gange som du gjør på tur eller som trening på fritiden.

5. Hvor mange dager i løpet av de **siste 7 dagene gikk** du i minst 10 minutter i strekk?

____**dager**

☐ Gikk ikke ⟶ *Gå til spørsmål 7*

---

6. Hvor lang tid brukte du vanligvis på å **gå** på en av disse dagene?

____**timer per dag**

____**minutter per dag**

☐ Vet ikke/usikker

Det neste spørsmålet omfatter all tid du tilbrakte **sittende** på ukedagene i løpet av de **siste 7 dagene**. Inkluder tid du har brukt på å sitte på jobb, hjemme, på kurs og på fritiden. Dette kan tilsvare tiden du sitter ved et arbeidsbord, hos venner, mens du leser, eller sitter eller ligger for å se på TV.

7. Hvor lang tid brukte du på å **sitte** på en **vanlig hverdag** i løpet av de **siste 7 dagene**?

____**timer per dag**

____**minutter per dag**

☐ Vet ikke/usikker

---

8. Tenk tilbake i tid. Hvor ofte drev du med fysisk aktivitet eller idrett så mye at du ble andpusten og/eller svett da du var:
Sett ett kryss for hver aldersgruppe

	< 10 år	10-14 år	15-20 år
Aldri	☐	☐	☐
Mindre enn en gang/måned	☐	☐	☐
1-3 ganger/måned	☐	☐	☐
1 gang/uke	☐	☐	☐
2-3 ganger/uke	☐	☐	☐
4-6 ganger/uke	☐	☐	☐
Hver dag	☐	☐	☐

Appendix.5 Regional Committees for Medical and Health Research

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst	Silje U. Lauvrak	22845520	19.11.2015	2015/1866 REK sør-øst D
			Deres dato:	**Deres referanse:**
			22.09.2015	

Vår referanse må oppgis ved alle henvendelser

Terje Gjøvaag
Høgskolen i Oslo og Akershus

2015/1866 Effekt av aerob utholdenhetstrening på akutt blodtrykksreduksjon etter trening hos menn og kvinner med mild hypertensjon

Forskningsansvarlig: Høgskolen i Oslo og Akershus
Prosjektleder: Terje Gjøvaag

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK sør-øst D) i møtet 28.10.2015. Vurderingen er gjort med hjemmel i helseforskningsloven (hfl.) § 10, jf. forskningsetikkloven § 4.

Prosjektleders prosjektbeskrivelse
Hypertensjon er en av de viktigste modifiserbare risikofaktorene for hjerte- og karsykdommer og dødelighet. Utholdenhetstrening med moderat intensitet fører til akutt reduksjon i blodtrykk (post-exercise hypotension; PEH) etter avsluttet trening. Det er imidlertid lite undersøkt om hvilken effekt utholdenhetstrening med høy intensitet har på PEH. Formålet med dette prosjektet er å sammenligne effekt av utholdenhetstrening med henholdsvis høy og moderat intensitet på PEH hos personer med mild hypertensjon og lett forhøyet normal blodtrykk. I dette prosjektet benyttes kvantitativ metode og et kvasi-eksperimentelt design. Blodtrykk, hjertefrekvens og hjertets minuttvolum vil bli målt før, under og etter en treningsøkt på ergometersykkel med henholdsvis høy og moderat intensitet. Dette prosjektet kan bidra til økt forståelse for hvordan man kan bruke trening som ikke-medikamentell behandling for personer med hypertensjon.

Vurdering
Formålet med prosjektet er å sammenligne effekt av utholdenhetstrening med henholdsvis høy og moderat intensitet på PEH hos personer med mild hypertensjon og lett forhøyet normal blodtrykk. Komiteen vurderer at prosjektet kan gi ny kunnskap om helse og sykdom ved at det belyser trening som ikke-medikamentell behandling for personer med hypertensjon. Prosjektet faller dermed innenfor REKs mandat etter helseforskningsloven.

Deltagelse innebærer at det skal gjøres to økter utholdenhetstrening på ergometersykkel med to forskjellige intensiteter. Blodtrykk, hjertefrekvens og hjertets minuttvolum vil bli målt før, under og etter treningsøkten, og det skal tas venøse blodprøver for å undersøke bla. kolesterolnivå, triglycerider, langtidsblodsukker, samt endotelspesifikke innflammasjonsmarkører. Blodprøvene destrueres etter analyse. Komiteen kan ikke se at det i søknaden er beskrevet noe om beredskap i forhold til blodprøvesvar. Etter komiteens syn bør det etableres en beredskap i prosjektet i form av at deltagere henvises til fastlege dersom blodprøvesvarene viser utslag som krever behandling. Komiteen ber om at også deltagerne informeres om dette.

På denne bakgrunn setter komiteen følgende vilkår for godkjenning:
- Dersom blodprøvesvarene viser utslag som krever behandling, skal deltagerne henvises til fastlege.
- Informasjon om dette må inkluderes i informasjonsskrivet. Det reviderte skrivet skal ettersendes komiteen til orientering.

Vedtak
Med hjemmel i helseforskningsloven § 9 jf. 33 godkjenner komiteen at prosjektet gjennomføres under forutsetning av at ovennevnte vilkår oppfylles.

I tillegg til vilkår som fremgår av dette vedtaket, er godkjenningen gitt under forutsetning av at prosjektet gjennomføres slik det er beskrevet i søknad og protokoll, og de bestemmelser som følger av helseforskningsloven med forskrifter.

Tillatelsen gjelder til 23.06.2016. Av dokumentasjonshensyn skal opplysningene likevel bevares inntil 23.06.2021. Forskningsfilen skal oppbevares atskilt i en nøkkel- og en opplysningsfil. Opplysningene skal deretter slettes eller anonymiseres, senest innen et halvt år fra denne dato.

Forskningsprosjektets data skal oppbevares forsvarlig, se personopplysningsforskriften kapittel 2, og Helsedirektoratets veileder for «Personvern og informasjonssikkerhet i forskningsprosjekter innenfor helse og omsorgssektoren».

Dersom det skal gjøres vesentlige endringer i prosjektet i forhold til de opplysninger som er gitt i søknaden, må prosjektleder sende endringsmelding til REK.

Prosjektet skal sende sluttmelding på eget skjema, senest et halvt år etter prosjektslutt.

Klageadgang
REKs vedtak kan påklages, jf. forvaltningslovens § 28 flg. Klagen sendes til REK sør-øst D. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK sør-øst D, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Vi ber om at alle henvendelser sendes inn på korrekt skjema via vår saksportal: http://helseforskning.etikkom.no. Dersom det ikke finnes passende skjema kan henvendelsen rettes på e-post til: post@helseforskning.etikkom.no.

Vennligst oppgi vårt referansenummer i korrespondansen.

Med vennlig hilsen

Finn Wisløff
Professor em. dr. med.
Leder

Silje U. Lauvrak
Rådgiver

Kopi til: trine.b.haugen@hioa.no
Høgskolen i Oslo og Akershus ved øverste administrative ledelse: postmottak@hioa.no

9.0 Table and figure list

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