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«Aerobic short or long high intensity interval training – does it matter?»

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Abbreviations

GE	Gross efficiency
HIT	High intensity training
HR	Heart Rate
HR_{max}	Maximum heart rate
$[La^-]$	Blood lactate concentration
La^-_{peak}	Peak lactate concentration
LI	Long interval
LIT	Low intensity training
NSD	Norwegian Centre of Research Data
MIT	Moderate intensity training
RPE	Rate of perceived exertion (BORG scale, 6-20)
$Power_{30s}$	Mean power during a 30 s all-out test (Wingate)
$Power_{40min}$	Mean power during a 40-min all-out
$Power_{4mM}$	Power corresponding to $4mMol \cdot L^{-1}$ $[la^{-1}]$
PP	Peak power
PPO	Peak power output
RER	Respiratory exchange ratio
SI	Short interval
sRPE	Session rating of perceived exertion (1-10)
$\%VO_{2peak}@4mM$	Percent peak oxygen uptake corresponding to $4mMol \cdot L^{-1}$
VO_2	Oxygen uptake
VO_{2max}	Maximal oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$)
VO_{2peak}	Peak oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$)

ABSTRACT

BACKGROUND: Endurance training involves the manipulation of intensity, duration and frequency. In addition, it is usual among athletes to manipulate the design of high intensity interval training (HIT), i.e. whether the intervals are performed with short or long duration of bouts.

PURPOSE: To compare the effects of short and long HIT conducted with the same total accumulated duration on physiological- and performance parameters during a 4-week training period.

METHODS: Twenty-six well-trained cyclists (30±9 yr, peak oxygen uptake (VO_{2peak}) 64±6 $mL \cdot kg^{-1} \cdot min^{-1}$) were randomly assigned into three training groups; long interval group (LI) (n=8), short interval group 1 (SI1) (n=9) and short interval group 2 (SI2) (n=9). All groups conducted HIT sessions three times per week for 4 weeks interspersed with high volume of low intensity training (LIT). The HIT sessions were performed as 4x8-min (32-min accumulated HIT duration), 4x(12x40/20-sec) (32-min accumulated HIT duration excluding interval recovery bouts) and 4x(8x40/20-sec) (32-min accumulated HIT duration including interval recovery bouts), in LI, SI1 and SI2 groups, respectively.

RESULTS: There were no significant differences between groups in any physiological- or performance outcomes after 4 weeks of intensified training. All groups significantly improved mean power during 40-min all-out ($Power_{40min}$) and peak power output during incremental test to exhaustion (PPO) from pre- to post-test ($P<0.05$). Further, both SI1 and LI improved significantly in VO_{2peak} ($P<0.05$).

CONCLUSION: The present study demonstrates that there are no differences between aerobic short or long high intensity interval training with the same accumulated HIT duration (i.e. 32 min) during a 4-week training period.

KEY WORDS: Cycling, endurance performance, intermittent exercise, maximal oxygen consumption, physiological adaptions, well-trained athletes

SAMMENDRAG

BAKGRUNN: Utholdenhetstrening består av manipulering av belastningsvariablene intensitet, varighet og frekvens. I tillegg er det vanlig blant utøvere å manipulere økt-design på høyintensiv intervalltrening (HIT), dvs. om intervaller skal gjennomføres med kort eller lang lengde på dragene.

HENSIKT: Sammenligne effekten av kort og lang HIT utført med lik total akkumulert varighet på fysiologiske parametere og prestasjonsparametere i løpet av en 4-ukers treningsperiode.

METODE: Tjue-seks godt trente syklister (30±9 alder, peak oksygen opptak (VO_{2peak}) 64±6 $mL \cdot kg^{-1} \cdot min^{-1}$) ble tilfeldig fordelt i tre treningsgrupper; langintervallgruppe (LI) (n=8), kortintervallgruppe 1 (KI1) (n=9) og kortintervallgruppe 2 (KI2) (n=9). Alle gruppene gjennomførte tre HIT økter per uke i 4 uker med innslag av høyt volum av lavintensiv trening (LIT). HIT øktene ble gjennomført som 4x8-min (32-min akkumulert varighet på HIT), 4x12x40/20-sec (32-min akkumulert varighet på HIT, ekskludert intervallpauser) og 4x8x40/20-sec (32-min akkumulert varighet på HIT, inkludert intervallpauser), i henholdsvis LI, SI1 og SI2.

RESULTATER: Det var ingen signifikante forskjeller mellom gruppene i noen målte fysiologiske parametere eller prestasjonsparametere etter 4 uker med intensivert trening. Alle gruppene forbedret gjennomsnittswatt i løpet av 40 minutters prestasjonstest ($Power_{40min}$) og høyeste målte watt i løpet av trinnvis test til utmattelse (PPO) fra pre- til post-test ($P<0.05$). Både KI1 og LI hadde en signifikant forbedring i VO_{2peak} ($P<0.05$).

KONKLUSJON: Denne studien viser at det er ingen forskjeller mellom aerob kort- og lang høyintensiv intervalltrening med lik akkumulert varighet (dvs. 32 min) i løpet av en 4-ukers treningsperiode.

NØKKELORD: Fysiologisk adaptasjoner, godt trente utøvere, intervall trening, maksimalt oksygenopptak, utholdenhetsprestasjon

Delimitation of the thesis

The following section (Part 1) consists of theory, method and methodological discussion. The paper (Part 2) consists of method, results, discussion regarding results and conclusion. Due to word limitation in the following section (Part 1) results, discussion regarding results and conclusion are excluded.

The authors of this master thesis have contributed equally to the final product.

Part 1:

Theoretical background and methods

1.0 Introduction

The importance of large amounts of training to perform at a high level in endurance sports is well documented among elite athletes (Fiskerstrand & Seiler, 2004; Seiler, 2010; Stöggl & Sperlich, 2015; Tønnessen et al., 2014; Zapico et al., 2007). It is also well documented that both low intensity training (LIT), moderate intensity training (MIT) and high intensity training (HIT) should be included in the overall training efforts (Fiskerstrand & Seiler, 2004; Laursen, 2010; Stöggl & Sperlich, 2015). Based on both descriptive and experimental studies it seems that a general intensity distribution of ~80% LIT and ~20% MIT/HIT is optimal for achieving a high level in different endurance sports (Billat, Demarle, Slawinski, Paiva, & Koralsztein, 2001; Esteve-Lanao, Foster, Seiler, & Lucia, 2007; Neal et al., 2013; Seiler & Kjerland, 2006; Seiler & Tønnessen, 2009; Steinacker, Lormes, Lehmann, & Altenburg, 1998).

HIT has been reported to have a positive effect on the aerobic endurance among both elite athletes and recreational athletes (Laursen, 2010; Midgley, McNaughton, & Wilkinson, 2006; Stöggl & Sperlich, 2015). Experimental studies have shown improved performance and physiological adaptions by increasing the number of HIT sessions from zero or one per week to two or three sessions per week in studies lasting 3-12 weeks (Franch, Madsen, Djurhuus, & Pedersen, 1998; Helgerud et al., 2007; Rønnestad, Hansen, Vegge, Tønnessen, & Slettaløkken, 2015; Seiler, Jøranson, Olesen, & Hetlelid, 2013; Stepto, Hawley, Dennis, & Hopkins, 1999; Sylta et al., 2016). A recent study also shows how different endurance parameters stagnate after only four weeks of HIT training during a 12-week training intervention (Sylta et al., 2017). Therefore, in certain experimental designs a 4-week intervention period will probably be sufficient to achieve the desired effect.

Although there is general agreement that HIT is an important part of the overall training, it is unclear how to best organize the HIT intervals. The adaptions of endurance performance seem to depend on both the intensity and the accumulated duration of the HIT sessions. Studies have recently demonstrated that a slight reduction in intensity in combination with increased accumulated work duration may be beneficial for improving aerobic endurance adaptions in well-trained cyclists and cross-country skiers (Sandbakk, Sandbakk, Ettema, & Welde, 2013; Seiler et al., 2013; Sylta et al., 2017).

In addition to manipulate the load variables, i.e. intensity and accumulated duration, it is usual among athletes to manipulate the design of HIT sessions, i.e. whether the intervals are performed with short or long duration of bouts (Billat, 2001). Only a few studies have compared the effects of aerobic short intervals (SI) and long intervals (LI) with approximately the same total training load (Franch et al., 1998; Helgerud et al., 2007; Rønnestad et al., 2015; Stepto et al., 1999). Helgerud et al. (2007) found no differences between the two designs of HIT. However, other studies have found different improvements between SI and LI designs (Franch et al., 1998; Rønnestad et al., 2015; Stepto et al., 1999). In the study by Franch et al. (1998) and Stepto et al. (1999) the LI design was found to be superior to the SI design. These two studies are contradictory to Rønnestad et al. (2015) who compared SI and LI with the same accumulated duration (i.e. 19.5 vs. 20 min). In that study it was found that SI resulted in the greatest improvement compared with LIs.

To our knowledge it is only Rønnestad et al. (2015) who have compared SI and LI with approximately the same accumulated duration of intervals, and simultaneously found the greatest improvement in the SI design. However, in that study the total HIT duration was only ~20 min, and it has been demonstrated that HIT sessions with a total duration of 30-45 min combined with a small reduction in intensity is more effective than 10 to 16 min with somewhat higher intensity (Sandbakk et al., 2013; Seiler et al., 2013). Hence, more research is therefore needed comparing SI and LI designs with >30 min accumulated HIT duration.

Therefore, the aim of this study was to compare the effects of aerobic SI and LI training, including equal accumulated HIT duration, during a 4-week intervention period, conducted as 4x8-min with 2-min recovery periods, 4x(12x40/20-sec) with 2-min recovery periods and 4x(8x40/20-sec) with 2-min recovery periods, in different physiological- and performance parameters among well-trained cyclists.

1.1 Research question and null-hypothesis

Research question

Are there differences between SI and LI training, with equal accumulated HIT duration, during a 4-week intervention period, conducted as 4x8-min with 2-min recovery periods, 4x(12x40/20-sec) with 2-min recovery periods and 4x(8x40/20-sec) with 2-min recovery periods, in different physiological- and performance parameters among well-trained cyclists?

Null-hypothesis

This study’s null hypotheses is the following:

- There are no differences in physiological- or performance parameters between aerobic SI and LI training.

2.0 Theory

2.1 Physiological factors influencing endurance performance

Endurance can be defined as *"the capacity to sustain a given velocity or power output for the longest possible time"* (Jones & Carter, 2000). Endurance exercise training results in great adaptions of the cardiorespiratory and neuromuscular systems that increase both the oxygen delivery capacity to the working muscles and the oxygen consumption, which in turn seems to induce an improvement in endurance performance (Hawley, 1995; Jones & Carter, 2000). There are four key parameters of aerobic fitness that are considered most important and that an athlete therefore wants to influence by training. The physiological factors maximal oxygen uptake (VO_{2max}), lactate threshold (LT), work economy and fractional utilization rate of VO_{2max} (% VO_{2max}) have all proved to be affected by different types of endurance training (Carl Foster & Lucia, 2007; Jones & Carter, 2000; Sjodin & Svedenhag, 1985; Sparling, 1984).

2.1.1 Maximal oxygen uptake (VO_{2max})

VO_{2max} is often defined as *"the maximum amount of oxygen that can be absorbed and consumed per unit of time"* (Hill, 1922), and is often considered as the best indicator of a person's aerobic capacity (Golden & Vaccaro, 1984; Midgley & Mc Naughton, 2006; Saltin & Astrand, 1967). Studies have reported a good correlation between VO_{2max}-values and performance in endurance sports (Billat, Demarle, et al., 2001; Esfarjani & Laursen, 2007; C Foster, Costill, Daniels, & Fink, 1978; Saltin & Astrand, 1967). Experimental studies examining the effect of different HIT prescription (both short and long duration) have shown increased VO_{2max} after only 4-12 weeks of training in different sports (Esfarjani & Laursen, 2007; Franch et al., 1998; Helgerud et al., 2007; Rønnestad et al., 2015; Sandbakk et al., 2013; Seiler et al., 2013; Sylta et al., 2017). Although VO_{2max} is a prerequisite for achieving good performance, it is not a sufficient precaution to be best (Impellizzeri, Marcora, Rampinini, Mognoni, & Sassi, 2005; Sjodin & Svedenhag, 1985). For instance, Sjodin and Svedenhag (1985) reported that marathon runners with approximately equal running capacity have shown considerable variation in VO_{2max}, indicating that other factors than VO_{2max} also seem to be of importance to a person's maximum performance.

2.1.2 Fractional utilization of VO_{2max}

Fractional utilization of VO_{2max} (%VO_{2max}) refers to *"the percentage of an athlete's VO_{2max} that can be utilized at a specified speed or work rate"* (Hawley, 1995). Due to methodological challenges of measuring the utilization rate during competition, the fractional utilization at lactate threshold (%VO_{2max}@LT) is often used as an indirect measure of an athlete's utilization rate (Impellizzeri et al., 2005). Well-trained athletes usually have a higher utilization rate than less well-trained (Jones & Carter, 2000). Indeed, it has been reported that high-level marathon runners may sustain an average %VO_{2max} at 80-85 %, whereas marathon runners on a lower level may sustain an average %VO_{2max} at 60-70 % during a marathon (Bassett & Howley, 2000; Sjodin & Svedenhag, 1985). An experimental study by Sylta et al. (2016) also found a significant increase in % VO_{2peak} at 4mM in a group of well-trained cyclists after a 12-week training period.

In order to achieve good performance in aerobic endurance, it is desirable to work as close to VO_{2max} as possible. A study by Coyle et al. (1991) demonstrated that elite national cyclists with similar VO_{2max} values (i.e. 69 $ml \cdot kg^{-1} \cdot min^{-1}$) were able to sustain 90 %VO_{2max} for the duration of a 40-km time-trial compared to 86 % for good provincial riders. The greater % VO_{2max} from the elite cyclists permitted them to ride considerably faster over the 40 km time-trial compared to the good riders. Moreover, a study by Impellizzeri et al. (2005) reported a significant correlation between %VO_{2max}@LT and performance in a group of elite cyclists. No correlation between VO_{2max} and performance was found in this study. Equivalent correlation between %VO_{2max} and performance has also been found in marathon runners (Sjodin & Svedenhag, 1985).

2.1.3 Work economy

In addition to a high VO_{2max} and % VO_{2max} it is important to have good work economy. Work economy refers to "the oxygen uptake required at a given exercise intensity" (Jones & Carter, 2000). Improvement in the work economy indicates lower oxygen uptake (VO_2) (measured in $ml \cdot kg^{-1} \cdot min^{-1}$) for a given absolute running speed or power output and may result in higher speed or power output with the same oxygen uptake (Hawley, 1995; Lucia et al., 2006; Svedenhag, 1995). The work economy is often referred to as gross efficiency (GE) (Sandbakk, Holmberg, Leirdal, & Ettema, 2010).

Studies have demonstrated a positive correlation between the work economy and performance in endurance sports (Lucia et al., 2006; Sjodin & Svedenhag, 1985). Indeed, it has been reported that in a group of marathon runners with approximately the same VO_{2max} and % VO_{2max}, the best group showed a significantly better work economy compared to the other groups (Scrimgeour, Noakes, Adams, & Myburgh, 1986). Based on previous studies it may also appear that a low VO_{2max} can be compensated by great work economy (Londeree, 1986; Morgan et al., 1995). However, there are also studies that have reported no correlation between work economy and performance (Farrell, Wilmore, Coyle, Billing, & Costill, 1979; Noakes, Myburgh, & Schall, 1990). It should be mentioned that top class athletes in a study by Billat et al. (2001) have proved to be less efficient than their high level counterparts. Moreover, a study also suggests that athletes with a high weakly training volume may experience better efficiency (Sjodin & Svedenhag, 1985). It has also been suggested that it takes longer time to improve the work economy than VO_{2max} (Jones, 1998). Experimental studies have reported improved work economy after 6-8 weeks of HIT (Franch et al., 1998; Helgerud et al., 2007). An athlete's work economy depends on several factors such as anthropometric, physiological and metabolic factors as well as biomechanical and technical factors. Further, an athlete's technique may also affect the work economy (Jones & Carter, 2000).

2.1.4 Lactate threshold (LT)

The velocity (power output) at lactate threshold (vLT), i.e. the highest intensity area with steady state between lactate production and lactate elimination, has proven to be an important factor for performance (Coyle, Coggan, Hopper, & Walters, 1988; Sjodin & Svedenhag, 1985). The term 'lactate threshold' is much debated, and different methods are being used to calculate this (Hawley, 1995). Often a fixed value of $4 mMol \cdot L^{-1}$ is used to reflect changes in velocity or power output (Bentley, McNaughton, & Batterham, 2001; Foxdal, Sjödin, Sjödin, & Östman, 1994).

With sufficient training containing both LIT and HIT a rightward shift of the LT curve to a higher velocity or power output may occur, meaning that one can work at a higher velocity or power output without further accumulation of lactate (Jones & Carter, 2000). It has been suggested that training at intensities close to or slightly above the LT may be important in eliciting improvement in this parameter (Carte, Jones, & Doust, 1999; Henritze, Weltman, Schurrer, & Barlow, 1985; Keith, Jacobs, & McLellan, 1992). Experimental studies examining the effect of different HIT prescriptions have reported significant increases in power output corresponding to 4 mMol·L^{-1} [la-] ($Power_{4mM}$) (Rønnestad et al., 2015; Seiler et al., 2013; Sylta et al., 2017).

2.2 Training organization influencing endurance performance

Both LIT and HIT are important parts of the training of endurance athletes (Seiler, 2010; Tønnessen et al., 2014), and the intention of endurance training is, among other factors, to achieve physiological adaptions in order to increase the endurance performance (Hawley, 1995; Jones & Carter, 2000). Based on both descriptive and experimental studies it seems that a general intensity distribution of approximately 80 % LIT and 20 % MIT/HIT is optimal in order to induce long-term training adaptions among endurance athletes (Billat et al., 2001; Esteve-Lanao et al., 2007; Neal et al., 2013; Seiler & Kjerland, 2006; Seiler & Tønnessen, 2009; Steinacker et al., 1998). This 80/20-rule has by Seiler and Kjerland (2006) been named a polarized training model where the largest share of training is LIT, combined with a small proportion of MIT and a somewhat higher proportion of HIT. Other research, however, has suggested a pyramidal intensity distribution to achieve superior endurance adaptions (Stöggl & Sperlich, 2015). This is an intensity distribution characterized by large amounts of LIT, a moderate amount of MIT and a small proportion of HIT. Regardless, further research regarding the optimal training intensity distribution is needed.

For well-trained athletes already performing a high training volume it does not appear that an increase in training volume will result in further improvement in endurance performance and physiological parameters. For these athletes it will therefore be important to supplement with HIT sessions in addition to the high volume of training (Laursen & Jenkins, 2002; Seiler & Tønnessen, 2009).

2.2.1 High intensity training

Training at high intensity has for a long time been an important part of the overall training picture for both elite athletes and athletes on a lower level in order to improve aerobic endurance (Billat, 2001; Laursen, 2010; Laursen & Jenkins, 2002). In the 1960's, Swedish physiologists led by Per Åstrand started to investigate the effects of different work durations and recovery ratios to intermittent high intensity exercise (Åstrand, Åstrand, Christensen, & Hedman, 1960). Their work laid the foundation for interval training to this date. In the same decade, Åstrand & Rodahl wrote the following quotation:

"It is an important but unsolved question which type of training is most effective: to maintain a level representing 90 percent of the maximal oxygen uptake for 40 min, or to tax 100 percent of the oxygen uptake capacity for 16 min" (Åstrand & Rodahl, 1986).

In the literature, the terms HIT and high intensity interval training (HIIT) are often used interchangeably. It the present thesis the term HIT will be used as both high intensity training and high intensity interval training. HIT can be performed in different forms and is today one of the most effective methods for improving physiological factors and performance in endurance athletes (Buchheit & Laursen, 2013; Laursen & Jenkins, 2002). HIT is often performed as repeated bouts of high-intensity exercise (equal or superior to maximal lactate steady-state velocity), interspersed with a period of either LIT or complete recovery between each repetition (Laursen, 2010). The purpose of HIT is to repeatedly stress the physiological systems used during a specific endurance-type exercise to a greater extent than that which is actually required during the activity (Buchheit & Laursen, 2013; Laursen, 2010). According to a review by Buchheit and Laursen (2013) there is reason to believe that one should spend several minutes above 90 % of VO_{2max} each interval session in order to achieve both central and peripheral adaptions. Two HIT sessions per week seem to be sufficient to induce physiological adaptions and improvements in performance among endurance athletes without causing a too high impact of stress on the body (Seiler, 2010).

Despite the fact that there is general agreement that HIT is an important part of the overall training, it is unclear how this part of the training should be organized in order to optimize the training effects. Achieving such clarity and agreement is important to ensure optimal performance and training adaptions and to prevent overtraining (Stöggl & Sperlich, 2015). Buchheit and Laursen (2013) suggest that HIT consists of the manipulation of up to nine variables. This includes the work interval intensity and duration, the relief interval intensity and duration, the exercise modality, the number of repetitions and series, and finally the between-series recovery duration and intensity. The manipulation of any of these variables may affect the acute physiological responses to HIT.

2.2.2 Intensity and duration of HIT

Based on previous research, the adaptions of endurance performance seem to depend on both the intensity and the accumulated duration of the HIT sessions. Helgerud et al. (2007) found, for example, that intervals with a total duration between 10-16 min at 90-95 % of maximum heart rate (HR_{max}) were more effective than 25 min at 85 % HR_{max} with three sessions a week. However, other studies have shown that intervals two to three times a week with a total duration of 30-45 min at 90 % of HR_{max} resulted in better adaptions than intervals with a total duration of 10-16 min at 90-95 % of HR_{max} (Sandbakk et al., 2013; Seiler et al., 2013; Sylta et al., 2017). This indicates that a slight reduction in intensity in combination with increased accumulated duration may be beneficial. Based on this, it seems that an intensity at 90 % of HR_{max} with a total duration of 30-45 min per session two to three times a week is beneficial for the development of key performance parameters in endurance sports. The bases of comparison in the mentioned studies have all been HIT training conducted as continuous work or long intervals (> 3 min per bout). Interesting, these findings are in harmony with the quotation above from Åstrand & Rodahl (1986).

2.2.3 Short and long interval training

The manipulation of the load variables intensity and accumulated duration of HIT seems to be important among athletes (Seiler, 2010; Seiler & Tønnessen, 2009). However, athletes also manipulate the design of the HIT-sessions (Billat, 2001). Suggested by Tschakert & Hofmann (2013) HIT can roughly be divided into longer work intervals of ~ 3-5 min at relatively high exercise intensity or into shorter work intervals ~ 15-45 sec at even higher exercise intensity. Studies examining the effects of HIT in cyclists have also used longer work intervals than 3-5 min (i.e. between 8 and 16 minutes) (Sandbakk et al., 2013; Seiler et al., 2013; Stepto et al., 1999; Sylta et al., 2017). Training intensities above 90 % of VO_{2max} are recommended in order to achieve optimal training stimulus (Buchheit & Laursen, 2013; Thevenet, Tardieu-Berger, Berthoin, & Prioux, 2007). Furthermore, it has been assumed that the advantage of the short intervals (< 60 seconds) is that it can extend the time spent at training intensities above 90 % of VO_{2max} (Billat et al., 2001; Gorostiaga, Walter, Foster, & Hickson, 1991). Moreover, it may provide higher mean power output, higher exercise intensity performed near or at velocities associated with VO_{2max} (vVO_{2max}) and higher lactate concentrations [la^-], which may result in larger training stimuli and improved neuromuscular adaption as well as mitochondrial production and buffering capacity (Buchheit & Laursen, 2013; Rønnestad et al., 2015).

2.2.4 Work over recovery ratio

Experimental studies examining the effects of SI training have used different fixed work over recovery ratios (2:1, 1:1, 1:2) with 2:1 and 1:1 as the most frequently reported ratio (Billat, Slawinksi, et al., 2001; Helgerud et al., 2007; Laursen & Jenkins, 2002; Rozenek, Funato, Kubo, Hoshikawa, & Matsuo, 2007; Rønnestad et al., 2015). A 4:1 work : recovery ratio has been reported to be an upper limit for some individuals in the initial phases of HIT (Rozenek et al., 2007). It has been demonstrated that a work : recovery ratio of 2:1 induces more time spent above 90 % of VO_{2max} than a 1:1 ratio (Rozenek et al., 2007), probably due to a longer time to achieve 90 % of VO_{2max} in combination with the micro recovery periods. This appears to produce responses that may benefit aerobic as well as anaerobic energy system development (Rozenek et al., 2007). In addition, the micro recovery between each interval allows the athletes to achieve a long accumulated duration of each series.

2.3 Experimental studies of aerobic short or long interval training

Experimental studies have examined the effects of aerobic SI training (Gorostiaga et al., 1991; Gunnarsson & Bangsbo, 2012) and LI training (Lindsay et al., 1996; Sandbakk et al., 2013; Seiler et al., 2013; Stepto et al., 1999; Sylta et al., 2017; Westgarth-Taylor et al., 1997; Weston et al., 1996) and found physiological and performance improvements.

To the best of our knowledge only a few studies have investigated the effects of only aerobic SI training (Table 1). Gorostiaga et al. (1991) reported significant improvements in VO_{2max} and maximal exercise intensity (MEC) in untrained cyclists performing SI as 30-sec work/30-sec rest in 20 min, three times per week for eight consecutive weeks. Further, Gunnarsson & Bangsbo (2012) reported significant improvements in VO_{2max} and performance in a 1500-m and 5-km run after assigning 10 runners into a HIT group performing 3-4x5 min running interspersed by 2 min recovery. Each 5 min bout consisted of five 1 min intervals divided into 30s – 20s – 10s at an intensity corresponding to <30%, <40% and 90-100% of maximal intensity, respectively.

The characteristics of studies that have examined the effects of LI training show that accumulating >30 min of HIT induces great endurance adaptions (Table 2). Both Lindsay et al. (1996), Westgarth-Taylor et al. (1997) and Weston et al. (1996) found significant improvements in mean power during 40-km all-out trial ($Power_{40km}$) after a 4- to 6-week intervention period with 1-2 LI sessions per week conducted as 6-9x5 min at 80 % of peak power output (PPO). Moreover, Weston et al. (1996) also observed an increased muscle buffering capacity following this LI prescription. However, small sample size, absence from control group and only 1-2 HIT sessions each week increase the limitations in these studies. On the other hand, both Sandbakk et al. (2013), Seiler et al. (2013) and Sylta et al. (2017) also found endurance adaptions when performing different forms of LI training and simultaneously found the greatest improvements when accumulating >30 min of HIT. This is approximately the same accumulated duration as Lindsay et al. (1996), Westgarth-Taylor et al. (1997) and Weston et al. (1996).

Table 1. Experimental studies examining the effects of aerobic SI training.

Study	Sport/level	Design	Quantification of intensity	Intervention period	Outcome
Gorostiaga et al. (1991)	Cycling n=12 Untrained	G1: CG G2: 30-sec work/30-sec rest in 20 min	vVO_{2max} G1:50 % vVO_{2max} G2: 100 % vVO_{2max}	8 weeks, 3 HIT/week	G2:↑VO_{2max}, ↑MEC
Gunnarsson and Bangsbo (2012)	Running n=18 Moderate-trained	G1: CG G2: 10-20-30-sec in 5 min x 3-4	% MI <30%, <60%, and >90% of MI	7 weeks, 3 HIT/week	G2: ↑VO_{2max}, ↑1.500-m and ↑5-km run

CG = control group; G = group; % MI = per cent of maximal intensity; VO_{2max} = maximal oxygen uptake; vVO_{2maks} = velocity at VO_{2max}; MEC = maximum exercise intensity; HIT = high intensity training; ↑ = significant increase; n = number of participants

Table 2. Experimental studies examining the effects of aerobic LI training.

Study	Sport/level	Design	Quantification of intensity	Intervention period	Outcome
Lindsay et al. (1996)	Cycling n=8 Well-trained	G1: 6-8x5-min, r=1 min	% PPO G1: 80 %	4 weeks, in total 6 HIT	↑$Power_{40km}$
Weston et al. (1996)	Cycling n=6 Well-trained	G1: 6-8x5-min, r=1 min	% PPO G1: 80%	4 weeks, in total 4 HIT	↑$Power_{40km}$, ↑β
Westgarth-Taylor et al. (1997)	Cycling n=8 Well-trained	G1: 6-9x5-min, r=1 min	% PPO G1: 80 %	6 weeks, in total 12 HIT.	↑$Power_{40km}$, $Watt_{peak}$
Swart et al. (2005)	Cycling n=21 Well-trained	CG: G1:8x4-min, r=90sec G2: 8x4-min, r=90sec	% PPO and HR@%PPO G1: 80 % PPO G2: HR@80% PPO	4 weeks, 2/week	G1: ↑ $Power_{40km}$
Sandbakk et al. (2013)	Cross-country-skiing n=21 National level	G1: 2 extra LIT/week G2: 2-4 min bouts, 15-20-min tot. G3: 5-10-min bouts, 40-45-min tot.	% HR_{max} G1: 65-74 % G2: 94 % G3: 91 %	8 weeks, 2 HIT/week	G2: ↑VO_{2max} G3: ↑7 km hill run, ↑12 km RS, ↑VO_{2max}, .
Seiler et al. (2013)	Cycling n=35 Moderate-trained	G1: LIT G2: 4x16-min, r=2 min G3: 4x8-min, r=2 min G4: 4x4-min, r=2 min	% HR_{max} G1: LIT G2: 88 % G3: 90 % G4: 94 %	7 weeks 2 HIT/week	G2: ↑VO_{2peak}, ↑$Watt_{peak}$, ↑TT_{80}, ↑$Power_{4mMol}$ G3: ↑VO_{2peak}, ↑$Watt_{peak}$ ↑TT_{80},↑$Power_{4mM}$ G4: ↑$Watt_{peak}$ ↑TT_{80},↑$Power_{4mMol}$ G3 ↑VO_{2peak} compared to G2 and G4 G3 tendency to ↑$Watt_{peak}$, ↑TT_{80}, ↑$Power_{4mMol}$ compared to G2 and G4
Sylta et al. (2017)	Cycling n=43 Well-trained	G1: 4x16-min, r=2 min G2: 4x4-min, r=2 min	% HR_{max} G1: 86 % G2: 89 %	4 weeks, 2-3 HIT/week	G1 greater adaptions in $Power4_{mM}$ and VO_{2peak} compared to G2.

CG = control group; G = group; β = buffering capacity; VO_{2max} = maximal oxygen uptake; VO_{2peak} = peak oxygen uptake; Power4mM = workload corresponding to 4 mMol·L^{-1} [la-]; $Power_{40min}$ = mean power during 40-min-all-out trial; $Power_{40km}$ = mean power during 40-km-all-out trial; $Watt_{peak}$ = peak watt; LIT = low intensity training; HIT = high intensity training; PPO = peak power output; HR@%PPO = heart rate at % of peak power output; TT80% = time to exhaustion 80 % of W_{max}; % HR_{max} = maximal heart rate; RS = roller-ski-skating; r = recovery periods; ↑ = significant increase; n = number of participants

2.4 Experimental studies comparing aerobic SI and LI training

A few studies have compared the effects of short and long intervals performed as aerobic endurance training with approximately the same total training load (Table 3) (Franch et al., 1998; Helgerud et al., 2007; Rønnestad et al., 2015; Stepto et al., 1999). Helgerud et al. (2007) found no difference between SI and LI. They compared interval sessions (3 sessions per week over 8 weeks) performed as 4x4 min at 90-95% of HR_{max} with 47 repetitions of

15/15-sec intervals at 90-95% of HR_{max}. The results showed that HIT performed as both SI and LI resulted in a significant increase of VO_{2max} and running efficiency (RE). However, there are methodological limitations in this study. Low levels of participants and intervention groups matched for total energy consumptions (isoenergetic) may explain why there was no difference between the SI and LI training.

Other studies, however, have found different improvements between SI and LI (Franch et al., 1998; Rønnestad et al., 2015; Stepto et al., 1999). Franch et al. (1998) compared intervals performed as 30-40 repetitions of 15/15-sec interval at 92 % of HR_{max} with 4-6x4 min at 94 % of HR_{max}. The results showed that HIT performed as LI had a significantly greater improvement on VO_{2max} and RE than HIT performed as SI. The total duration of the HIT sessions in the LI group was longer than the duration of the HIT sessions in the SI group. This may explain why HIT conducted as LI showed greater improvements. Stepto et al. (1999) also found superior adaptions in the LI design (8x4-min) compared to the SI design (12x60-sec). However, the intervention period lasted only 3 weeks, including 2 HIT sessions per week, with only four cyclists in each group.

In a study by Rønnestad et al. (2015), on the other hand, it was found that HIT performed as SI resulted in the greatest improvement in both physiological- and performance parameters compared with LI. In this study, SI, performed as repetitions of 30/15-sec for 9,5 min x 3, was compared with LI performed as 4x5-min. The last three studies show contradictory findings. In the study by Rønnestad et al. (2015) the total duration of the SI is similar to the LI, respectively 19.5 and 20 min, if the recovery periods of 15 seconds are not counted in the total work duration. However, the recovery periods of 15 seconds are short, and it is reasonable to assume that the heart rate (HR) will not drop that much during those seconds. This may have resulted in a greater cardiac output during the workouts in the SI group. If the recovery periods are included in the total work, however, the total duration of the SI is longer compared to the LI. This may explain why the SI group showed the best results. Another weakness of the study by Rønnestad et al. (2015) is that they did not have any control croup. Results from these three studies are contradictory to Helgerud et al. (2007) who found approximately identical results between SI and LI. Methodological differences such as different duration of the intervention period, different number of HIT sessions, different sports and different work : recovery ratio may explain the contradictory findings.

Table 3. Experimental studies comparing aerobic SI training and LI training.

Study	Sport/level	Design	Quantification of intensity	Intervention period	Outcome
Franch et al. (1998)	Running n=36 Moderate-trained	G1: LIT 20-30 min G2: LI 4-6x4 min, r=2 min G3: SI (15x15) sec x 30-40	% HR_{max} G1: 93 % G2: 94% G3: 92 %	6 week, 3 HIT/week	G1: ↑VO_{2maks}, ↑vVO_{2maks}, ↑RE, utmattelsestest G2: ↑VO_{2maks}, ↑vVO_{2maks}, ↑RE, utmattelsestest G3: ↑VO_{2maks}, ↑vVO_{2maks}, ↑TE LI greater improvment on VO_{2max} and RE than SI.
Stepto et al. (1999)	Cycling n=20 Well-trained	G1: 12x30-sec, r=4.5 min G2: 12x60-sec, r=4 min G3: 12x2-min, r=3 min G4: 8x4-min, r=1.5 min G5: 4x8-min, r=1 min	% PPO G1: 175 % G2: 100 % G3: 90 % G4: 85 % G5: 80 %	3 weeks, 2 HIT/week	G1: ↑$Power_{40min}$, ↑PPO G4: ↑$Power_{40min}$, ↑PPO
Helgerud et al. (2007)	Running n=40 Moderate-trained	G1: LIT 45-min G2: THT 24-min G3: 15/15-sec x 47 G4: 4x4-min, r=3 min	% HR_{max} G1: 70 % G2: 85 % G3: 90-95 % G4: 90-95 %	8 weeks, 3HIT/week	G1: ↑RE G2: ↑RE G3: ↑ VO_{2max}, ↑RE G4: ↑ VO_{2max}, ↑RE
Rønnestad et al. (2015)	Cycling n=20 Well-trained	G1: SI 30/15-sec in 9.5 min x 3 G2: LI 4x5-min, p=2min	Isoeffort	10 weeks, 2 HIT/week	G1: ↑VO_{2maks}, W_{max}, $Power_{30s}$ ↑$Power_{4mMol}$, ↑$Power_{40min}$ G2: ↑$Power_{40min}$ G1 larger relative increase in VO_{2max}, W_{max}, $Power_{30s}$ and tendency in $Power_{4mMol}$, compared to G2

G = group; SI = short interval; LI = long interval; VO_{2max} = maximal oxygen uptake; VO_{2peak} = peak oxygen uptake; vVO_{2maks} = velocity at VO_{2max}; PPO = peak power output; RE = running economy; Power4mM = workload corresponding to 4 mMol·L^{-1} [la-]; $Power_{40min}$ = mean power during 40-min-all-out trial; TE = test to exhaustion; LIT = low intensity training; THT = threshold training; HIT = high intensity training; % HR_{max} = maximal heart rate; r = recovery periods; n = number of participants; ↑ = significant increase

Other studies have also compared the effects of SI and LI training (Stepto et al., 1999; Laursen et al., 2002; Laursen et al., 2005; Esfarjani & Laursen, 2007; Inoue et al., 2016). However, with the combination of higher work intensity and longer recovery periods up to 4.5 min, these studies represent a more anaerobic approach, defined as sprint interval training, and may therefore not be comparable to the presented studies.

3.0 Methods

This master thesis was conducted as a randomized intervention study where three matched training groups completed a 4-week training period consisting of high volume of LIT in addition to three HIT sessions each week. Training groups differed in HIT session structure (short vs. long interval duration), and were compared in relation to changes in physiological- and performance parameters pre- and post- intervention period.

3.1 Subjects

Thirty cyclists (28 male, 2 female) were recruited through local clubs and announcements in social media. They were all active on a regional level and had experience with competing in road cycling. The following initial inclusion criteria were used to assess whether the cyclists should be included: (1) male < 40 years, (2) peak oxygen uptake ($\dot{V}O_{2peak}$) > 60 ml·kg^{-1}·min^{-1}, (3) training volume >3 sessions per week (within cycling) and (4) absence of disease and injuries. Exclusion criteria were: (1) disease/injuries and (2) frequent absence of HIT sessions during the period. The physical baseline characteristics of the cyclists are presented in Table 4 and according to Jeukendrup, Craig, & Hawley (2000) all groups were categorized as well trained. The cyclists were randomly assigned into three training groups; long interval group (LI), short interval group 1 (SI1) and short interval group 2 (SI2) according to the aim of the study.

Two cyclists from the LI group (1 male and 1 female) and one cyclist from the SI1 group did not complete the study because of illness and injuries. Further, one cyclist from the SI2 group was excluded from the final analysis due to irregular attendance at HIT-sessions. One cyclist from the SI1 group had to extend the intervention period by one week due to illness in the middle of the intervention period, while one cyclist in the LI group had to delay the post-test by one week due to illness post intervention (Figure 1). Due to suspicion of measurement errors in the incremental test to exhaustion for one cyclist in the LI group in the pre-test we used his familiarization test as a starting point.

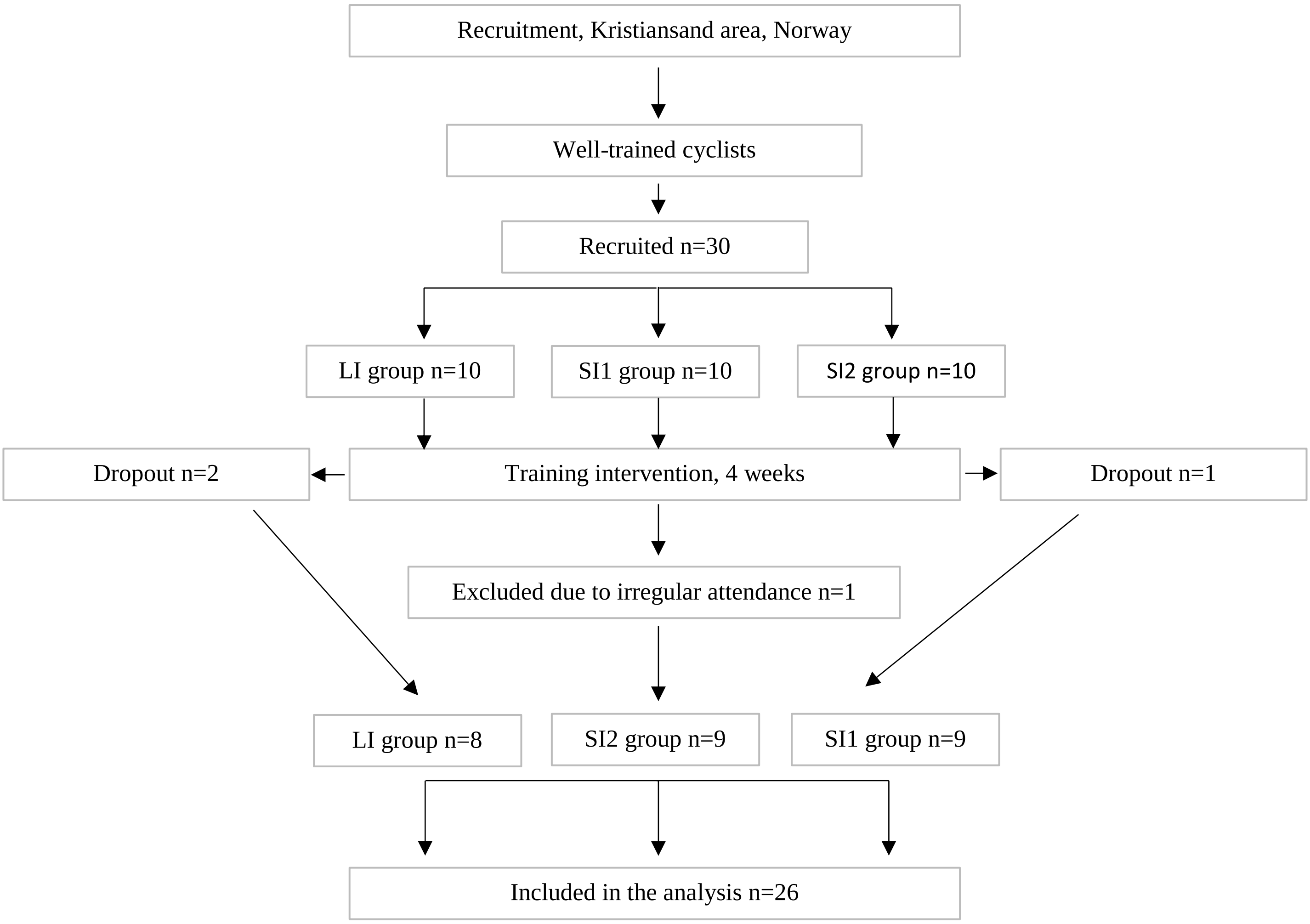

Figure 1. Recruitment of cyclists, dropouts and exclusion in the study. LI group = long interval group, SI1 = short interval group 1 and SI2 =short interval group 2, n = number of cyclists.

3.2 Pre-intervention period (familiarization and de-training)

Initially, the cyclists were invited to an information meeting where all details about the project were given. They also learned how to use the training diary and the Polar V400 for HR monitoring. The cyclists completed a 5-week familiarization and de-training period. In this period the cyclists were only allowed to perform one HIT session each week and freely chosen LIT (*ad libitum*). During the first two familiarization weeks the cyclists completed a lab-test and a 40 min all-out trial ($Power_{40min}$). The next weeks the cyclists were familiarized with interval sessions included in the intervention period. Pre-testing was performed at the end of the pre-intervention period. The cyclists were then randomized into one of the three interval groups (LI, SI1 and SI2), matched for (1) age, (2) VO_{2peak} and (3) $Power_{40min}$ (Table 4).

Table 4. Descriptive data of cyclists at randomization.

	Total (n=26)	**LI (n=8)**	**SI1 (n=9)**	**SI2 (n=9)**
Age	29.9 ± 9.1	27.9 ± 8.9	30.4 ± 9.2	31.2 ± 9.8
Weight (kg)	74.5 ± 7.6	77.3 ± 7.1	73.7 ± 9.0	72.9 ± 6.4
Hight (cm)	179 ± 5.9	180 ± 5.3	179 ± 7.8	179 ± 4.6
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	63.8 ± 6.3	64 ± 6.7	62.9 ± 5.5	64.5 ± 7.3

Values are presented as mean ± standard deviation (SD). LI = long interval; SI1 = short interval 1; SI2 = short interval 2; VO_{2peak} = Peak oxygen uptake; n = number of cyclists,

3.3 Training intervention

The training intervention was performed from early November to early December (4 weeks). In this period the cyclists were allowed to perform *ad libitum* LIT in addition to HIT sessions that were determined to each group. The cyclists completed 12 supervised HIT sessions during the training intervention period, i.e. three HIT sessions per week with at least 48 hours between each HIT-session (Figure 2).

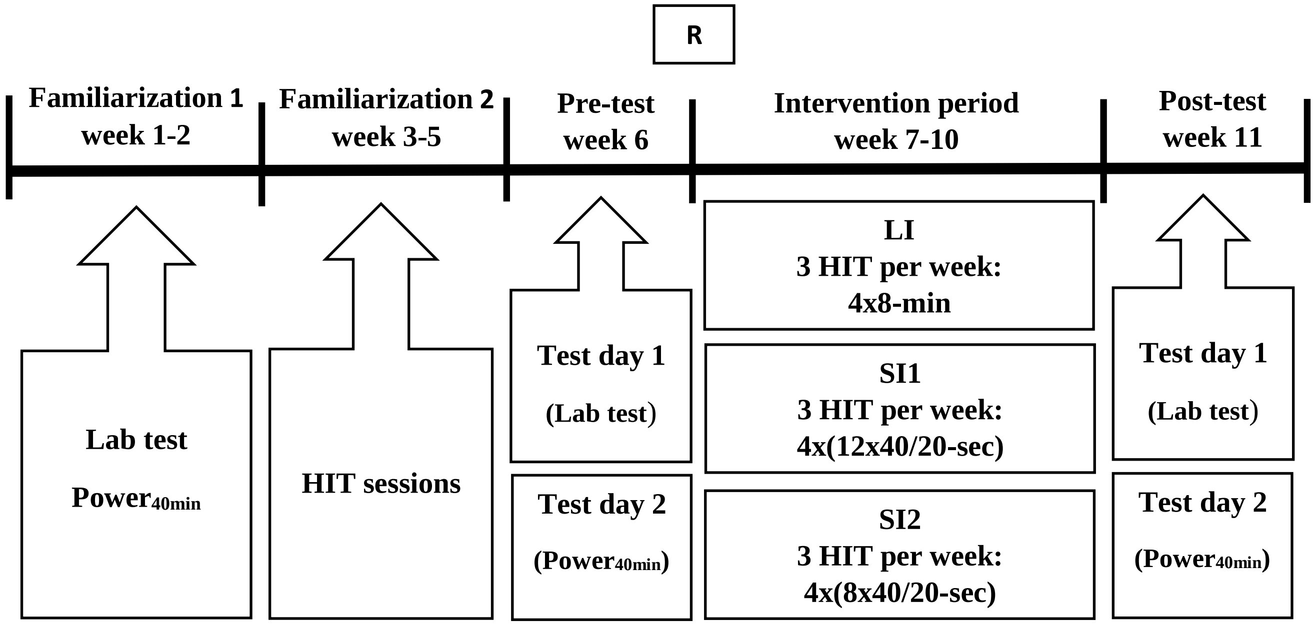

Figure 2: Study overview. Week 1-2; Familiarization to lab test (submaximal incremental test, incremental test to exhaustion and 30 s all-out Wingate test) and 40 min-all-out trial ($Power_{40min}$). Week 3-5; Familiarization to HIT sessions (4x8x40/20-sec and 4x12x40/20-sec). Week 6; Pre-test (test day 1 and test day 2) followed by randomization (R) into long interval (LI), short interval 1 (SI1) and short interval 2 (SI2). Week 7-10; Intervention period. Week 11; Post-test (test day 1 and test day 2).

3.3.1 HIT sessions

The cyclists followed one of three intervention groups with the same accumulated HIT duration;

- LI – 4x8-min intervals with 2-min recovery periods
- SI1 – 4x(12x40/20-sec) intervals with 2-min recovery periods
- SI2 – 4x(8x40/20-sec) intervals with 2-min recovery periods

The same accumulated duration of these three interval groups means that the total interval time is the same for each group. I.e.:

- 4x8-min = 32 min
- 4x(12x40/20-sec) = 32 min if the 20-sec recovery is not included in the total time of HIT
- 4x(8x40/20-sec) = 32 min if the 20-sec recovery is included in the total time of HIT

All HIT sessions were performed as supervised group interval training sessions. Each HIT session started with an individual 20-30 minutes' warm up at low intensity (55-70% HR_{max}) interspersed by freely chosen progressive sprints. All HIT sessions were programmed in the rollers via the software. For all groups the power output during the recovery periods was 50 % of the power output used during work intervals. The cyclists in all groups were instructed to perform each interval session at their maximal sustainable intensity *(isoeffort)* (Seiler et al., 2013). Each session ended with 15-20 minutes' cool down (55-70% HR_{max}). All HIT sessions were supervised and performed in groups on the University of Agder's (UiA) premises at Spicheren fitness center in Kristiansand. The sessions were performed Mondays, Wednesdays and Fridays at the same time of day throughout the 4-week intervention period.

HIT sessions were performed on the cyclists` own bikes mounted on electromagnetic rollers. The rollers were connected to a PC that controlled the rollers via a software. The cyclists were able to adjust the load electronically with ± 2-3 W precision. They got continuous feedback on power output and mean power, HR and remaining interval time through a TV connected to the software. Mean power, mean HR (HR_{mean}) and peak HR (HR_{peak}) and rate of perceived exertion (RPE) using Borg`s 6-20 scale (Borg, 1982) were recorded by the test leaders after each interval bouts in the LI group and every 12th or 8th minute bouts for SI1 and SI2 group, respectively. After the warm-up all rollers were calibrated using a standardized "roll-down resistance" procedure prescribed by the producer in order to quantify deck ergometer wheel resistance. The resistance was calibrated to 3.0 lb ± 0,10 lb in all HIT sessions. The calibration value was saved on the control module that was mounted on a rack beside each cyclist and used for workload calculations during the HIT sessions. Air pressure in the tires was standardized to 6.0 Bar prior to each HIT session.

In total, 165 blood samples (~6 per cyclist) from the fingertip were taken during the HIT sessions in the intervention period in order to measure the blood [la^-]. In the LI group, blood samples were taken at the end of the 3rd and 4th interval bout. In both SI groups blood samples were taken at the end of the 3rd and 4th 8 minute or 12 minute interval bout.

3.3.2 Training diary

All training during the whole period was recorded in a training diary by each cyclist. The cyclists registered the following variables for each training session: (1) activity form duration ("cycling", "another endurance training" "strength/mobility"), (2) duration in each endurance zone (Session Goal/Time In Zone (SG/TIZ)) (Sylta, Tønnessen, & Seiler, 2014), (3) perceived exertion (1-10) 30 min post exercise (sRPE) and (4) overall feeling (1-10). They were also instructed to write a comment for each training session. The cyclists delivered the diary online at the end of each week.

3.4 Test procedure

In addition to the familiarization test, the cyclists completed two test periods during the participation in this project. The pre-test was performed the week before the intervention period, while the post-test was performed at least 2-5 days after the last interval session for each cyclist. The test period lasted two days (test day 1 and test day 2) including at least 48 hours' recovery between each of the two test days to ensure sufficient recovery and optimal performance. The cyclists were not allowed to perform any kind of intense exercise the day before each of the two test days. Furthermore, the cyclists were also instructed to consume the same type of meal and avoid consumption of products containing caffeine during the 2.5 hours preceding testing. The same test leaders supervised all tests, and strong verbal encouragement was given to ensure maximal effort. Test day 1 is illustrated in Figure 3.

3.4.1 Test day 1

Submaximal incremental test

The first test day was preceded by a submaximal incremental test. The test started with the cyclists completing 5 minutes' submaximal bouts with increasing work load in order to identify the workload corresponding to 4 mMol·L^{-1} [la$^-$] (Power4$_{mM}$). The cyclists started with 5 minutes' cycling at 125 W. The workload increased by 50 W every 5 minutes. If the blood [la$^-$] exceeded 3 mMol·L^{-1}, the power output was increased by 25 W. The test was terminated when [la$^-$] reached ≥ 4 mMol·L^{-1}. VO_2, HR and respiratory exchange ratio (RER) were measured during the last 2.5 minutes on each bout. Further, [la$^-$] was measured after 4.5 minutes at each workload. The RPE was recorded at the end of each 5 minutes' bout, using Borgs' 6-20 RPE scale. Power and VO_2 corresponding to 4 mMol·L^{-1} [la$^-$] were identified after making a power-lactate curve based on [la$^-$] and VO_2 at each workload (Newell et al., 2007). Energy expenditure was calculated using gross VO_2 from the workloads 125, 175 and 225 W and GE was further calculated using the method of Coyle, Sidossis, Horowitz, & Beltz (1992).

Incremental test to exhaustion

After 10 minutes' active recovery the cyclists conducted an incremental test to exhaustion to quantify: (1) VO_{2peak}, (2) PPO, (3) HR_{peak} and (4) peak blood lactate concentration [la^-_{peak}]. The test started with one minute of cycling at a power output corresponding to 3 W/kg (rounded down to nearest 50 W). The power output increased by 25 W every minute until voluntary exhaustion. The test leaders gave strong verbal encouragement during the test to ensure maximal effort and optimal performance. Mean power during the last minute decided the cyclists' PPO. VO_2 was measured every 30 seconds. The average of the two highest VO_2 measurements determined the cyclists' VO_{2peak}. [la^-_{peak}] was measured one minute after the test was completed. In addition, HR_{peak} was recorded after termination of the test. Objective criteria such as plateau of the oxygen uptake, HR ≥ 95 % of known HR_{max}, RER ≥ 1.10 and [la$^-$] ≥ 8.0 mMol·L^{-1} were used to ensure that VO_{2max} was reached. To estimate fractional utilization of VO_{2peak}, the VO_2 corresponding to 4 mMol·L^{-1}, was calculated as percentage of VO_{2peak} (%VO_{2peak}@4mM).

30 s all-out Wingate test

After the incremental test to exhaustion, the cyclists got another 10 minutes' recovery before they completed a 30 s all-out Wingate test to determine (1) peak power (PP) and (2) mean power during 30 seconds ($Power_{30s}$). The test started with the cyclists pedaling seated, at a frequency of 120 RMP for 20 seconds with a resistance of 120 W, including a 3 seconds' countdown before a braking resistance, equivalent to 0.7 $Nm{\cdot}kg^{-1}$ body mass (Lode Excalibur), was applied to the wheel and remained constant throughout the subsequent 30 seconds of the test. The cyclists were instructed to pedal with maximal effort and remain standing throughout the 30 s all-out.

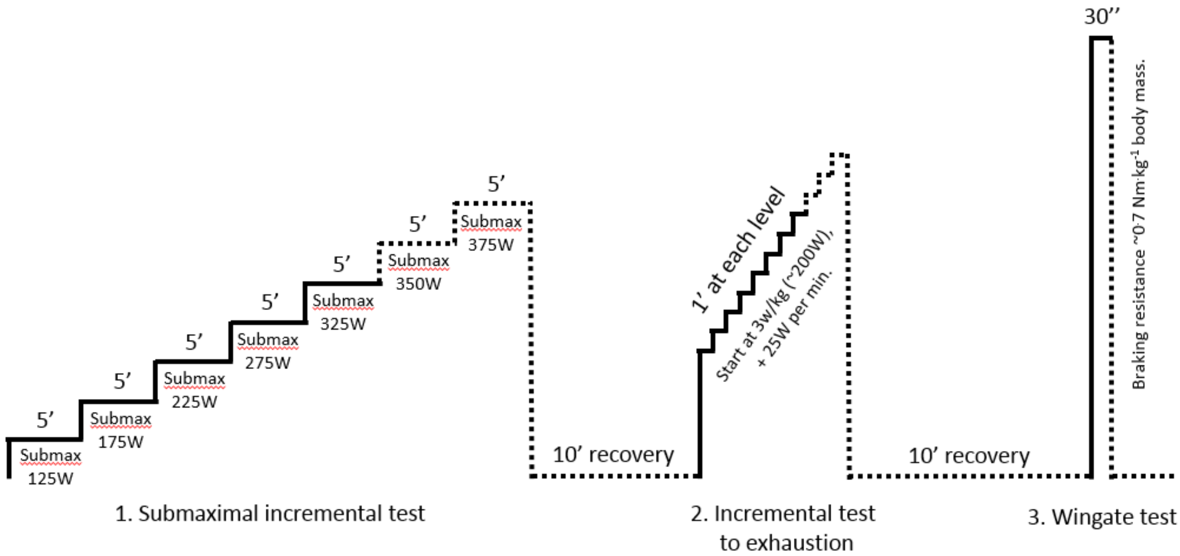

Figure 3. Study protocol (test day 1). The first test day started with a submaximal 5-min steps incremental test to identify the workload corresponding to 4 $mMol{\cdot}L^{-1}$ [la^-] ($Power_{4Mm}$) and gross efficiency (GE). After 10-min recovery, an incremental test to exhaustion was performed to quantify (1) peak oxygen uptake (VO_{2peak}), (2) peak power output (PPO), (3) peak heart rate (HR_{peak}) and (4) peak blood lactate concentration [la^-_{peak}]. After another 10-min recovery, the cyclists completed a 30 s-all-out Wingate test to determine (1) Peak power (PP) and (2) mean power output during 30 s all-out ($Power_{30s}$). Published after permission (Sylta et al., 2016).

3.4.2 Test day 2

40-min-all-out trial ($Power_{40min}$)

The second test day consisted of a $Power_{40min}$. The test was performed in groups on the cyclists' own bikes that were mounted on electromagnetic rollers ergometers with a fan circulating air around the cyclists. The test started with an individual 20-30 min warm-up. Thereafter, the cyclists were instructed to cycle at the highest possible mean power during 40-min. The cyclists were blinded during the test, i.e. they were not able to see HR and power output. However, they were allowed to see the remaining time. The test was performed seated, but the cyclists were allowed to stand if needed. Mean power, HR_{mean}, HR_{peak}, RPE and [la^-] were recorded by the test leaders at the end of the test.

3.5 Instruments

All tests on test day 1 were performed on the same cycle ergometer, Lode Excalibur Sport (Lode B. V., Groningen, Nederland). Each cyclist was able to adjust the bike as desired which included handlebar position, saddle height and distance between tip of the saddle and the bottom bracket. After the pre-test the bike position for each cyclist was saved and they were able to resume the same position at the post-test. All tests were performed under similar environment conditions (17-22°C) and were attempted to be performed at the same time of day (± 2h).

VO_2 during test day 1 was measured using Oxycon Pro™ with mixing chamber and 30 s sampling time (Oxycon, Jaeger GmbH, Hoechberg, Germany). Gas sensors were calibrated via an automated process using certified calibration gases of known concentrations before every test. The flow turbine (Triple V, Erich Jaeger) was calibrated using a 3L calibration syringe (5530 series; Hans Rudolph, Kansas, MO, USA). Blood [la^-] during all tests and HIT sessions were analyzed using a stationary lactate analyzer (EKF BIOSEN, EKF diagnostic, Cardiff, UK). HR was measured using Polar V400 (Polar Elektro Oy, Kempele, Finland). All HIT sessions and test day 2 were performed on the cyclists` own bikes mounted Computrainer Lab™ ergometers (Race Mate, Seattle, WA, USA). The Computrainer Lab™ ergometers were connected to a PC that controlled the Computrainers via a software (PerfPRO Studio Hartware Technologies).

The training diary was made by the test leaders using Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington, USA).

3.6 Statistics

Data were analyzed using SPSS 24.0 (SPSS Inc, Chicago, IL, USA) and are presented as mean ± standard deviation. Tables and figures were made using Microsoft Word, Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington, USA) and GraphPad Prism 7 (GraphPad Software, Inc., 7825 Fay Avenue, La Jolla, CA 92037, USA). Baseline and training characteristics within the groups and differences among the groups in $Power_{40min}$, PPO, VO_{2peak}, Power4mM, GE and $\%VO_{2peak}$@4mM were compared using a one-way between groups analysis of variance (ANOVA) with Bonferroni post-hoc test. A General Linear Model (GLM) repeated measures model (ANOVA) was used to compare the percentage change in power output within the groups from week to week during the intervention period. Absolute changes in physiological responses and performance responses pre- to post- intervention were compared in all groups using a paired sample *t*-test. Effect size (ES) was calculated in order to identify trends according to the criteria from Cohen's d (0.2=small, 0.5=medium, 0.8=large). All analyses resulting in $P \leq 0.05$ were considered statistically significant.

4.0 Methodological discussion

Methodological challenges arise in connection with scientific research. To minimize the error sources and to ensure high quality of the research it is desirable that the work performed is valid and reliable. In this context validity refers to the extent in which the test or instrument measures what it is supposed to measure. The validity of the test also depends on the reliability of the measurements or the instrument, that is whether they are accurate (Polit & Beck, 2014).

4.1 Design

In the present study a structured randomized design was used. An advantage of this kind of design is that the selection of cyclists to the various groups occurs randomly (Polit & Beck, 2014; Thomas, Silverman, & Nelson, 2015). Further, before the random selection the cyclists in the current study were stratified by age, VO_{2peak} and $Power_{40min}$ in order to obtain homogeneous groups (Thomas et al., 2015). A disadvantage using this type of design is the lack of a control group used in a randomized controlled trial (RCT), which is considered the "gold standard" method for intervention studies (Polit & Beck, 2014; Thomas et al., 2015). Due to possible challenges by recruiting cyclists to a control group, we instead chose to include three intervention groups. In order to increase the strength of the design this study was divided into different phases.

4.1.1 The familiarization and de-training phase

The study was preceded by a 5 weeks' familiarization and de-training period where the cyclists were familiarized with HIT sessions and test protocols. The cyclists were only allowed to perform one HIT session each week in addition to *ad libitium* LIT. The aim of this period was to prevent the "pace" learning ability concerning the repeating performance of the HIT sessions and test protocol in the intervention period, and to make sure that the cyclists had the same amount of HIT sessions prior to the start of intervention. It is also conceivable that the results of the pre- and post-test are more comparable when familiarization and de-training period are added. This approach has been used in recent studies examining the effects of HIT (Sylta et al., 2016; Sylta et al., 2017).That being said, the potential to achieve improvements in endurance performance after an intervention period focusing on HIT is larger when no HIT sessions has been performed during the prior 1-2 months (Seiler et al., 2013).

4.1.2 The intervention phase

The present intervention period lasted only 4 weeks. This is somewhat contradictory to other studies focusing on HIT lasting 6-12 weeks (Franch et al., 1998; Helgerud et al., 2007; Rønnestad et al., 2015; Sandbakk et al., 2013; Seiler et al., 2013; Sylta et al., 2016). Due to limitations in time in this master thesis, we choose 4 weeks. That being said, however, a recent study by Sylta et al. (2016) shows that endurance parameters stagnate after 4 weeks of training, supporting the view that a 4 weeks' intervention period may be sufficient to achieve endurance adaptions.

To compensate for the short intervention period, compared to other studies, we included three HIT sessions per week. Forty-eight hours' recovery between each HIT session was determined in an attempt to promote recovery and to facilitate physiological and performance adaptions. Importantly, a high amount of HIT may lead to overtraining and decreased functional capacity (Seiler, 2010). In fact, Billat, Flechet, Petit, Muriaux, and Koralsztein (1999) found that well-trained athletes who performed three HIT sessions per week for 4 weeks developed signs indicative of overtraining. Two HIT sessions per week seem to be sufficient for physiological and performance adaptions without inducing symptoms of overtraining (Seiler, 2010). Three HIT sessions per week may have been a too great burden for some cyclists and may have resulted in a decreased performance during the intervention period in the present study. However, the compliance was almost 100 % and the power output in the HIT sessions increased throughout the intervention period, indicating that the muscles of the cyclists seemed to have recovered well before workouts throughout the intervention period. Indeed, the cyclists were recommended to enter a period of low training load after completing this project, and therefore there is reason to believe that a short period of high amounts of HIT will not induce overtraining.

4.1.3 Test-phase

Each test period consisted of two test-days with minimum 48 hours in-between. A minimum of 48 hours of rest between each test day as well as each HIT sessions seem to be sufficient in order to promote recovery (Parra, Cadefau, Rodas, Amigo, & Cusso, 2000). The cyclists were further allowed to choose which day they wanted to test as long as they followed the instructions of minimum 48 hours between the two test days. Therefore, it is reasonable to assume that the cyclists were recovered between the two test days.

4.2 Study sample

The present study recruited 30 well-trained cyclists (28 male and 2 female) from the regional area in Kristiansand, Norway. Four cyclists out of 30 were eliminated from the final analysis. To increase the external validity of a study it is important with a high statistical power. Statistical power may be achieved in different ways. A large N is considered essential to increase the statistical power (Polit & Beck, 2014). Although four cyclists were eliminated from this study, the number of cyclists in each intervention group are acceptable and about equal or higher compared to other studies examining the effects of SI- or LI training (Franch et al., 1998; Helgerud et al., 2007; Rønnestad et al., 2015; Stepto et al., 1999) and the effects of HIT in general (Sandbakk et al., 2013; Seiler et al., 2013). In those studies, the number of participants in each intervention group are between 4 and 12. Whether our results can be generalized based on this sample size and on the fact that we had no control group is uncertain.

Initially, one of the inclusion criteria was male only. This was later changed to include also females. Based on previous studies demonstrating that the physiological impact of endurance training is not gender specific (Kohrt et al., 1991; Skinner et al., 2001), there was no reason to exclude female from this study.

4.3 Measurements

Both physiological and performance tests are today widely used tools for athletes at both high level and lower level to measure the progress and effectiveness of a training period. Testing is also widely used in sport science to assess the impact of different intervention studies or for measuring the prevalence of a phenomenon. Testing is an “objective” method for measuring different variables, and several factors must be considered to ensure valid and reliable measurements (Thomas et al., 2015).

In the present study, necessary precautions were done to increase both the reliability and the validity of all measurements and to prevent different elements influencing the variables. Well-established and objective measuring methods were used in this study (Lode Excalibur, Oxycon Pro, EKF Biosen C-line and Computrainer Lab^{TM}). The calibrations were done before each test and HIT sessions according to procedures prescribed by the manufacturers. The same test leaders supervised all tests and HIT sessions throughout the period, and clear instructions were given during the workouts. Furthermore, as an important part of the accuracy and the verifiability the cyclists were instructed to enter the tests and HIT sessions according to a written guidance given beforehand by the test leaders. The test procedures were also put into order so that they would not affect the variables.

4.3.1 Testing equipment – test day 1

In studies where submaximal and maximal oxygen uptake are evaluated before and after an intervention, stability on the instrument is important. In the present study the Oxycon Pro mixing chamber was used for VO_2 measuring both in the incremental test to exhaustion and in the submaximal incremental test. With a margin error of 3 %, Foss & Hallen (2005) demonstrated that the Oxycon Pro mixing chamber is a very accurate system for measuring oxygen uptake which was important for the stability of the VO_2 measurements during this project. The accuracy of the Oxycon Pro has also been shown in a study by Rietjens, Kuipers, Kester, & Keizer (2001). The Oxycon Pro was also brought to maintenance prior to the pre-test in order to ensure accurate and stable measurements.

Lode Excalibur used on the lab-test are considered the “gold standard” (Earnest, Wharton, Church, & Lucia, 2005) and are commonly used in several experimental studies (Gibala et al., 2006; Laursen, Shing, Peake, Coombes, & Jenkins, 2005; Rønnestad et al., 2015; Sylta et al., 2016; Talanian, Galloway, Heigenhauser, Bonen, & Spriet, 2007). Earnest et al. (2005) investigated the test-retest reliability on the Lode Excalibur and found no significant differences, which strengthens the accuracy of this ergometer. Further, the adjustment possibilities described in section 3.5 in the method, which were saved for each cyclist at the familiarization test, ensured that the cyclists kept the same bike position pre- and post-test. Due to identical positions in pre- and post-test, it is fair to assume that this may induce higher reliability.

The EKF Biosen C-line for lactate analyses has widely been used in previous studies (Glaister et al., 2009; Hauser, Bartsch, Baumgärtel, & Schulz, 2013; Santtila, Keijo, Laura, & Heikki, 2008). To the authors’ knowledge, there are no studies which have been validating the EFK Biosen C-line and compared it to other lactate analyzers.

4.3.2 Testing equipment – test day 2/HIT sessions

A number of factors were identified as potential measuring errors. The equipment was therefore controlled regularly, and the procedure was standardized in order to increase both the reliability and the validity on test day 2 and during all HIT sessions. The cyclists were therefore assigned a personal roller throughout the experiment in order to prevent possible differences in power output that might occur between the rollers. Further, the cyclists used their own personal bike and were instructed to use a roller tire. The tire pressure was standardized to 6.0 BAR. In a study by Davison, Corbett, & Ansley (2009) they showed that the calibration pressure dropped significantly during a warm-up on the Computrainer Lab ergometer, which was also used in the current study. In order to ensure stable power output values all rollers in the present study were calibrated to 3.00 lbs and re-calibrated before start according to the manufacturer.

4.3.3 Test protocol

Submaximal incremental test

Measuring the blood lactate accumulation during an incremental exercise test is commonly used in sport to evaluate the effects of training and to predict performance. In the current study a submaximal incremental test was conducted to identify the workload at fixed blood lactate concentrations of 4 $mMol \cdot L^{-1}$ to see the change from pre-test to post-test. When using a method like this a number of factors may affect the blood lactate-intensity relationship. Both the duration of each step, techniques associated with blood collection, handling and analysis as well as environmental and athlete conditions during tests, such as temperature, altitude, circadian rhythms, nutritional status or other subject attributes, are all factors that have been identified to affect the lactate response to exercise and were therefore necessary to control if valid data were to be collected (Bentley et al., 2001; Buckley, Bourdon, & Woolford, 2003; Dassonville et al., 1998; Fink, Costill, & Van Handel, 1975; Maassen & Busse, 1989).

A number of studies have shown that incremental stage duration can affect the blood lactate response curve where longer stage duration may lead to lower exercise intensity corresponding to a maximal lactate steady state (Bentley et al., 2001; Foxdal, Sjödin, & Sjödin, 1996; Freund et al., 1989; Stockhausen, Grathwohl, Bürklin, Spranz, & Keul, 1997). Studies also suggest that duration periods of at least 5 to 8 min are necessary to attain steady-state lactate concentrations (Foxdal et al., 1994; Rieu, Miladi, Ferry, & Duvallet, 1989; Stegmann & Kindermann, 1982), and it is possible that shorter work duration than 5 min may overpredict a given exercise intensity. In the present study we used a 5 minutes' work duration in the submaximal incremental test both in the pre- and post-test, and there is reason to believe that this duration is adequate to attain a steady state lactate concentration for the fixed 4 $mMol \cdot L^{-1}$. Furthermore, the test leaders also standardized blood sampling site, treatment procedure and analyze method in order to get comparable results between pre- and post-test. For example, studies have reported different blood lactate levels measured at different locations on the body (Dassonville et al., 1998; Feliu et al., 1999) and therefore in this study blood samples were consistently taken from the fingertip in both test periods.

The same lactate analyzer (Biosen C-line) was also used throughout the project, as some studies have documented different result values using different analyzers from the same samples (Buckley et al., 2003; Medbø, Mamen, Holt Olsen, & Evertsen, 2000). High ambient temperatures is another factor that may induce increased blood lactate concentrations (Fink et al., 1975; MacDougall, Reddan, Layton, & Dempsey, 1974), and the temperature in the present study was therefore tried to be standardized between 18 and 22°C.

Based on a study from Madsen & Lohberg (1987) it is recommended that blood lactate-intensity profiles should be conducted at the same time of the day that athletes normally train, because circadian rhythms have been reported to affect the blood lactate-intensity relationship. Further, an athlete’s nutritional status may also create problems when using the fixed method for determination of intensity at a given lactate concentration. In fact, the blood lactate concentrations appear to decrease at any given intensity when muscle glycogen stores are depleted and therefore may overestimate endurance capacity when using this method (Hughes, Turner, & Brooks, 1982; Maassen & Busse, 1989). The cyclists in this study were therefore instructed to have a similar preparation before each test to avoid possible sources of error. However, the fact that several cyclists in this study were working full time and had family responsibilities may have affected the preparations prior to test.

Incremental test to exhaustion

The incremental test to exhaustion was conducted 10 min after the submaximal incremental test. A disadvantage of having the submaximal incremental test before the incremental test to exhaustion may be that the cyclists were tired and therefore could not perform with maximum effort to reach VO_{2max} and their maximum PPO. The incremental test to exhaustion in the present study increased with 25 W per minute to exhaustion. Regardless of the rate of work increase during ramp testing it is suggested by Amann, Subudhi, & Foster (2004) that VO_{2max} is substantially the same during incremental ergometer testing. This corresponds to other studies (Davis et al., 1981; Pierce, Hahn, Davie, & Lawton, 1999; Whipp, Davis, Torres, &

Wasserman, 1981), supporting that the present protocol may be acceptable to use. However, as described in the method we used several criteria to secure that VO_{2max} was attained. Because some cyclists did not achieve the criteria for VO_{2max}, the term VO_{2peak} was used.

30s Wingate test

The Wingate protocol has been widely used as a part of the physiological test battery in experimental studies (Rønnestad et al., 2015; Sylta et al., 2016; Weber, Chia, & Inbar, 2006). The cyclists did a familiarization test before the pre-test as recommended by Barfield, Sells, Rowe, & Hannigan-Downs (2002). The cyclists were several times told about the details of the protocol and encouraged verbally throughout the test. The Wingate test has in previous studies been performed seated (Collomp et al., 2005; Patton, Murphy, & Frederick, 1985). However, the cyclists in this study did a standing Wingate test, which can be more natural for cyclists (Reiser, Maines, Eisenmann, & Wilkinson, 2002).

4.3.4 Training diary

The cyclists in this study recorded all training in a training diary throughout the period (a total of 11 weeks). The data were closely supervised throughout the study by the project leaders and were further used for analyzes. A study by Sylta, Tønnessen, & Seiler (2014a) investigated whether elite athletes in endurance sports reported their training accurately. The authors concluded that they self-reported their training data accurately. However, the credibility and the validity of the reported training diary can always be questioned, especially among moderately trained athletes (Borresen & Lambert, 2006) and among athletes with less experience with training diaries. Unreported observation in this study may indicate that cyclists who had previous experience with training diaries reported more accurate diaries compared to those with less experience. However, there is still reason to assume that the cyclists have registered training data by the guidance provided by the project leaders. The cyclists learned how to use the diary at the information meeting prior to start of the project. The cyclists also received a mail with a description of the training diary and examples of a completed diary.

4.4 Strengths and limitations

The main strengths in the present study was the structured randomized design and the homogenous group. Further, the compliance in this study was ~100 %. Prior to the intervention period, there was a 5-week familiarization period to familiarize cyclists with the test procedures and the HIT sessions. The 5-week familiarization period also served to ensure a steady state training baseline prior to the intervention period. All HIT sessions were supervised by the same test leaders throughout the period, and the cyclists recorded all training in a training diary during the whole project. Therefore we managed to have rigorous monitoring of all training variables. We further increased the strength of this study by using several well-established objective measured methods, where the incremental test to exhaustion is considered the gold standard for measuring VO_{2max}, and the same equipment was used during the whole period. In addition, all equipment used in this project were calibrated prior to use according to manufacturer in order to avoid erroneous measurements. Furthermore, this study had a relatively high number of participants were the cyclists were considered well trained. Another strength of this study was that the cyclists used the same cycle ergometer roller during all HIT sessions during the intervention period and on the $Power_{40min}$ test both in the pre- and post-test. To the best of our knowledge, this is the only study comparing SI and LI training with the same accumulated duration >30 min.

However, there are limitations in this study. For instance, despite homogeneous groups the level of the cyclists varied. Several cyclists had a great experience with cycling prior to this study while some had less experience. This was also reflected in the training hours where the variations between the cyclists were substantial. In addition, there was also a gap in age where the youngest cyclists were 17 years and the oldest 45 years. Another possible limitation in the current study was the short time frame of only 4 weeks. This may be a too short period to induce further increase in both physiological parameters and performance parameters. Further, three HIT sessions per week may also have been a too great burden for some cyclists. Another limitation of this study was lack of a control group. It should also be mentioned that none of the cyclists had familiarization to the 4x8-min interval due to limit of time.

5.0 Ethics

This study was performed on healthy well-trained cyclists. All cyclists received written information prior to the study, explaining that the study involved testing to exhaustion, requirements regarding attendance on tests and HIT sessions throughout the period as well as being well prepared prior to all kind of workouts, all of which could cause some discomfort. The study was approved by the ethics committee of the Faculty for Health and Sport Science, University of Agder, and the Norwegian Center for Research Data (NSD). The cyclists were informed that they could at any time withdraw from the study without giving any reason. All the cyclists provided informed written consent before participation. The cyclists had the full right to look into their own test results. The collected data were anonymized and can be used for publications in journals, education purposes and congresses. The data were stored anonymized on password protected computers and hard drives, and will be stored for 10 years after completing this study.

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Part 2:

Paper

«Aerobic short or long high intensity interval training – does it matter?»

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«Aerobic short or long high intensity interval training – does it matter?»

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ABSTRACT

PURPOSE: To compare the effects of short and long high intensity interval training (HIT) conducted with the same total accumulated duration on physiological- and performance parameters during a 4-week training period.

METHODS: Twenty-six well-trained cyclists (30±9 yr, peak oxygen uptake (VO_{2peak}) 64±6 $mL\cdot kg^{-1}\cdot min^{-1}$) were randomly assigned into three training groups; long interval group (LI) (n=8), short interval group 1 (SI1) (n=9) and short interval group 2 (SI2) (n=9). All groups conducted HIT sessions three times per week for 4-weeks interspersed with high volume of low intensity training (LIT). The HIT sessions were performed as 4x8-min (32-min accumulated HIT duration), 4x(12x40/20-sec) (32-min accumulated HIT duration excluding interval recovery bouts) and 4x(8x40/20-sec) (32-min accumulated HIT duration including interval recovery bouts), in LI, SI1 and SI2 groups, respectively. All HIT sessions were performed as supervised group interval training.

RESULTS: There were no significant differences between groups in any physiological- or performance outcomes after 4 weeks of intensified training. All groups significantly improved mean power during 40-min all-out ($Power_{40min}$) and peak power output during incremental test to exhaustion (PPO) from pre- to post-test ($P<0.05$). Further, both SI1 and LI improved significantly in VO_{2peak} ($P<0.05$).

CONCLUSION: The present study demonstrates that there are no differences between aerobic short or long high intensity interval training with the same accumulated HIT duration (i.e. 32 min) during a 4-week training period.

KEY WORDS: Cycling, endurance performance, intermittent exercise, maximal oxygen consumption, physiological adaptions, well-trained athletes

INTRODUCTION

Studies among elite athletes have documented the importance of large amounts of training volume in order to perform at a high level in endurance sports (9, 26, 32, 37, 40). It is also well documented that both low intensity training (LIT), moderate intensity training (MIT) and high intensity training (HIT) should be included in the overall training efforts (9, 15, 32). Based on both descriptive and experimental studies it seems that a general intensity distribution of ~80% LIT and ~20% MIT/HIT is optimal for achieving a high level in different endurance sports (3, 8, 22, 28-30). However, Seiler & Kjerland (28) have nuanced the 80/20-rule, and suggests that well-trained endurance athletes follows a so-called polarized training model where the largest share of training is LIT, combined with a small proportion of

MIT and a somewhat higher proportion of HIT. On the other hand, in a review by Stöggl & Sperlich (32) there has been suggested a pyramidal intensity distribution among well-trained endurance athletes. This is an intensity distribution characterized by large amounts of LIT, a moderate amount of MIT and a small proportion of HIT.

It is well documented that HIT has a positive effect on the aerobic endurance among both elite athletes and recreational athletes (15, 21, 32). Experimental studies have shown improved performance and physiological adaptions by increasing the number of HIT sessions from zero or one per week to two or three sessions per week in studies lasting 3-12 weeks (10, 12, 24, 27, 31, 34). A recent study also shows how different endurance parameters stagnate after only four weeks of HIT training during a 12-week training intervention (35). In light of this, in certain experimental designs a 4-week intervention period will probably be sufficient to achieve the desired effect.

Despite the fact that there is general agreement that HIT is an important part of the overall training, it is unclear how this part of the training should be organized in order to optimize the training effects. The adaptions of endurance performance seem to depend on both the intensity and the accumulated duration of the HIT sessions. Studies have recently demonstrated that a slight reduction in intensity in combination with increased accumulated work duration may be beneficial for improving aerobic endurance adaptions in well-trained cyclists and cross-country skiers (25, 27, 35).

In addition to manipulate the load variables, i.e. intensity and accumulated duration, it is usual among athletes to manipulate the design of HIT sessions, i.e. whether the intervals are performed with short or long duration of bouts (2). Only a few studies have compared the effects of aerobic short intervals (SI) and long intervals (LI) with approximately the same total training load (10, 12, 24, 31). Helgerud et al. (12) compared interval sessions performed as 4x4-min at 90-95% of maximum heart rate (HR_{max}) with 47 repetitions of 15/15-sec intervals at 90-95% of HR_{max} and found no differences between the two designs of HIT. However, other studies have found different improvements between SI and LI designs (10, 24, 31).

Franch et al. (10) compared SI performed as 15/15-sec intervals with LI performed as 4-6x4-min. The results demonstrate that the LI group had significantly greater improvement than the

SI group. However, the total work duration was longer in the LI group. Stepto et al. (31) also found superior adaptions in the LI group (8x4-min) compared to the SI group (12x60-sec). These two studies are contradictory to Rønnestad et al. (24) who compared SI (30/15-sec) and LI (4x5-min) with the same accumulated duration (i.e. 19.5 vs. 20 min). In that study it was found that SI resulted in the greatest improvement in both physiological- and performance parameters compared with LI.

To our knowledge it is only Rønnestad et al. (24) who have compared SI and LI with approximately the same accumulated duration of intervals, and simultaneously found the greatest improvement in the SI design. However, in that study the total HIT duration was only ~20 min, and it has been demonstrated that HIT sessions with a total duration of 30-45 min combined with a small reduction in intensity is more effective than 10 to 16 min with somewhat higher intensity (25, 27). Hence, more research is therefore needed comparing SI and LI designs with >30 min accumulated HIT duration.

Therefore, the aim of this study was to compare the effects of SI and LI training, including equal accumulated HIT duration, during a 4-week intervention period, conducted as 4x8-min with 2-min recovery periods, 4x(12x40/20-sec) with 2-min recovery periods and 4x(8x40/20-sec) with 2-min recovery periods, in different physiological- and performance parameters among well-trained cyclists.

METHODS

This study was conducted as a randomized intervention study where three matched training groups completed a 4-week training period consisting of high volume of LIT in addition to three HIT sessions each week. Training groups differed in HIT session structure (short vs. long interval duration), and were compared in relation to changes in physiological- and performance parameters pre- and post- intervention period.

Subjects

Thirty cyclists (28 male, 2 female) were recruited through local clubs and announcements in social media. They were all active on a regional level and had experience with competing in road cycling. The following initial inclusion criteria were used to assess whether the cyclists should be included: (1) male < 40 years, (2) peak oxygen uptake ($\dot{V}O_{2peak}$) > 60 ml·kg^{-1}·min^{-1}, (3) training volume >3 sessions per week (within cycling) and (4) absence of disease and injuries. Exclusion criteria were: (1) disease/injuries and (2) frequent absence of HIT sessions during the period. The physical baseline characteristics of the cyclists were age: 30±9 yr; weight: 75±8 kg; VO_{2peak}: 64±6 $mL \cdot kg^{-1} \cdot min^{-1}$, and according to Jeukendrup et al. (14) all groups were categorized as well trained. The cyclists were randomly assigned into three training groups; long interval group (LI), short interval group 1 (SI1) and short interval group 2 (SI2) according to the aim of the study.

Two cyclists from the LI group (1 male and 1 female) and one cyclist from the SI1 group did not complete the study because of illness and injuries. Further, one cyclist from the SI2 group was excluded from the final analysis due to irregular attendance at HIT-sessions. One cyclist from the SI1 group had to extend the intervention period by one week due to illness in the middle of the intervention period, while one cyclist in the LI group had to delay the post-test by one week due to illness post intervention. Due to suspicion of measurement errors in the incremental test to exhaustion for one cyclist in the LI group in the pre-test we used his familiarization test as a starting point. The study was approved by the ethics committee of the Faculty for Health and Sport Science, University of Agder, and the Norwegian Center for Research Data (NSD). All the cyclists provided informed written consent prior to participation.

Pre-intervention period (familiarization and de-training)

Initially, the cyclists were invited to an information meeting where all details about the project were given. They also learned how to use the training diary and the Polar V400 for heart rate (HR) monitoring. The cyclists completed a 5-week familiarization and de-training period. In this period the cyclists were only allowed to perform one HIT session each week and freely chosen LIT (*ad libitum*). During the first two familiarization weeks the cyclists completed a lab-test and a 40 min all-out trial ($Power_{40min}$). The next weeks the cyclists were familiarized with interval sessions included in the intervention period. Pre-testing was performed at the end of the pre-intervention period. The cyclists were then randomized into one of the three interval groups (LI, SI1 and SI2), matched for (1) age, (2) VO_{2peak} and (3) $Power_{40min}$.

Training intervention

The training intervention was performed from early November to early December (4 weeks). In this period the cyclists were allowed to perform *ad libitum* LIT in addition to HIT sessions that were determined to each group. The cyclists completed 12 supervised HIT sessions during the training intervention period, i.e. three HIT sessions per week with at least 48 hours between each HIT session (Figure 1).

Insert Figure 1 here

HIT sessions

The cyclists followed one of three intervention groups with the same accumulated HIT duration;

- LI – 4x8-min intervals with 2-min recovery periods
- SI1 – 4x(12x40/20-sec) intervals with 2-min recovery periods
- SI2 – 4x(8x40/20-sec) intervals with 2-min recovery periods

The same accumulated duration of these three interval groups means that the total interval time is the same for each group. I.e.:

- 4x8-min = <u>32 min</u>
- 4x(12x40/20-sec) = <u>32 min</u> if the 20-sec recovery is not included in the total time of HIT
- 4x(8x40/20-sec) = <u>32 min</u> if the 20-sec recovery is included in the total time of HIT

All HIT sessions were performed as supervised group interval training sessions. Each HIT session started with an individual 20-30 minutes' warm up at low intensity (55-70% HR_{max}) interspersed by freely chosen progressive sprints. All HIT sessions were programmed in the rollers via the software. For all groups the power output during the recovery periods was 50 % of the power output used during work intervals. The cyclists in all groups were instructed to perform each interval session at their maximal sustainable intensity *(isoeffort)* (27). Each session ended with 15-20 minutes' cool down (55-70% HR_{max}). The sessions were performed Mondays, Wednesdays and Fridays at the same time of day throughout the 4-week intervention period.

HIT sessions were performed on the cyclists` own bikes mounted on electromagnetic rollers. The rollers were connected to a PC that controlled the rollers via a software. The cyclists were able to adjust the load electronically with ± 2-3 W precision. They got continuous feedback on power output and mean power, HR and remaining interval time through a TV connected to the software. Mean power, mean HR (HR_{mean}) and peak HR (HR_{peak}) and rate of perceived exertion (RPE) using Borg`s 6-20 scale were recorded by the test leaders after each interval bouts in the LI group and every 12th or 8th minute bouts for SI1 and SI2 group, respectively. After the warm-up all rollers were calibrated using a standardized "roll-down resistance" procedure prescribed by the producer in order to quantify deck ergometer wheel resistance. The resistance was calibrated to 3.0 lb ± 0,10 lb in all HIT sessions. The calibration value was saved on the control module that was mounted on a rack beside each cyclist and used for workload calculations during the HIT sessions. Air pressure in the tires was standardized to 6.0 Bar prior to each HIT session.

In total, 165 blood samples (~6 per cyclist) from the fingertip were taken during the HIT sessions in the intervention period in order to measure the blood lactate concentration [la^-]. In the LI group, blood samples were taken at the end of the 3rd and 4th interval bout. In both SI groups blood samples were taken at the end of the 3rd and 4th 8 minute or 12 minute interval bout.

Training diary

All training during the whole period was recorded in a training diary by each cyclist. The cyclists registered the following variables for each training session: (1) activity form duration ("cycling", "another endurance training" "strength/mobility"), (2) duration in each endurance zone (Session Goal/Time In Zone (SG/TIZ)) (36), (3) perceived exertion (1-10) 30 min post exercise (sRPE) and (4) overall feeling (1-10). They were also instructed to write a comment for each training session. The cyclists delivered the diary online at the end of each week.

Test procedure

In addition to the familiarization test, the cyclists completed two test periods during the participation in this project. The pre-test was performed the week before the intervention period, while the post-test was performed at least 2-5 days after the last interval session for each cyclist. The test period lasted two days (test day 1 and test day 2) including at least 48 hours' recovery between each of the two test days to ensure sufficient recovery and optimal performance. The cyclists were not allowed to perform any kind of intense exercise the day before each of the two test days. Furthermore, the cyclists were also instructed to consume the same type of meal and avoid consumption of products containing caffeine during the 2.5

hours preceding testing. The same test leaders supervised all tests, and strong verbal encouragement was given to ensure maximal effort.

Test day 1

Submaximal incremental test

The first test day was preceded by a submaximal incremental test. The test started with the cyclists completing 5 minutes' submaximal bouts with increasing work load in order to identify the workload corresponding to 4 $mMol \cdot L^{-1}$ [la-] (Power4_{mM}). The cyclists started with 5 minutes' cycling at 125 W. The workload increased by 50 W every 5 minutes. If the blood [la^-] exceeded 3 $mMol \cdot L^{-1}$, the power output was increased by 25 W. The test was terminated when [la^-] reached $\geq$ 4 $mMol \cdot L^{-1}$. Oxygen uptake (VO_2), HR and respiratory exchange ratio (RER) were measured during the last 2.5 minutes on each bout. Further, [la^-] was measured after 4.5 minutes at each workload. The RPE was recorded at the end of each 5 minutes' bout, using Borgs' 6-20 RPE scale. Power and VO_2 corresponding to 4 $mMol \cdot L^{-1}$ [la^-] were identified after making a power-lactate curve based on [la^-] and VO_2 at each workload (23). Energy expenditure was calculated using gross VO_2 from the workloads 125, 175 and 225 W and gross efficiency (GE) was further calculated using the method of Coyle et al. (6).

Incremental test to exhaustion

After 10 minutes' active recovery the cyclists conducted an incremental test to exhaustion to quantify: (1) VO_{2peak}, (2) peak power output (PPO), (3) HR_{peak} and (4) peak blood lactate concentration [la^-_{peak}]. The test started with one minute of cycling at a power output corresponding to 3 W/kg (rounded down to nearest 50 W). The power output increased by 25 W every minute until voluntary exhaustion. The test leaders gave strong verbal encouragement during the test to ensure maximal effort and optimal performance. Mean power during the last minute decided the cyclists' PPO. VO_2 was measured every 30 seconds. The average of the two highest VO_2 measurements determined the cyclists' VO_{2peak}. [la^-_{peak}] was measured one minute after the test was completed. In addition, HR_{peak} was recorded after termination of the test. Objective criteria such as plateau of the oxygen uptake, HR $\geq$ 95 % of known HR_{max}, RER $\geq$ 1.10 and [la^-] $\geq$ 8.0 $mMol \cdot L^{-1}$ were used to ensure that VO_{2max} was reached. To estimate fractional utilization of VO_{2peak}, the VO_2 corresponding to 4 $mMol \cdot L^{-1}$, was calculated as percentage of VO_{2peak} (%VO_{2peak}@4mM).

30 s all-out Wingate test

After the incremental test to exhaustion, the cyclists got another 10 minutes' recovery before they completed a 30 s all-out Wingate test to determine (1) peak power (PP) and (2) mean power during 30 seconds ($Power_{30s}$). The test started with the cyclists pedaling seated, at a frequency of 120 RMP for 20 seconds with a resistance of 120 W, including a 3 seconds' countdown before a braking resistance, equivalent to 0.7 $Nm·kg^{-1}$ body mass (Lode Excalibur), was applied to the wheel and remained constant throughout the subsequent 30 seconds of the test. The cyclists were instructed to pedal with maximal effort and remain standing throughout the 30 s all-out.

Test day 2

40-min-all-out trial ($Power_{40min}$)

The second test day consisted of a $Power_{40min}$. The test was performed in groups on the cyclists' own bikes that were mounted on electromagnetic rollers ergometers with a fan circulating air around the cyclists. The test started with an individual 20-30 min warm-up. Thereafter, the cyclists were instructed to cycle at the highest possible mean power during 40-min. The cyclists were blinded during the test, i.e. they were not able to see HR and power output. However, they were allowed to see the remaining time. The test was performed seated, but the cyclists were allowed to stand if needed. Mean power, HR_{mean}, HR_{peak}, RPE and [la^-] were recorded by the test leaders at the end of the test.

Instruments and materials

All tests on test day 1 were performed on the same cycle ergometer, Lode Excalibur Sport (Lode B. V., Groningen, Nederland). Each cyclist was able to adjust the bike as desired which included handlebar position, saddle height and distance between tip of the saddle and the bottom bracket. After the pre-test the bike position for each cyclist was saved and they were able to resume the same position at the post-test. All tests were performed under similar environment conditions (17-22°C) and were attempted to be performed at the same time of day (± 2h).

VO_2 during test day 1 was measured using Oxycon Pro™ with mixing chamber and 30 s sampling time (Oxycon, Jaeger GmbH, Hoechberg, Germany). Gas sensors were calibrated via an automated process using certified calibration gases of known concentrations before every test. The flow turbine (Triple V, Erich Jaeger) was calibrated using a 3L calibration syringe (5530 series; Hans Rudolph, Kansas, MO, USA). Blood [la^-] during all tests and HIT sessions were analyzed using a stationary lactate analyzer (EKF BIOSEN, EKF diagnostic, Cardiff, UK). HR was measured using Polar V400 (Polar Elektro Oy, Kempele, Finland).

All HIT sessions and test day 2 were performed on the cyclists` own bikes mounted Computrainer Lab™ ergometers (Race Mate, Seattle, WA, USA). The Computrainer Lab™ ergometers were connected to a PC that controlled the Computrainers via a software (PerfPRO Studio Hartware Technologies).

The training diary was made by the test leaders using Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington, USA).

Statistical analyses

Data were analyzed using SPSS 24.0 (SPSS Inc, Chicago, IL, USA) and are presented as mean ± standard deviation. Tables and figures were made using Microsoft Word, Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington, USA) and GraphPad Prism 7 (GraphPad Software, Inc., 7825 Fay Avenue, La Jolla, CA 92037, USA). Baseline and training characteristics within the groups and differences among the groups in $Power_{40min}$, PPO, VO_{2peak}, Power4mM, GE and $\%VO_{2peak}$@4mM were compared using a one-way between groups analysis of variance (ANOVA) with Bonferroni post-hoc test. A General Linear Model (GLM) repeated measures model (ANOVA) was used to compare the percentage change in power output within the groups from week to week during the intervention period. Absolute changes in physiological responses and performance responses pre- to post- intervention were compared in all groups using a paired sample *t*-test. Effect size (ES) was calculated in order to identify trends according to the criteria from Cohen's d (0.2=small, 0.5=medium, 0.8=large). All analyses resulting in $P \leq 0.05$ were considered statistically significant.

RESULTS

Weekly training characteristics

Weekly training characteristics during the pre-intervention period and the intervention period for the three groups are presented in Table 1. HIT sessions/week increased significantly in all groups from pre-intervention period to intervention period ($P<0.05$), while specific training (cycling) increased significantly in the LI group ($P<0.05$). Total training volume and endurance training, however, remained unchanged during the same period. There were no significant differences among groups in any training variables measured as mean during both the pre-intervention period and the intervention period.

Insert Table 1 here

Physiological- and perceptual responses during HIT

Mean physiological- and perceptual responses during 12 HIT sessions in all 26 cyclists are presented in Table 2. Mean power ($W \cdot kg^{-1}$) during the interval sessions was significantly higher in SI2 compared to LI ($P<0.05$). PPO (%) was significantly higher in SI2 compared to both LI and SI1 ($P<0.05$). SI1 and SI2 showed a significantly higher $Power_{40min}$ (%) and $Power_{4mM}$ (%) compared to LI ($P<0.05$). There were no significant differences between groups in blood $[la^-]$ at the end of interval lap 3 and 4, HR (mean and peak), RPE and sRPE. Further, there were no significant differences in total compliance (number of completed interval sessions) among the groups.

Insert Table 2 here

Evolution in power output during interval sessions

Evolution in power output during the HIT sessions are presented in Figure 2. During the training period, the maximal percentage increase in mean power output from baseline was 11.7 %, 11.6 % and 7.8 % in SI1, SI2 and LI, respectively ($P<0.05$). Maximal percentage increase was reached at the last HIT session for each group. There were no significant differences between the groups.

Insert Figure 2 here

Physiological and performance changes pre- and post intervention

Physiological and performance test results of the pre- and post intervention are presented in Table 3. All training groups improved significantly in $Power_{40min}$ and PPO ($P<0.05$). VO_{2peak} increased significantly in the LI and SI1 group ($P<0.05$), while it was unchanged in the SI2 group. $Power_{4mM}$, $\%VO_{2peak}$@4mM and GE did not have a significant increase in any of the training groups. The same pattern occurred in PP and $Power_{30s}$. Body mass remained stable pre- to post intervention.

Insert Table 3 here

Differences in physiological- and performance parameters between groups

95% confidence intervals (95% CI) for change in $Power_{40min}$, PPO, VO_{2peak}. $Power_{4mM}$, GE and $\%VO_{2peak}$@4mM are presented in Figure 3 (A-F). As shown in Figure 3 there are no significant differences between groups in any parameters. However, ES analysis revealed a large effect of SI1 compared with SI2 (ES = 0.98) and a medium effect of LI compared with SI2 (ES = 0.65) in VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$). ES analysis also shows a large effect of SI2 compared with LI (ES = 0.88), a medium effect of SI1 compared with LI (ES = 0.56) in $\%VO_{2peak}$@4mM and a medium effect of SI1 compared with both LI and SI2 (ES = 0.62 and 0.74, respectively) in GE.

Insert Figure 3 here

DISCUSSION

The present study demonstrates that there are no differences between aerobic short or long high intensity interval training with the same accumulated HIT duration (i.e. 32 min). The present study also demonstrates that performing HIT as both short and long intervals induces significant improvements in $Power_{40min}$, PPO and VO_{2peak} during only 4 weeks of intensified training.

The main finding in the present study is that there are no differences when performing aerobic high intensity interval sessions as short or long interval bout duration with the same accumulated HIT duration. The different groups were matched based on effort. In practice, this means that the cyclists followed the same recipe, indicating that all intervals should be performed with the maximum sustainable effort *(isoeffort)* that could be tolerated through all the intervals. This approach has previously been suggested to be closer to how athletes actually train than an *isoenergetic* approach, where interventions are matched for total work (12, 27). Prior to start of the project, we wanted the groups to be as equal as possible. They should only differ in HIT structure (SI and LI). Based on physiological and perceptual responses, the groups showed approximately equal RPE, sRPE, HR_{mean}, HR_{max} and $[la^-]$ values during the HIT sessions (Table 2). Further, the power output (W) during the HIT sessions between the groups was also non-significant, except SI2 who had a significantly higher power output ($W \cdot kg^{-1}$) compared to LI. Based on these characteristics, there is reason to assume that the groups have been too equal during the intervention period. This may have been an important reason for the non-significant differences in the physiological- and performance parameters between the groups.

The present intervention period lasted only 4 weeks, whereas other comparable studies lasted 6-10 weeks (10, 12, 24). The intervention period may have been too short to induce sufficient training stimulus and thus create a difference between the SI and LI. However, a recent study by Sylta et al. (34) showed that HIT performed during the initial 4 weeks of a 12-week training period appeared to have larger impact on specific performance outcomes than what occurred later in the training period. Moreover, the cyclists in the present study also performed 12 HIT sessions during the intervention period which is more or approximately equal to other studies examining the effects of HIT (19, 27, 31, 33, 35, 38, 39).

Even though there were no significant differences between the groups, we found a large ES in VO_{2peak} when comparing SI1 with SI2. A potential contributor to this may be that the accumulated duration in the SI1 group was longer than the LI and the SI2 group, if the 20 sec recovery periods are included in the total work duration, as studies have recently demonstrated the advantage of a slight reduction in intensity in combination with increased accumulated duration when performing HIT (25, 27, 35). On the other hand, this was the only parameter that showed a difference in ES between the groups and simultaneously increased significantly from pre to post test. Therefore, it is fair to assume that this may have been a coincidence.

The main finding in the present study corroborates with Helgerud et al. (12) who also found no differences between the SI and LI design. However, there are methodological differences as Helgerud et al. (12) matched the groups on total work, while the present study used effort matching of the groups with the same accumulated HIT duration. In addition, the number of HIT sessions per week as well as the intervention period were different. Subjects in Helgerud et al. (12) were recreational level subjects while the subjects in the present study were considered well-trained.

The present findings are contradictory to other studies who have found differences between the aerobic SI and LI design (10, 24, 31). In the study by Franch et al. (10) they found that the

LI design had a significantly greater improvement on VO_{2max} and running economy (RE) compared with the SI design. However, the accumulated duration in the LI group was somewhat longer compared to the SI group and may have caused larger stimulus in the LI group. It should also be mentioned that the cyclists in that study were on a recreational level and therefore on a lower level than the cyclists in the current study. In addition, Stepto et al. (31) also found superior adaptions in the LI design (8x4-min) compared to the SI design (12x60-sec). However, the intervention period lasted only 3 weeks, including 2 HIT sessions per week, with only four cyclists in each group.

Rønnestad et al. (24) have also reported differences between aerobic SI and LI. In that study it was found that performing HIT as SI induced superior training adaptions on several physiological- and performance parameters compared with performing HIT as LI. The accumulated duration of the LI and SI was similar, 20 and 19.5 min, respectively. However, the micro recovery periods of 15 seconds in the SI group are short, and it is reasonable to assume that the HR will not drop significantly during those seconds. Therefore, a high cardiac output may sustain throughout the micro recovery periods. Unreported observation in the present study supports this assumption that the HR was high during the micro recovery periods. This may have resulted in greater physiological stress in the SI group. However, if the micro recovery periods are included in the total work, the total duration of the SI may be longer compared to the LI (28 vs 20 min). This may explain why the SI group showed the best results.

In accordance with the study by Rønnestad et al. (24), the accumulated duration of both the SI and the LI in the present study was equal. Unlike Rønnestad et al. (24), we wanted the manipulation of the SI to be twofold, i.e where the micro recovery period was included in the total work duration in one group and not in the other. Therefore, two SI groups were included in the present study. Despite this, none of the SI groups differed significantly in physiological- and performance parameters compared to the LI group.

As opposed to the present study, the SI group in the study by Rønnestad et al. (24) performed the HIT sessions with a significantly higher power output than the LI group, which may have led to superior stimulus on the cardiovascular and neuromuscular system. This may also have been an important reason for the superior effect in the SI group. In the current study, on the other hand, the accumulated duration was 32 min, and there is reason to believe that the accumulated duration was too long to induce a significant difference in power output (W) between the groups during the HIT sessions. This may further have been an important reason why there were no significant differences between the groups.

To the best of our knowledge, only limited research comparing aerobic SI and LI training exists. However, in addition to aerobic SI and LI training, research has revealed that repeated supramaximal sprint interval training (SIT) may be equally effective for eliciting improvements in endurance performance (13, 17, 18, 31). Indeed, Stepto et al. (31) found that improvements in PPO and $Power_{40min}$ were the same after performing either SIT, conducted as 12x30-sec 175 % PPO, or aerobic HIT, conducted as 8x4-min 85 % PPO. Other studies have also reported improvements after approximately similar SIT protocol used in the study by Stepto et al. (31) (5, 7, 11, 13, 20). It has been suggested that an important contributor to the improvement in endurance performance following SIT may have been accompanied by an increase in muscle buffering capacity and oxidative enzyme capacity (1).

The second main finding in the present study is that after only 4 weeks of intensified training, including 12 HIT sessions, both physiological (VO_{2peak}) and performance ($Power_{40min}$ and PPO) parameters increase when performing SI and LI. These responses are consistent with other studies investigating the effect of HIT over similar time frames (19, 33, 39), or after longer interventions (10, 12, 24, 25, 27, 35, 38) involving recreational to elite athletes. No changes occurred in GE and $\%VO_{2peak}$@4mM. This is probably due to the fact that the stimuli from short-term HIT are more effective in inducing central cardiovascular adaptions (17).

Practical applications

HIT is a commonly used method for achieving enhancement in endurance performance in well-trained athletes (2, 4, 15, 16). However, it is unclear how this part of the training should be organized in order to optimize the training effects. It is usual among athletes to manipulate the design of HIT sessions, i.e. whether the intervals are performed with short or long duration of bouts (2). The present study demonstrates that performing aerobic SI and LI training during a 4-week training period with an accumulated duration of 32 min results in increased performance and physiological adaptions. There were no differences between SI and LI. However, this topic has revealed little attention in literature, and future studies comparing SI and LI training with the same accumulated duration >30 min are needed, also on a larger sample size and during a longer time frame than the present study.

CONCLUSION

The present study demonstrates that there are no differences between aerobic short or long high intensity interval training with the same accumulated HIT duration (i.e. 32 min) during a 4-week training period. The present study also demonstrates that performing HIT as both SI and LI induces significant improvements in physiological- (VO_{2peak}) and performance ($Power_{40min}$ and PPO) parameters.

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CONFLICT OF INTEREST:

The authors have no conflicts of interests in this study. The results of the present study do not constitute endorsement by the American College of Sports Medicine. The data are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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FIGURE LEGENDS

FIGURE 1: Study overview. Week 1-2; Familiarization to lab-test (submaximal incremental test, incremental test to exhaustion and 30 s all-out Wingate test) and 40 min-all-out trial (Power$_{40min}$). Week 3-5; Familiarization to HIT sessions (4x8x40/20-sec and 4x12x40/20-

sec). Week 6; Pre-test (test day 1 and test day 2) followed by randomization (R) into long interval (LI), short interval 1 (SI1) and short interval 2 (SI2). Week 7-10; Intervention period. Week 11; Post-test (test day 1 and test day 2).

FIGURE 2. Percentage change in power output during the long interval sessions (LI), short interval sessions 1 (SI1) and short interval sessions 2 (SI2) during the 4-week intervention period. *Larger than week 2 and 3 in the SI1 group ($P<0.05$). $^{\#}$Larger than week 2 and 3 in the SI2 group ($P<0.05$). $^{\$}$Larger than week 2 and 3 in the LI group ($P<0.05$). $^{€}$Tendency to larger than week 1 in the SI2 group ($P=0.07$). Note: Week 1 = baseline when comparing weeks. HIT session 1 = baseline when comparing HIT sessions.

FIGURE 3. 95% confidence intervals (95% CI) for relative change after a 4-week training period (Pre-Post) in A) $Power_{40min}$, B) PPO, C) VO_{2peak}, D) $Power_{4mM}$ E) GE and F) $\%VO_{2peak}$@4mM, in long interval (LI) (N=8), short interval 1 (SI1) (N=9) and short interval 2 (SI2) (N=9) intervention groups. Each marker* indicates one cyclist. $Power_{40min}$ = Mean power during 40-min all-out trial, PPO = Peak Power Output, VO_{2peak} = Peak oxygen uptake and $Power4_{mM}$ = Power corresponding to 4 $mMol \cdot L^{-1}$ lactate, GE = Gross Efficiency, $\%VO_{2peak}$@4mM = Percent peak oxygen uptake corresponding to 4$mMol \cdot L^{-1}$ lactate

Table 1: Weekly training characteristics during the pre-intervention period (PIP) and the intervention period (IP) in 26 cyclists, randomized to long interval (LI), short interval 1 (SI1) and short interval 2 (SI2). Values are mean ± SD.

	Total (N=26)		**LI (N=8)**		**SI1 (N=9)**		**SI2 (N=9)**	
	PIP	**IP**	**PIP**	**IP**	**PIP**	**IP**	**PIP**	**IP**
Training volume ($h{\cdot}wk^{-1}$)	8.1 ± 3,6	8.8 ± 4.0	8.8 ± 5.6	10.0 ± 5.7	7.9 ± 2.8	8.1 ± 3.2	7.8 ± 2.3	8.4 ± 3.1
Endurance ($h{\cdot}wk^{-1}$)	7.2 ± 3.1	8.0 ± 3.2	7.5 ± 4.4	8.7 ± 4.3	7.0 ± 2.8	7.6 ± 2.9	7.0 ± 2.1	7.7 ± 2.6
Specific training ($h{\cdot}wk^{-1}$)	4.6 ± 2.8	6.0 ± 2.5*	4.3 ± 3.6	6.4 ± 4.0*	4.8 ± 2.3	5.8 ± 0.9	4.7 ± 2.7	6.0 ± 2.1
HIT session/week	1.3 ± 0.2	3.0 ± 0.1*	1.3 ± 0.1	3.0 ± 0.1*	1.3 ± 0.2	3.0 ± 0.1*	1.3 ± 0.3	3.1 ± 0.2*

*$P<0.05$

Table 2. Physiological and perceptual responses from HIT sessions during the 4 weeks' intervention period.

	LI (n=8)	**SI1 (n=9)**	**SI2 (n=9)**
Complience % HIT sessions	99 ± 2.9	99.1 ± 2.8	100 ± 0.0
Power (W)£	287 ± 26.8	290 ± 25.8	311 ± 32.7
Power ($W \cdot kg^{-1}$) £	3.7 ± 0.5	4.0 ± 0.3	4.3 ± 0.6*
Percent of Peak Power Output (%)£	70 ± 2.9	74 ± 2.9	78 ± 4.0*§
Percent of $Power_{40min}$ (%)£	104 ± 3.5	111 ± 3.3*	115 ± 5.2*
Percent of 4mM lactate power (%)£	104 ± 5.9	113 ± 6.5*	116 ± 6.3*
Blood lactate ($mMol \cdot L^{-1}$) interval lap 3	6.2 ± 1.2	6.0 ± 1.0	7.6 ± 1.8
Blood lactate ($mMol \cdot L^{-1}$) interval lap 4	8.1 ± 1.4	7.2 ± 2.0	9.3 ± 2.2
Interval lap HR_{mean} ($\%HR_{peak}$)£	86 ± 1.7	86 ± 3.3	87 ± 1.4
Interval lap HR_{peak} ($\%HR_{peak}$)£	90 ± 1.3	90 ± 2.9	91 ± 1.2
RPE (6-20)£	16.8 ± 0.7	16.7 ± 0.3	16.8 ± 0.3
sRPE 30 min post session (1-10)	8.8 ± 0.9	8.7 ± 0.8	8.7 ± 0.5

All values are presented as mean ± standard deviation of 12 HIT sessions in 26 cyclists. Compliance is calculated as percent of the total HIT sessions described (12 sessions per cyclist). £All values of power, mean/peak heart rate (HR) and rate of perceived exertion (RPE) were calculated as the mean of 4 interval laps. Session RPE (sRPE) was recorded 30 min after each HIT session. In total, 165 lactate samples were collected at the end of interval lap 3 and 4 (~6 per cyclist). *Significantly larger than LI. §Significantly larger than SI1.

Table 3. Pre to post changes in physiological- and performance parameters during the 4 weeks' intervention period. All values are mean ± SD.

	LI (n=8)		**SI1 (n=9)**		**SI2 (n=9)**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Body composition						
Body mass (kg)	77.3 ± 7.1	77.6 ± 7.1	73.7 ± 9.0	73.8 ± 9.5	72.9 ± 6.4	72.5 ± 6.2
Performance						
$Power_{40min}$ (W)	267 ± 24.4	286 ± 21.8*	251 ± 24.9	271 ± 24.2*	259 ± 29.1	274 ± 27.9*
PPO (W)	405 ± 37.4	424 ± 32.8*	386 ± 32.7	403 ± 37.4*	392 ± 39.9	408 ± 34.8*
Aerobic						
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	64 ± 6.7	65.8 ± 7.5*	62.9 ± 5.5	65.4 ± 6.0*	64.5 ± 7.3	65.0 ± 7.4
VO_{2peak} ($L \cdot min^{-1}$)	4.9 ± 0.4	5.1 ± 0.4*	4.6 ± 0.4	4.8 ± 0.5*	4.7 ± 0.5	4.7 ± 0.4
$Power_{4mM}$ (W)	273 ± 27.8	277 ± 31.4	256 ± 29.8	259 ± 25.8	263 ± 19.7	270 ± 19.5
$\%VO_{2peak}$@4mM (%)	80.4 ± 4.7	77.8 ± 5.6	78.1 ± 3.9	78.3 ± 5.3	78.8 ± 5.8	81.0 ± 4.5
GE (%)	18.2 ± 0.8	18.4 ± 1.1	19.1 ± 0.9	18.8 ± 1.3	19.0 ± 0.6	19.3 ± 0.7
Anaerobic						
PP (W)	1223 ± 180.8	1234 ± 154.9	1055 ± 251.7	1053 ± 265.7	1099 ± 150.0	1102 ± 95.1
$Power_{30s}$ (W)	744 ± 84.6	745 ± 76.1	639 ± 67.7	641 ± 68.5	651 ± 42.0	649 ± 54.6

$Power_{40min}$ = Mean power during 40-min all-out trial, PPO = Peak Power Output, VO_{2peak} = Peak oxygen uptake, $Power4_{mM}$ = Power corresponding to 4 $mMol \cdot L^{-1}$ lactate, $\%VO_{2peak}$@4mM = Percent peak oxygen uptake corresponding to 4$mMol \cdot L^{-1}$ lactate, GE = Gross Efficiency, PP = Peak Power, $Power_{30s}$ = Mean power during 30 s all-out test.

* $P<0.05$

Figure 1

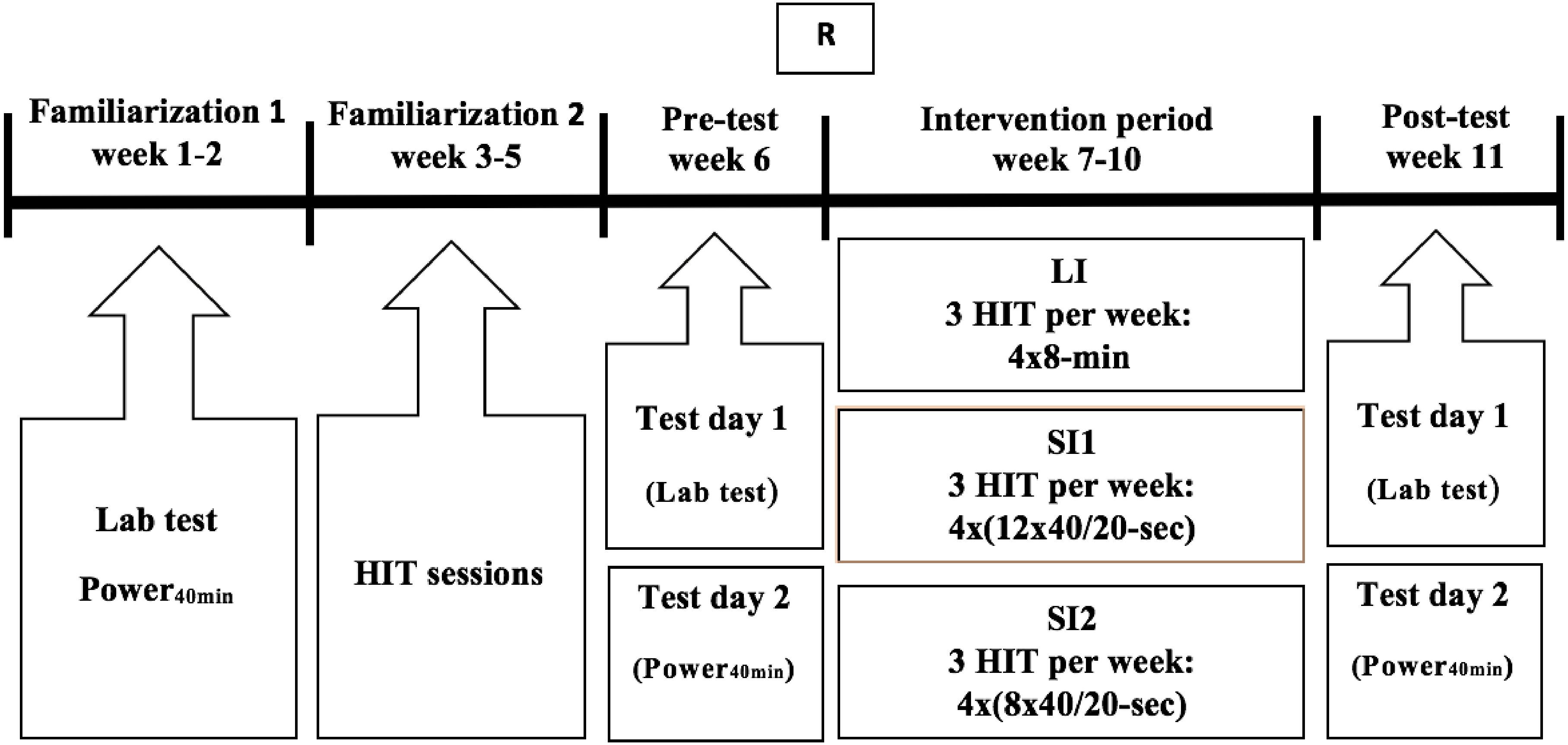
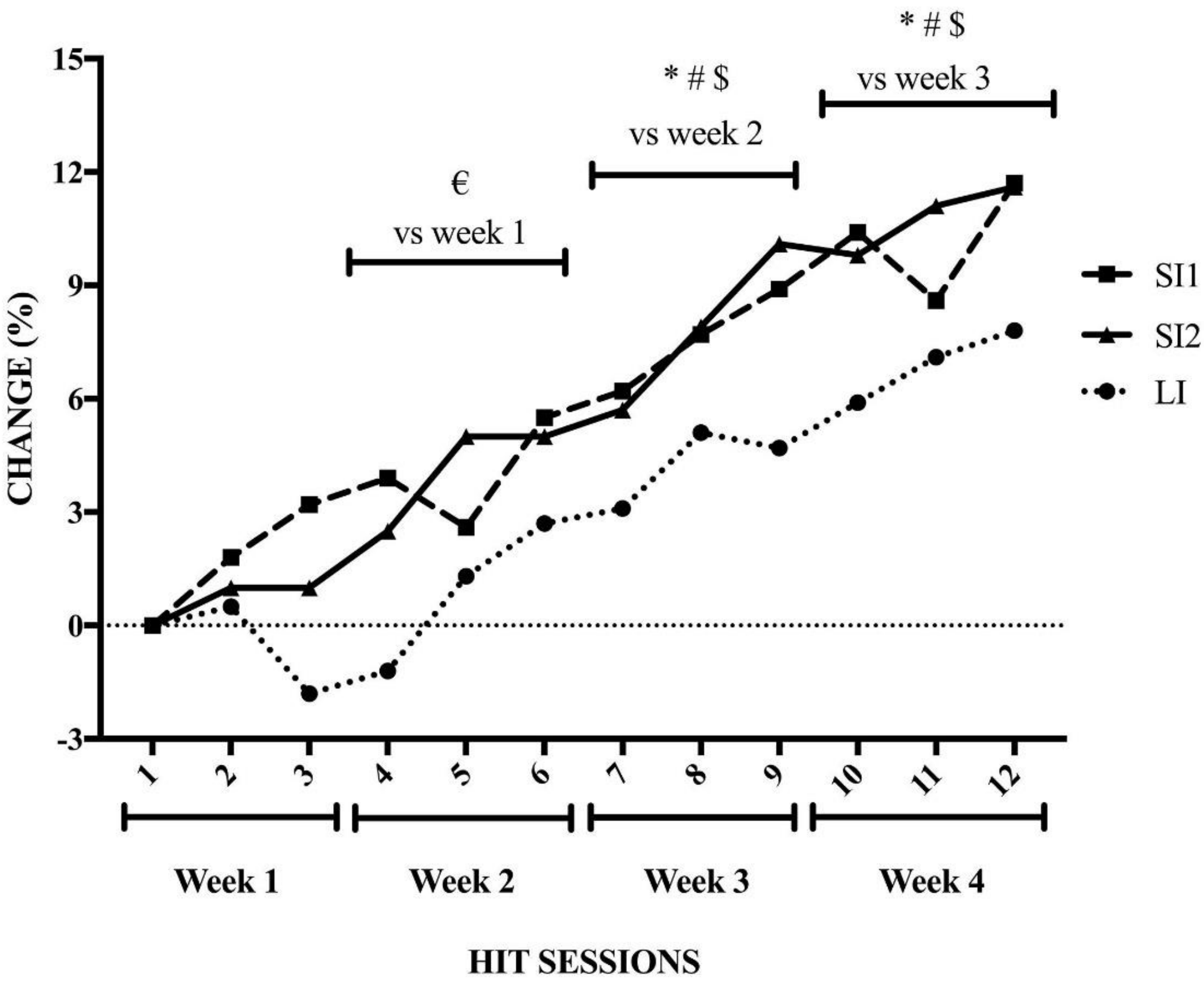
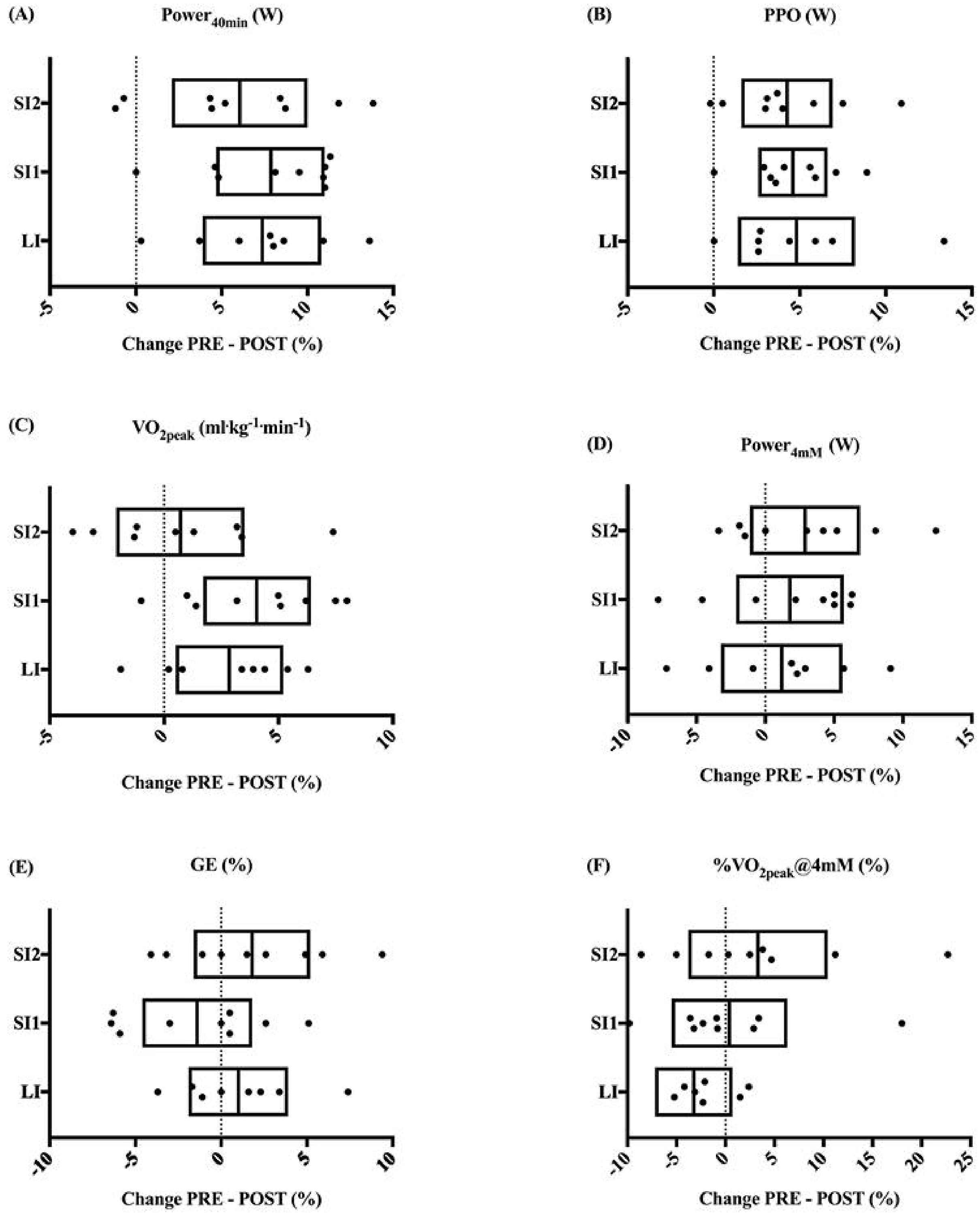

R
Familiarization 1
week 1-2
Familiarization 2
week 3-5
Pre-test
week 6
Intervention period
week 7-10
Post-test
week 11
Lab test
Power40min
HIT sessions
Test day 1
(Lab test)
Test day 2
(Power40min)
LI
3 HIT per week:
4x8-min
SI1
3 HIT per week:
4x(12x40/20-sec)
SI2
3 HIT per week:
4x(8x40/20-sec)
Test day 1
(Lab test)
Test day 2
(Power40min)

Figure 2



CHANGE (%)
15
12
9
6
3
0
-3
€
vs week 1
* # $
vs week 2
* # $
vs week 3
SI1
SI2
LI
1
2
3
4
5
6
7
8
9
10
11
12
Week 1
Week 2
Week 3
Week 4
HIT SESSIONS

Figure 3



(A)
Power40min (W)
SI2
SI1
LI
-5
0
5
10
15
Change PRE - POST (%)
(B)
PPO (W)
SI2
SI1
LI
-5
0
5
10
15
Change PRE - POST (%)
(C)
VO2peak (ml·kg-1·min-1)
SI2
SI1
LI
-5
0
5
10
Change PRE - POST (%)
(D)
Power4mM (W)
SI2
SI1
LI
-10
-5
0
5
10
15
Change PRE - POST (%)
(E)
GE (%)
SI2
SI1
LI
-10
-5
0
5
10
Change PRE - POST (%)
(F)
%VO2peak@4mM (%)
SI2
SI1
LI
-10
-5
0
5
10
15
20
25
Change PRE - POST (%)

Part 3:

Appendix

Contents:

Appendix 1

Informasjon og forespørsel om deltakelse i forskningsprosjekt

«Effekten av ulike treningsintervensjoner på fysiologiske parametere, prestasjon og helsevariabler»

– en eksperimentell studie i idrettsvitenskap.

Andreas M. Pedersen; 952 99 695 eller Ole E. Wåle; 980 39 396. Felles epost; uiaprosjekttao@gmail.com
UNIVERSITETET I AGDER

Kjære syklist!

Vi søker syklister til å bli med på et treningsprosjekt i forbindelse med en masteroppgave og et doktorgradsprosjekt i idrettsvitenskap ved Universitetet i Agder (UIA).

Bakgrunn og hensikt

For å prestere på høyt nivå innen utholdenhetsidrett er det viktig at treningsvariablene intensitet, varighet og frekvens implementeres i treningsopplegget på en hensiktsmessig måte, i tillegg til en hensiktsmessig fordeling av rolig (LIT), moderat (MIT) og hard (HIT) trening. I tillegg til nevnte variabler, er det vanlig blant utøvere å manipulere økt-design på HIT økter gjennomført som intervalltrening, dvs. for eksempel om intervaller skal gjennomføres med kort eller lang lengde på dragene. Videre ses et økt fokus i en oppkjøringsperiode på blant annet vekt og kroppssammensetning for å optimalisere kroppen mest mulig inn mot en konkurranseperiode. Et slikt fokus på vekt og kroppssammensetning har hos kvinner blitt assosiert med mulige negative prestasjons- og helsekonsekvenser, men det finnes veldig lite forskning knyttet til mannlige utøvere.

Hensikten med denne studien er å undersøke effekten av ulike økt-design på HIT økter, gjennomført som langintervall eller kortintervall på ulike fysiologiske parametere og prestasjon, samt undersøke effekten av en tøff treningsperiode på parametere som kroppssammensetning, energitilgjengelighet, blodtrykk og blodvariabler hos godt trente mannlige utholdenhetsutøvere.

Forsøkspersoner

Vi ønsker å rekruttere 30 forsøkspersoner som oppfyller følgende inklusjonskriterier:

- Mann < 40 år
- Maksimalt oksygenopptak > 60 $ml \cdot kg^{-1} \cdot min^{-1}$
- Treningsfrekvens pr nå >3 økter/uke innen sykling det siste året (minimum 6 timer)
- Fravær fra sykdom og skader

Som forsøksperson må du være villig til å bli tilfeldig plassert i en av tre treningsgrupper og gjennomføre treningsopplegget på prosjektets premisser. Som førsøksperson må du ha mulighet til å stille på samtlige intervalløkter og tester i løpet av perioden.

Hva innebærer deltakelse i studien?

Dette er en eksperimentell studie som totalt vil foregå over en periode på 11 uker, fra uke 39-49. Periodene deles inn i flere ulike faser (**se figur 1 for oversikt**):

Tilvenning til lab-tester (uke 39): Hensikten med tilvenningsperioden er å gjøre deg kjent med prosedyrer og utstyr samt de ulike intervaller som benyttes under intervensjonen. Dette innebærer at du må sette av én dag til testing i lab i uke 39.
Tilvenning til intervalløkter (uke 41-43): I uke 40 (høstferien) skal dere ikke møte hos oss. Denne uken kan/skal dere gjennomføre kun en valgfri intervalløkt på egenhånd.
I uke 41-43 gjennomføres tilvenning til intervalløktene. Dette innebærer at du som deltaker må møte i UIAs lokaler på Spicheren treningssenter en dag i uke 41, en dag i uke 42 og en dag i uke 43.

Testfasen/pre-test (uke 44): Testfasen består av to testdager. På dag 1 skal du møte fastende i laboratoriet for måling av hvilestoffskiftet, blodtrykk, blodprøve, skanning av kroppssammensetningen din (dobbel røntgen absorpsjonsmetri; DXA) samt utfylling av spørreskjemaer.

> ***NB:*** *De siste 24 timer før testdagen må du ikke utføre intensiv eller utmattende trening/konkurranser eller drikke alkohol. Du har ikke tillatelse til å spise de siste 12 timene før testene (disse gjennomføres tidlig på morgenen). De siste tre timer før testene må du ikke drikke te, kaffe eller annen koffeinholdig drikke. Som forsøksperson vil du bli nøye overvåket av testledere.*

På dag 2 skal vi måle fysiologiske parametere knyttet til prestasjon. Du skal gjennomføre en laktatprofiltest, VO_{2maks} test samt en 30 sekunders all-out Wingate-test.

> **NB**: *De siste 48 timene før denne test (dag2) kan du ikke utføre intensiv trening eller konkurranser. Som forsøksperson vil du bli nøye overvåket av testledere.*

Videre vil du bli bedt om å registrere kostholdet ditt samt trenings- og aktivitetsnivået ditt i 4 dager før intervensjonen starter, samt 4 dager ved intervensjonsslutt. All kostholdsregistrering gjøres elektronisk via PC eller Mac med et kostholdsprogram som også benyttes av Olympiatoppen. Du vil få låne en vekt hvor du skal veie all mat og væske du inntar disse 4 dagene. Aktivitet og trening registreres med en utlevert pulsklokke fra Polar (M400) samt et lite akselerometer montert på armen (Sensewear).

Intervensjonsfasen (uke 45-48): Deretter vil du som forsøksperson bli tilfeldig fordelt i en av tre grupper som skal gjennomføre et 4 ukers eksperiment (uke 45-48) fordelt som følger;

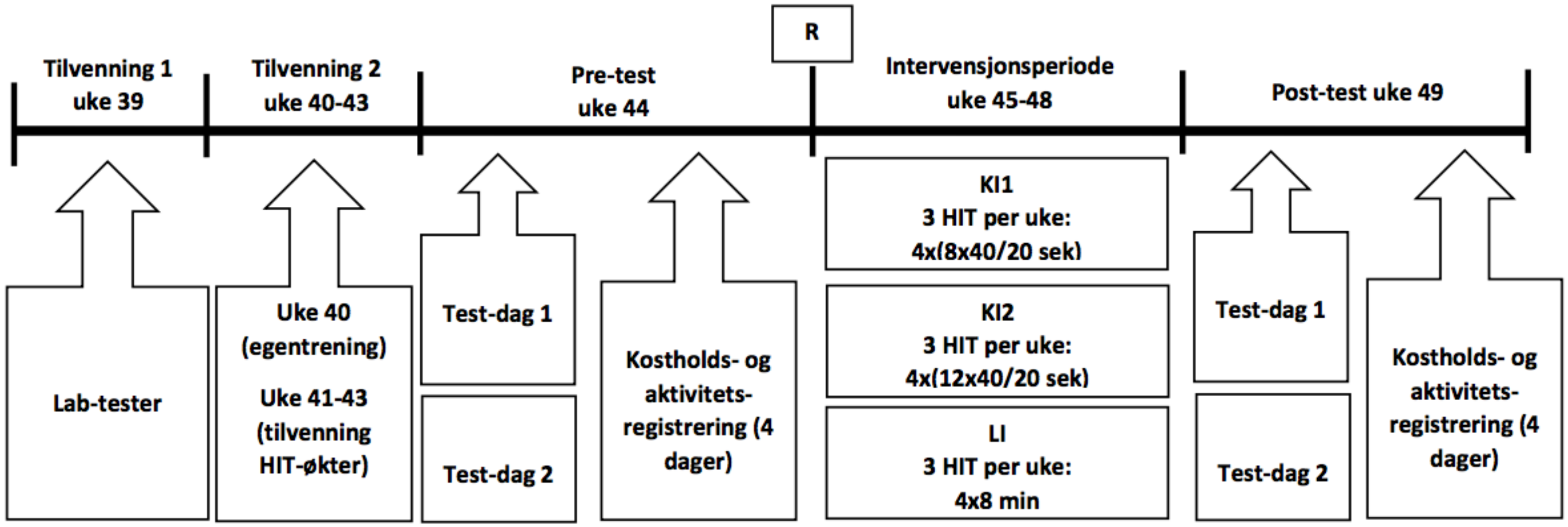
- Kortintervall-gruppe 1 (KI1) (4x(8x40/20sek) med 2 min seriepause)
- Kortintervall-gruppe 2 (KI2) (4x(12x40/20) med 2 min seriepause)
- Langintervall-gruppe (LI) (4x8 min med 2 min seriepause)

Du skal totalt gjennomføre 12 HIT økter i løpet av en fire ukers intervensjonsperiode. Det vil si tre HIT økter per uke i tillegg til 2-3 rolige økter, med en anbefalt treningsmengde på 10-12 timer per uke eller mer. HIT øktene skal gjennomføres i grupper på 10 stk. mandag, onsdag og fredag i UIAs lokaler på Spicheren treningssenter. Klokkeslett for treningen er satt til 16.00, 18.00 og 20.00 avhengig av hvilken gruppe du blir plassert i. «Heart rate variability» (HRV) vil bli målt på utvalgte forsøkspersoner før og etter utvalgte intervalløkter for å undersøke variasjonen i tidsintervallene mellom hvert hjerteslag. Dette gir en indikasjon på hvor stressende den aktuelle økta er på det autonome nervesystemet. Målingen gjøres med Polar V800 og krever ingen fysisk anstrengelse eller ubehag.

***NB:** I løpet av hele perioden (uke 39-49) må du som forsøksperson fylle ut treningsdagbok som dere får utdelt. Du vil bli utstyrt med Polar M400 til bruk og innsamling av data fra både fellesøkter og individuelle økter.*

Testperiode/post-test (uke 49): Her gjennomføres samme tester i samme rekkefølge som i den første testperioden (pre-test).

Tidslinje (uke 39-49):



***Figur 1**: Studiens faser. Fire ukers tilvenningsfase består av en test-dag (laktatprofil-, VO_{2maks}- og Wingatetest) i uke 39, egentrening i uke 40 (kun en intervalløkt) og totalt tre HIT-økter (4x8x40/20 sek, 4x12x40/20 sek og 4x8 min) i løpet av uke 41-43. Deretter følger to test-dager i uke 44 (pre-test), 4 dagers kostholds- og aktivitetsregistrering samt randomisering (R) i kortintervall 1 (KI1), kortintervall 2 (KI2) og langintervall (LI) etterfulgt av 4 ukers intervensjonsperiode med 3 intervensjonsgrupper. Til slutt gjennomføres to test-dager (post-test), samt 4 dagers kostholds- og aktivtetsregistrering.*

Mulige fordeler og ulemper:

Som deltaker vil du:

- Skaffe kunnskap for å utvikle toppidretten i samarbeid med Olympiatoppen og UIA.
- Få delta på et vitenskapelig eksperiment som kan bidra til å skaffe ytterligere kunnskap for å utvikle vår forståelse av ulik trening.
- Få mulighet til å teste din fysiske kapasitet uten kostnad på UIA.
- Få kartlagt din energitilgjengelighet med muligheter for tilbakemelding på kostholdet ditt og utvalgte helsevariabler.
- Få målt din kroppssammensetning uten kostnad med gullstandard målemetode (DXA) med detaljerte opplysninger om din fett-, muskel- og beinmasse.
- Få målt ditt hvilestoffskifte som sier noe om din forbrenning i hvile.
- Få være med på et sosialt og spennende treningsprosjekt som kan gi inspirasjon til hvordan trene videre i etterkant av intervensjonen.
- Få delta på et effektivt treningsprogram med god oppfølging.

Mulige ulemper:

- Må møte på fellesøkter og tester til fastsatte tider i løpet av perioden.
- Kan ikke trene intensive økter utover det som er inkludert i intervensjonsperioden. Det er kun lavintensive økter som kan gjennomføres valgfritt.
- All trening må dokumenteres etter gitte krav i treningsdagbok.
- Kostholdet og aktivitetsnivået må kartlegges ved to anledninger (4 dager hver).
- Må være opplagt til hver trening/test og gjennomføre disse med god innsats.
- Risiko for overbelastning både ved testing og HIT-økter.

Hva skjer med informasjon om deg?

Data som blir registrert skal kun brukes slik som beskrevet i hensikten med studien. Opplysningene vil bli behandlet uten navn og fødselsnummer, eller andre direkte gjenkjennende opplysninger. Som deltaker vil du få et ID nummer som representerer ditt navn. Tester som blir gjennomført og data som blir innhentet, vil knyttes til dette ID nummeret. Det er kun autorisert personell knyttet til prosjektet som har adgang til ID nummeret. Innsamlet data vil bli benyttet i masterprosjektet og doktorgradsprosjektet, men alltid anonymt. Dataene vil også kunne bli brukt til publisering i tidsskrift, undervisning og kongresser. Som deltaker har du rett til å få innsyn i data som er registrert på deg selv. Data vil oppbevares avidentifisert på prosjektlederes passordbelagte PC. Data vil bli oppbevart i opptil 10 år etter at prosjektet er avsluttet.

Rett til innsyn og sletting av opplysninger om deg

Hvis du sier ja til å delta i studien, har du rett til å få innsyn i hvilke opplysninger som er registrert om deg. Du har videre rett til å få korrigert eventuelle feil i de opplysningene vi har registrert. Dersom du trekker deg fra studien, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner

Frivillig deltakelse:

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

Ytterligere detaljert informasjon om prosjektet og de ulike testene kan utleveres ved å kontakte Andreas eller Ole.

Annet:

Som forsøksperson må du også delta på et obligatorisk informasjonsmøte onsdag 14. september kl. 1930 eller tirsdag 20. september kl. 18 i UIAs lokaler på Spicheren treningssenter.

Hvordan bli med?

Dersom du ønsker å være en del av dette prosjektet kan du sende en mail til uiaprosjekttao@gmail.com der du beskriver følgende:

- Hvem du er
- Nivå
- Treningsmengde det siste året
- Dine muligheter for å delta på samtlige økter og tester

Mvh

Andreas M. Pedersen, Ole E. Wåle og Thomas B Stenqvist.

Kontaktinfo:

Prosjektledere

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Monica K. Torstveit
Førsteamanuensis
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Samtykke til deltakelse i undersøkelsen:

Ved å signere samtykkeerklæringen bekrefter du også at du ikke har kjent hjertesykdom eller andre lidelser/sykdom som medfører at din fastlege har frarådet deg å trene intensivt. Alle deltakere i studien er for øvrig forsikret via UIAs egen forsikringsordning for forskningsprosjekter.

Jeg bekrefter å ha fått og forstått informasjon om studien

(Signert av prosjektdeltaker evt. foresatt, dato)

Jeg er villig til å delta i studiet?

Ja

____

(Signert av prosjektdeltaker evt. foresatt hvis under 18 år, dato)

Appendix 2

Thomas Stenqvist
Institutt for folkehelse, idrett og ernæring Universitetet i Agder
Serviceboks 422
4604 KRISTIANSAND S

Vår dato: 20.10.2016   Vår ref: 49943 / 3 / BGH   Deres dato: Deres ref:

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 12.09.2016. Meldingen gjelder prosjektet:

49943	*Effekten av ulike treningsintervensjoner på fysiologiske parametere – en eksperimentell studie i idrettsvitenskap*
Behandlingsansvarlig	*Universitetet i Agder, ved institusjonens øverste leder*
Daglig ansvarlig	*Thomas Stenqvist*

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, ombudets kommentarer samt personopplysningsloven og helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/meldeplikt/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://pvo.nsd.no/prosjekt.

Personvernombudet vil ved prosjektets avslutning, 01.10.2020, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Kjersti Haugstvedt

Belinda Gloppen Helle

Kontaktperson: Belinda Gloppen Helle tlf: 55 58 28 74
Vedlegg: Prosjektvurdering

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

Appendix 3

Lab-test

Forberedelser (info til utøvere)

- Generelt forberedelser som til konkurranse
- Bare rolig trening siste 2 dager før test
- Kosthold: innta samme type måltid/innhold før hver test
- Ikke spise siste 2 timer før test
- Ikke innta koffeinholdig drikke/produkter siste 3 timer før test

Prosedyre for utøver

1. Innveiing
2. Lett oppvarming 10 min
3. Laktat profil test
   10 min pause
4. VO_{2maks} test
   10 min pause
5. Wingate test

Laktatprofil test

1. Testen gjennomføres som sammenhengende sykling med økende belastning hvert 5. minutt
2. Sittende sykling med selvvalgt RPM (noteres)
3. Utgangsbelastning er 125w
4. Øker med 50w hvert 5 min opp til laktat 2,9mmol/L
5. Øker med 25w fra laktat > 2,9mmol/L
6. VO_2, VE, RER og HF måles som steady state verdier fra 2-5min pr drag
7. BORG –skala, spørres om etter 4.30min
8. Laktat stikk etter 4.45min
9. Testen avsluttes når laktat er 4mmol/L eller høyere
10. VO_2 måles med miksekammer og 30 sek frekvens
11. Pause: 10 min med valgfri belastning (tillat med do-pause) før VO_{2maks} test

VO_{2maks} test

1. Testen gjennomføres som sammenhengende sykling med økende belastning hvert minutt
2. Sittende sykling med selvvalgt RPM >60 (noteres)
3. VO_2, VE, RER og HF måles kontinuerlig gjennom hele testen
4. Utgangsbelastning er 3w/kg rundet ned til nærmeste 50w (~200w)
5. Øker med 25w hvert minutt til utmattelse (RPM < 60)

Ved utmattelse:

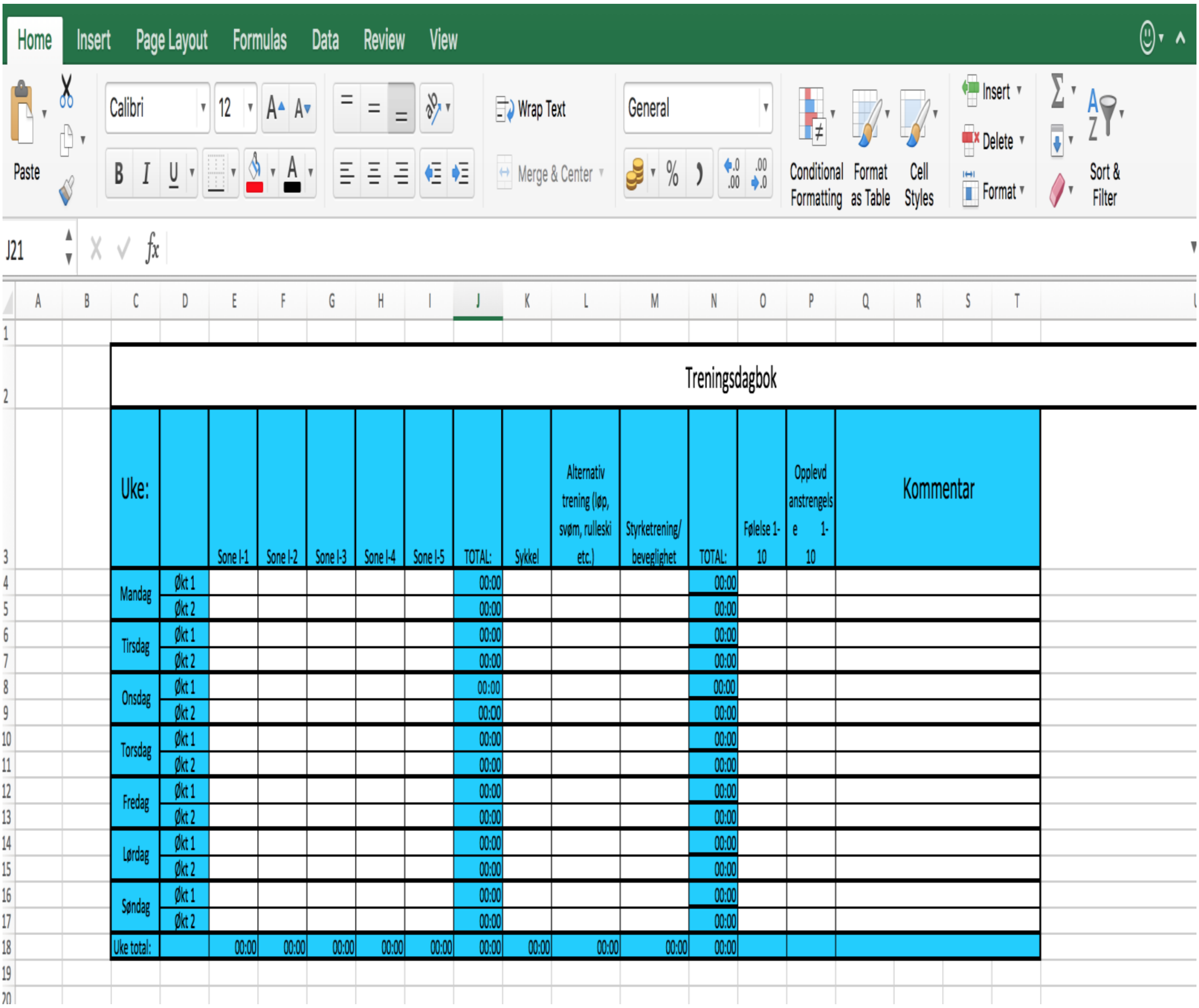
1. Registrer total tid til utmattelse (antall sekunder) og slutt belastning (watt)
2. Registrer slutt HF
3. Registrer opplevd anstrengelse (BORG-skala)
4. Laktat stikk tas ett min etter avsluttet test
5. Pause: 10 min med valgfri belastning (tillat med do-pause) før wingate-test

VO_{2maks} = snitt av 2 høyeste 30s målinger hvis utflating. Hjelpekriterier: >95 % av oppgitt maks HF, RER > 1.05 og laktat > 8.0 mmol/L

Wingate test

1. Testen gjennomføres som stående sykling med høyest mulig frekvens
2. 120 RPM siste 20 sek før start test
3. Belastning settes til torque 0.70
4. Registrer torque, peak watt, mean (30s) watt og fatique (watt/s)

Appendix 4



Treningsdagbok

Uke:		Sone I-1	Sone I-2	Sone I-3	Sone I-4	Sone I-5	TOTAL:	Sykkel	Alternativ trening (løp, svøm, rulleski etc.)	Styrketrening/ bevegelighet	TOTAL:	Følelse 1-10	Opplevd anstrengelse 1-10	Kommentar
Mandag	Økt 1						00:00				00:00			
	Økt 2						00:00				00:00			
Tirsdag	Økt 1						00:00				00:00			
	Økt 2						00:00				00:00			
Onsdag	Økt 1						00:00				00:00			
	Økt 2						00:00				00:00			
Torsdag	Økt 1						00:00				00:00			
	Økt 2						00:00				00:00			
Fredag	Økt 1						00:00				00:00			
	Økt 2						00:00				00:00			
Lørdag	Økt 1						00:00				00:00			
	Økt 2						00:00				00:00			
Søndag	Økt 1						00:00				00:00			
	Økt 2						00:00				00:00			
Uke total:		00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00	00:00			

Appendix 5

Kort veiledning i bruk av Polar M400 aktivitetsmåler og pulsklokke

Klokken og ladning av batteri:
Klokken har oppladbart batteri som lades via USB-porten på en datamaskin. Hvis klokken ikke brukes til trening m. Puls og GPS, vil batteritiden vare ca. 14 dager. Brukes puls og GPS vil batteritiden være ca. 24 timer.
Det kan derfor godt skje at du må lade klokken ila de 3-4 dager (kostholdsregistreringsdagene) du skal gå med den (24 timer i døgnet). Viktig at du lader klokken når du sitter ned over en lengre periode (typisk kveldstid, foran TV´en, på jobb foran PC'en osv).
Klokken lades med det medfølgende USB kabel og ladeporten finnes på baksiden av klokken (Se instruksjonsbok i esken om du er i tvil).

KNAPPEFUNKSJONER

Aktivitetsregistrering:
Inni klokken finnes en aktivitetsmåler, som måler akselerasjon. Det er derfor **VIKTIG** at du har klokken på deg 24 timer i døgnet samtidig som du registrerer kostholdet ditt (også når du sover). Klokken må derfor kun tas av *hvis* dere må lade den! Alle aktivitetsmålere sliter med å registrere og "tolke" når en sykler, med mindre en har på seg pulsbelte og lagrer dette som en økt. Skal du derfor levere barna i barnehage, sykle til jobb/skole, sykle ned å handle mat osv. **SKAL** du registrere dette med puls (som en treningsøkt)! **Regelen er**: sykler du, registrerer du puls, uansett om du skal sykle 3km eller 150km. Klokken vil gi anmerkning når du har sittet for lenge i ro, og gi tilbakemelding på, hvor mye av dagens "anbefalte" aktivitet du har gjort. Ikke tenkt på hvor mange % av dagens aktivitet du har oppnådd. Dette er et fiktivt tall som Polar fremsetter og som ikke er relevant i denne sammenhengen!

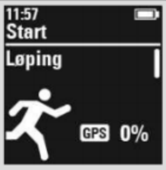
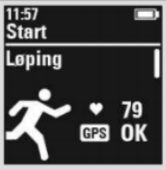
Trening:
Når du trener **SKAL** du bruke det medfølgende pulsbelte og ta opp og lagre treningen som en økt på klokken. Klokken har predefinert 6 økt-typer. Disse er følgende:
Innendørs sykling: Denne brukes når dere sykler inne på rulle, spinning osv. Brukes til alle felles intervensjonsøkter dere har med Andreas og Ole.
Sykling: Denne brukes til al type sykling ute.
Løping på tredemølle: Bruk **KUN** denne hvis du trener inne på tredemølle.
Løping: Denne brukes på al type løping ute.
Annen utendørs: Bruk denne om du skal en tur i skogen eller gå en fjelltur.
Annen innendørs: Brukes til al annen trening som gjøres inne (styrketrening, sirkeltrening osv.)

Har du egen pulsmåler du benytter under trening, må du i tillegg til denne bruke vår Polar M400 – da må du altså ha på deg 2 klokker og 2 pulsbelter under trening. Helst ser vi at du kun benytter vår måler under trening.

Starte en treningsøkt:

START EN TRENINGSØKT

Ha på deg pulssensoren, og kontroller at du har koblet den til M400.

	**Trykk på START i tidsvisning for å gå til førtreningsmodus.**
	**Velg sportsprofilen du vil bruke, med OPP/NED.** *Hvis du vil endre sportsprofilinnstillingene før du starter økten (i førtreningsmodus), trykker du på og holder nede LYS for å gå til Hurtigmeny. For å gå tilbake til førtreningsmodus trykker du på TILBAKE.* Hvis du har aktivert GPS-funksjonen, begynner M400 automatisk å søke etter signalene.
	**Hold deg i førtreningsmodus til M400 har funnet GPS-satellittsignalene og pulssensoren din for å sikre nøyaktige treningsdata.** For å fange opp GPS-satellittsignalene bør du være utendørs og i god avstand fra høye bygninger og trær. Ha på deg M400 på håndleddet med displayet i retning oppover for å oppnå best mulig GPS-ytelse. Hold M400 i horisontal posisjon foran deg og bort fra brystet. Hold armen i ro og hevet over brystnivå mens søket pågår. Stå i ro og hold posisjonen til M400 har funnet satellittsignalene. Prosentverdien ved siden av GPS-ikonet indikerer når GPS-funksjonen er klar. Når verdien når 100 %, vises OK og du er klar til å starte. M400 har funnet signalet fra pulssensoren når pulsen din vises. Når M400 har funnet alle signalene, trykker du på START. Registrering startet vises, og du kan begynne å trene. GPS-posisjonsbestemmelse går raskt ved hjelp av assistert GPS (A-GPS). A-GPS-datafilen oppdateres automatisk til M400 når du synkroniserer M400 med Flow-nettjenesten via FlowSync-programvaren. Hvis A-GPS-datafilen er utløpt eller du ennå ikke har synkronisert M400, kan det ta lengre tid å fastsette gjeldende posisjon. Du finner mer informasjon under Assistert GPS (A-GPS).

Når du er **ferdig med treningsøkten**, trykker du en gang på "tilbakeknappen" for å sette treningen på pause. Når treningen er i pause-modus trykker du og holder "tilbakeknappen" inne i min. 3 sekunder. Treningsøkten er lagret og du vil få en tilbakemelding på treningen. Trykk tilbake igjen for å gå i klokkemodus.

Synkronisering:
Klokken har begrenset lagringsplass for treningsøkter – Dette skal ifølge Polar være 24 timers trening. For å synkronisere klokken med Polar flow tjenesten må du laste ned flow-programmet

1. Gå inn på https://flow.polar.com/start
2. Trykk på knappen som definerer om du har Windows eller Mac.
3. Programmet lastes ned
4. Installer programmet
5. Kople M400 til dataen med det medfølgende USB kabel.
6. Start flow-sync (gjøres sikkert automatisk).
7. Synkroniseringen skal nå gå automatisk! Dette kan ta litt tid! Du må være på internettet for at dette skal fungere!
8. Du trenger **IKKE** en epost og passord for å logge inn på kontoen. Data blir likevel synkronisert.

Går det hele opp i fisk, ring Thomas (452 90 621) for eksperthjelp!
NB: Det er viktig at du IKKE retter eller stiller om på innstillingene på klokkene! Dette vil føre til feil tolkning av resultatene og gi et feil bilde av energiforbruk!!!

Manual finnes her:
http://www.polar.com/e_manuals/M400/Polar_M400_user_manual_Norsk/manual.pdf