Can integration of sprint interval training in the transition period maintain physical performance in highly-trained cyclists?

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ABBREVIATIONS

[La^-]	Blood lactate concentration
%VO_{2max}	Fractional utilization of VO_{2max}
60% W of VO_{2peak}	Power output corresponding to 60% of VO_{2peak}
CG	Control Group
DXA	Dual x-ray absorptiometry
ES	Effect size
HIT	High Intensity Training
HR	Heart Rate
HR_{max}	Maximal heart rate
iTRIMP	Individualized training impulse
LIT	Low Intensity Training
LT	Lactate threshold
MIT	Moderate Intensity Training
MLSS	Maximum lactate steady state
$Power_{20min}$	Average power output during 20-min all-out time-trial
$Power_{4mMol}$	Power output corresponding to lactate concentration 4 mMol·L^{-1} [La^-]
RMR	Resting Metabolic Rate
RPE	Rate of perceived exertion
RPM	Revolutions per minute
SG	Sprint Group
SIT	Sprint Interval Training
VO_{2max}	Maximal oxygen uptake
VO_{2peak}	Peak oxygen uptake
W	Watt
W_{max}	Maximal power output last minute of maximal incremental test

ABSTRACT

PURPOSE: To explore the possible effects on physical performance and performance-related variables when adding sprint intervals to endurance athlete's low intensity training regime as they enter their transition period after the competitive season.

METHODS: Sixteen highly-trained male cyclists (21.4 ± 3.6 years, 73.3 ± 6.7 kg, 185.2 ± 7.2 cm, VO_{2peak}: 73.2 ± 4.7 $ml \cdot kg^{-1} \cdot min^{-1}$) completed a ~2.5-hour race simulation protocol (including sub- and maximal incremental tests, four repeated all-out sprints and a 20-min all-out performance test). Subjects were assigned to Control- or Sprint group (CG; n=9. SG; n=7), based on VO_{2peak} and training load characteristics, for a 3-week intervention period. In addition to low intensity training (LIT), SG performed one session of sprint interval training (SIT) per week. SIT sessions consisted of 9x30s maximal sprints (4-min rest) performed in bouts of three. CG was only allowed to perform LIT during the intervention period. Both groups were instructed to reduce their weekly training load by 70% compared to their in-season load. Training load was calculated using iTRIMP.

RESULTS: There was no substantial between group effects in relative VO_{2peak} (ES -0.31 ±0.68), W_{max} (ES 0.16 ±67), Power output at 4 $mMol \cdot L^{-1}$ [La^{-}] (ES 0.07 ±0.37) or mean power output during the 20 min all-out time trial (ES 0.19 ±0.5).

CONCLUSION: SIT in addition to traditional LIT training had no meaningful effects on performance or performance-related variables in our study. However, relatively large individual variations were evident, suggesting that the impact from SIT can be quite individual. More research is needed to conclude if SIT can maintain performance during the transition period.

KEY WORDS: endurance, off-season, SIT, time-trial, athletes.

SAMMENDRAG

INTRODUKSJON

Få har undersøkt om prestasjon kan vedlikeholdes under restitusjonsperioden som etterfølger konkurransesesong, derfor undersøker denne oppgaven om inklusjon av sprint intervaller i tillegg til lav-intensitetstrening kan beholde prestasjonsevnen i godt trente utøvere sammenlignet med å bare utføre lav-intensitetstrening.

METODE

Godt trente mannlige syklister (n=16) (21.4 ± 3.6 år, 73.3 ± 6.7 kg, 185.2 ± 7.2 cm, VO_{2peak}: 73.2 ± 4.7 $ml \cdot kg^{-1} \cdot min^{-1}$) deltok i en 3 ukers intervensjonsperiode. Deltakerne gjennomførte en rittsimuleringsprotokoll (inkludert laktatprofil, 6sek all-out sprint VO_{2max}-test, 60 min rolig sykling m/ 4 repeterte sprinter og 20-min all-out tempo). Deltakerne ble delt inn i en kontroll-gruppe og en sprint-gruppe. Sprintgruppen gjennomførte en sprint-økt i uken bestående av 9x30sek all-out sprinter utført i sett på 3 og 3, med 4 min hvile etter hver sprint. Utover dette var kun lav-intensitetstrening tillatt. Treningsbelastningen ble kalkulert med iTRIMP og deltakerne ble bedt om å redusere treningsbelastningen med 70% sammenlignet med treningsbelastningen de siste 4 ukene av konkurransesesongen.

RESULTATER

Det ble ikke observert betydningsfulle effekter mellom gruppene i relativ VO_{2peak} (ES -0.31 ±0.68), W_{max} (ES 0.16 ±67), Power output ved 4 $mMol \cdot L^{-1}$ [La^{-}] (ES 0.07 ±0.37) eller gjennomsnitt Power under 20-min tempo (ES 0.19 ±0.5).

KONKLUSJON

En økt á 4.5 minutter med sprint intervaller per uke utgjorde ingen meningsfulle utslag sammenlignet med kun lav-intensitetstrening. Tematikken bør utforskes videre for å undersøke hvilke doser som er nødvendige og om vedlikeholdelse av prestasjon i resitasjonsperioden faktisk forbedrer prestasjon i den påfølgende sesongen. Da vår studie viste betydelige individuelle forskjeller vil det være avgjørende å inkludere adekvate populasjoner for å besvare dette spørsmålet.

NØKKELORD: Utholdenhet, Godt trente utøvere, Maksimalt oksygen opptak, Syklister, Ritt simulering.

STRUCTURE OF THE THESIS

The thesis is presented in two parts followed by part 3: appendices. Part 1 represents the theoretical framework, a chapter of how the study was conducted (methods) and a methodical discussion. Part 2 presents a research paper regarding the current experimental study and is written after the submission guidelines of “International journal of Sports Physiology and Performance”. Due to word limitations of the master thesis, results, discussion and conclusion of the present experimental study is only included in part 2.

Part 1:

THEORETICAL BACKGROUND AND METHODS

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1.0 Introduction

Endurance athletes perform approximately 500 to 1000 training hours per year, depending on the sport and discipline (Tonnessen et al., 2014). These hours are set into a well-organized system making sure that the athlete is in his/her best physical condition at a specific period of the year. Some athletes prepare for a season lasting several months, while others prepare for one specific race (e.g., the world championships). Many different approaches have been explored in the search for the optimal training organization (sessions duration and intensity, tapering, altitude training, etc.). A training year is divided into different phases, having a special focus on either high training volume, high intensity or race specific sessions (such as, general preparatory period, specific preparatory period, competition season, transition period etc.) (Issurin, 2010; Tonnessen et al., 2014).

Several studies have searched for the optimal "recipe" needed to win a gold medal, both in regards to the training organization, as well as interventions made to enhance specific endurance related variables, such as VO_{2max}, fractional utilization, lactate threshold and work economy (Joyner & Coyle, 2008; Seiler, 2010; Stöggl & Sperlich, 2015; Sylta et al., 2016; Tonnessen et al., 2014). However, few of these studies are performed on elite athletes as one of the issues working with the very elite, is that they regularly don't accept being randomly assigned into a training regime (Laursen & Jenkins, 2002; Stepto, Hawley, Dennis, & Hopkins, 1999). Therefore, it is at best, challenging to associate findings from less well-trained to elite athletes (Tonnessen et al., 2014).

One of the areas where limited research has been conducted is the period between the last race in the competitive season and the beginning of the preparatory period for the subsequent season. Several terms (e.g., off-season period, recovery period or transition period), and different durations (2-8 weeks) are used for this period, however in the current thesis the term "transition period" will be used. It is normal to reduce training volume and only focus on low intensity training (LIT) during this period (Lucía, Hoyos, Pardo, & Chicharro, 2000; Paton & Hopkins, 2005; Sassi, Impellizzeri, Morelli, Menaspa, & Rampinini, 2008). Some training should be maintained as total cessation of training is strongly associated to a decline in performance and performance related variables (Mujika & Padilla, 2000a, 2000b). To avoid this decline, García-Pallarés, Carrasco, Díaz, and Sánchez-Medina (2009) found that maintaining some moderate

intensity training (MIT) during a 5-week recovery period reduced the decline in performance related variables compared to total cessation of training in 14 top-level kayakers.

There's a potential research question to whether it could be beneficial to maintain the athlete's physical fitness throughout the transition period. Theoretically, starting the following preparatory period with improved fitness, could result in an improved performance in the competitive season. Different approaches to enhance performance have been performed in the general- and special preparatory period as well as during the competitive period (i.e., tapering, altitude training, block periodization). But to the author's knowledge, Rønnestad, Askestad, and Hansen (2014) is the first study to intervene with athletes training organization during the transition period. By incorporating one session of high intensity training (HIT) per 7-10 days, highly-trained cyclists maintained their performance for an 8-week intervention period and likely increased their performance during the following preparatory period (16 weeks after the intervention period).

Recently, sprint interval training (SIT) has acquired increased focus as SIT has been shown to rapidly increase physical performance in moderately trained subjects (Burgomaster, Heigenhauser, & Gibala, 2006), as well as maintaining performance, even with a markedly lower training volume (Gibala et al., 2006). SIT is, in contrast to regular HIT, performed as short (~30s) and supramaximal (>VO_{2max}) sprint-intervals, often performed as "all-out sprints" with long period of rest between each sprint (~4min) (Sloth, Sloth, Overgaard, & Dalgas, 2013).

The aim of this study was to explore the effects of adding a session of SIT per week into the athletes training regime during their off-season period when training volume is naturally reduced. Training was reduced for 3 weeks, and the athletes were only allowed to perform traditional LIT in addition to the SIT sessions. Athletes where tested before and after the intervention with a special focus on physiological performance related variables.

1.1 Overall aim and objective of the present study

The aim of the present study was to explore the possible effects of incorporating sprint interval training into a traditional low intensity training regime during the transition period for highly trained endurance athletes. The intervention period was individualized and initiated at the end of each athlete's competitive season and lasted 21 days.

Primary outcome:

The main objective of this thesis is to investigate if one session of SIT per week for 3 weeks can maintain aerobic fitness and performance compared to a control group only performing LIT.

Research question: The subjects performing one session of SIT per week will maintain their physical performance to a greater extent, compared to a control group only performing LIT.

2.0 Theoretical background

2.1 Physiological factors influencing endurance performance

Endurance performance depend upon several factors. According to Joyner and Coyle (2008), can endurance performance generally be determined by maximum oxygen uptake (VO_{2max}), work economy and the relative intensity (fractional utilization of VO_{2max}) that can be sustained throughout the exercise (Bangsbo, 2015). Several other factors will also potentially influence the actual performance such as equipment, weather conditions, optimal pacing and psychological factors. This thesis will focus on how physiological factors can impact performance.

2.1.1 VO_{2max}

VO_{2max} can be described as the maximum amount of oxygen that can be absorbed and consumed per unit of time (Hill, 1922). VO_{2max} is suggested as the single most important factor determining success in endurance performance, and is considered the best indicator of a person's aerobic capacity (Bassett & Howley, 2000; Sylta, 2017).

Endurance champions have shown 50-100% higher VO_{2max} values compared with healthy active young subjects (Joyner & Coyle, 2008). Naturally, a strong relationship is seen between VO_{2max} and race performance across large heterogenous groups. However, it is highlighted that for highly-trained athletes with already high VO_{2max} values, the relationship between performance and maximal oxygen uptake is not necessarily as clear (McLaughlin, Howley, Bassett, Thompson, & Fitzhugh, 2010). This relationship will however vary across sports and disciplines. The same differences between professionals and amateurs are not necessarily that clear in cycling, as Lucía, Hoyos, Santalla, Pérez, and Chicharro (2002) state that the main difference is seen in their ability to perform high intensity power output over a longer period of time. Athletes have also been shown to improve race performance times, without increasing VO_{2max} (Jones, 1998, 2006). These findings suggest that other factors than VO_{2max} may contribute to the differences in actual endurance performance (Bentley, McNaughton, Thompson, Vleck, & Batterham, 2001; McLaughlin et al., 2010; Sylta, 2017).

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). As few, if any, endurance

events are performed at VO_{2max} (McLaughlin et al., 2010), the ability to utilize a high percentage of one's VO_{2max} is seen as an important component potentially influencing the performance. The differences in fractional utilization can be exemplified by imagining two identical persons; If both have the same VO_{2max} and given that all other factors are equal (i.e., pacing, psychology, physical characteristics etc.), the one that can utilize the highest percentage of his/hers VO_{2max} will outperform the other in an endurance race.

According to Støa, Støren, Enoksen, and Ingjer (2010), fractional utilization of VO_{2max} is negligible for time performance lasting <20 min, but the importance increases as the duration of the competition extends beyond 30 min (Davies & Thompson, 1979). Due to methodological challenges of measuring the utilization rate during competition, the fractional utilization at lactate threshold (percent of VO_{2max} at lactate threshold) is often used as an indirect measure of an athlete's utilization rate (Impellizzeri, Marcora, Rampinini, Mognoni, & Sassi, 2005).

2.1.3 Lactate threshold

The term Lactate threshold (LT) refers to a person's highest velocity (or power output) where there is a steady state between lactate production and lactate elimination, often called maximum lactate steady state (MLSS). Several methods can be used to calculate a person's LT and there is a close relationship between the calculation of different LT's and MLSS (Sylta, 2017). It should however be mentioned that differences are observed and that LT is one of the most debated areas within exercise physiology (Seiler, 2011).

To evaluate submaximal endurance capacity, a fixed lactate concentration [La^-] is frequently used, whereas 4 $mMol \cdot L^{-1}$ onset of blood lactate accumulation (OBLA) may represent the most common value (Sylta, 2017). Critically, a fixed value does not take into account the interindividual physiological differences and can, therefore under- or overestimate real submaximal endurance capacity (Seiler, 2010; Sylta, 2017).

2.1.4 Gross efficiency / work economy

Work efficiency can be referred to as the ratio between work output and oxygen cost, and is often calculated as gross efficiency. Jobson, Hopker, Korff, and Passfield (2012) were able to re-analyze data from five previous studies and found that variation in gross efficiency explained 34% and 26% of the variation in power output during long and short cycling time-trials,

respectively. Furthermore, work efficiency can, according to Conley and Krahenbuhl (1980), account for up to 2/3 of the variation in performance in groups of highly trained athletes with similar abilities. These results are in line with previous studies and gross efficiency is therefore suggested to be a key determinant of endurance performance (Joyner & Coyle, 2008). This should be considered when evaluating endurance performance, as a change in VO_{2max} is often highlighted as the key physiological variable when evaluating the response to endurance training or a training intervention designed for enhancing performance. Two studies by Jones (1998, 2006) on track and field runner Paula Radcliff, is frequently used for exemplifying this point, as she enhanced performance without increasing her VO_{2max}. It is therefore highlighted that for trained experienced athletes with already well developed Oxygen power (i.e., VO_{2max}), both LT and work efficiency may be more responsive (Sylta, 2017).

Summary of section 2.1

Endurance performance depends upon several factors, where VO_{2max}, fractional utilization of VO_{2max}, lactate threshold and gross efficiency are the most frequently used. VO_{2max} may be the single most important factor when determine endurance performance in a large population, but one can assume that in a population with well-trained athletes (e.g., competitive cyclists) factors beyond VO_{2max}, may be equally important. Some factors are subject to change over a shorter period of time (e.g. can VO_{2max} be reduced quickly without enough training, and some can take years to improve (i.e., gross efficiency/technique).

2.2 Organization of training influences endurance performance

Athletes´ training regime consists of manipulation of different physiological variables. Endurance training can be divided into aerobic- or anaerobic endurance training. Aerobic training can be categorized into three overlapping intensity zones; LIT, MIT and HIT (se Figure 1 and Table 1). These zones correspond to heart rate ranges of 50-80%, 65-95% and 80-100% of maximal heart rate (HR_{max}), respectively (Bangsbo, 2015). A relationship between heart rate (HR) and lactate values is also frequently used in determination of intensity zones. LIT is performed below the first lactate turnpoint (LT_1), while HIT is performed above the second lactate turnpoint (LT_2, also referred to as MLSS. Table 2) (Seiler, 2010). It should be pointed out that these zones do not consider the individual variations between HR and corresponding lactate [La^-] values. Furthermore, HR can be influenced by day to day variability making it difficult to use absolute values to determine intensity zones (Sylta, 2017).

Anaerobic training can be defined as: "*training performed at supramaximal intensities (>VO_{2max}) and where the primary aim is to stimulate the anaerobic energy production (Bangsbo, 1994)*". Anaerobic training can also be divided into three different training zones with increasing intestines; Maintenance training lasting 10-90 s with rest <3x exercise time, Speed endurance production lasting 10-40 s with rest >5x exercise time, and Speed training lasting 2-10 s with rest >10x exercise time (Bangsbo, 2015). The overall goal of anaerobic training is to increase the athlete's potential to perform high intensity exercise (Bangsbo, 2015).

2.2.1 Intensities and duration; LIT, MIT, HIT.

Training is normally divided into a three or five zone model as exemplified in Figure 1. Zone 1 training or LIT is the most frequently used and there is little doubt that endurance athletes accumulate most of their training hours in this zone (Seiler, 2010; Stöggl & Sperlich, 2015; Tonnessen et al., 2014). Training is performed as prolonged continuous training lasting from one to several hours depending on the various endurance sports/events and the athletes' individual preferences. Zone 2 or MIT training is often referred to as threshold training and is performed between the first and second lactate turnpoint. Most of the training in this zone is performed as continued training, but with shorter time than in zone 1 and with higher speed. HIT or zone 3 training (defined as training intensities from MLSS, LT_2 or VT_2 to "all-out" supramaximal exercise intensities) involves repeated short-to-long bouts of relatively high-intensity exercise interspersed with recovery periods (interval training), or training at high-intensities executed as continuous work (Buchheit & Laursen, 2013). It is common for athletes to favor HIT performed as interval training, as it allows athletes to accumulate additional minutes at higher intensities compared to training performed in a continuous mode (Billat et al., 2000). High intensity training (HIT) and high intensity interval

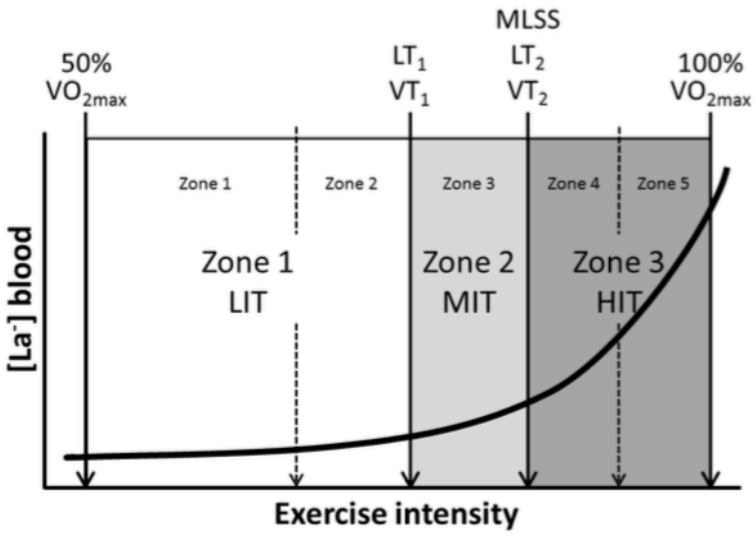

***Figure 1**: Relationships between intensity and lactate accumulation in a 3/5 zone model. A 3-zone intensity model based on identification of lactate- and ventilatory thresholds (solid lines), and OLT's 5-zone model (dashed lines). Relative width of intensity zones requires individual adjustments. Redrawn after Seiler 2010*

training (HIIT) are terms that are used interchangeably. In the present study, the term HIT will be used for both high intensity training and high intensity interval training. Table 1 shows the guidelines from the Norwegian Olympic Federations, to witch intensity and duration normally used when prescribing and monitoring training in the different zones for endurance athletes.

Table 1: Example of a five-zone intensity scale to prescribe and monitor training of endurance athletes.

Intensity Zone	**VO_2 (% max)**	**Heart Rate (% max)**	**Lactate ($mMol \cdot L^{-1}$)**	**Typical accumulated duration within zone**
1	50-65	60-72	0.8-1.5	1-6 h
2	66-80	72-82	1.5-2.5	1-3 h
3	81-87	82-87	2.5-4.0	50-90 min
4	88-93	88-92	4.0-6.0	30-60 min
5	94-100	93-100	6.0-10.0	15-30 min

Note: This scale is typical of intensity zone scale used for endurance training prescription and monitoring. The scale above was developed by the Norwegian Olympic Federation as a general guideline based on years of testing of cross-country skiers, rowers and biathletes. Drawn after the guidelines of the Norwegian Olympic federation and Seiler (2010).

Today, the training intensity distribution (TID) among endurance athletes differs between individuals and sports, but in general, the largest volume of the training is performed in zone 1, with the remaining training performed in zone 2 or 3 (Laursen, 2010). Several authors have made TID models for explaining the organization of athletes training programs in different phases across the year or in specific periods. Among the most frequently used is the *pyramid model*. In this model, most of the training is performed in zone 1, some in zone 2 and the remaining in zone 3 (Stöggl & Sperlich, 2015). In addition, Seiler and Kjerland (2006) found that elite athletes seem to spend most of their time in zone 1 (~80%) and the remaining time in zone 3 (~20%) with little or no time in zone 2. This model has been named the *polarization-model*. Despite that most of the training is performed as LIT, there is a strong consensus that for elite endurance athletes, HIT is the necessary component for enhancing performance (Seiler, 2010). However, there is currently, no consensus of "best practice" regarding the organization of HIT (Tonnessen et al., 2014).

2.2.2 Different regimes of HIT

Buchheit and Laursen (2013) suggest that HIT consists of manipulation of up to nine different variables; 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. Manipulation of any of these variables may affect the acute physiological responses to HIT.

There are several ways to perform HIT, but it can roughly be divided into longer work intervals of ~3-5 min at relatively high exercise intensity (i.e., between LT_2 and maximal power output (W_{max})) and shorter intervals of ~15-45 s at even higher exercise intensity (>W_{max}) than used during longer intervals (Tschakert & Hofmann, 2013; Åstrand & Rodahl, 1986). The search for the optimal duration and intensity for HIT has been going on for decades, where the question is whether it could be more beneficial to perform shorter intervals (which allows an individual to accumulate more time near VO_{2max}) or longer intervals to gain additional time at high intensity >90% (Åstrand & Rodahl, 1986). Currently, there's no consensus and question are still under debate (Seiler & Tønnessen, 2009; Tonnessen et al., 2014)

In recent years, some sports scientists have found that including a number of repeated sprints at supramaximal intensities (>VO_{2max}) have induced similar performance related adaptations as "classical" HIT. Several studies have included a sprint interval training (SIT) regime to explore these effects. Many of these studies conclude that there are similar adaptations between HIT and SIT, and that SIT represent a time-efficient way to train (Gibala et al., 2006). SIT can be described as a category of HIT, but at the highest end of the intensity spectrum, performed as "all-out" or a given supramaximal intensity. (Sloth et al., 2013).

Some studies highlight positive effects in aerobic performance and VO_{2max}, while some conclude that no effect is seen after a period of SIT (Sloth et al., 2013). A limitation to SIT-studies is the substantial difference in training status in participants included in these studies, as well as different methods of conducting these trials. Two review papers seem to conclude that recreational active, sedentary and young healthy adults can benefit from SIT (Gist, Fedewa, Dishman, & Cureton, 2014; Sloth et al., 2013). However, the is limited knowledge on how SIT can impact well-trained endurance athletes.

Some studies including a SIT regime, have reduced subjects training volume while a control group perform traditional endurance training (45-90 min LIT/MIT). Iaia et al. (2009) conducted a 4-week trial on moderately endurance trained runners. The experimental group replaced their habitual training with speed endurance training (training volume reduced by 65%) while a control-group maintained their regular training. After 4 weeks, the experimental group improved their running economy ($p<0.05$) compared to the control group, while VO_{2max} and 10km race times remained unchanged in both groups. This might be an important finding regarding the optimal training organization of elite endurance athletes. An overview of studies including a HIT or SIT regime is presented in table 2 and 3.

2.2.3 Transition period

As endurance athletes start their transition period, they lower their training load, and it is common to only focus on LIT during this period (Lucía et al., 2000; Paton & Hopkins, 2005; Sassi et al., 2008). Only focusing on LIT for a longer period of time (i.e., under the transition period), normally results in a performance decline. The magnitude of this decline depends on several factors, such as initial fitness level, magnitude of training stimulus (or total absence of training), and total duration of the period (Mujika & Padilla, 2000a, 2000b). Under other circumstances where training is reduced (i.e., tapering), it is common to still maintain the training intensity (Mujika & Padilla, 2003). Interestingly, it seems like few have explored the possibilities to incorporate HIT during the transition period. Rønnestad et al. (2014) explored the possible effects of adding sessions of HIT into well-trained cyclists transition period. They found that adding a HIT session of 30 min (6x5 / 5x6 min, rest: 2,5 / 3 min) every 7-10 days for an 8-week period, maintained and likely increased performance from the end of one season to the beginning of the subsequent season. Interestingly, the method of Iaia et al. (2009), only required a SIT session of 4.5 min performed three times a week (total load of ~13.5 min). There is, however, a challenge as athletes strongly desire a period of physical and mental rest after a long competition season. Incorporation of any HIT should therefore be, as all training, individualized (Rønnestad et al., 2014).

Table 2: Studies involving classic interval training (HIT).

Study	Sport/Level	Design	Intensity?	Intervention period	Outcome
Rønnestad et al. (2014)	Well trained cyclists (n=13) (~69 ml/kg^{-1}/min^{-1})	G1: Control G2: 5x6min/6x5min, r=50%	% of HR_{max} G1: 60-80% G2: 88-100%	8 (16) weeks G2: 1 session/7-10 day.	G2: ↑$Power_{40min}$, G2: Likely increase in: VO_{2max}, PO_{4mMol} compared to G1.
Rønnestad, Hansen, Vegge, Tønnessen, and Slettaløkken (2015)	Well trained cyclists (n=20) (~66 ml/kg^{-1}/min^{-1})	G1: 3x9.5-min (13x30s), r=15s/3min G2: 4x5-min, r=2.5min	Highest possible intensity: Isoeffort G1: ~363W G2: ~324W	10 weeks, 2 sessions/week. + LIT training.	G1: ↑VO_{2max}, ↑W_{max}, ↑PO_{4mMol}, ↑$Power_{40min}$ G2: ↑$Power_{40min}$
Driller, Fell, Gregory, Shing, and Williams (2009)	Well trained Rowers (n=10) (~4.3 L/min^{-1})	G1: 8x2,5min, r=~Time to 70%HR_{max} G2: 1x55-60min.	G1: 90% of νVO_{2peak} ([a^-] ~10mMol·L^{-1}) G2: W @~ 2-3 mMol·L^{-1}	4 (8) weeks (crossover design). 1-2 sessions / week.	G1: ↑VO_{2peak}, ↑$Power_{2000m}$, ↑TT_{2000m}.
Helgerud et al. (2007)	Healthy students (n=40) (~55 ml//kg^{-1}/min^{-1})	G1: 45min G2: 25min G3: 47x15s, r=15s G4: 4x4min, r=3min	% of HR_{max} G1: 70% G2: 85% G3: 90-95%, r=70% G4: 90-95%, r=70%	8 Weeks 3 sessions / week	G1: ↑RE G2: ↑RE G3: ↑RE, ↑VO_{2max} G4: ↑RE, ↑VO_{2max}
Menz, Strobl, Faulhaber, Gatterer, and Burtscher (2015)	Well-trained individuals (n= 35) (~63 ml/kg^{-1}/min^{-1})	G1: Control G2 4x4min, r=4min	% of HR_{max} G2: 90-95%	3 Weeks 3-4 sessions / week	G2: ↑$VO_{2max.}$ (Not significant p>0.05 compared to G1)
Seiler, Jøranson, Olesen, and Hetlelid (2013)	Trained cyclists (n=35) (~53 ml/kg^{-1}/min^{-1})	G1: Control G2: 4x16min, r=3min G3: 4x8min, r=2min G4: 4x4min, r=2min	G1: Low intensity Isoeffort: G2: ~ 88% HR_{max} G3: ~ 90% HR_{max} G4: ~ 94% HR_{max}	7 weeks G1: 4-6 sessions/week G2, G3 & G4: 2 sessions/week + 2-3 LIT sessions/week	G2: ↑VO_{2peak}, ↑W_{max}, ↑TTE_{80}, ↑PO_{4mMol} G3: ↑VO_{2peak}, ↑W_{max}, ↑TTE_{80}, ↑PO_{4mMol} G4: ↑W_{max}, ↑TT_{80}, ↑PO_{4mMol} G3: ↑VO_{2peak} compared to G2 & G4 G3: Tendency towards ↑W_{max}, ↑TTE_{80}, ↑PO_{4mMol} compared to G2 & G4

Skovereng et al. (2018)	Well-trained cyclists (n=60) (~61 ml/kg^{-1}/min^{-1})	G1: 4x4/8/16min, r= 2min	G1: Isoeffort	12 weeks, 24 HIT sessions. Ad libitum LIT.	↑VO_{2peak}, ↑$Power_{40min}$, ↓GE, ↑PPO.

GE = Gross efficiency. HR_{max} = Maximal heart rate. ml/kg^{-1}/min^{-1} = relative oxygen consumption. ml/min^{-1} = Absolute oxygen consumption. $PO_{4mMol \cdot L}$: Power output corresponding to [La^{-}] concentration of 4 mMol·L^{-1}. $Power_{40min}$ = Average power output during 40-min time-trial. PPO = Peak power output. r = rest. RE: Running economy. TT = time-trial. TTE_{80} = Time to exhaustion at 80% of VO_{2peak}. V_{LT} = Velocity at lactate threshold. W_{max} = Power output at VO_{2max}.

Table 3: studies involving SIT – Sprint interval training.

Study	Sport/level	Design	Intensity	Intervention period	Outcome
Bailey, Wilkerson, DiMenna, and Jones (2009)	Recreational active students (n=24) (~44 ml/kg^{-1}/min^{-1})	G1: 4-6x30s, r=4min G2:14-25-min G3: Control	G1: all-out Wingate G2: 90% of GET (gas exchange threshold) G3: No training	2 weeks, 3 sessions / week.	G1: ↑VO_{2peak}, ↑Workrate (W), ↑VO_2Kinetics
Bangsbo, Gunnarsson, Wendell, Nybo, and Thomassen (2009)	Well-trained runners (n=17) (~63 ml/kg^{-1}/min^{-1})	G1: 8-12x30s, r=3min 4x4min, r=2min G2: Control	G1: ~95% max speed. >85% of Max HR G2: Regular training	6-9 weeks. G1: 2-3 SIT + 1 HIT per week	G1: ↑TT_{3km}, ↑TT_{10km}, ↑TTE, - VO_{2max} G2: - VO_{2max}
Bayati, Farzad, Gharakhanlou, and Agha-Alinejad (2011)	Non-active students (~47 ml/kg^{-1}/min^{-1})	G1: 3-5x30s, r=4min G2: 6-10x30s, r=2min G3: Control	G1: All-out Wingate G2: 125% P_{max}	4 weeks 3 sessions / week	G1: ↑P_{max}, ↑T_{max}, ↑PPO, ↑MPO, ↑ $[La^{-}]_{max}$ G2: ↑P_{max}, ↑T_{max}, ↑PPO
Burgomaster et al. (2008)	Active untrained (n=20) (~41 ml/kg^{-1}/min^{-1})	G1: Control, 40-60min G2:4-6x30s, r=4.5min	G1:65% of VO_{2peak} G2: all-out Wingate	6 Weeks G1= 5 sessions / week. G2= 3 sessions / week	No differences between groups
Burgomaster et al. (2006)	Helthy young men (n=16) (3.85 L/min^{-1})	G1: 4-7x30s, r=4min G2: Control	G1: All-out Wingate	2 weeks, 6 sessions	G1: ↑TT_{250KJ}, ↑PPO, ↑[La^{-}]
Burgomaster, Hughes, Heigenhauser, Bradwell, and Gibala (2005)	Helthy Individuals (n=8) (~45 ml/kg/min)	G1: 4-7x30s, r=4min G2: Control	G1: All-Out Wingate	2 Weeks, 6 sessions	G1: ↑Endurance capacity (time at ~80% of VO_{2peak}) Time to fatigue
Esfarjani and Laursen (2007)	Moderately trained runners (n=17) (~51 ml/kg^{-1}/min^{-1})	G1: 8x60% of T_{max}, r=3.5min G2: 12x30s, r=4.5min G3: Control, 60min	G1: V_{VO2max} G2: 130% of V_{VO2max} G3: 75% of V_{VO2max}	10 Weeks G1 & G2: 2 sessions (+ 2 recovery runs / week G3: 4 sessions / week	G1: ↑VO_{2max}, ↑T_{max}, ↑V_{LT}, ↑TT_{3km} G2: ↑VO_{2max}, ↑T_{max}, ↑TT_{3km} G3: -

Gibala et al. (2006)	Active men (n=16) (~4 L/min^{-1})	G1: Control, 90-120min G2: 4-6x30s, r=4min	G1: 65% of VO_{2peak} G2: "all-out" ~250% of VO_{2peak}	2 weeks 3 sessions / week	G1: ↑TT_{750KJ}, G2: ↑TT_{750KJ},
Iaia et al. (2009)	Endurance trained runners (n=17) (~55 ml/kg^{-1}/min^{-1})	G1: 8-12x30s, r=3 min G2: Control	G1: ~93% of 30s all-out performance G2: AMT	4 weeks. G1: ~3.5 times per week G2: ~4 times a week.	G1: ↑VO_2 submax, -[La^-], -VO_{2max}, -10km. G2: -VO_2 submax, -[La^-], -VO_{2max}, -10km.
Laursen, Shing, Peake, Coombes, and Jenkins (2002)	Well trained Cyclists and triathletes (n=38) (~65 ml/kg^{-1}/min^{-1})	G1: 8x60% of T_{max}, r=120% of T_{max} G2: 8x60% of T_{max}, r=65% of HR_{max} G3: 12x30s, r=4,5min G4: Control	G1: P_{max} G2: P_{max} G3: 175% of PPO	4 Weeks 2 sessions / week	G1, G2 & G3: ↑VO_{2peak}, ↑PPO ↑TT_{40km}, ↑VT_1, ↑VT_2.
Skovgaard, Almquist, and Bangsbo (2018)	Trained male runners (n=8) (~59 ml/kg^{-1}/min^{-1})	G1: 10x30s, r=3.5min (AMT=30-60min)	G1: All-out (60-80% HR_{max})	2 periods á 40 days (separated by 80 day of habitual training): 10 SET 10 AMT	P1: ↑VO_{2max} (2.1%), ↑TT_{10km} (2.9%), ↑RE (60% *v*VO_{2max}) (1.9%), ↑RE (*v*10km) (1.6%) P2: ↑VO_{2max} (2.6%), ↑TT_{10km} (2.3%), ↑RE (60% *v*VO_{2max}) (1.9%), ↑RE (*v*10km) (2.0%) P1 vs P2 ↑RE
Stepto et al. (1999)	Cyclist, well trained (n=20) (~4.8 L/min^{-1})	G1: 12x30s, r=4.5 min G2: 12x60s, r=4min G3: 12x2-min, r=3min G4: 8x4-min, r=1.5min G5: 4x8-min, r=1min	% of P_{max} G1: 175% G2: 100% G3: 90% G4: 85% G5: 80%	3 weeks 2 sessions / week	G1: ↑TT_{40km} & ↑PPO G4: ↑TT_{40km} & ↑PPO

[La^-]$_{max}$ = Maximal lactate concentration. AMT: Aerobic Moderate intensity (60-80% of max HR). ml/kg^{-1}/min^{-1} = relative oxygen consumption. ml/min^{-1} = Absolute oxygen consumption. MPO = Mean Power Output. P_{max} = Highest power output reached during maximal incremental test. $PO_{4mMol·L}$: Power output corresponding to [La^-] concentration of 4 mMol·L^{-1}. $Power_{40min}$ = Average power output during 40 min time-trial. PPO = Peak Power Output. r = rest. RE: Running economy. SET: Speed endurance training. T_{max} = Time to exhaustion at P_{max}. TT = time-trial. V_{LT} = Velocity at lactate threshold. VT_1 = First ventilatory threshold. VT_2 = Second ventilatory threshold. *v*VO_{2max}: Velocity at VO_{2max}.

Rønnestad et al. (2014) succeeded in avoiding the performance decline normally associated with the transition period, but with the cost of performing ~30 min HIT per week. Iaia et al. (2009) maintained fitness using SIT, despite a ~65% reduction in training volume. Based on the findings regarding SIT, there's an interesting question to whether elite athletes can benefit from as little as one session SIT per week (~4.5 min). Due to the difficulties of recruiting professional- or elite athletes, we aim to recruit highly-trained cyclist to answer this question.

Summary of section 2.2

Athletes perform the majority of their training as LIT. Different models are suggested to describe the distribution of moderate to high intensity training (Stöggl & Sperlich, 2015). Åstrand and Rodahl (1986) started their search for which intensity and what duration potentially inducing the best performance already in the 1960's but didn't succeed. As of today, the optimal organization of HIT still remains to be determined (Tonnessen et al., 2014).

SIT has proven to be time-effective, as it maintains performance with reduced training volume/load. However, to the author's knowledge, no high level/well trained endurance athletes have been included in any SIT study. Few, if any, endurance athletes would allow scientists to experiment with their training in season. The transition period is, therefore, a golden opportunity to take advantage of the natural reduction in training volume and explore the potential effects of SIT. At the same time, the off-season is a period of vacation and relaxation, so any high intensity training regime would need full dedication and effort from the participants included in the study.

3.0 Methods

3.1 Design

The intervention period was individualized and started 3-4 days after the last race of the competitive season for each cyclist but included training load the last 4 weeks (28 days) prior to the start of the intervention period (lead-in phase). Training load from the race simulation protocol was used as the last training session in the lead-in phase. In the intervention period subjects were instructed to reduce their training by 70%, compared to their training load during lead-in phase. Post-testing was completed after the 3-week intervention period. All subjects were invited back for a voluntary re-test ~6 weeks after completing post-testing (not discussed in this thesis). Subjects were free to organize their training to their own preferences during this final period. A time line for the project is presented in Figure 2. Protocol for test day- one and two are described under section 3.4 and 3.5, respectively.

3.1.1 Experimental design

Cyclist were divided into two groups; sprint and control. Each subject in both groups was asked to decrease their weekly training load by 70% and only perform LIT training. Subjects in the control group (CG) were asked to perform one session (90 min at 60% of VO_{2peak}) per week at the test laboratory. The sprint group (SG) performed one session per week (90 min at 60% of VO_{2peak}) which included 9 x 30-s all-out sprints. Sprints was performed in 3 x 3 sets per session. Set one started at 20:00 min, set two started at 43:30 min and set three started at 67:00 min. Each sprint was performed as an all-out Wingate sprint. A fingertip blood sample for [La^-] was taken after each set.

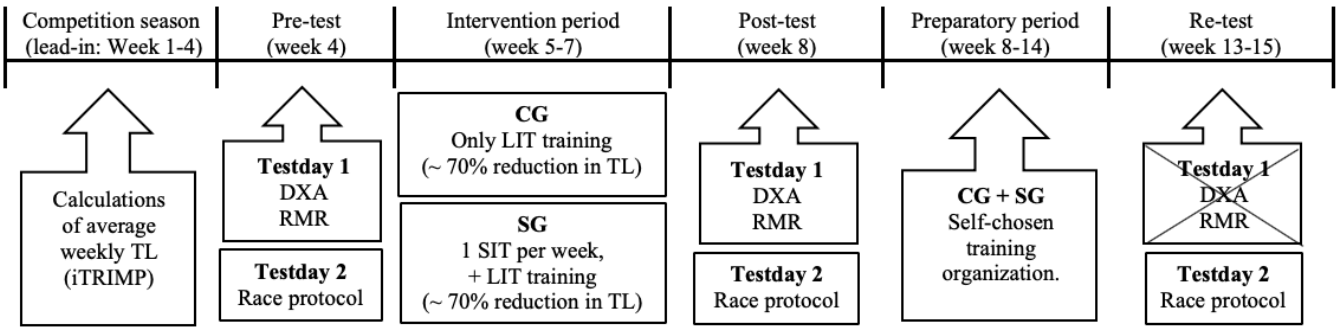

Figure 2: Timeline for the study. TL: Training load. CG: Control Group. SG: Sprint Group. DXA: Dual x-ray scan. RMR: Resting metabolic rate. LIT: Low intensity training. SIT: Sprint interval training.

3.2 Subjects

Twenty-two (n=22) subjects were assessed for participation in the study. Two subjects were excluded before pre-test due to sickness and injury. Twenty (n=20) male cyclists categorized as highly trained (Jeukendrup, Craig, & Hawley, 2000) competing at a national level volunteered to participate in this study. After being fully informed of the risks and stresses associated with the project, all subjects signed a written consent (appendices 2-3) to participate in the study. One subject was excluded as he refrained to compile with the intervention protocol (i.e., reduce training load), before the cyclists were divided into two groups; control (n=10) or Sprint (n=9). The groups were matched on VO_{2peak} results from pre-tests and training load variables prior to the study to ensure homogenous groups. If athletes strongly desired attendance to one group, they were allowed to choose. The reason for this is that well-trained athletes do usually not accept being randomly assigned to a group in an intervention regime effecting their training (Rønnestad et al., 2014). Two subjects withdrew themselves from the study (circumstance unrelated to the intervention) and one subject was excluded due to sickness/injury. A total sample of sixteen subjects (n=16) completed the intervention including pre- and post-tests (age: 21.4 ± 3.6 years; height: 185 ± 7 cm; body mass: 73.3 ± 6.7 kg; VO_{2peak}: 73.2 ± 4.7 $ml^{-1} \cdot kg^{-1} \cdot min^{-1}$), further 12 subjects also completed re-testing six weeks later. An overview is presented in the flow-chart (Figure 3). This study was performed according to the ethical standards established by the Helsinki Declaration of 1975 and was approved by the local ethical committee at the University of Agder, Kristiansand.

3.3 Baseline testing

Physical tests were performed at the start of each individual cyclist´s off-season, three to four days after the last race in their competition season. On test day one, each subject arrived fasted to the test location between 06.00 am and 07.30 am. Subjects underwent a dual x-ray absorptiometry scan (DXA), measuring body-composition and bone mineral density, measurement of resting metabolic rate (RMR) and a blood sample was taken for measurement of hormonal biomarkers (Procedure described elsewhere; Torstveit, Fahrenholtz, Stenqvist, Sylta, and Melin (2018)). All subjects were asked to arrive hydrated and restrain from intense exercise on the day prior to testing. All cyclists performed a standardized training session after the tests on test day one. On test day two, subjects were instructed to not consume coffee or other products containing caffeine before and under the tests. Some subjects completed both

test day one- and test day two protocol on the same day (morning and afternoon) due to practical reasons (i.e., distance to test-location). Post-tests and re-tests were performed accordingly.

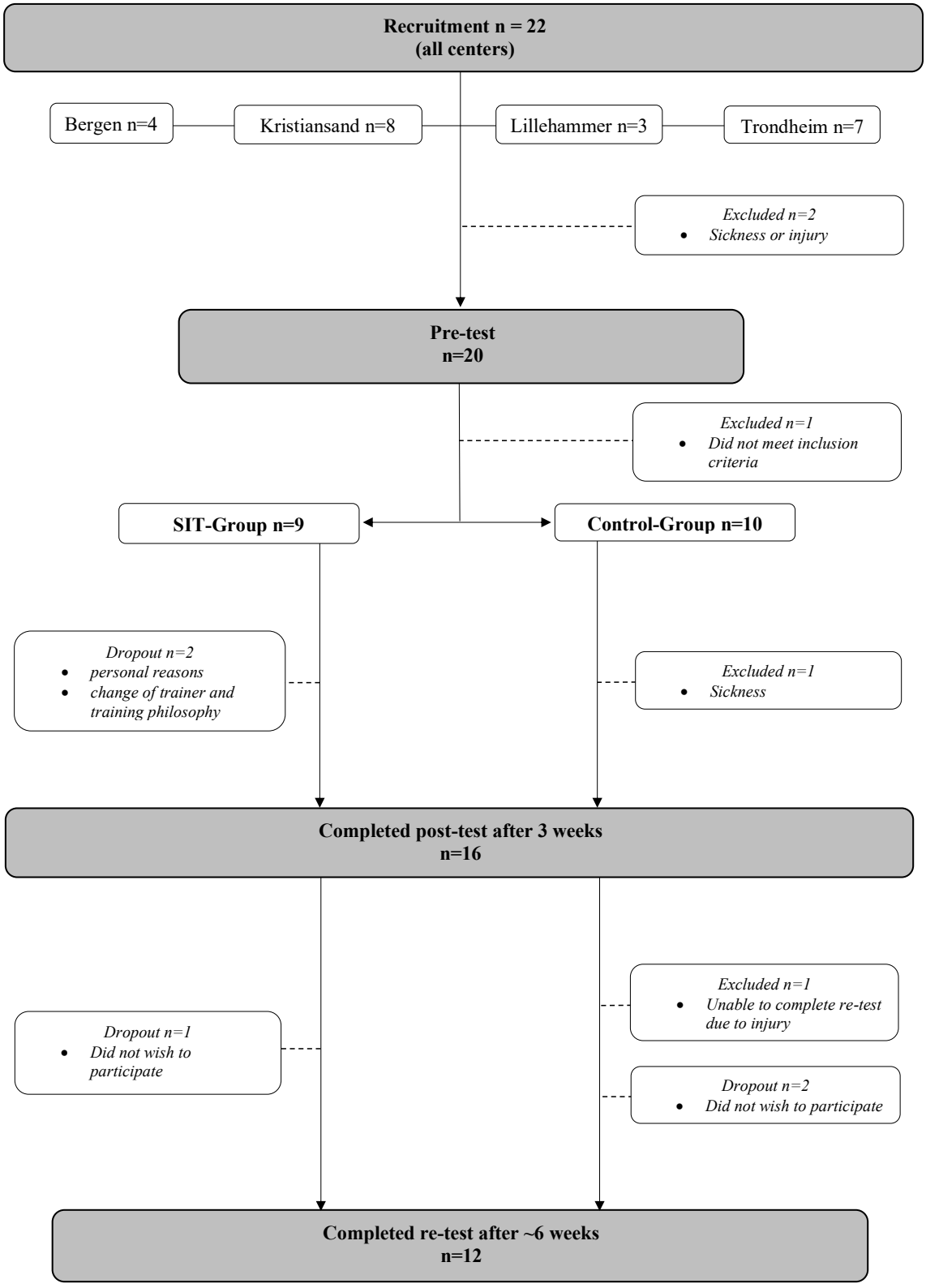

Figure 3: Participants flow-chart and reasons for drop-out or exclusion of subjects

On test day two, subjects arrived at the same test laboratory for performance-tests. The test-protocol started with a *strength-test* (Keiser AIR300 leg press, Sport health equipment INC., Fresno, CA), followed by a *submaximal incremental test* to measure gross efficiency and power output at 4 $mMol \cdot L^{-1}$ (lactate threshold). After 5 min recovery at 100 Watt (W), a *6-s all-out sprint* from zero cadence was performed. After 5 min cycling at 100 W the cyclists performed a *maximal incremental test* to determine VO_{2max} and maximal power output (W_{max}). In the following 10 min, each cyclist was free to step off the bike if they preferred so. After 10 min, each cyclist started cycling at 60% W of their individual VO_{2peak}. This steady state intensity was maintained for 60 min, with the exception of a period between 36-54 min where the subjects performed *4 x 30 s all-out Wingate sprints*. Each sprint was followed by 1 min passive recovery and 3 min active recovery at 100 W. At the 60-min time point, the cyclists started a self-paced *20-min all-out time-trial*. Figure 4 presents a schematic overview of the race simulation protocol.

The same test order was performed for post-testing. At re-test, only the protocol described under test day two was conducted. All subjects completed post- and re-tests 21 ± 1 and 42 ± 5 days, respectively, after pre-tests. All subjects performed post- and re-tests at the same time of day (± 2 h) at the same laboratory and under similar environmental conditions (18-21°C, 39-65% relative humidity [28% at re-test], 998-1020 Barometric pressure; hPa). All testing was performed on the same electromagnetically braked cycle ergometer (Lode Excalibur Sport, Lode BV, Groningen, The Netherlands), which was adjusted according to each cyclist's preference for seat height, horizontal distance between tip of seat and bottom bracket, and handle bar position. Crank length was standardized to 172.5 mm for all cyclists. Identical positions were used for each subject at all tests. The subjects were allowed to choose their preferred cadence during all cycling, and they used their own cycle shoes at all tests. The same test leaders supervised all tests and strong, consistent verbal encouragement was given during testing to ensure maximal effort. VO_2 was measured using Oxycon Pro™ (Oxycon, Jaeger GmbH, Hoechberg, Germany) with a mixing chamber and 30-s sampling time (60-s during RMR measurement) using a two-way T-shape non-rebreathing valve and a reusable nose clip series 9015 (Hans Rudolph, Kansas, MO, USA). The flow turbine (Triple V, Erich Jaeger) was calibrated according to the manufactures recommendations. Gas sensors were calibrated via an automated process using two certified calibration gases of known concentrations. VO_2 calibration procedure was performed three times during the cycling protocol; (1) before initiating the submaximal incremental test, (2) after the incremental test to exhaustion and (3)

before the 20 min all-out. Blood [La^-] during all tests and sprint sessions were analyzed using a stationary lactate analyzer (EKF BIOSEN, EKF Diagnostics, Cardiff, UK) calibrated according to manufactures guidelines before each subject. HR was measured by the athlete's own heart rate monitor (*Polar* Elektro Oy, Kempele, Finland. *Garmin*, Kansas City, Kansas, USA)

3.4 Test day one

3.4.1 DXA & RMR

Subjects arrived at the laboratory between 6 and 8 am and the testing was estimated to last approximately 1 - 1.5 hours. Best practice for measurement of RMR are described by Compher, Frankenfield, Keim, Roth-Yousey, and Group (2006), and our subjects performed testing accordingly. Briefly, all subjects arrived in a fasting state, and were instructed not to eat or drink anything the same morning. No use of alcohol or tobacco was allowed for a minimum of 12 hours prior to the test. Furthermore, the subjects were instructed to travel to the lab using only motorized transportation, and under no circumstances where they allowed to walk or ride a bicycle. Training was restricted to a maximum of 60 min of low intensity endurance training the day before the test, and at least 12 hours before the test (strength training was not allowed).

Body composition including bone mineral density, percentage body fat and fat-free mass was measured with DXA (Prodigy, Lunar, software version 5.6). All scanning and analyses were conducted by the same operator and all measurements were double checked for possible mistakes in the analysis. DXA was calibrated each day using manufactories guidelines. A quality assurance test by using a calibration block and a quality assurance test measuring the aluminum spine phantom to monitor the stability of the scanner over time was performed each test day.

RMR was measured via indirect calorimetry using a canopy hood (Oxycon Pro) and a stationary oxygen analyzer (Oxycon Pro) with 60-s sampling time. The subjects were instructed to lie on a bed for ~15 min, in order to minimize errors in measuring RMR before the test began (Compher et al., 2006). The measuring of RMR lasted a total of 30 minutes, bringing the total resting time to ~45 minutes. The Oxycon Pro was calibrated before the test was initiated. During the RMR test, the subjects were not allowed to move, talk or fall asleep and were checked up on every 5 min by lab personnel. A HR monitor from Polar (M400, Polar Elektro Oy, Kempele,

Finland) was used to record the lowest resting HR during the test. An RMR test was declared successful if the coefficient of variation for VO_2 and VCO_2 for the last 20 minutes of the test was ≤10% (Compher et al., 2006).

3.5 Test day two

3.5.1 10RM Keiser strength test

After a 10-min self-paced warm-up (150-200 W) on a cycle ergometer (Lode Excalibur Sport, Lode BV. Groningen, The Netherlands) each participant underwent a 10RM leg press strength-test on a Keiser AIR300 leg press (Keiser Sport health equipment INC., Fresno, CA). Subjects completed a predetermined 10 RM manufactural protocol where the expected 10RM load was set to 250 kg for all subjects. The protocol consisted of incremental loads starting at 41 kg and where the 10^{th} load was 250kg. The Keiser A300 horizontal leg-press dynamometer uses pneumatic resistance and measures force and velocity across each effort (Colyer, Stokes, Bilzon, Holdcroft, & Salo, 2018) The test was performed in a seated position with knee joints placed in a 90-degree angle. Each subject was instructed to push as quickly and explosively as possible. The test was terminated when the subject failed to increase or maintain Power.

3.5.2 Blood lactate profile test

The subjects started with a 10-min warm-up cycling at 150 W before the test commenced at 175 W. The test continued with a power output increase of 50 W every 5 min. Blood samples were taken from a fingertip at the end of every 5 min bout and were analyzed for whole blood [La^-] using a stationary lactate analyzer (BIOSEN) and a rate of perceived exhaustion (RPE) was given using Borgs' 6-20 scale (Borg, 1982). The test was terminated when a [La^-] of ≥4 $mMol \cdot L^{-1}$ was reached. VO_2, respiratory exchange ratio (RER), and HR where measured from 2:00-4:30 min on every bout and mean values were used for statistical analysis. HR was monitored by each subjects own HR computer (Garmin/Polar). VO_2 was measured by Oxycon Pro™.

3.5.3 6-s all-out

The test started with the subject being seated, at a pedaling frequency of zero RPM the last 30 s before initiating the test. During this period, the subject was only allowed to pedal backwards to find and place the right foot at a 45-degree angle. The subject had to remain still the last 10 s. The test started with a 5-s countdown before a breaking resistance, equivalent to 0.8 $Nm \cdot kg^-$

[1] body mass (Lode Excalibur), was applied to the wheel and remained constant throughout the subsequent 6 s of the test. The subject was instructed to pedal with maximal effort and remain seated throughout the 6-s all-out.

3.5.5 VO_{2max} test

Approximately 10 min after the blood lactate test and ~5 min after 6-s all-out sprint the subject started an incremental test at 200/250 W, depending on their previous individual results. Power output was increased by 25 W every minute until exhaustion. To evaluate if the subject reached a true VO_{2max}, a plateau in VO_2 had to be reached. Further, HR ≥95% of the subjects reported maximal HR, RER ≥1.10, and [La^-] ≥8.00 mMol L^{-1} were required as criteria to evaluate if subjects attained VO_{2max}. If the subject did not have a VO_2-plateau, the test was classified as a VO_{2peak}-test, showing the highest possible VO_2 the subject could attain on that day, and not the true VO_{2max} level of the subject. The test was terminated when the cyclists failed to maintain ≥60 RPM. Maximal power output (W_{max}) was calculated as mean power output the last minute of the incremental test.

3.5.6 60 min at 60% W of VO_{2peak}, including 4 x 30-s all-out sprints

Based on each subject's performance, 60% W of VO_{2peak} was calculated based on the lactate profile and VO_{2max} test. Subjects started their 60 min test ten minutes after finishing the VO_{2max} test. To calculate gross efficiency, Oxygen consumption was measured between 5-10 min and 30-35 min during the cycling at 60% W. After 10- and 35 min a fingertip blood sample for measurement of [La^-] was taken. Fingertip lactate was also measured at 53 and 58 minutes. Subjects completed 4 x 30-s all-out Wingate sprints (described under "30-s all-out Wingate test") between 36 and 54 min. The first Wingate started from a resistance equivalent to 60% W of VO_{2peak}, while the following three started from a resistance off 100 W. Borgs' scale was used for RPE at 10, 35, 53 and 58 min, as well as after each of the four Wingate's.

3.5.7 20-min all out

After completion of the 60-min test, subjects started a self-paced 20-min all-out time-trial. Subjects began at their preferred self-chosen power output (W) and were free to change their power output (W) during the all-out trial on a remote controller mounted on the handlebar. During the test, oxygen consumption was measured from 4-5 min, 9-10 min and 14-20 min. A

fingertip blood sample for [La^-] was taken at 10 min and 1 min after finishing the 20-min all-out. Borgs' scale for RPE was used at 5, 10, 15 and 20 min.

3.5.8 30-s all-out Wingate test

Wingate sprints were performed at pre- and post-testing (all subjects) and during the intervention (only SG) to determine (1) peak power, (2) mean power, and (3) rate of fatigue during 30 s. Subjects were instructed to produce maximal effort from the start of the test and not save energy until later. The test started with the cyclist pedaling seated, at a frequency of 80 RPM for 10 s, including a 5 s countdown before a breaking resistance, equivalent to 0.8 $Nm \cdot kg^{-1}$ body mass (Lode Excalibur), was applied to the wheel and remained constant throughout the subsequent 30 s of the test. The cyclist was instructed to pedal with maximal effort and remain seated throughout the 30-s all-out. Each Wingate sprint was followed by 1 min passive recovery and 3 min active recovery cycling at 100 W.

3.6 Training load

Data from each subject's training diaries were collected the last 4 weeks prior to the commencement of the study. Training load was calculated for each subject based on their performance on pre-test, and HR-data from each training sessions during the 4 weeks of recorded training data.

Training load was quantified by using the i*ndividual training impulse (iTRIMP*) method described by Manzi, Iellamo, Impellizzeri, D'ottavio, and Castagna (2009), where exercise intensity is weighted by the athletes own HR vs [La^-] relationship (relationship calculated by line of best fit from the lactate profile and VO_{2max}-test at pre-test). iTRIMP uses the weighting factor y_i, which increases exponentially based on the HR vs [La^-] relationship to weight every HR. An accumulated iTRIMP score was calculated by the following equation:

$$iTRIMP\ (arbitrary\ units\ (AU)) = D\ (min) \times \Delta HR_{ratio} \times y_i.$$

Where ΔHR_{ratio} is calculated from $(HR_{work}\text{-}HR_{rest})/(HR_{max}\text{-}HR_{rest})$, and D is time spent exercising. Microsoft® Excel 2016 (Microsoft corporation, Redmond, Washington, USA) and a spreadsheet developed by Ø. Sylta (unpublished) was used to calculate the individual training load of each athlete (appendix 7).

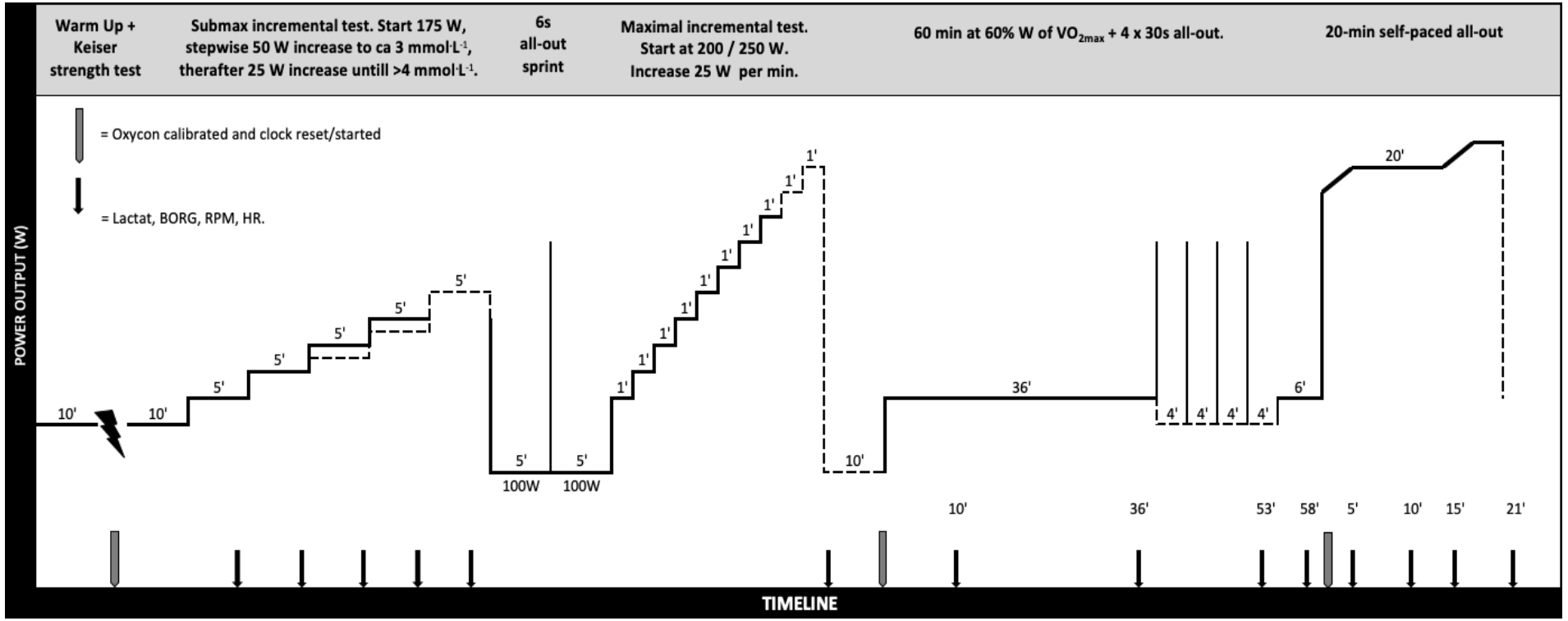

Figure 4: Overview of the Race-simulation protocol and time points for measurements and calibration.

3.7 Statistics

All values presented in the text, figures, and tables are mean ± SD unless stated otherwise. Data were assessed for practical significance using magnitude-based inferences (Hopkins, 2017). All data were log-transformed before analysis to reduce bias arising from nonuniformity error. Data analysis involved comparing the magnitude of changes in physiological variables between SG and C during each training period. These analyses were performed using a modified statistical spreadsheet (Hopkins, 2017). The spreadsheet calculates between-groups standardized difference or effect sizes (ES, 90% confidence limits [CL]) using the pooled SD. The criteria to interpret the magnitude of the ES were 0.0 to 0.2 trivial, 0.2 to 0.6 small, 0.6 to 1.2 moderate, 1.2 to 2.0 large, and >2.0 very large (Hopkins, Marshall, Batterham, & Hanin, 2009). Furthermore, the probabilities to establish whether the true (unknown) differences were lower, similar to, or higher than the smallest worthwhile change or difference were calculated. The smallest worthwhile change/difference was 1%, based on previous findings from elite cyclists (Paton & Hopkins, 2006), except for training data, where it was calculated as 0.2 multiplied by the between-subjects SD. Quantitative chances of higher or lower differences between groups were evaluated qualitatively as follows: <1%, almost certainly not; 1% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possible; 75% to 95%, likely; 95% to 99%, very likely; and >99%, almost certain. If the chance of higher or lower differences was >5%, the true difference was assessed as unclear. The mechanistic inference refers to the threshold chances of 5% for substantial magnitudes.

4.0 Methodical discussion

This study was a part of a doctoral thesis. The chosen methods and other decisions regarding the protocol was therefore pre-determined and not chosen by the author of this thesis. However, some specific aspects (i.e., minimum performance level of the cyclist to be recruited; timing for pre- and post-testing and duration of the training intervention, methods etc.), were debated among the team of representatives from the institutions involved in the study. The effects of SIT have been shown in groups of untrained and moderately trained, but not in highly trained athletes. To allow for an adequate population, this study was conducted as a multicenter study, allowing athletes from different regions of the country to participate. All of the institutions were regional test centers connected to the Norwegian Olympic Federation and used the same testing equipment. The PhD student and project leader Nicki W Almquist visited all of the institutions before initiating the project to ensure that the protocol was performed accurately on all test-sites. Test-leaders at all locations performed several pilot-tests to ensure consistency of testing and was given feedback from Mr. Almquist to ensure that the equipment settings, and load calculations (e.g., 60 min at 60% W of VO_{2peak}) were correct before initiating the project.

4.1 Design

The current study is an experimental study with a traditional *parallel two groups* pre-test/post-test design (Polit & Beck, 2014). The "gold standard" *Randomized Controlled Trial* (RCT) requires randomization into the two groups. This is difficult and often not possible with well-trained athletes (Rønnestad et al., 2014), therefore if some athletes had a strong desire towards one of the groups, they were allowed to choose (athletes were not informed about this possibility). Athletes who did not express a specific preference of training intervention, were randomly placed in one of the groups. Some of the participants was placed in a specific group by the project leaders to ensure that the groups were matched on VO_{2peak} (first) and training load / iTRIMP score (second). The intervention was carried out over 3 weeks, before the subjects were free to return to their preferred training programs (i.e., start preparing for the new season). As in the study by Rønnestad et al. (2014), we were also interested in how the intervention affected their pre-seasonal training and therefore invited all subjects back for a re-test 6 weeks after post-test (not further discussed in the current thesis). A more adequate design which could have been used is a cross-over design were both groups act as intervention and control. There is however a considerable challenge with this option, as this design require a lot of extra time (two intervention periods, a 'washout' in-between periods, and several additional

test-days). The current intervention was individualized to each athlete and started 3 to 4 days after they finished their last race in the competition season.

4.2 Study sample

The current study aimed for 40 participants which would allow for three different intervention groups: One control group, one performing SIT twice per week and one performing SIT once per week to address the possible "dose" response required for SIT. The main goal was to explore the effect SIT has on already highly-trained endurance athletes. We aimed to recruit highly-trained, but sub-elite cyclists with minimum VO_{2max} of 65 $ml \cdot kg^{-1} \cdot min^{-1}$ to explore the potential effects from SIT.

The study recruited a total sample of 22 male cyclists. Due to the difficulties of including highly-trained athletes, we experience some drop-outs. Notably, a relatively large drop-out percentage is seen in Kristiansand (50%). In Kristiansand, a local cycle club wanted to participate with some of their cyclists. All cyclists volunteered to participated but some may not have had the same inner motivation as individual cyclists who volunteered for the project at their own initiation. However, none of the dropouts were as a consequence of the current intervention, but due to sickness/injury or change of trainer/training philosophy. There is a considerable limitation in regard to the number of participants completing the intervention. However, the final sample size (n=16) is similar to other studies including well-trained athletes with high maximal oxygen uptakes. Rønnestad et al. (2015) included exactly the same sample size in their two groups (n=7 and n=9 in intervention and control, respectively). Furthermore, several other studies have included the similar number of participants (n=~15) in their studies (Rønnestad et al., 2014; Rønnestad, Hansen, Hollan, Spencer, & Ellefsen, 2016; Rønnestad et al., 2015; Tonnessen et al., 2014).

A study by Hopkins, Schabort, and Hawley (2001), highlights that athletes are more reliable in physical performance tests than non-athletes. Athletes are more frequently exposed to high intensity exercise during training and in competition, which can reduce the variability in performance. Fitness may not change to the same extent in athletes compared to non-athletes. Finally, since it's not possible to blind these kinds of studies, researchers may take extra care or push the subjects harder when knowing their potential.

4.3 Training protocols

All athletes were asked to reduce their training load by 70% compared to their last 4 weeks in the competition period. Training load was calculated using iTRIMP (described in methods). Specifically, by using iTRIMP method to quantify training load, we were able to individualize and monitor each athlete on a daily basis. Each athlete gave access to their digital online training diary: "Training Peaks". By using Training Peaks, we were able to download and transform each training session into excel files with heart rate per second (required for iTRIMP calculations). In some cases, athletes had completed training sessions without logging heart rate (HR). Whenever this happened, comparable training sessions were used to calculate iTRIMP scores for these sessions. Description on how to transform the heart rate files from Training Peaks can be found in appendix 6.

Due to the lack of participants, the study was reduced to only two groups; Sprint and Control. Control group performed one LIT session per week at the test-location at the same resistance as calculated in the test-protocol; 60% W of VO_{2peak}. If a subject was unable to perform the session at the test-location, they were allowed to perform the session on their own bicycle. SIT group performed three SIT sessions during the 3-week intervention, averaging one session/week. SIT sessions were completed in bouts of three, separated by 1 min passive rest and 3 min active rest cycling at 100 W. The bouts where separated by 20-10-10-10 min of cycling at power output corresponding to 60% W of VO_{2peak}. In addition to these sessions, all participants were only allowed to perform LIT. iTRIMP calculation of each subjects' sessions was performed on a daily basis to ensure that the accumulated training load was in accordance with the calculated weekly reduction.

4.4 Measurements

4.4.1 VO_2

Whenever submaximal and maximal oxygen uptake are evaluated as a pre-post value, there is a high importance of reliability of the instrument measuring VO_2 (Foss & Hallen, 2005). This project used the Oxycon Pro mixing chamber for VO_2 measurements. Foss and Hallen (2005) reported the accuracy of the Oxygen Pro for both short- (e.g. 25 min) and longer periods (e.g. intervention period of 94 days) as well as for high and low intensities, with a total CV of 1.2%. Further, Rietjens, Kuipers, Kester, and Keizer (2001) validated the Oxycon Pro against the

Douglas bag method, and found that the Oxycon pro was an accurate system for measurement of V_E, VO_2 and CO_2.

4.4.2 Cycle ergometer

The Lode Excalibur used in lab-tests are considered as the "gold standard" for cycle ergometers (Earnest, Wharton, Church, & Lucia, 2005), and is used in several studies (Burgomaster et al., 2007; Burgomaster et al., 2005; Gibala et al., 2006; Gibala & McGee, 2008; Rønnestad et al., 2015). The study by Earnest et al. (2005) investigated the test-retest reliability of the Lode Excalibur and found no significant differences (CV ≤5%), which strengthens the accuracy of this ergometer. The adjustment procedure described in the methods where the rider positions (seat/handlebar height and horizontal distance to crank) were saved and ensured that the cyclists maintained the same positions at all visits to the lab. One can assume that maintaining identical positions during testing improves the reliability.

4.4.3 Lactate measurements

The EFK Biosen C-line for lactate analyses has been used in several previous studies (Rønnestad & Hansen, 2018; Santtila, Keijo, Laura, & Heikki, 2008; Skovereng et al., 2018; Sylta et al., 2016). However, to the author's knowledge, no studies have been published validating the Biosen C-line and compared it to other models. One study by Davison et al. (2000) tested a model prior the C-line (the 5030). They discovered a significant difference between the first- and second test-point. However, the difference observed was very small, and practical trivial (0.03 $mMol \cdot L^{-1}$ 95% CI: 0.01-0.05). The calculated CV for test-retest was 1.4%.

4.5 Physiological tests

The methodological chapter describes the protocol in full. However, the current thesis focuses on a small part of the multicenter project and all tests described in the methods will therefore not be discussed. The focus will be placed on tests specifically investigating the aim of the current thesis.

4.5.1 Submaximal incremental test

Measurement of blood accumulation during an incremental test is commonly used in endurance sports to evaluate the effects of training and predict potential performance (Bassett & Howley, 2000; Bentley et al., 2001; Sjödin & Jacobs, 1981). For the current study a submaximal

incremental test was used to identify the power output corresponding to a fixed lactate concentration of 4 mMol·L^{-1}. It has been considerably debated on what's the best way to assess the pre-test/post-test to a threshold power output. Hoefelmann et al. (2015) compared different methods for calculating threshold power output corresponding to LT_2 and showed the same low CV for both an individual calculation and fixed-value approach (e.g. 4 mMol·L^{-1}) for assessing the effects of an intervention on threshold power output.

4.5.2 Incremental test to exhaustion

An incremental test to exhaustion is a commonly used test to assess aerobic performance. However, it depends upon several factors. In this protocol, the test was performed after a 10RM Keiser leg-press strength test, a submaximal incremental test and a 6-s all out test. All of which accumulates a pre-load on the subject before the test begins and may therefore make it difficult to obtain a maximal effort to attain a true VO_{2max} and W_{max}. Thus, this study used several criteria (described in the methods) to ensure that VO_{2max} was reached. However, since not all subjects reach a plateau in VO_2, or failed to reach other criteria's (e.g. RER >1.10, [La^-] >8.0 mMol·L^{-1}) the term VO_{2peak} was used.

4.5.3 20-min all-out time-trial

The all-out time-trial was performed as the last element in the cycle protocol after ~2 hours of cycling. There is a question to whether athletes managed to pace themselves optimally when performing an entire new protocol. The same issue was described in a study by Schabort, Hawley, Hopkins, and Blum (1999), who tested rowers on a rowing ergometer. The rowers performed a 2000 m time-trial and repeated the time trial three times. Results showed that the last attempt produced the best performance. The rowers had long experience with the ergometer in training but had never "competed" or performed time-trials on the same ergometer. This might be the reason to why they didn't perform optimally on the first attempt and that there might be a potential learning-effect, even for well-trained subjects who are used to the specific testing equipment. Even though our subjects had been in the lab before, none of them had performed any time-trials on the Lode ergometer.

Cyclists complete 40-min all-out time-trials on a regular basis to monitor their performance and fitness. This test is however (mostly) conducted on a separate day to ensure consistent performance. The test is also mostly performed on the athlete's own bike with a separate

braking system (e.g. SMR cranks). These systems are shown to be reliable when measuring PO during time trials (Paton & Hopkins, 2001). However, there are several types, brands and models and cyclists don't necessarily have the same type and model, which makes it difficult to standardize any test.

4.6 Training diary

This study uses the athletes own training diary on the digital platform Training Peaks. To avoid any instability or variation in self-reporting training, or insecurity by asking them to report their training in a new way, we used digital heart rate files. All athletes who reported interest in the project were followed up to make sure all training-sessions were logged by heart rate monitors and that the settings were adjusted according to the protocol (i.e., logged HR per second). Then the test leaders could easily monitor and calculate the individual training load while the athletes could proceed as normal (log their training with their own HR monitor in TP). By using the lactate-HR relationship, the quantification of training load score could be standardized and used as a baseline score for calculation of training reduction. Notably, we asked the athletes to reduce their load (iTRIMP score), not necessarily volume (i.e., hours). If athletes kept their HR low (e.g. $<LT_1$) while training, they could still perform a relatively high volume of training. This depended upon the training the last 4 weeks prior to pre-test. If athletes had a high volume of HIT, it would result in a high iTRIMP score (load).

4.7 Strengths and limitations

The main limitation of this study is the lack of participants in the study, making it difficult to identify clear effects. However, the present study is not the first one to deal with this kind of issue (Paton & Hopkins, 2005, 2006; Rønnestad et al., 2014; Rønnestad et al., 2016; Sassi et al., 2008). In contrast, one strength of this study is the physical characteristics of the athletes participating with an average of ~73 $ml \cdot kg^{-1} \cdot min^{-1}$ in VO_{2peak}. Some of the included subjects were young, but the range in age was only 8 years (18-26). Further, the main aim was to investigate if SIT could prove effective for highly-trained athletes, and we succeeded in recruiting a population according to these criteria. For example, one of the cyclists involved in this study competed in the UCI Road World Championship individual time-trial in Austria 2018. Contrarily, some of the subjects were junior riders, and had only competed a few years

To strengthen the study and to avoid any instability, all tests were performed in the lab, at the same time of day (± 2 h) and under the same environmental conditions. In addition, the same test-leaders were used at all tests and under the SIT sessions to ensure consistent monitoring and feedback. Strong verbal encouragement was given whenever needed during the tests (i.e., under maximal incremental test, Wingate sprints and during the all-out time-trial).

We admit a limitation to the amount of training, as training load during the lead-in phase differed considerably between the cyclists (relatively large SD in training load). There is also a clear limitation to the fact that none of the cyclists had any familiarization to the test- and SIT-protocol. All of the participants had been to the lab previously and performed some of the tests included in the race simulation (i.e., Wingate sprint, submaximal- and maximal incremental test). However, none of the cyclists were familiar with the race simulation protocol. Hence, it has to be taken into account that there might be some learning effects between the test points. This is unfortunately the reality in undertaking research studies involving highly-trained athletes. There was simply no time for familiarization tests as we had to start the intervention period at the end of the competitive season, as all of the athletes would be preparing for races and didn't want to spend hours/days in the lab. etc.

There is a limitation in regard to the psychology and motivation of the cyclists. All of the cyclists had just completed a long competition season and almost ten months of dedicated training. Generally, to perform well in the lab, subjects need to push and pace themselves to the limit in order to achieve their best results. And there's a question to whether the cyclists are willingly to do so with maximal effort and dedication at this particular period of the year.

5.0 Ethics

The current study was performed on healthy highly trained cyclists competing at a national level. All cyclists were informed about the study both verbally and written. They were informed of potential risks, and possibilities of any discomfort during the tests and intervention. This 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. Se appendix 5). All cyclists were informed that they could withdraw from the study at any point and without having to give any reason for dropping out. The cyclist provided written consent before participation in the study (appendices 2-3). The cyclist where blinded of their results during the study but had full insight to their results after completing the intervention. All data were anonymized and stored in password protected files locally on computers and with a copy on hard drives. Data will be stored for 10 years from the completion of the study.

REFERENCES

Bailey, S. J., Wilkerson, D. P., DiMenna, F. J., & Jones, A. M. (2009). Influence of repeated sprint training on pulmonary O2 uptake and muscle deoxygenation kinetics in humans. *Journal of applied physiology, 106*(6), 1875-1887. doi:10.1152/japplphysiol.00144.2009

Bangsbo, J. (1994). The physiology of soccer--with special reference to intense intermittent exercise. *Acta Physiologica Scandinavica. Supplementum, 619*, 1-155.

Bangsbo, J. (2015). Performance in sports–With specific emphasis on the effect of intensified training. *Scand J Med Sci Sports, 25*(S4), 88-99. doi:10.1111/sms.12605

Bangsbo, J., Gunnarsson, T. P., Wendell, J., Nybo, L., & Thomassen, M. (2009). Reduced volume and increased training intensity elevate muscle Na+-K+ pump α2-subunit expression as well as short-and long-term work capacity in humans. *Journal of applied physiology, 107*(6), 1771-1780. doi:10.1152/japplphysiol.00358.2009

Bassett, D. R., & Howley, E. T. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine and science in sports and exercise, 32*(1), 70-84. doi:10.1097/00005768-200001000-00012

Bayati, M., Farzad, B., Gharakhanlou, R., & Agha-Alinejad, H. (2011). A practical model of low-volume high-intensity interval training induces performance and metabolic adaptations that resemble 'all-out'sprint interval training. *Journal of sports science & medicine, 10*(3), 571.

Bentley, D. J., McNaughton, L. R., Thompson, D., Vleck, V. E., & Batterham, A. M. (2001). Peak power output, the lactate threshold, and time trial performance in cyclists. *Medicine & Science in Sports & Exercise, 33*(12), 2077-2081.

Billat, V. L., Slawinski, J., Bocquet, V., Demarle, A., Lafitte, L., Chassaing, P., & Koralsztein, J.-P. (2000). Intermittent runs at the velocity associated with maximal oxygen uptake enables subjects to remain at maximal oxygen uptake for a longer time than intense but submaximal runs. *Eur J Appl Physiol, 81*(3), 188-196. doi:10.1007/s004210050

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Med Sci Sports Exerc, 14*(5), 377-381. doi:10.1249/00005768-198205000-00012

Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle. *Sports medicine, 43*(10), 927-954. doi:10.1007/s40279-013-0066-5

Burgomaster, K. A., Cermak, N. M., Phillips, S. M., Benton, C. R., Bonen, A., & Gibala, M. J. (2007). Divergent response of metabolite transport proteins in human skeletal muscle after sprint interval training and detraining. *Am J Physiol Regul Integr Comp Physiol, 292*. doi:10.1152/ajpregu.00503.2006

Burgomaster, K. A., Heigenhauser, G. J. F., & Gibala, M. J. (2006). Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance. *Journal of applied physiology, 100*(6), 2041-2047. doi:10.1152/japplphysiol.01220.2005

Burgomaster, K. A., Howarth, K. R., Phillips, S. M., Rakobowchuk, M., MacDonald, M. J., McGee, S. L., & Gibala, M. J. (2008). Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. *The Journal of physiology, 586*(1), 151-160. doi:10.1113/jphysiol.2007.142109

Burgomaster, K. A., Hughes, S. C., Heigenhauser, G. J. F., Bradwell, S. N., & Gibala, M. J. (2005). Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. *Journal of applied physiology, 98*(6), 1985-1990. doi:10.1152/japplphysiol.01095.2004

Colyer, S. L., Stokes, K. A., Bilzon, J. L., Holdcroft, D., & Salo, A. I. (2018). Training-related changes in force–power profiles: implications for the skeleton start. *International journal of sports physiology and performance, 13*(4), 412-419. doi:10.1123/ijspp.2017-0110

Compher, C., Frankenfield, D., Keim, N., Roth-Yousey, L., & Group, E. A. W. (2006). Best practice methods to apply to measurement of resting metabolic rate in adults: a systematic review. *Journal of the American Dietetic Association, 106*(6), 881-903. doi:10.1016/j.jada.2006.02.009

Conley, D. L., & Krahenbuhl, G. S. (1980). Running economy and distance running performance of highly trained athletes. *Med Sci Sports Exerc, 12*(5), 357-360.

Davies, C., & Thompson, M. (1979). Aerobic performance of female marathon and male ultramarathon athletes. *European journal of applied physiology and occupational physiology, 41*(4), 233-245. doi:10.1007/BF00429740

Davison, R. R., Coleman, D., Balmer, J., Nunn, M., Theakston, S., Burrows, M., & Bird, S. (2000). Assessment of blood lactate: practical evaluation of the Biosen 5030 lactate analyzer. *Med Sci Sports Exerc, 32*(1), 243-247. doi:10.1097/00005768-200001000-00036

Driller, M. W., Fell, J. W., Gregory, J. R., Shing, C. M., & Williams, A. D. (2009). The effects of high-intensity interval training in well-trained rowers. *International journal of sports physiology and performance, 4*(1), 110-121. doi:10.1123/ijspp.4.1.110

Earnest, C. P., Wharton, R. P., Church, T. S., & Lucia, A. (2005). Reliability of the Lode Excalibur Sport Ergometer and applicability to Computrainer electromagnetically braked cycling training device. *The Journal of Strength & Conditioning Research, 19*(2), 344-348. doi:10.1519/R-15714.1

Esfarjani, F., & Laursen, P. B. (2007). Manipulating high-intensity interval training: Effects on $\dot{V}O_2$ max, the lactate threshold and 3000 m running performance in moderately trained males. *Journal of science and medicine in sport, 10*(1), 27-35. doi:10.1016/j.jsams.2006.05.014

Foss, Ø., & Hallen, J. (2005). Validity and stability of a computerized metabolic system with mixing chamber. *International journal of sports medicine, 26*(07), 569-575. doi:10.1055/s-2004-821317

García-Pallarés, J., Carrasco, L., Díaz, A., & Sánchez-Medina, L. (2009). Post-season detraining effects on physiological and performance parameters in top-level kayakers: comparison of two recovery strategies. *Journal of sports science & medicine, 8*(4), 622.

Gibala, M. J., Little, J. P., Van Essen, M., Wilkin, G. P., Burgomaster, K. A., Safdar, A., . . . Tarnopolsky, M. A. (2006). Short‐term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. *The Journal of physiology, 575*(3), 901-911. doi:10.1113/jphysiol.2006.112094

Gibala, M. J., & McGee, S. L. (2008). Metabolic adaptations to short-term high-intensity interval training: a little pain for a lot of gain? *Exerc Sport Sci Rev, 36*. doi:10.1097/JES.0b013e318168ec1f

Gist, N. H., Fedewa, M. V., Dishman, R. K., & Cureton, K. J. (2014). Sprint interval training effects on aerobic capacity: a systematic review and meta-analysis. *Sports medicine, 44*(2), 269-279. doi:10.1007/s40279-013-0115-0

Hawley, J. (1995). State-of-the-art training guidelines for endurance performance. *South African Journal of Sports Medicine, 2*(4), 7-12.

Helgerud, J., Høydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., . . . Bach, R. (2007). Aerobic high-intensity intervals improve V˙ O2max more than moderate training. *Medicine & Science in Sports & Exercise, 39*(4), 665-671. doi:10.1249/mss.0b013e3180304570

Hill, A. V. (1922). The maximum work and mechanical efficiency of human muscles, and their most economical speed. *The Journal of physiology, 56*(1-2), 19-41. doi:10.1113/jphysiol.1922.sp001989

Hoefelmann, C. P., Diefenthaeler, F., Costa, V. P., De Lucas, R. D., Shambrook, P., & Guglielmo, L. G. A. (2015). Test–retest reliability of second lactate turnpoint using two different criteria in competitive cyclists. *European journal of sport science, 15*(4), 265-270. doi:10.1080/17461391.2014.944874

Hopkins, W. G. (2017). Spreadsheets for analysis of controlled trials, crossovers and time series. *Sportscience, 21*, 1-4.

Hopkins, W. G., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine+ Science in Sports+ Exercise, 41*(1), 3. doi:10.1249/MSS.0b013e31818cb278

Hopkins, W. G., Schabort, E. J., & Hawley, J. A. (2001). Reliability of power in physical performance tests. *Sports medicine, 31*(3), 211-234. doi:10.2165/00007256-200131030-00005

Iaia, F. M., Hellsten, Y., Nielsen, J. J., Fernström, M., Sahlin, K., & Bangsbo, J. (2009). Four weeks of speed endurance training reduces energy expenditure during exercise and maintains muscle oxidative capacity despite a reduction in training volume. *Journal of applied physiology, 106*(1), 73-80. doi:10.1152/japplphysiol.90676.2008

Impellizzeri, F., Marcora, S., Rampinini, E., Mognoni, P., & Sassi, A. (2005). Correlations between physiological variables and performance in high level cross country off road cyclists. *British journal of sports medicine, 39*(10), 747-751. doi:10.1136/bjsm.2004.017236

Issurin, V. B. (2010). New horizons for the methodology and physiology of training periodization. *Sports medicine, 40*(3), 189-206. doi:10.2165/11319770-000000000-00000

Jeukendrup, A. E., Craig, N. P., & Hawley, J. A. (2000). The bioenergetics of world class cycling. *Journal of science and medicine in sport, 3*(4), 414-433. doi:10.1016/S1440-2440(00)80008-0

Jobson, S. A., Hopker, J. G., Korff, T., & Passfield, L. (2012). Gross efficiency and cycling performance: a brief review. *Journal of Science and Cycling, 1*(1), 3. doi:10.28985/jsc.v1i1.12

Jones, A. M. (1998). A five year physiological case study of an Olympic runner. *British journal of sports medicine, 32*(1), 39-43. doi:10.1136/bjsm.32.1.39

Jones, A. M. (2006). The physiology of the world record holder for the women's marathon. *International Journal of Sports Science & Coaching, 1*(2), 101-116. doi:10.1260/174795406777641258

Joyner, M. J., & Coyle, E. F. (2008). Endurance exercise performance: the physiology of champions. *The Journal of physiology, 586*(1), 35-44. doi:10.1113/jphysiol.2007.143834

Laursen, P. B. (2010). Training for intense exercise performance: high‐intensity or high‐volume training? *Scand J Med Sci Sports, 20*, 1-10. doi:10.1111/j.1600-0838.2010.01184.x

Laursen, P. B., & Jenkins, D. G. (2002). The scientific basis for high-intensity interval training. *Sports medicine, 32*(1), 53-73. doi:10.2165/00007256-200232010-00003

Laursen, P. B., Shing, C. M., Peake, J. M., Coombes, J. S., & Jenkins, D. G. (2002). Interval training program optimization in highly trained endurance cyclists. *Medicine & Science in Sports & Exercise, 34*(11), 1801-1807. doi:10.2165/00007256-200232010-00003

Lucía, A., Hoyos, J., Pardo, J., & Chicharro, J. L. (2000). Metabolic and neuromuscular adaptations to endurance training in professional cyclists: a longitudinal study. *The Japanese journal of physiology, 50*(3), 381-388. doi:10.2170/jjphysiol.50.381

Lucía, A., Hoyos, J., Santalla, A., Pérez, M., & Chicharro, J. L. (2002). Kinetics of VO2 in professional cyclists. *Medicine & Science in Sports & Exercise, 34*(2), 320-325. doi:10.1097/00005768-200202000-00021

Manzi, V., Iellamo, F., Impellizzeri, F., D'ottavio, S., & Castagna, C. (2009). Relation between individualized training impulses and performance in distance runners. *Medicine & Science in Sports & Exercise, 41*(11), 2090-2096. doi:10.1249/MSS.0b013e3181a6a959

McLaughlin, J. E., Howley, E. T., Bassett, J. D., Thompson, D. L., & Fitzhugh, E. C. (2010). Test of the classic model for predicting endurance running performance. *Medicine and science in sports and exercise, 42*(5), 991-997. doi:10.1249/MSS.0b013e3181c0669d

Menz, V., Strobl, J., Faulhaber, M., Gatterer, H., & Burtscher, M. (2015). Effect of 3-week high-intensity interval training on VO2max, total haemoglobin mass, plasma and blood volume in well-trained athletes. *Eur J Appl Physiol, 115*(11), 2349-2356. doi:10.1007/s00421-015-3211-z

Mujika, I., & Padilla, S. (2000a). Detraining: loss of training-induced physiological and performance adaptations. Part I. *Sports medicine, 30*(2), 79-87. doi:10.2165/00007256-200030020-00002

Mujika, I., & Padilla, S. (2000b). Detraining: loss of training-induced physiological and performance adaptations. Part II. *Sports medicine, 30*(3), 145-154. doi:10.2165/00007256-200030030-00001

Mujika, I., & Padilla, S. (2003). Scientific bases for precompetition tapering strategies. *Medicine & Science in Sports & Exercise, 35*(7), 1182-1187. doi:10.1249/01.MSS.0000074448.73931.11

Paton, C. D., & Hopkins, W. G. (2001). Tests of cycling performance. *Sports medicine, 31*(7), 489-496. doi:10.2165/00007256-200131070-00004

Paton, C. D., & Hopkins, W. G. (2005). Seasonal changes in power of competitive cyclists: implications for monitoring performance. *Journal of science and medicine in sport, 8*(4), 375-381. doi:10.1016/S1440-2440(05)80052-0

Paton, C. D., & Hopkins, W. G. (2006). Variation in performance of elite cyclists from race to race. *European journal of sport science, 6*(01), 25-31. doi:10.1080/17461390500422796

Polit, D., & Beck, C. (2014). Essentials of nursing research: Appraising evidence fornursing practice. In: Wolters Kluwer/Lippincott/Williams Wilkins Health, Philadelphia, PA, USA.

Rietjens, G., Kuipers, H., Kester, A., & Keizer, H. (2001). Validation of a computerized metabolic measurement system (Oxycon-Pro®) during low and high intensity exercise. *International journal of sports medicine, 22*(04), 291-294. doi:10.1055/s-2001-14342

Rønnestad, B. R., Askestad, A., & Hansen, J. (2014). HIT maintains performance during the transition period and improves next season performance in well-trained cyclists. *Eur J Appl Physiol, 114*(9), 1831-1839. doi:10.1007/s00421-014-2919-5

Rønnestad, B. R., & Hansen, J. (2018). A scientific approach to improve physiological capacity of an elite cyclist. *International journal of sports physiology and performance, 13*(3), 390-393. doi:10.1123/ijspp.2017-0228

Rønnestad, B. R., Hansen, J., Hollan, I., Spencer, M., & Ellefsen, S. (2016). Impairment of performance variables after in-season strength-training cessation in elite cyclists. *International journal of sports physiology and performance, 11*(6), 727-735. doi:10.1123/ijspp.2015-0372

Rønnestad, B. R., Hansen, J., Vegge, G., Tønnessen, E., & Slettaløkken, G. (2015). Short intervals induce superior training adaptations compared with long intervals in cyclists–An effort‐matched approach. *Scand J Med Sci Sports, 25*(2), 143-151. doi:10.1111/sms.12165

Santtila, M., Keijo, H., Laura, K., & Heikki, K. (2008). Changes in cardiovascular performance during an 8-week military basic training period combined with added endurance or strength training. *Military medicine, 173*(12), 1173-1179. doi:10.7205/MILMED.173.12.1173

Sassi, A., Impellizzeri, F. M., Morelli, A., Menaspa, P., & Rampinini, E. (2008). Seasonal changes in aerobic fitness indices in elite cyclists. *Applied physiology, nutrition, and metabolism, 33*(4), 735-742. doi:10.1139/H08-046

Schabort, E., Hawley, J., Hopkins, W. G., & Blum, H. (1999). High reliability of performance of well-trained rowers on a rowing ergometer. *Journal of sports sciences, 17*(8), 627-632. doi:10.1080/026404199365650

Seiler, S. (2010). What is best practice for training intensity and duration distribution in endurance athletes? *International journal of sports physiology and performance, 5*(3), 276-291. doi:10.1123/ijspp.5.3.276

Seiler, S. (2011). A brief history of endurance testing in athletes. *Sportscience, 15*, 40-88.

Seiler, S., Jøranson, K., Olesen, B., & Hetlelid, K. (2013). Adaptations to aerobic interval training: interactive effects of exercise intensity and total work duration. *Scand J Med Sci Sports, 23*(1), 74-83. doi:10.1111/j.1600-0838.2004.00418.x

Seiler, S., & Kjerland, G. Ø. (2006). Quantifying training intensity distribution in elite endurance athletes: is there evidence for an "optimal" distribution? *Scand J Med Sci Sports, 16*(1), 49-56. doi:10.1111/j.1600-0838.2004.00418.x

Seiler, S., & Tønnessen, E. (2009). Intervals, thresholds, and long slow distance: the role of intensity and duration in endurance training. *Sportscience, 13*(13), 32-53.

Sjödin, B., & Jacobs, I. (1981). Onset of blood lactate accumulation and marathon running performance. *International journal of sports medicine, 2*(01), 23-26. doi:10.1055/s-2008-1034579

Skovereng, K., Sylta, Ø., Tønnessen, E., Seiler, S., Hammarström, D., Danielsen, J., . . . Sandbakk, Ø. (2018). Effects of initial performance, gross efficiency and V˙O2peak characteristics on subsequent adaptations to endurance training in competitive cyclists. *Frontiers in physiology, 9*, 713. doi:10.3389/fphys.2018.00713

Skovgaard, C., Almquist, N. W., & Bangsbo, J. (2018). The effect of repeated periods of speed endurance training on performance, running economy, and muscle adaptations. *Scand J Med Sci Sports, 28*(2), 381-390. doi:10.1111/sms.12916

Sloth, M., Sloth, D., Overgaard, K., & Dalgas, U. (2013). Effects of sprint interval training on VO2max and aerobic exercise performance: a systematic review and meta‐analysis. *Scand J Med Sci Sports, 23*(6). doi:10.1111/sms.12092

Stepto, N. K., Hawley, J. A., Dennis, S. C., & Hopkins, W. G. (1999). Effects of different interval-training programs on cycling time-trial performance. *Medicine and science in sports and exercise, 31*, 736-741. doi:10.1097/00005768-199905000-00018

Støa, E. M., Støren, Ø., Enoksen, E., & Ingjer, F. (2010). Percentage utiliztion of VO2-max at 5-km competition velocity does not determine time performance at 5 km among elite distance runners. *Journal of strength and conditioning research, 24*(5), 1340. doi:10.1519/JSC.0b013e3181cc5f7b

Stöggl, T. L., & Sperlich, B. (2015). The training intensity distribution among well-trained and elite endurance athletes. *Frontiers in physiology, 6*, 295. doi:10.3389/fphys.2015.00295

Sylta, Ø. (2017). *Endurance training organization in elite endurance athletes : From description of best practice towards individualized prescription.* (Doctoral dissertation), Universitetet i Agder, Kristiansand.

Sylta, Ø., Tønnessen, E., Hammarström, D., Danielsen, J., Skovereng, K., Ravn, T., . . . Seiler, S. (2016). The effect of different high-intensity periodization models on endurance adaptations. doi:10.1249/MSS.0000000000001007

Tonnessen, E., Sylta, Ø., Haugen, T. A., Hem, E., Svendsen, I. S., & Seiler, S. (2014). The road to gold: training and peaking characteristics in the year prior to a gold medal endurance performance. *PLoS One, 9*(7), e101796. doi:10.1371/journal.pone.0101796

Torstveit, M. K., Fahrenholtz, I., Stenqvist, T. B., Sylta, Ø., & Melin, A. (2018). Within-day Energy Deficiency and Metabolic Perturbation in Male Endurance Athletes. *International journal of sport nutrition and exercise metabolism*, 1-28. doi:10.1123/ijsnem.2018-0142

Tschakert, G., & Hofmann, P. (2013). High-intensity intermittent exercise: methodological and physiological aspects. *International journal of sports physiology and performance, 8*(6), 600-610. doi:10.1123/ijspp.8.6.600

Åstrand, P., & Rodahl, K. (1986). Textbook of Work Physiology. Physiological Bases of Exercise, New York City. In: McGraw-Hill Book Co 1986.

Part 2:

Research paper

"Trivial effect of integrating repeated sprints to low intensity training post-season in highly-trained cyclists"

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"Trivial effect of integrating repeated sprints to low intensity training post-season in highly-trained cyclists."

Submission type: *Original investigation.*

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Preferred running head: SIT in the transition period

ABSTRACT

PURPOSE: To investigate the effects on 20-min time-trial performance and physiological performance-related variables when adding sprint intervals to highly-trained cyclist's low intensity training regime as they enter their transitional period after the competitive season.

METHODS: Sixteen (n=16) highly-trained cyclists (21.4 ± 3.6 years, 73.3 ± 6.7 kg, 185.2 ± 7.2 cm, VO_{2peak}: 73.2 ± 4.7 $ml \cdot kg^{-1} \cdot min^{-1}$) completed a ~2.5-hour race simulation protocol (including sub- and maximal incremental tests, four repeated all-out sprints and a 20-min all-out performance test). Subjects were assigned to Control- (CG; n=9) or Sprint-group (SG; n=7), based on VO_{2peak} and training load characteristics, for a three-week intervention period. In addition to low intensity training (LIT), SG performed one session of sprint interval training (SIT) per week. SIT sessions consisted of 9x30 s maximal sprints (4 min rest) performed in bouts of three. CG was only allowed to perform LIT during the intervention period. Both groups were instructed to reduce their weekly training load by 70% compared to their in-season load. Training load was calculated using iTRIMP.

RESULTS: No substantial differences were evident in relative mean power output during 20-min time-trial (ES: 0.19 ±0.5). A trivial decrease was seen in relative VO_{2peak} (ES: -0.31 ±0.68), with no change in relative Power output at 4 $mMol \cdot L^{-1}$ [La^{-}] (ES: 0.07 ±0.37) or relative W_{max} 0.16 ±0.67)

CONCLUSION: SIT in addition to traditional LIT training had no substantial effects on Power output at lactate threshold, VO_{2max}, W_{max} or 20-min time-trial. However, relatively large individual variations were evident, suggesting that the impact from SIT can be quite individual. More research is needed to conclude if SIT can maintain performance during the transition period.

KEY WORDS: Endurance Athletes, Time-trial, VO_{2max}, SIT, Transition period.

INTRODUCTION

For most endurance athletes, training is performed all year around including a long competitive season. Following the competitive season, there is a need for a transition period with focus on recovery and relaxation. However, this period is normally associated with a decline in performance and performance related variables[1,2]. Endurance athletes do traditionally reduce their training load in this period, and its common to only focus on low intensity training (LIT) during this period[3-5]. Its suggested that LIT induces low stress on the athlete, and facilitates

recovery from high intensity training (HIT)[6]. Performing LIT may therefore be a good strategy to allow for physical and mental recovery during the transition period.

There is, however, a question to whether its beneficial to avoid the decline in fitness-level during the transition period and if avoiding this decline would result in an advantage in the following preparatory period. Rønnestad and colleagues[7] are, to the author's knowledge, the only researchers to intervene with the training regime of highly-trained athletes during the transition period. By incorporating one session of HIT (6x5 min/5x6 min) every 7-10 days for 8 weeks, they managed to maintain physical performance during the transition period as well as improving the next seasons performance after returning to regular training.

Recently, increased interest has been placed in sprint interval training (SIT), as it has shown to maintain aerobic fitness levels even when reducing training volume up to ~60% in moderately trained subjects[8]. To our knowledge, no studies have explored the possible effects of incorporating SIT to high-level endurance athletes regular training regime after the competitive season. Thus, the current study investigates if three session of SIT (4.5 min/session) for 3 weeks can maintain performance and performance related physiological variables in highly-trained cyclists. We postulated that athletes incorporating one session of SIT per week in addition to traditional LIT would maintain their physical performance to a greater extent than athletes only performing LIT.

METHODS

Subjects

Twenty-two (n=22) participants were recruited to the study, where 20 completed pre-tests (n=2 excluded prior to pre-testing due to sickness and injury). One subject refrained from complying with the intervention protocol (i.e. reduce training load) and was excluded from the study. 19 male cyclists categorized as highly-trained[9] competing at a national level volunteered to participate in this study which was approved by the local ethical committee at the University of Agder and was carried out in accordance with the Helsinki declaration of 1975. After being fully informed of the risks and stress associated with the project, all subjects signed a written consent and were assigned to either the Control- (CG; n=10) or Sprint group (SG; n=9) after pre-tests. The groups were matched on VO_{2peak} results from pre-testing and training load variables prior to the study. After initiation of the intervention, two subjects (SG) withdrew

themselves from the study (circumstances unrelated to the study). One subject (CG) was excluded due to sickness at the end of the intervention period. Sixteen (n=16) subjects (CG n=9; age: 20.4 ± 3.6 years; height: 186 ± 6 cm; body mass: 73.1 ± 4.8 kg; VO_{2peak}: 71.3 ± 4.5 $ml \cdot kg^{-1} \cdot min^{-1}$. (SG n=7; age: 22.6 ± 2.8 years; height: 184 ± 9 cm; body mass: 73.6 ± 9.0 kg; VO_{2peak}: 73.4 ± 4.9 $ml \cdot kg^{-1} \cdot min^{-1}$) completed the intervention period, including pre- and post-test. One subject was excluded from all analysis of performance results (20-min all-out) due to failing to complete the 20-min all-out performance test at pre-testing.

Design

The current study was designed as a traditional parallel two groups pre-test – post-test intervention. The intervention period was individualized and initiated 3-4 days after the last race of the subjects´ competitive seasons and was carried out over 3 weeks (21 days). CG were asked to perform one session (90 min at 60% W of VO_{2peak}) per week at the test laboratory. SG performed one 90 min SIT session per week which included 9 x 30-s all-out sprints. Sprints were performed in 3 x 3 sets per session. Set one started at 20:00 min, set two started at 43:30 min and set three started at 67:00 min. Each sprint was performed as all-out Wingate sprint. Sprint sets was separated by a cycling a power output corresponding to 60% of VO_{2peak}. A fingertip blood sample for [La^-] was taken after each set.

Methodology

Training load. Prior to the intervention, all participants gave access to their training diary. The last 4 weeks of the competition period prior to the intervention were used as baseline data for calculation of training load, and was calculated using *individualized training impulse-(iTRIMP*) method[10]. iTRIMP uses the weighting factor y_i, which increases exponentially based on the HR vs [La^-] relationship to weight every HR. An accumulated iTRIMP score was calculated by the following equation:

$$iTRIMP\ (arbitrary\ units\ (AU)) = D\ (min) \times \Delta HR_{ratio} \times y_i.$$

Where ΔHR_{ratio} is calculated from $(HR_{work}\text{-}HR_{rest})/(HR_{max}\text{-}HR_{rest})$, and D is time spent exercising. Subjects were followed up on a daily basis to ensure that reduction in training load was adhered to during the intervention period.

Testing. All subjects performed a comprehensive race-simulation protocol which included: strength tests, submaximal incremental test, a 6-s all-out sprint, a maximal incremental test, a 60 min cycling at a power output corresponding to 60% of VO_{2peak}, including 4x30-s all-out sprint and a 20-min all-out time-trial. A schematic overview of the race simulation protocol is presented in Figure 1.

All subjects completed post-tests 21 ± 1 days after pre-tests. Post-tests were performed at the same time of day (± 2h), at the same laboratory and under the same environmental conditions (18-21°C, 39-65% relative humidity, 998-1020 Barometric pressure; hPa). All testing was performed on the same electromagnetically braked cycle ergometer (Lode Excalibur Sport, Lode BV, Groningen, The Netherlands), which was adjusted according to each cyclist's preference for seat height, horizontal distance between tip of seat and bottom bracket, and handle bar position. Crank length was standardized to 172.5 mm for all cyclists. Identical positions were used for each subject at pre- and post-tests. The subjects were allowed to choose their preferred cadence during tests, and they used their own cycle shoes. The same test leaders supervised all tests and strong consistent verbal encouragement was given during testing to ensure maximal effort. VO_2 was measured using Oxycon Pro™ (Oxycon, Jaeger GmbH, Hoechberg, Germany) with a mixing chamber and 30-s sampling time using a two-way T-shape non-rebreathing valve and a reusable nose clip series 9015 (Hans Rudolph, Kansas, MO, USA). The flow turbine (Triple V, Erich Jaeger) was calibrated according to manufactural procedure. Gas sensors were calibrated via an automated process using two certified calibration gases of known concentrations. VO_2 calibration procedure was performed three times during the race simulation protocol; (1) before initiating the submaximal incremental test, (2) after the incremental test to exhaustion and (3) before the 20 min all-out. Blood [La^-] during all tests and sprint sessions where analyzed using a stationary lactate analyzer (EKF BIOSEN; EKF Diagnostics, Cardiff, UK) calibrated according to manufactures guidelines before each subject. Heart rate (HR) was measured by the athlete's own heart rate monitor (*Polar* Elektro Oy, Kempele, Finland. *Garmin*, Kansas City, Kansas, USA).

10RM Keiser strength test. After a 10-min self-paced warm-up (150-200 W) on a cycle ergometer (Lode Excalibur Sport, Lode BV. Groningen, The Netherlands) each participant underwent a 10RM leg press strength-test on Keiser AIR300 leg press (Keiser Sport health equipment INC., Fresno, CA). The Keiser A300 horizontal leg-press dynamometer uses pneumatic resistance and measures force and velocity across each effort[11]. Subjects completed

a predetermined 10 RM manufactural protocol with incremental loads, where the expected 10RM load was set to 250 kg for all subjects. The test was performed in a seated position with knee joints placed in a 90-degree angle. Each subject was instructed to push as quickly and explosively as possible. The test was terminated when the subject failed to increase or maintain power.

Blood Lactate Profile Test. The subjects started with a 10-min warm-up cycling at 150 W before the test commenced at 175 W. The test continued with a power output increase of 50 W every 5 min. Blood samples were taken form a fingertip at the end of every 5 min bout and were analyzed for whole blood [La^-] using a stationary lactate analyzer (EKF BIOSEN; EKF Diagnostics, Cardiff, UK) and a rate of perceived exhaustion (RPE) was given using Borgs' 6-20 scale[12]. The test was terminated when a [La^-] of ≥4 mMol·L^{-1} was reached. VO_2, respiratory exchange ratio (RER), and HR where measured from 2:00-4:30 min on every bout and mean values were used for statistical analysis. HR was monitored by each subjects own HR computer (Garmin/Polar). VO_2 was measured by Oxycon Pro™.

6-s all-out. The test started with the subject being seated, at a pedaling frequency of zero RPM the last 30 s before initiating the test. During this period, the subject was only allowed to pedal backwards before positioning the right foot at a 45-degree angle. The subject had to remain stationary the final 10 s. The test started with a 5-s countdown before a breaking resistance, equivalent to 0.8 Nm·kg^{-1} body mass (Lode Excalibur), was applied to the wheel and remained constant throughout the subsequent 6 s of the test. The subject was instructed to pedal with maximal effort and remain seated throughout the 6-s all-out.

VO_{2max} test. Approximately 10 min after the blood lactate test and ~5 min after 6-s all-out sprint the subject started an incremental test at 200/250 W, depending on their previous individual results. Power output was increased by 25 W every minute until exhaustion. To evaluate if the subject reached a true VO_{2max}, a plateau in VO_2 had to be reached. Further, HR ≥95% of the subjects reported maximal HR, RER ≥1.10, and [La^-] ≥8.00 mMol L^{-1} were required as criteria to evaluate if subjects attained VO_{2max}. If the subject did not have a VO_2-plateau, the test was classified as a VO_{2peak}-test, showing the highest possible VO_2 the subject could attain on that day, and not the true VO_{2max} level of the subject. The test was terminated when the cyclists failed to maintain ≥60 RPM. Maximal power output (W_{max}) was calculated as mean power output the last minute of the incremental test.

60 min at 60% W of VO_{2peak} + 4 x 30-s all-out sprints. Power output corresponding to 60% W of VO_{2peak} was calculated based on the lactate profile and VO_{2max} test. Subjects started their 60 min test, ten minutes after finishing the VO_{2max} test. To calculate gross efficiency (GE), oxygen consumption was measured between 5-10 min and 30-35 min. A fingertip blood sample for measurement of [La^-] was taken at 10-, 35-, 53- and 58-min timepoints. Subjects completed 4 x 30-s all-out Wingate sprints between 36 and 54 min. The first Wingate started from a resistance equivalent to 60% W of VO_{2peak}, while the following three started from a resistance off 100 W. Borg's scale was used for RPE at 10, 35, 53 and 58 min, as well as after each of the four Wingate's.

30-s all-out Wingate test. Wingate sprints were performed at pre- and post-test (all subjects) and during the intervention (only SG) to determine (1) peak power, (2) mean power, and (3) rate of fatigue during 30 s ($Power_{30s}$). Subjects were instructed to produce maximal effort from the start of the test and not save energy until later. The test started with the cyclist pedaling seated, at a frequency of 80 RPM for 10 s, including a 5 s countdown before a breaking resistance, equivalent to 0.8 $Nm{\cdot}kg^{-1}$ body mass (Lode Excalibur), was applied to the wheel and remained constant throughout the subsequent 30 s of the test. The cyclist was instructed to pedal with maximal effort and remain seated throughout the 30-s all-out. Each Wingate sprint was followed by 1 min passive recovery and 3 min active recovery cycling at 100 W.

20-min all out. After completion of the 60-min test, subjects started a self-paced 20-min all-out time-trial. Subjects began at their preferred self-chosen power output (W) and were free to change their power output (W) during the all-out trial on a remote controller mounted on the handlebar. During the test, oxygen consumption was measured from 4-5 min, 9-10 min and 14-20 min. A fingertip blood sample for [La^-] was taken at 10 min and 1 min after finishing the 20-min all-out. Borgs' scale for RPE was used at 5, 10, 15 and 20 min.

Insert Figure 1 here

Statistical analysis

The study used magnitude based interreferences for smallest worthwhile change to asses results. All values presented in the text, figures, and tables are mean ± SD unless stated otherwise. Data were assessed for practical significance using magnitude-based inferences[13]. All data were log-

transformed before analysis to reduce bias arising from nonuniformity error. Data analysis involved comparing the magnitude of changes in physiological variables between SG and CG during each training period. These analyses were performed using a modified statistical spreadsheet[13]. The spreadsheet calculates between-groups standardized differences or effect sizes (ES, 90% confidence limits [CL]) using the pooled SD. The criteria to interpret the magnitude of the ES were 0.0 to 0.2 trivial, 0.2 to 0.6 small, 0.6 to 1.2 moderate, 1.2 to 2.0 large, and >2.0 very large[14]. Furthermore, the probabilities to establish whether the true (unknown) differences were lower, similar to, or higher than the smallest worthwhile change or difference were calculated. The smallest worthwhile change/difference was 1%, based on previous findings from elite cyclists[15], except for training data, where it was calculated as 0.2 multiplied by the between-subjects SD. Quantitative chances of higher or lower differences between groups were evaluated qualitatively as follows: <1%, almost certainly not; 1% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possible; 75% to 95%, likely; 95% to 99%, very likely; and >99%, almost certain. If the chance of higher or lower differences was >5%, the true difference was assessed as unclear. The mechanistic inference refers to the threshold chances of 5% for substantial magnitudes.

RESULTS

Baseline; There was no clear difference between SG and CG before the intervention with respect to body mass, VO_{2peak}, W_{max}, power output at 4 $mMol \cdot L^{-1}$ [La^{-}], and 20-min all-out performance (table 1). A small difference (ES: 0.48) between CG and SG can be observed in high-level cycling experience, where SG had ~2 years longer experience (7.1 ± 3.6 vs 5.3 ± 3.8 years for SG and CG respectively).

Training Load: iTRIMP score for CG and SG during lead-in phase and intervention is presented in Figure 2. A small difference in iTRIMP score for the 4-week lead-in phase (CG vs SG: 2697 ± 1187 vs 3453 ± 1447) was observed (ES: 0.57). Both groups reduced their training load to the same extent during the 3-week intervention period (-63.14 ± 10.68% vs -62.32 ± 13.95% for CG and SG respectively) with no difference between groups (CG -64.6 ± 33.8%, SG -61.4 ± 36.2) 8.9 ±29.8% [Mean ±90%CI]; ES 0.20 ±0.63).

Insert Figure 2 here

Body mass, Power output at 4 mMol·L^{-1}, W_{max} and VO_{2peak}: No substantial differences were observed in body mass for CG and SG between pre- and post-test (CG 0.7 ± 1%, SG 0.7 ± 1.0; group difference 0.0 ±0.9%; ES 0.0 ±0.1). No substantial differences were seen in absolute power output at 4 mMol·L^{-1} [La^{-}] (CG -4.2 ± 6.3%, SG -3.5 ± 3.9%; group difference 0.7 ±4.5%; ES 0.04 ±0.25) or in relative power output at 4 mMol·L^{-1} [La^{-}] (W·kg^{-1}) (CG -4.9 ± 5.6%, SG -4.2 ± 3.7%; group difference 0.7 ±4.1%; ES 0.07 ±0.37). There was a trivial decrease in relative VO_{2peak} (CG -0.5 ± 4.1%, SG -2.6 ± 6.1%, group difference -2.1 ±4.6%; ES -0.31 ±0.68), with no change in relative W_{max} (W·kg^{-1}; CG -1.0 ± 5.1%, SG -0.1 ± 5.5%; group difference 1.1 ±4.7%; ES 0.16 ±67. Absolute VO_{2peak} (L·min^{-1}) (CG -0.2 ± 4.4%, SG -1.9 ± 6.3%; group difference -2.1 ±4.6%; ES -0.31 ±0.68) and absolute W_{max} (CG -0.3 ± 5.7%, SG 0.8 ± 5.7%; group difference 1.1 ±5.0%; ES 0.08 ±0.38) did not have any meaningful differences. All mechanistic interreferences was unclear (Table 1).

Insert Table 1 here

Power output during 20-min all-out trial: Relative mean power output during the 20-min all-out time-trial was lower in both SG and CG from pre- to post-test but with no clear between group difference observed (CG -4.1 ± 5%, SG -1.8 ± 8.3%; group difference 2.5 ±6.6%; ES 0.19 ±0.5). Further, no differences were seen in absolute mean power output (CG -3.3 ± 4.9%, SG -1.1 ± 8.1%; group difference 2.4 ±6.4%; ES 0.13 ±0.36).

Insert Figure 3 here

Pacing: Mean power output at 5-, 10-, 15-, and 20-min were similar at both pre- and post-test, with all mean values within the SD (Figure 4 and Table 1). There was a tendency towards a moderate decline in CG at 15-min (CG -9.7 ± 18.9% vs SG -0.2 ± 12.3%; group difference 10.6 ±14.9%; ES 0.52 ±0.70). SG experienced a moderate increase in power output at the 20-min time point pre to post (CG -4.0 ± 14.9%, SG 8.4 ± 24.3%; group difference 12.9 ±19.9%; ES 0.63 ±0.91), but with unclear mechanistic interferences. When adjusting body mass, there was a moderate reduction in mean relative power output for CG at both the 15- and 20-min compared with SG (CG -10.4 ± 19.4%, SG -0.9 ± 12.6%; group difference 10.7 ±15.2%; ES 0.69 ±0.93 at 15-min and CG -4.8 ± 15.7%, SG 7.6 ± 24.7%; group difference 13.0 ±20.2%; ES 0.74 ±1.09 for the 20-min time point). However, the mechanistic interferences (% chances that the true value is positive/trivial/negative) was unclear at both the 15- and 20-min time point.

Only trivial differences were seen at the 5- and 10-min time points (5 min: CG -3.5 ± 9.4%, SG -3.9 ± 5.9%; group difference -0.5 ± 6.8%; ES 0.03 ±0.52; 10 min: CG -3.2 ± 6.8%, SG -0.8 ± 12.1%; group difference 2.5 ± 9.2%; ES 0.17 ±0.62).

Insert Figure 4 here

DISCUSSION

Our main finding is that performing 4.5 min of SIT in addition to LIT during a 3-week transition period, does not maintain performance or performance related physiological variables to a further extent compared to only perform LIT. While both CG and SG had a decline in performance during the 20-min all-out time-trial, there was a tendency towards a smaller decline in the CG group, but with trivial differences.

Mean power output during 20-min all-out time-trial

No meaningful differences were observed in relative mean power output ($W \cdot kg^{-1}$) during the 20-min performance test, as both groups had a trivial decline in power output from pre- to post-test. A similar trivial decline was found in absolute mean power output (W). When Rønnestad and colleagues incorporated 30 min of HIT every 7-10 days, the experimental group experienced an increase in mean power output during the 8-week transition period, where the control group experienced a ~6% decline[7]. However, 30 min of HIT is a markedly higher load than 4.5 min of SIT. The present study did, therefore not expect to increase performance during the transition period, however aimed for a lower reduction in the decline expected following a reduction in training load[2]. A small tendency towards a reduced decline in power output between CG (-4.1 ± 5%) and SG (-1.8 ± 8.3%; (ES 0.19 ±0.44) could be observed at post-test, but with no meaningful differences.

Pacing during 20-min all-out time-trial

When exploring the power output at different timepoints (i.e., at 5-, 10-, 15-, and 20-min) it is possible SG had a more optimal pacing during the post-test. As expected, no increase in power output was seen from pre- to post test in SG. In contrast to CG, SG's performance was maintained to a further extent, as CG experienced a moderate decrease in power output at the 15- and 20-in time point from pre to post-test (Figure 4).

Sub- and Maximal incremental test: Lactate threshold, VO_{2peak} and W_{max}.

No meaningful differences were observed in power output at 4 $mMol \cdot L^{-1}$ [La^{-}] from pre- to post-test or between groups. SG showed a moderate increase in fractional utilization of VO_{2peak}, compared to CG, suggesting they become more inefficient at lactate threshold.

A trivial reduction in VO_{2peak} was observed, with no difference between CG and SG. This is in contrast to the 4-14% reduction reported by Mujika & Padilla[2], and the study performed by Rønnestad and colleagues where the control group experienced a ~3% likely reduction in VO_{2max}[7]. However, their intervention period was 8 weeks, and there is a notably difference between a short and long period of insufficient training stimulus[1,2]. There were, however, large individual variations observed (Figure 3). Interestingly, W_{max} was unchanged in both groups, suggesting that any small change in VO_{2peak} do not interfere with maximal power output.

Limitations

Our study sample is small, but similar to other studies conducting trials on highly-trained athletes[4,5,7,8,16]. The intervention started shortly after each cyclist's competitive period, leaving no time for familiarization to the test- or SIT-protocol. All athletes had experience from the laboratory, however they had never completed a test protocol this extensive. In similar studies including a performance measure (time-trials), subjects completed sub-maximal and maximal incremental tests on day one in the laboratory, often followed by a 40 min time-trial on the athlete's own bike on day two. We did not observe large differences in regard to the pacing between pre- and post-test in our subjects, however we cannot rule out that there might have been a learning effect to the race simulation protocol as none of the included cyclists had any experience or familiarization to this specific protocol.

PRACTICAL IMPLICATIONS

The clear benefits from SIT in untrained to moderately trained subjects do not seem to be present in the highly-trained cyclists included in our study. Our study was performed on a small sample which limits our possibilities to conclude if SIT has any effect on highly-trained athletes with a reduced training load. Thus, more research is needed to conclude if highly-trained athletes could benefit from SIT during their transition period. Furthermore, a longitudinal design incorporating the following season is needed to explore if maintaining performance during the transition period, actually improves next season performance. Finally, these studies should include several doses of SIT (e.g., 1 vs 2 sessions/week), as well as a group performing HIT in addition to a control group.

CONCLUSION

There were no clear effects from adding one session of SIT into endurance athlete's traditional LIT regime during their off-season period. However, large individual variations were evident, suggesting that there could be an individual response to including SIT in the transition period. More research is needed to conclude if SIT can be beneficial for highly-trained endurance athletes.

ACKNOWLEDGEMENTS

The authors would like to thank all participants for the time and effort, and all test leaders that contributed to the project. The authors have no conflict of interests.

REFERENCES

1. Mujika I, Padilla S. Detraining: loss of training-induced physiological and performance adaptations. Part II. *Sports Medicine.* 2000;30(3):145-154.

2. Mujika I, Padilla S. Detraining: loss of training-induced physiological and performance adaptations. Part I. *Sports Medicine.* 2000;30(2):79-87.

3. Lucía A, Hoyos J, Pardo J, Chicharro JL. Metabolic and neuromuscular adaptations to endurance training in professional cyclists: a longitudinal study. *The Japanese journal of physiology.* 2000;50(3):381-388.

4. Paton C, Hopkins WG. Seasonal changes in power of competitive cyclists: implications for monitoring performance. *Journal of science and medicine in sport.* 2005;8(4):375-381.

5. Sassi A, Impellizzeri FM, Morelli A, Menaspa P, Rampinini E. Seasonal changes in aerobic fitness indices in elite cyclists. *Applied physiology, nutrition, and metabolism.* 2008;33(4):735-742.

6. Seiler S, Haugen O, Kuffel E. Autonomic recovery after exercise in trained athletes: intensity and duration effects. *Medicine & Science in Sports & Exercise.* 2007;39(8):1366-1373.

7. Rønnestad BR, Askestad A, Hansen J. HIT maintains performance during the transition period and improves next season performance in well-trained cyclists. *European journal of applied physiology.* 2014;114(9):1831-1839.

8. Gunnarsson TP, Christensen PM, Thomassen M, Nielsen LR, Bangsbo J. Effect of intensified training on muscle ion kinetics, fatigue development, and repeated short-term performance in endurance-trained cyclists. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology.* 2013;305(7):R811-R821.

9. Jeukendrup AE, Craig NP, Hawley JA. The bioenergetics of world class cycling. *Journal of science and medicine in sport.* 2000;3(4):414-433.

10. Manzi V, Iellamo F, Impellizzeri F, D'ottavio S, Castagna C. Relation between individualized training impulses and performance in distance runners. *Medicine & Science in Sports & Exercise.* 2009;41(11):2090-2096.

11. Colyer SL, Stokes KA, Bilzon JL, Holdcroft D, Salo AI. Training-related changes in force–power profiles: implications for the skeleton start. *International journal of sports physiology and performance.* 2018;13(4):412-419.

12. Borg GA. Psychophysical bases of perceived exertion. *Med sci sports exerc.* 1982;14(5):377-381.

13. Hopkins WG. Spreadsheets for analysis of controlled trials, crossovers and time series. *Sportscience.* 2017;21:1-4.

14. Hopkins WG, Marshall S, Batterham A, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Medicine+ Science in Sports+ Exercise.* 2009;41(1):3.

15. Paton CD, Hopkins WG. Variation in performance of elite cyclists from race to race. *European Journal of Sport Science.* 2006;6(01):25-31.

16. Tonnessen E, Sylta Ø, Haugen TA, Hem E, Svendsen IS, Seiler S. The road to gold: training and peaking characteristics in the year prior to a gold medal endurance performance. *PloS one.* 2014;9(7):e101796.

17. Schabort E, Hawley J, Hopkins WG, Blum H. High reliability of performance of well-trained rowers on a rowing ergometer. *Journal of Sports Sciences.* 1999;17(8):627-632.

TABLE AND FIGURE LEGENDS:

Figure 1: Schematic overview of the test protocol.

Figure 2: iTRIMP load during lead-in and intervention. Mean ± SD iTRIMP score per week for Control group (black columns) and Sprint group (grey columns) during lead-in (week 1-4) and intervention (week 5-7).

Figure 3: Individual data points (dotted lines) and mean values (solid line) for a) Relative VO_{2peak}, b) Relative W_{max}, c) Relative power output during 20-min all-out time-trial and d) Power output corresponding to 4 $mMol \cdot L^{-1}$ $[La^{-}]$ before and after the intervention (pre-test, post-test). CG: Control group, SG: Sprint group.

Figure 4: Pacing during 20-min all-out time-trial for CG (a) and SG (b) at pre-test (solid lines) and post-test (dotted lines).

Table 1: Between group changes for cyclists only performing LIT (Control Group) and the experimental group (Sprint Group) performing a session of SIT per week in addition to LIT from pre- to post-test during the 3-week intervention. Data presented as Mean ± SD, or MEAN ± 95%CL. Abbreviations: LIT: Low intensity training, PO_{20min}: mean power output during 20-min all-out time-trial, $PO_{4mMol \cdot L}$: Power output at blood lactate concentration of 4 $mMol \cdot L^{-1}$ [la^{-}], SIT: Sprint interval training, VO_{2peak}: peak oxygen uptake, W_{max}: maximal aerobic power.

Figure 1

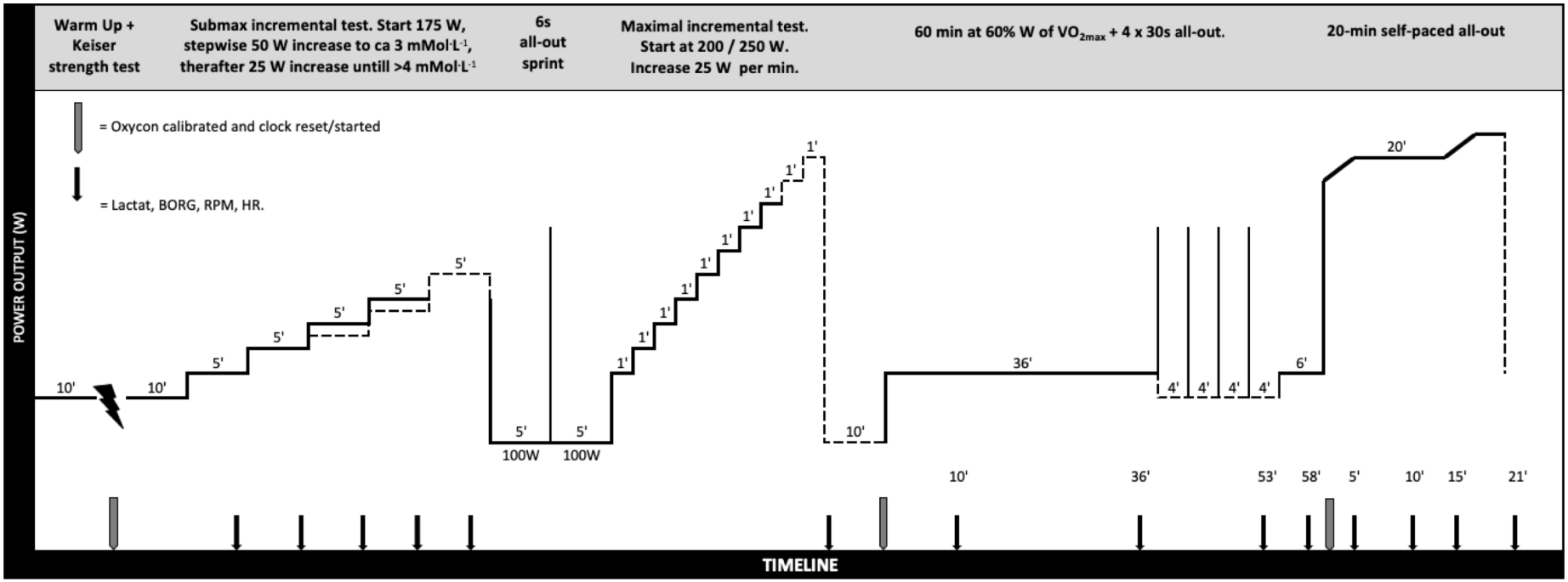

Warm Up + Keiser strength test
Submax incremental test. Start 175 W, stepwise 50 W increase to ca 3 mMol·L-1, therafter 25 W increase untill >4 mMol·L-1
6s all-out sprint
Maximal incremental test. Start at 200 / 250 W. Increase 25 W per min.
60 min at 60% W of VO2max + 4 x 30s all-out.
20-min self-paced all-out
= Oxycon calibrated and clock reset/started
= Lactat, BORG, RPM, HR.
POWER OUTPUT (W)
TIMELINE
100W
100W

Figure 2

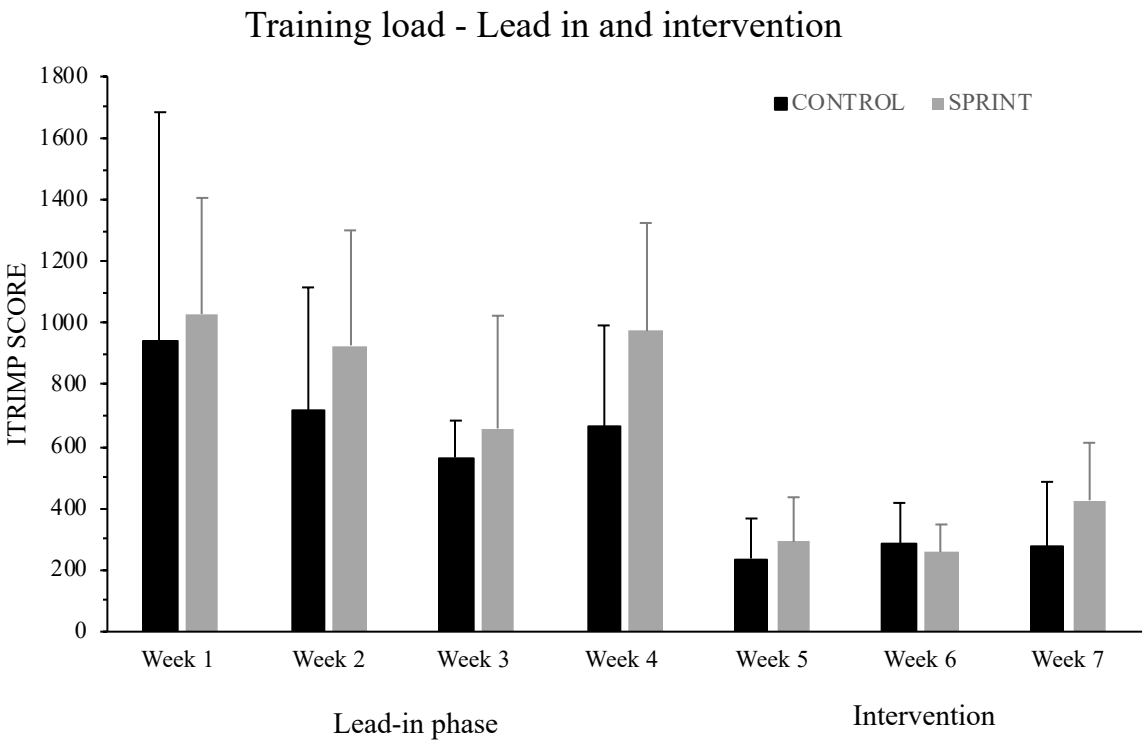

Training load - Lead in and intervention
CONTROL
SPRINT
ITRIMP SCORE
1800
1600
1400
1200
1000
800
600
400
200
0
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Lead-in phase
Intervention

Figure 4

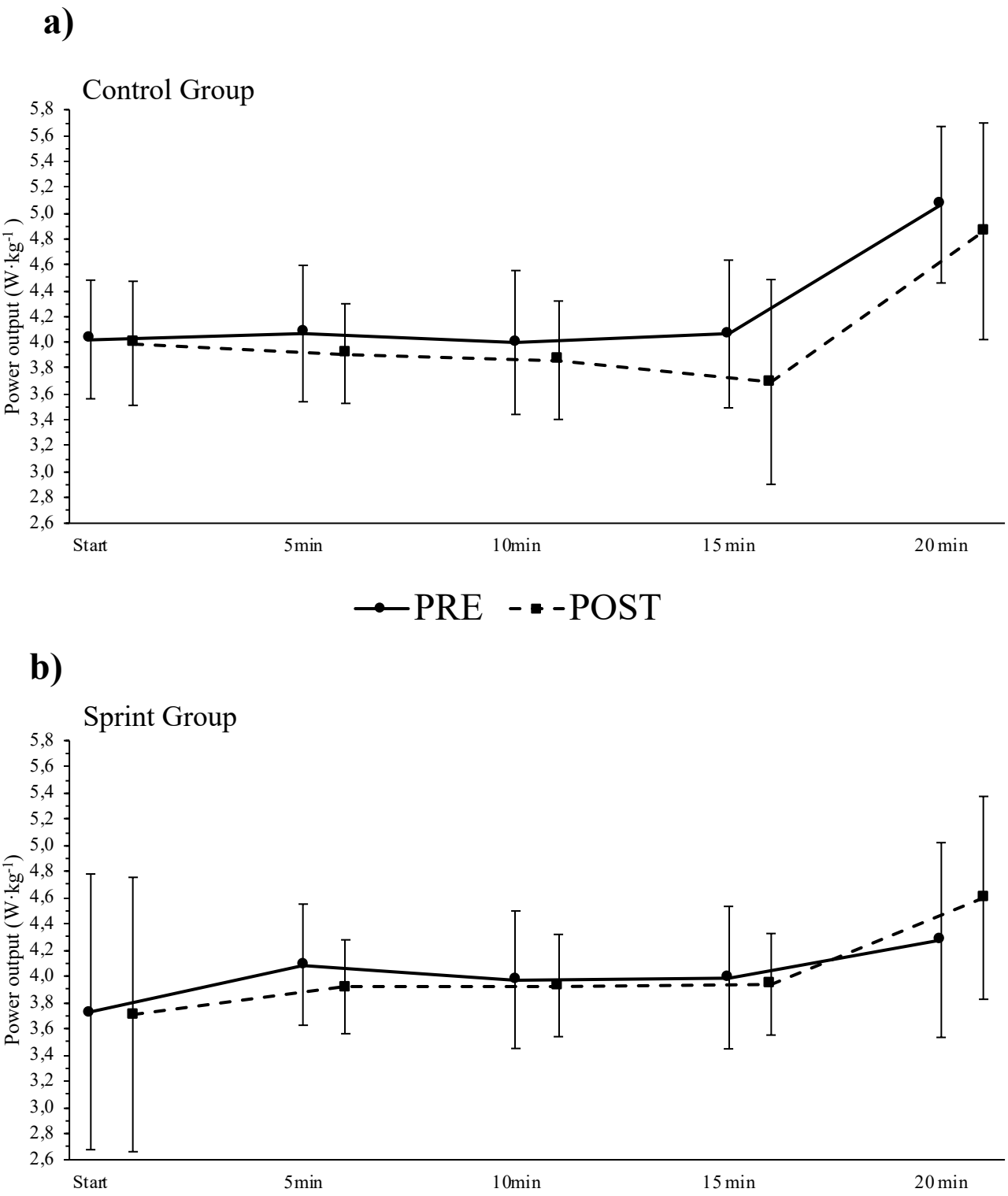

a)
Control Group
Power output (W·kg-1)
5,8
5,6
5,4
5,2
5,0
4,8
4,6
4,4
4,2
4,0
3,8
3,6
3,4
3,2
3,0
2,8
2,6
Start
5 min
10 min
15 min
20 min
PRE
POST
b)
Sprint Group
Power output (W·kg-1)
5,8
5,6
5,4
5,2
5,0
4,8
4,6
4,4
4,2
4,0
3,8
3,6
3,4
3,2
3,0
2,8
2,6
Start
5 min
10 min
15 min
20 min

Figure 3

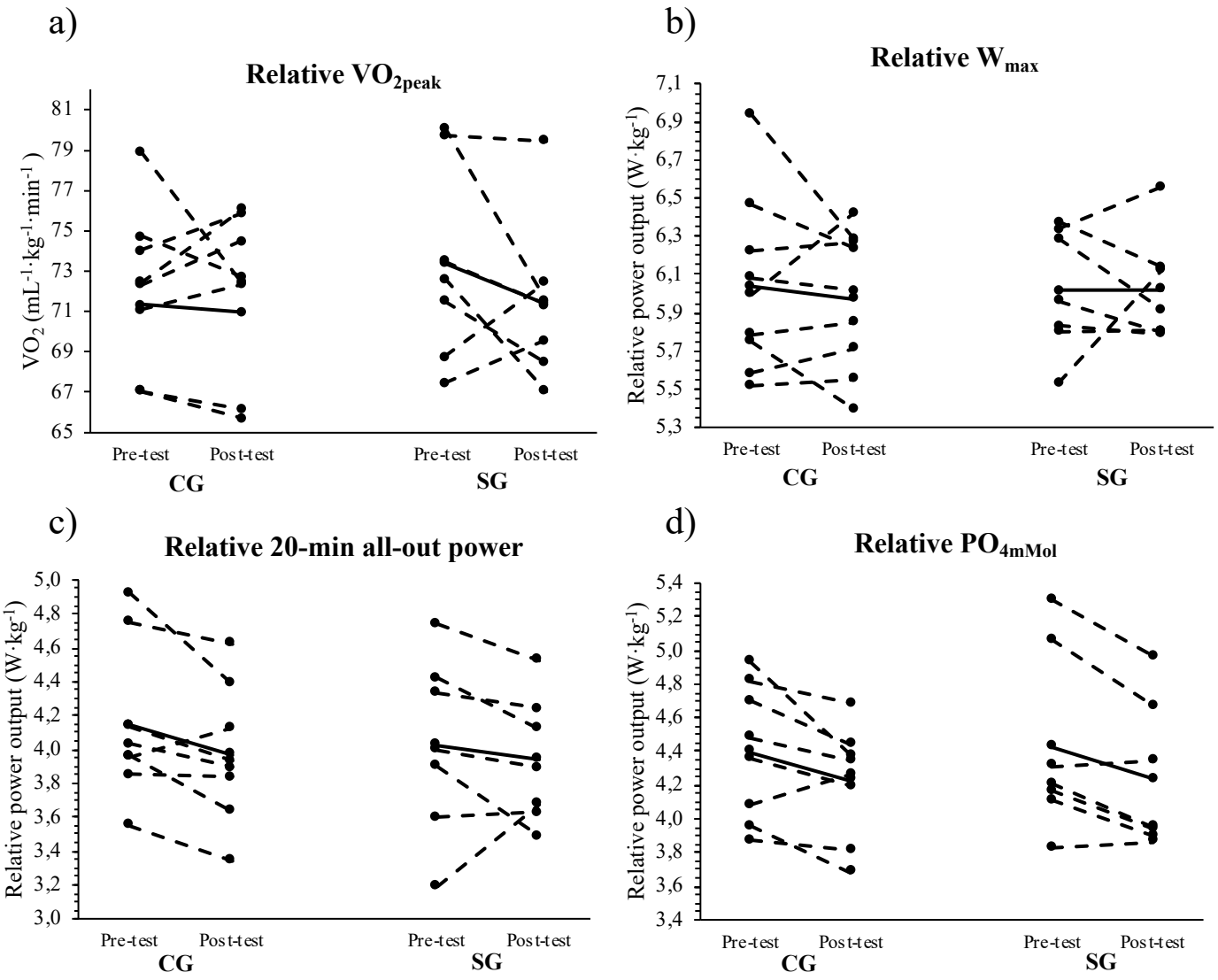

a)
Relative VO_{2peak}
VO_2 ($mL^{-1} \cdot kg^{-1} \cdot min^{-1}$)
81
79
77
75
73
71
69
67
65
Pre-test
Post-test
Pre-test
Post-test
CG
SG
b)
Relative W_{max}
Relative power output ($W \cdot kg^{-1}$)
7,1
6,9
6,7
6,5
6,3
6,1
5,9
5,7
5,5
5,3
Pre-test
Post-test
Pre-test
Post-test
CG
SG
c)
Relative 20-min all-out power
Relative power output ($W \cdot kg^{-1}$)
5,0
4,8
4,6
4,4
4,2
4,0
3,8
3,6
3,4
3,2
3,0
Pre-test
Post-test
Pre-test
Post-test
CG
SG
d)
Relative PO_{4mMol}
Relative power output ($W \cdot kg^{-1}$)
5,4
5,2
5,0
4,8
4,6
4,4
4,2
4,0
3,8
3,6
3,4
Pre-test
Post-test
Pre-test
Post-test
CG
SG

Table 1: Between group changes for cyclists only performing LIT (Control Group) and the experimental group (Sprint Group) performing a session of SIT pr week in addition to LIT from pre- to post-test during the 3-week intervention.

	RAW DATA				SPRINT VS CONTROL (% DIFFERENCE ±90% CL)	SPRINT VS CONTROL (Chances that the true value is Positive / Trivial / Negative)	SPRINT VS CONTROL (Mechanistic interferences)
	Control Group		Sprint Group				
	Pre	Post	Pre	Post	Pre to Post	Pre to Post	Pre to Post
Body mass (kg)	73.1 ± 4.8	73.7 ± 4.9	73.6 ± 9	74.2 ± 9.4	0.0 ±0.9	3/93/4	Likely trivial
VO_{2peak} ($ml^{-1}\cdot kg^{-1}\cdot min^{-1}$)	73.4 ± 4.3	71.4 ± 4.0	71.3 ± 4.5	71 ± 4.8	-2.1 ±4.6	13/21/66	Unclear
VO_{2peak} ($L\cdot min^{-1}$)	5.222 ± 0.531	5.236 ± 0.570	5.395 ± 0.678	5.278 ± 0.678	2.1 ±4.8	13/20/66	Unclear
W_{max} (W)	441.9 ± 47.7	439.9 ± 39.1	443.0 ± 57.2	445.3 ± 48.6	1.1 ±5.0	51/25/24	Unclear
W_{max} ($W\cdot Kg^{-1}$)	6.04 ± 0.45	5.97 ± 0.36	6.02 ± 0.32	6.02 ± 0.28	1.1 ±4.7	52/26/22	Unclear
$PO_{4mMol\cdot L}$	320.8 ± 41.0	307.7 ± 42.3	327.6 ± 66.3	315.5 ± 61.1	0.7 ±4.5	45/29/26	Unclear
$PO_{4mMol\cdot L}$ ($W\cdot Kg^{-1}$)	4.38 ± 0.38	4.16 ± 0.36	4.43 ± 0.54	4.23 ± 0.44	0.7 ±4.1	45/31/23	Unclear
PO_{20min} (W)	303.4 ± 45.4	293.1 ± 42.8	296.3 ± 53.1	291.3 ± 38.4	2.4 ±6.4	65/17/17	Unclear
PO_{20min} ($W\cdot Kg^{-1}$)	4.15 ± 0.46	3.97 ± 0.41	4.03 ± 0.52	3.94 ± 0.37	2.5 ±6.6	66/17/18	Unclear
Pacing during 20-min all-out ($W\cdot Kg^{-1}$)							
5 min	4.07 ± 0.53	3.91 ± 0.39	4.09 ± 0.46	3.92 ± 0.36	-0.5 ±6.8	36/20/45	Unclear
10 min	4.00 ± 0.56	3.86 ± 0.46	3.97 ± 0.52	3.93 ± 0.39	2.5 ±9.2	62/14/25	Unclear
15 min	4.06 ± 0.57	3.69 ± 0.79	3.99 ± 0.54	3.94 ± 0.39	10.7 ±15.2	87/4/9	Unclear
20 min	5.06 ± 0.61	4.86 ± 0.84	4.28 ± 0.74	4.60 ± 0.77	13.0 ±20.2	86/4/10	Unclear

Abbreviations; LIT: Low intensity training, PO_{20min}: mean power output during 20-min all-out time-trial, $PO_{4mMol\cdot L}$: Power output at blood lactate concentration of 4 $mMol\cdot L^{-1}$ [la^{-}],
SIT: Sprint interval training, VO_{2peak}: peak oxygen uptake, W_{max}: maximal aerobic power.

PART 3:

APPENDICES

CONTENT:

Per Thomas Byrkjedal

University of Agder

May 2019

Appendix 1: Information letter to clubs in the Kristiansand area

Kristiansand, 21. mars 2018

Til daglig leder/sportssjef

På vegne av Universitetet i Agder og Olympiatoppen Sør kontakter vi deg/dere i forbindelse med en landsdekkende multisenterstudie innenfor utholdenhetstrening. Prosjektet som vil foregå i september/oktober 2018, og formålet vil være å optimalisere nedtrappingsperioden fra konkurranseslutt og frem til forberedelsene mot ny sesong.

Bakgrunn
Som en følge av at utholdenhetsutøvere senker sin totale treningsbelastning etter endt konkurransesesong svekkes også den fysiske kapasiteten før man senere starter oppkjøringen til en ny sesong. Nyere forskning har vist at ved å legge til sprinter/høyintensitetsdrag etter rolige langkjøringsøkter kan man opprettholde fysisk kapasitet selv ved en reduksjon i treningsmengde på inntil 65%! Tendensen synes å være lik innenfor en rekke utholdenhetsidretter (langrenn, skiskyting, kombinert, roing og sykling). Disse funnene vekker stor interesse hos fagavdelingen til Olympiatoppen, men er pr dags dato enda ikke er systematisk undersøkt. Sammen med Norges Teknisk Naturvitenskapelige Universitet, Norges Idrettshøyskole, Høyskolen på Vestlandet (Bergen) og Høyskolen i Innlandet (Lillehammer) skal vi ved Universitetet i Agder undersøke til sammen ca 40 syklister. Denne store multisenterstudien vil potensielt bidra til å optimalisere treningen til fremtidige olympiske mestere i utholdenhetsidretter!

Treningsintervensjon
Treningsintervensjonen vil vare i 4 uker og starte umiddelbart etter konkurransesesong. Hver uke vil bestå av ca. 6-8 timer trening fordelt på 4 økter. Deltakerne vil tilfeldig bli plassert i en av tre grupper. Hver gruppe gjennomfører et eget treningsopplegg med tilsvarende treningsmengde. Det er kun antall økter med innlagt sprint som skiller gruppene, henholdsvis 0, 1 og 2 økter (se tabell).

	Rolig langkjøring (per uke)	**Rolig langkjøring med innlagt sprint (per uke)**	**Totalt antall økter per uke**
Gruppe 1	4 økter	0	4
Gruppe 2	3 økter	1 økt	4
Gruppe 3	2 økter	2 økter	4

***Rolig langkjøring** = Ca. 2 timer. **Sprint** = 3 x 30 sek maksimal sprint (4 sett).*

Tester
Utøverne vil bli testet på en rekke fysiologiske variabler (VO2-maks, laktatprofil, arbeidsøkonomi, hemoglobinnivå, kappilærtethet mm.) før og etter treningsintervensjonen. Det vil ikke bli gjennomført muskelbiopsier.

Kristiansand, 21. mars 2018

Deltakere

Vi er på jakt etter potensielle utøvere til den foreliggende studien og av den grunn tar vi kontakt med deg/dere. Vi ønsker å rekruttere mannlige syklister som avslutter sin konkurransesesong i perioden september-oktober 2018. I henhold til studiens formål, bør utøverne ha opprettholdt en stabil og høy treningsmengde gjennom sesongen. Syklistene bør ha en Vo2-maks på ca 65ml/o2/kg, samt ha deltatt jevnlig i Kontinentalcupen eller Norgescupen. Vi er også interessert i utøvere som ikke oppfyller disse kravene, men som er like ved et gjennombrudd (f. eks. Juniorutøvere).

Mvh.

OLYMPIATOPPEN

UNIVERSITETET I AGDER

Appendix 2: Informed written consent form signed by the participants

Forespørsel til deltagelse i forskningsprosjekt for elite-syklister
-Optimalisering av den aktive avkoplingsperiode etter konkurransesesongen

Bakgrunn og hensikt med studien
I løpet av de første 3 ukene etter konkurransesesongen reduseres treningsmengden relativt mye hos de fleste syklister (Lucia et al. 2001). Denne reduksjonen og avbrekket fra treningen er viktig for motivasjonen frem mot neste sesong, men et langt avbrekk fører for noen til en redusert prestasjonsevne (Maldonado-Martin et al. 2017).

Vi planlegger et forskningsprosjekt der vi gjennom de 3 første ukene etter siste konkurranse vil undersøke effekten av redusert treningsbelastning med ulikt innhold. De to gruppene reduserer treningsmengden med 50% fra konkurransesesong. Du vil bli inndelt i en av to følgende grupper:

1) Tradisjonell gruppe som kun gjennomfører rolig langkjøring
2) Sprintgruppe som gjennomfører en økt med 9x30 s maksimale sprinter underveis på en 2-t langkjøring hver uke, mens det resterende er rolig langkjøring

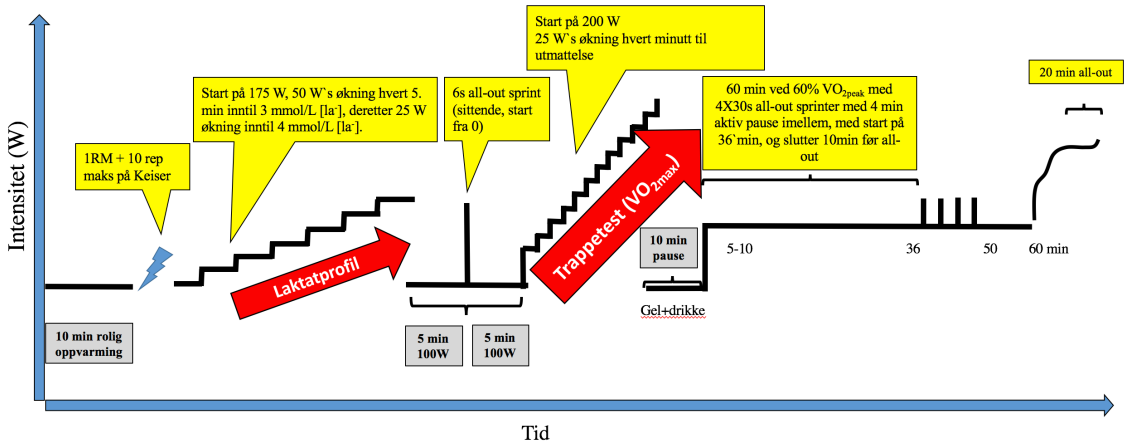
Begge grupper trener ~4-8 timer per uke og treningen din blir registrert 4 uker i forkant og underveis i prosjektet. En økt hver uke gjennomføres på testlabben, mens det resterende gjennomføres på egen sykkel. Prosjektet gjennomføres med løpende oppstart, rett etter din siste konkurranse (fra september-oktober 2018). Effekten av disse to treningsmetodene vil vi måle på blodvolum, mengden røde blodceller, blodhormoner og prestasjonstester på sykkel.

Kriterier for deltakelse er følgende: Du må være i alderen 18-40 år, sykling må være din utholdenhetsidrett med i snitt over 13 treningstimer per uke og ha jevnlig deltakelse i Norgescupen. Maksimalt oksygenopptak må være over 70 ml/kg/min.

Resultatet av studien vil kunne bidra til å optimalisere utholdenhetstrening for elite-syklister spesielt og andre utholdenhetsutøver generelt. Prosjektet er initiert og ledet av Høgskolen i Innlandet (Lillehammer) i samarbeid med Olympiatoppen, NTNU, Høgskulen på Vestlandet (Bergen), Universitetet i Agder og Norges Cykleforbund.

Hva innebærer studien?
Pre- og post- testing
Du møter en eller to ganger til testing (dag 1 gjelder bare for deltakere på Lillehammer, Agder og Trondheim).
<u>På dag 1</u> møter du fastende tidlig på morgenen til måling av kroppssammensetning (DXA), hvilestoffskiftemåling og veneblodprøve. Dette varer omtrent 1 time. Du leverer og inn en urinprøve på morgenen som straks analyseres for hydreringsstatus, hvoretter prøven kastes.
Alle gjennomfører på dag 1 en standardisert rolig økt på ~1t der du kjører 4x30s maksimale sprinter med 4min pause imellom. Økta gjennomføres på egen hånd.
<u>På dag 2</u> fyller ut spørreskjema (RESTQ-Sport, LEAM-Q og ABQ), gjennomfører en beinpress test, laktatprofil, 6-s sprinttest, maksimalt oksygenopptaks-test og en prestasjonstest (60 min rolig sykling med 4x30-s maksimale sprinter og en 20 min temposykling til slutt) og avslutningsvis får du målt blodvolum. Dette tar i alt ~4 t.

Prestasjonstest



Treningsintervensjonen og avsluttende testing

Etter dette blir du tildelt en treningsgruppe og trener i 3 uker. All trening loggføres via sykkelcomputer i online treningsdagbok (TrainingPeaks). Etter de 3 ukers trening møter du til avsluttende testing hvor de samme tester som ble gjennomført første gang repeteres. Alle testene for den enkelte blir gjennomført på samme sted, under tilnærmet like forhold for alle forsøkspersonene og innenfor samme tidsrom på døgnet (± 1 time) for hver person. Samme testleder blir også benyttet.

Hvordan påvirkes den planlagte trening?

24 timer før testing må du avstår fra høyintensiv trening og alkohol. Kosthold registreres og gjentas ved pre- og post- testing. Vi måler mengden av røde blodceller ved at du inhalerer en kjent, ikke-skadelig mengde av gassen karbon monooxid. Mengden av dette i blodet er halvert etter ~5 t og vil ikke påvirke deg i din daglige, rolige aktivitet.

Dersom du trener styrketrening i forkant av studien, kan du fortsette dette uten endring i treningsprogrammet (må rapporteres i dagbok med øvelser, kg, antall sett og repetisjoner). Utholdenhetstreningen de ukene prosjektet varer er imidlertid låst til det beskrevne treningsprogrammet du får tildelt.

Du får ytterligere tilbud om en oppfølgende test ~8 uker etter siste test, for å se hvordan prestasjonen din utvikler seg videre. Hvis du ønsker denne oppfølgningstesten er der ingen restriksjoner på treningen i de 8 ukene, men trening må fortsatt registreres i treningsdagbok.

Hva skjer med informasjonen om deg?

Opplysningene som er innhentet om deg (testresultatene) og informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kode knytter deg til dine opplysninger og prøver gjennom en navneliste. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten og som kan finne tilbake til deg. Forsker er underlagt taushetsplikt og data behandles konfidensielt. All informasjon og de fysiske testresultatene som samles inn slettes senest i desember 2032. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres. Så lenge du kan indentifiseres i datamaterialet, har du rett til følgende: innsyn i hvilke personopplysninger som er registrert om deg, å få rettet personopplysninger om deg, få slettet personopplysninger om deg, få utlevert en kopi av dine personopplysninger (dataportabilitet), og sende klage til personvernombudet eller Datatilsynet om behandlingen av dine

personopplysninger. Prosjektet er meldt til Personvernombudet for forskning, Norsk senter for forskningsdata AS (NSD). Dataene som fremkommer i studien vil i hovedsak bli benyttet i vitenskapelige artikler, men vil også kunne bli presentert på nasjonale og internasjonale konferanser og seminarer.

Alle blodprøver, samt informasjon som blir utledet fra dette materialet vil bli lagret i kodet tilstand i en forskningsbiobank tilknyttet prosjektet, situert ved Høgskolen i Lillehammer/Sykehuset Innlandet. Blodprøvene vil etterhvert bli overført til den generelle biobanken «The TrainsOME – humane cellers tilpasning til trening og miljø» innen 31/8-2032 (se eget samtykkeskjema). Gjennom den generelle biobanken skal prøvene analyseres sammen med prøver fra en rekke andre prosjekter, hvor den overordnete målsettingen er å studere faktorer som er bestemmende for generell trenbarhet. Hvis du sier ja til å delta i studien, gir du samtidig samtykke til at det biologiske materialet og analyseresultater inngår i biobanken. Prøvematerialet vil bli oppbevart i låsbar fryser på låsbart lagerrom og lagres i den generelle biobanken til og med 2038. Deler av blod-/vevsprøvene vil kunne bli sendt til øvrige nasjonale eller utenlandske laboratorier for analyse. I slike tilfeller vil prøvene kun være merket med identifikasjonsnummer, d.v.s. de vil bli sendt i kodet tilstand. Gjenværende material vil bli returnert til Lillehammer i etterkant av analysene. Analyser utført på blod- og vevsprøver vil være begrenset til de som beskrives i informasjonsskriv/forskningsprotokoll tilhørende prosjektet. Analysene vil etter hvert bearbeides sammen med øvrige data innsamlet fra vev som inngår i den generelle biobanken «The TrainsOME – humane cellers tilpasning til trening og miljø». Hovedansvarlig for biobanken er professor Stian Ellefsen (stian.ellefsen@inn.no).

Ved å delta i studien får du testet sentrale prestasjonsbestemmende faktorer, mengden røde blodceller og hormon-nivåer, samt at du får innsikt i effekten av hvordan du responderer på ditt spesifikke treningsprogram gjennom den aktive avkoplingsperioden etter sesongslutt. Videre vil det bli holdt et infomøte om hovedfunnene av studien lenge før resultatene blir offentlig publisert, slik at du kan bruke dem videre i ditt treningsarbeid.

Samtykke til deltakelse i studien

Jeg har mottatt skriftlig informasjon og er villig til å delta i studien. Jeg giver lov til at mine personopplysninger behandles som beskrevet i dette prosjektet. Jeg er klar over at jeg når som helst og uten å oppgi grunn, kan trekke meg fra prosjektet uten at det gir noen som helst form for konsekvenser.

Dato/Sted_______________

_ _
Forsøksperson
Hvis du vil melde din interesse vennlig kontakt en av oss på telefon eller mail og ta med samtykkeerklæringen på første møte. På forhånd hjertelig takk for at du vil stille opp!

Dersom det er noe som du lurer på kan du kontakte:
Lillehammer
Nicki Winfield Almquist, PhD stipendiat (Prosjektleder): Nicki.almquist@inn.no, Tel: 96 91 19 17
Bent Rønnestad, Professor (Prosjektansvarlig): bent.ronnestad@inn.no, Tel: 61 28 81 93

Trondheim
Knut Skoveregn (Postdoktor): knut.skovereng@ntnu.no, Tel: 73 59 16 78

Bergen
Morten Kristoffersen (Lektor): Morten.Kristoffersen@hvl.no, Tel: 55 58 59 24

Kristiansand
Matthew Spencer (Professor): matthew.spencer@uia.no, Tel: 98 40 43 78
Jan Fredrik Stiansen (Sportssjef i Kristiansand CK): stians1@online.no

Appendix 3: Informed written consent for blood tests

FORESPØRSEL OM AVGIVELSE AV BLODPRØVER TIL EN GENERELL FORSKNINGSBIOBANK

The TrainsOme – humane cellers tilpasning til trening og miljø

Dette er en forespørsel til deg om du ønsker å bidra med blodprøver i den generelle forskningsbiobanken the TrainsOME.

Hva er The TrainsOME?
The TrainsOME er en generell forskningsbiobank som er godkjent av regional etisk komité (REK) og som legger til rette for oppbevaring av biologisk materiale som skal benyttes til forskning og kartlegging av sammenhengen mellom trenbarhet og cellulære egenskaper. Biobanken inkluderer vevs- og blodprøver fra en rekke enkeltstående forskningsprosjekt, som hver og en har blitt vurdert av regional etisk komite. Hvilke analyser som vil bli gjort på dine prøver vil i sin helhet være definert i det prosjektspesifikke informasjonsskrivet. For ytterligere informasjon, ta kontakt med hovedansvarshavende for forskningsbiobanken, Stian Ellefsen (epost: stian.ellefsen@inn.no; tlf: 61288103).

Hva skjer med prøvene og informasjonen om deg?
Prøvematerialet vil bli oppbevart i låsbar fryser på låst lagerrom, situert ved Høgskolen i Lillehammer/Sykehuset Innlandet. Alle opplysninger og prøver vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kode knytter deg til dine opplysninger og prøver gjennom en navneliste. Denne vil bli oppbevart adskilt fra øvrige data, enten i låst skap lokalisert til låsbart kontor eller i passord-beskyttet tilstand i Høgskolen i Lillehammers elektroniske saksbehandlings- og arkivsystem (Ephorte) og vil kun være tilgjengelig for autorisert personell. Det vil ikke være mulig å identifisere deg i resultatene som kommer ut av biobanken når disse publiseres. Deler av materialet vil kunne bli sendt til utlandet for analyse. Merking vil i slike tilfeller være begrenset til identifikasjonsnummer; d.v.s. de vil bli sendt i kodet tilstand. Ubenyttet materiale vil bli returnert til Lillehammer i etterkant av analysene. Det biologiske materialet vil bli anonymisert innen 31.12.2038, hvorpå det vil bli destruert innen fem år. Høgskolen i Lillehammer ved administrerende direktør er databehandlingsansvarlig.

Dine rettigheter
Det er frivillig om du vil la ditt biologiske materiale inngå i The TrainsOME-biobanken og du kan når som helst trekke tilbake ditt samtykke uten at du trenger oppgi grunn for dette. Hvis du sier ja til innlemmelse i biobanken, har du rett til å få innsyn i opplysninger som er registrert på deg og også rett til å få korrigert eventuelle feil som oppdages. Du vil etter loven ha krav på jevnlig informasjon om hvordan materialet blir benyttet. Om du trekker ditt samtykke, vil ditt biologiske materiale samt utledete data bli slettet, med mindre opplysningene allerede inngår i analyser eller har blitt brukt i vitenskapelige publikasjoner.

Prosjektkoordinator eller øvrige prosjektmedarbeidere kan kontaktes når som helst i arbeidstiden:

Stian Ellefsen (hovedansvarshavende), tlf: 61288103, epost: stian.ellefsen@inn.no
Bent Rønnestad (prosjektkoordinator), tlf: 61288193, epost: bent.ronnestad@inn.no
Gunnar Slettaløkken (prosjektkoordinator), tlf: 61288182, epost: gunnar.slettalokken@inn.no.

Samtykke til deltakelse i den generelle forskningsbiobanken

Jeg bekrefter med dette å ha lest informasjonsskrivet knyttet til den generelle biobanken «The TrainsOME – humane cellers tilpasning til trening og miljø» og samtykker til at mine vevs- og blodprøver kan inngå i biobanken:

Sted:…… Underskrift: ……

Dato: …../…. 20…..

Appendix 4 Approval from the local ethics committee at Inland Norway University of applied Science.

HØGSKOLEN i INNLANDET

Høgskolen i Innlandet
Lokal etisk komite

Lillehammer 20. august 2018

Vedrørende prosjekt «Optimalisering av den aktive avkoplingsperiode etter konkurransesesongen»

Det vises til innsend søknad av 1. august 2018 om forskningsetisk vurdering at prosjektet «Optimalisering av den aktive avkoplingsperiode etter konkurransesesongen»

Til søknaden ble vedlagt følgende dokumentasjon:
1. Informasjonsskriv til deltagere i studier
2. Samtykkeerklæring
3. Tilrådning fra NSD Personvernombudet for forskning § 7-27, datert 17. juli 2018

Studien inngår i Nicki Almquist's doktorgradsarbeid
Prosjektleder: Nicki Almquist
Faglig ansvarlig og veileder: Professor Bent Rønnestad

Lokal etisk komite har behandlet søknaden og tilrår at prosjektet gjennomføres i henhold til prosjektets plan og intensjoner.

På vegne av lokal etisk komite
Marit Rolland
Marit Rolanc

Appendix 5: Approval from the Norwegian Center for research data (NSD)

Idrettshøgskolen Innlandet Høgskolen Innlandet
Att: Nicki Winfield Almquist nicki.almquist@inn.no
2406 ELVERUM

Vår dato: 19.07.2018 *Vår ref: 61039/3/MSS* *Deres dato:* *Deres ref:*

Tilrådning fra NSD Personvernombudet for forskning § 7-27

Personvernombudet for forskning viser til meldeskjema mottatt 11.6.2018 for prosjektet

Vurdering

Den 20. juli trer EUs personvernfordning, samt den nye norske personopplysningsloven, i kraft. Prosjektet ditt er vurdert etter dagens personopplysningslov (personopplysningsloven av 14.4.2000),
ettersom prosjektet ble meldt inn før det nye regelverket begynner å gjelde. Personvernombudet vurderer at prosjektet kan gjennomføres med behandlingsgrunnlag i personopplysningsloven 2000 § 9 a,
jf. § 8 første ledd, jf. personopplysningsforskriften § 7-27.

Forutsatt at informasjonsskrivet og samtykkeskjemaet tilpasses etter våre kommentarer (se side 3) vurderer personvernombudet at prosjektet vil ha gyldig behandlingsgrunnlag også etter det nye personvernregelverket. Behandlingen vil da ha behandlingsgrunnlag i personvernforordningen artikkel 9
nr. 2, bokstav a), jf. ny personopplysningslov (15.6.2018) § 10 (behandling på grunnlag av utvalgets
informerte samtykke).

Vilkår for vår anbefaling

Vår anbefaling forutsetter at du gjennomfører prosjektet i tråd med:
•opplysningene gitt i meldeskjemaet og øvrig dokumentasjon
•vår prosjektvurdering, se side 3
•eventuell korrespondanse med oss

Meld fra hvis du gjør vesentlige endringer i prosjektet

Dersom prosjektet endrer seg, kan det være nødvendig å sende inn endringsmelding. På våre nettsider
finner du svar på hvilke endringer du må melde, samt endringsskjema.

Opplysninger om prosjektet blir lagt ut på våre nettsider og i Meldingsarkivet

Vi har lagt ut opplysninger om prosjektet på nettsidene våre. Alle våre institusjoner har også tilgang til
egne prosjekter i Meldingsarkivet.

Vi tar kontakt om status for behandling av personopplysninger ved prosjektslutt

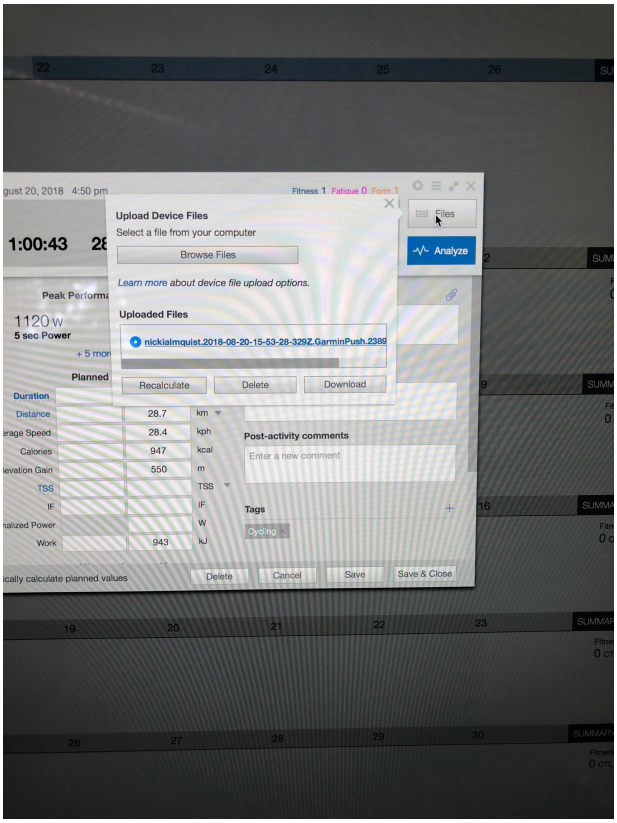
Ved prosjektslutt 31.12.2032 vil vi ta kontakt for å avklare status for behandlingen av personopplysninger.
Se våre nettsider eller ta kontakt dersom du har spørsmål. Vi ønsker lykke til med prosjektet!

Appendix 6: How to transform training sessions to iTRIMP

Loggføre treningsvolum via iTRIMP

Når iTRIMP er innstillet med data fra laktat+VO2max testen kan den reelle iTRIMP beregnes.

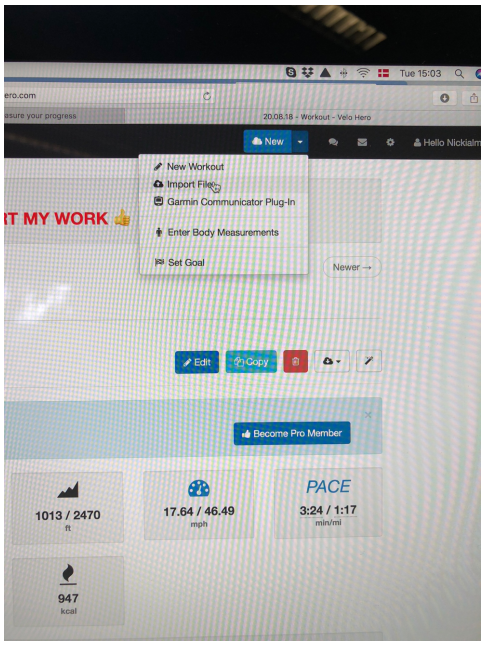
Gå til TrainingPeaks og last ned hver økt: Klikk på økten -> Files -> Download.
En .fit fil er nå lastet ned.



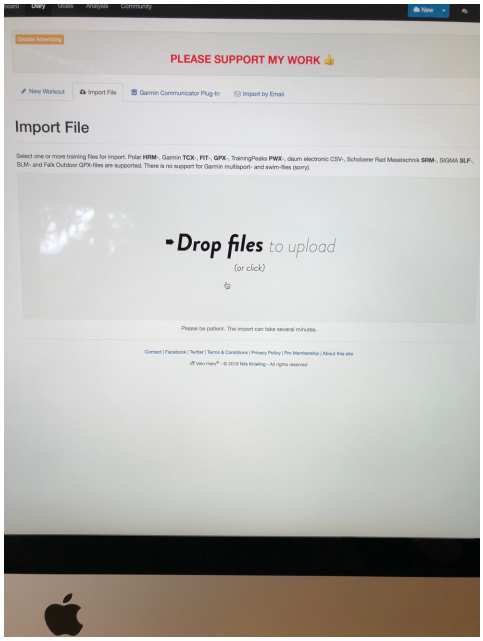
Gå til velohero.com og opprett en gratis profil.

Importer fil ved å dra dem over fra download-mappen på PC'en -> gå til analysis i VeloHero -> scroll ned til "Workouts" og velg pågjeldende workout -> eksporter som CSV-fil og slett deretter filen for å unngå dupletter. Omdøp filen til dato_økttype (LIT,MIT,HIT,SPRINT)

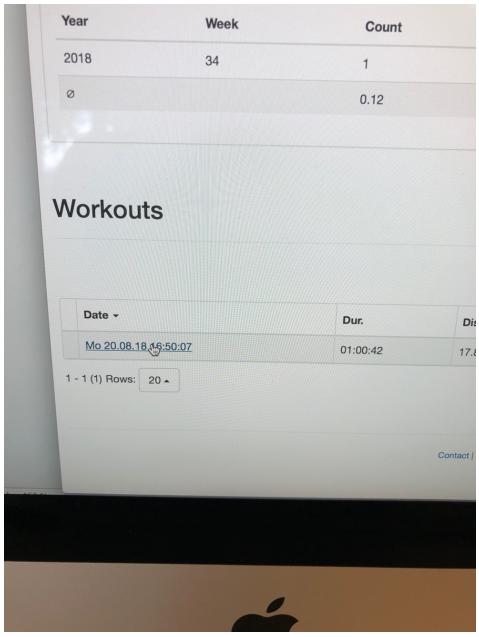
1


Tue 15:03
20.08.18 - Workout - Velo Hero
New
New Workout
Import File
Garmin Communicator Plug-In
Enter Body Measurements
Set Goal
Newer →
Edit
Copy
Become Pro Member
1013 / 2470
ft
17.64 / 46.49
mph
PACE
3:24 / 1:17
min/mi
947
kcal

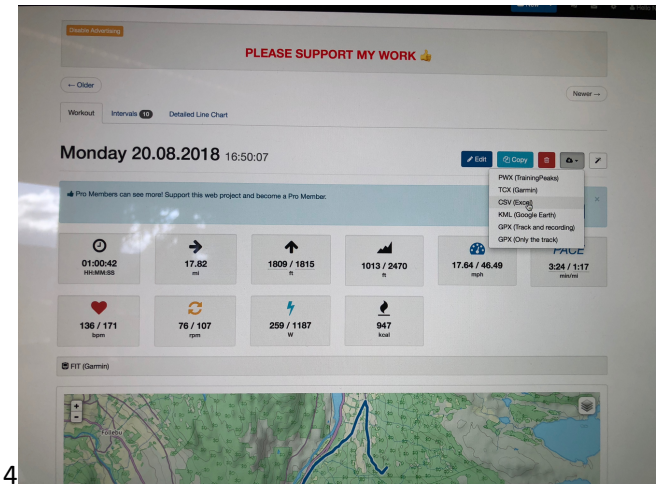
2

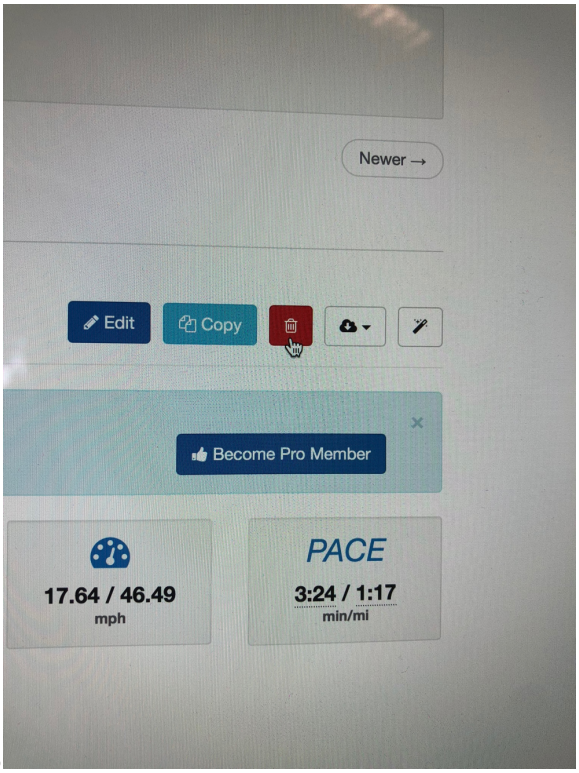

PLEASE SUPPORT MY WORK
Import File
Drop files to upload
(or click)

3

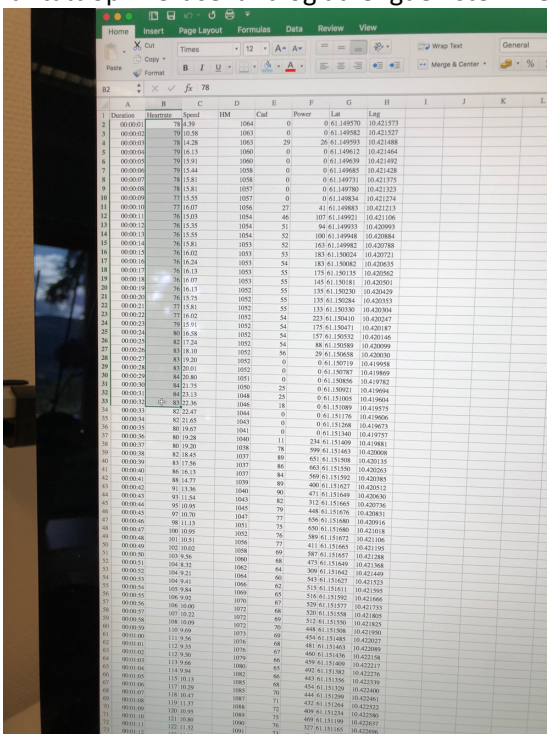

Year
Week
Count
2018
34
1
Ø
0.12
Workouts
Date
Dur.
Mo 20.08.18 16:50:07
01:00:42
1 - 1 (1) Rows:
20

4

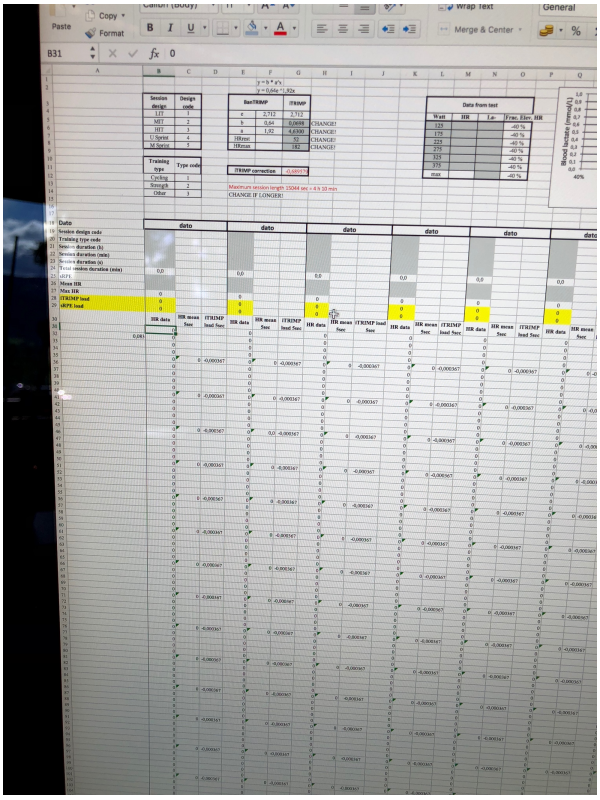

PLEASE SUPPORT MY WORK
Monday 20.08.2018 16:50:07
Edit
Copy
Pro Members can see more! Support this web project and become a Pro Member.
PWX (TrainingPeaks)
TCX (Garmin)
CSV (Excel)
KML (Google Earth)
GPX (Track and recording)
GPX (Only the track)
01:00:42
17.82
1809 / 1815
1013 / 2470
17.64 / 46.49
3:24 / 1:17
136 / 171
76 / 107
259 / 1187
947
FIT (Garmin)

5 

Filen ligger nå som CSV-fil og kan åpnes via excel. Kopier hele raden med puls-data. Tjekk at det har tatt op hvert sekund og at lengden stemmer.



Før data inn i treningsvolumarket og noter dato og økt-type som FP har angitt i TrainingPeaks.



VIKTIG! Kontroller i treningsvolum-arket at iTRIMP beregningen dekker hele pulsfilen. Hvis den er lengere end 4t må beregningene dras nedover, så hele filen inkluderes! Slet overskydende beregninger i bunden.

Appendix 7: Screenshot of iTRIMP calculation spreadsheet