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# Should we be recommending altitude training to swimmers?

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*Master's thesis in Sport Sciences … 05/2018*

# Abstract

**Introduction:** Many swimmers continue to use altitude training as part of their preparation despite questions of its efficacy. This belief seems to be strongly tied to the notion that an increase in hemoglobin mass will transfer over to increased sea-level performance. The purpose of the presents study was to examine whether altitude training lead to greater increases in competitive performance compared to sea-level training, and whether changes in hemoglobin mass was associated with changes in time-trial performance following altitude training.

**Methods:** Race records of 44 elite swimmers were sourced from several online databases. Swimmers were allocated to either altitude or sea-level groups based on whether they sojourned to altitude or not. Competitive performance over two long course seasons were investigated, and changes in performance where calculated before and after each altitude training period. In addition, hemoglobin mass and time-trial performance were measured in 8 Norwegian swimmers before and after an altitude camp during the early short course season.

**Results:** The inclusion of altitude training during the early season both increased (0.8%) and decreased (-0.3%) competitive performance compared to sea-level. However, these changes were unclear. Large individual responses were observed (0.6%-1.0%), and results from altitude training were not reproducible across seasons. In addition, altitude training increased hemoglobin mass substantially by 5.8%, but time-trial performance only by 0.4%. Overall, there was a lack of association between these two variables.

**Conclusion:** Altitude training was associated with similar increases in competitive performance compared to regular sea-level training. Although, hemoglobin mass increased as a result of training at altitude, this adaption did not seem to carry over into improved performance. It is thus questionable if an early season altitude training camp is conducive in improving performance in elite swimmers.

## Abbreviations

| | |
|---|---|
| LHTH | Living and training at ≥ 1800 meters. |
| LHTL | Living at ≥ 1800 meters, training at sea-level. |
| LH-TH-TL | Living and training at low intensities at ≥ 1800, high-intensity workouts at sea-level. |
| $Hb_{mass}$ | Hemoglobin mass (grams) |
| HbCO | Carboxyhemoglobin (%) |

# Forewords

There are many people I'd like to give a shout out to for making this thesis possible. First and foremost, my supervisor Odd-Egil Olsen, thanks for all the support and feedback throughout this strenuous process.

I would also like to thank Johan Setterberg for answering my every question and for sharing years of valuable data. Also, thanks to Espen Tønnessen and Ida Svendsen at Olympiatoppen for provision of time-trial and hemoglobin data.

This thesis would also not be possible without the help from Carl Jenner, Ulrika Sandmark, and Johan Wallberg at Svensk Simidrott, and Lars Green Bach at Dansk Svømmeunion. Best of luck to you in the championships to come.

Thanks to all the employees and students at the School of Sports Sciences. I was never motivated by school growing up, but these last five years has allowed me to delve into one of my main passions in life, and to that I'm ever grateful.

Finally, I'd like to thank my Mom and Dad, Elisabeth, and Mira, for all the support throughout these years. I'll make sure to come visit more often.

# Content

# 1 Introduction

Ever since the 1968 Mexico City Olympics altitude training has become a common strategy in the preparation of athletes (Wilber, 2004). Noticing the dominance of Eastern African runners, many were quick to adopt a form of altitude training known as “live high-train high” (LHTH). As the name implies this strategy involves living and training at a higher altitude than what one would normally do. While this acutely affects performance, the benefits of acclimatization to chronic hypoxia is seen as a major benefit. The prevailing paradigm being that the fall in partial pressure due to hypoxia would lead to an accelerated production of erythrocytes, leading to increased uptake of oxygen, leading to increased performance (Bailey & Davies, 1997).

Later on, several sports hitched their wagon on to the altitude horse, so to speak, and today this form of altitude training is a commonly used strategy among athletes. Although, more modern versions “live high-train low” (LHTL) and “live high-train high-train-low” (HiHiLo) that allow for better maintenance of training intensity has since been adopted. While in the past, altitude settings where only available by travelling to high altitude areas, a variety of artificial methods has since been developed. These methods involve subjecting athletes to normobaric and hypobaric stimuli, such as hypoxic masks, tents, trucks, and hotels (Rodríguez, 2002). However, while altitude training is a growing industry, the scientific support for altitude training in general has been questioned (Lundby, Millet, Calbet, Bärtsch, & Subudhi, 2012).

The question of whether we should be recommending altitude training to swimmers is an important one. Many swimmers continue to use altitude training as part of their preparation despite questions of its efficacy. For example, British Swimming are already underway with a systematic series of altitude camps in preparation for the 2020 Tokyo Olympics (Keith, 2016), while several Spanish swimmers where just recently at Font Romeu (Penland, 2018). Especially LHTH is done out of practicality, as there are few venues that can offer swimmers the opportunity to train at sea-level while simultaneously resting and sleeping at higher altitudes. Additionally, both tents and hotels confine the swimmers to small spaces for a considerable amount of time. Combined with the many hours of training and large training volumes, this can mentally drain the swimmers, making this form of altitude training counterproductive. While LHTH is probably better from a practical standpoint, this form of altitude training been showed to not improve performance compared to regular sea-level training. Despite recent findings many swimming organizations continue to heavily invest in LHTH altitude camps at locations such as in Flagstaff, Sierra Nevada, and Font Romeu (Truijens & Rodríguez, 2010). It is doubtful that elite swimming organizations would invest so heavily into training strategies if they did not think it would provide any benefit what so ever. Because of this it seems reasonable to believe that performance following altitude has not been sufficiently investigated, and that more research is needed on this topic. While few studies have examined altitude training in the context of swimming, even fewer have examined the relationship between swimming and performance, and only one study has examined the relationship between altitude training and actual competitive performance (Gough et al., 2012). Additionally, most of these studies have utilized fully controlled experimental designs, which may impact the ecological validity. Altitude training is never done in isolated and the context in which altitude training is done will vary based on the goal of each individual athlete. There is a clear lack of pragmatism in the current literature, i.e. investigations into how coach-described altitude camps pan out, without the interaction of experimental manipulation. In the end, what matters is how fast you can cross the finish line, or rather touch the wall, and the efficacy of altitude training from the perspective of improving actual competitive performance warrants further investigation.

An increase in hemoglobin mass ($Hb_{mass}$) is a highly sought-after response to altitude training (Tjelta, Enoksen, & Tønnessen, 2013). This seems sensible as an increase in Hb could potentially improve performance by allowing for increased oxygen transport to the muscles (Tjelta et al., 2013). Research has demonstrated this relationship by examining the impact of both reductions and increases in Hb and how this affects endurance performance (Calbet, Lundby, Koskolou, & Boushel, 2006). Ideally one would want to increase $Hb_{mass}$ as much as possible within healthy limits, and research has showed a strong relationship between initial $Hb_{mass}$ and increases in $Hb_{mass}$ following hypoxic interventions (Robach & Lundby, 2012). From a swimming perspective this is highly interesting as studies have showed that swimmers have a relatively low initial $Hb_{mass}$ compared to other endurance disciplines (Heinicke et al., 2001). One could therefore suspect, given the strong relationship between $Hb_{mass}$ and endurance performance, that swimmers would greatly increase their performance after altitude training.

The present study set out to examine whether the inclusion of altitude training camps is associated with greater increases in performance compared to sea-level training, and if increases in performance following altitude training is associated with an increase in $Hb_{mass.}$ The knowledge obtained from this study can be considered of great value to national swim teams and other Olympic sports. This is highlighted by the notion that swimming and other endurance sports has singled out altitude training as an important training strategy to optimize in preparation for the 2020 Olympics. Hopefully this thesis can contribute to medal-winning knowledge towards the coming championships.

## 1.1 Research questions

The research questions can be stated as follows:

Question 1:

Is altitude training in elite swimmers associated with better competitive performance compared to sea-level training?

Question 2:

Does altitude training lead to an increase in hemoglobin mass in elite swimmers, and does this correlate with performance?

## 1.2 Thesis overview

The central theoretical background is provided in chapter 2, which consists of a systematic review of all current literature regarding the effects of altitude training on performance and hemoglobin mass in elite swimmers. This is followed by a short section on how to interpret changes in performance using the smallest worthwhile difference.

Chapter 3 outlines the research and statistical methods that were used to answer the research questions. The rationale behind the study design, sample sizes, procedures for data collection, and data quality is discussed in detail.

Chapter 4 presents the results of the study. The research question is presented and analyzed based on findings from the collected data.

A discussion of the major findings, along with methodical considerations, practical recommendations, and future directions is presented in Chapter 5, before the conclusion is stated in chapter 6.

# 2 Theory

This chapter presents the relevant research concerning the thesis subject. Firstly, a systematic review of the effects of altitude training on performance and hemoglobin mass in elite swimmers is given. This is followed by a short note on how to assess performance enhancing strategies that could affect an athletes chance of winning. Taken together, this will provide insight into have large an effect one could predict would come as a result of altitude training, and how large effect one should see before deciding to invest in it. This will set the stage for later discussion part where the results from the present study will be discussed against findings from other studies.

## 2.1 Effects of altitude training on swimming performance and hemoglobin mass

### 2.1.1 Selection of studies

Searches in the databases of Pubmed and Google Scholar were performed to identify relevant studies published in English, up to and including January 2018. The following keywords were used: “altitude training and swimming performance”, “hypoxic training and swimming performance”, “hemoglobin mass and swimming performance”. Reference lists of retrieved full-text articles and recent reviews were examined to identify additional articles not found during the initial search.

Studies were included if they had: (1) examined a valid performance measures, such as either step-test, time-trial, or competitive performance, (2) and/or hemoglobin mass, in elite swimmers. “Elite swimmers” were defined as being a part of a national team and/or competing regularly at international level. Only full text sources were included so that methodology could be assessed; therefore, abstracts and conference papers were not included in the review. The whole selection process is showed in figure 1, while an overview of the studies selected for review are shown in table 1.

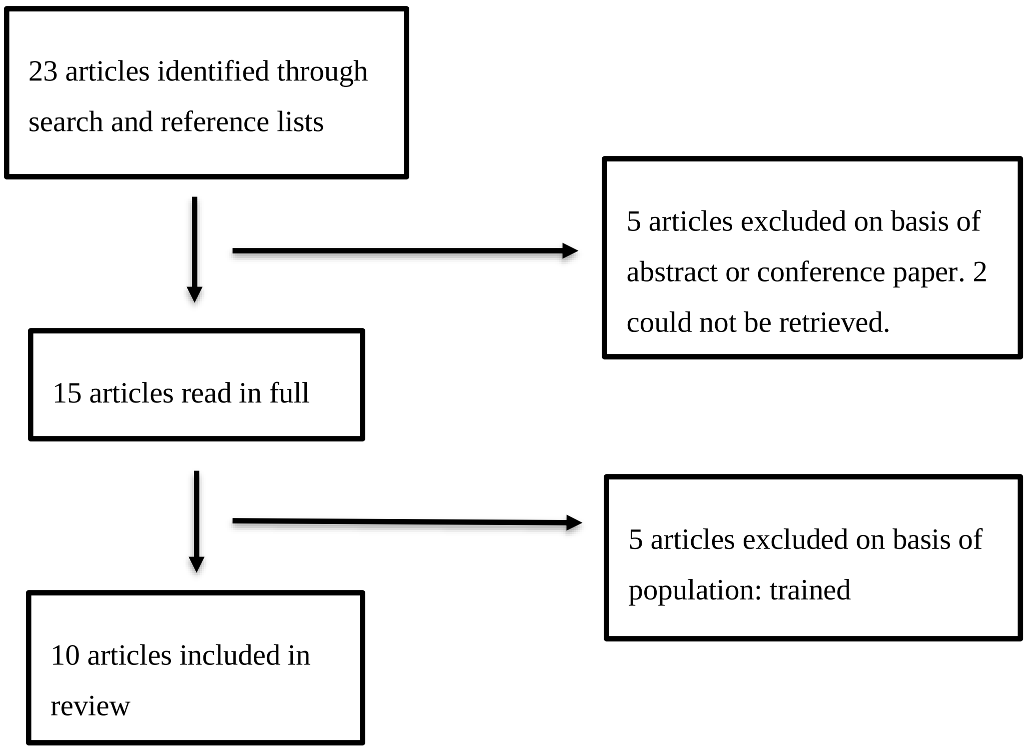



*Figure 1: Flowchart of the selection process for inclusion of articles in the systematic review*

*Table 1: Overview of studies that have examined the effects of altitude training on performance and/or hemoglobin mass in elite swimmers*

| Reference | N | CG | Altitude model | Weeks at altitude (w) | Altitude level (m) | Performance test(s) | $Hb_{mass}$ measured |
|---|---|---|---|---|---|---|---|
| Rodriguez et al., 2015 | 43 | ✓ | LHTHTL<br>LHTH<br>LHTL | 4<br>3-4<br>4 | 2320 | 50-400m TT | ✓ |
| Bonne et al., 2014 | 10 | ✓ | LHTH | 3 | 2320 | 4x50m RS<br>6x200m ST<br>3000m TT | ✓ |
| Gough et al., 2012 | 26 | ✓ | LHTH<br>LHTL* | 3 | 2135 | Race performance (100-200m) | ✓ |
| Wachsmuth et al., 2013 | 31 | ✓ | LHTH | ~3-4 | 2320 | Race performance | ✓ |
| Robertson et al., 2010 | 9 | ✓ | LHTL* + LMTM | 4 × 2 | 2600<br>1350 | 7x200m ST<br>2000m TT<br>Race performance | ✓ |
| Robach et al., 2006 | 9 | ✓ | LHTL* | ~2 | 2500-3000 | 2000m TT | ✓ |
| Roels et al., 2006 | 9 | | LHTH | ~2 | 1850 | 2000m TT<br>5x200m ST | |
| Friedmann et al., 2005 | 16 | | LHTH | 3 | 2100-2300 | 5x100-400m ST | ✓ |
| Chung et al., 1995 | 10 | | LHTH | 3 | 1890 | Race performance (100 and 200m) | |
| Miyashita et al., 1988 | 20 | | LHTH | 3 | 2300 | Race performance | |

*indicates simulated altitude. CG = control group. RS = repeated sprint. ST = incremental step test. TT = time-trial.

### 2.1.2 Controlled studies

Six controlled studies have examined the effects of altitude training on performance and hemoglobin mass in elite swimmers.

Robach et al. (2006) subjected 9 swimmers to living/sleeping in hypoxic rooms for 16 hours/day (5 days at a simulated altitude of 2500 meters followed by 8 days at 3000 meters), while the other group (n=9) lived and slept at 1200 meters. Both groups trained at 1200 meters. $Hb_{mass}$ was measured 1-day post altitude, while 2000-meter time-trials were measured both 1 day and 15 days post altitude. The altitude group improved their $Hb_{mass}$ significantly ($P < 0.05$) from pre to post but did not improve their time-trial performance. In contrast, the control group did not experience a significant increase in $Hb_{mass}$ but did improve their time-trial performance ($P < 0.05$). After two weeks, time-trial performance was still significantly improved in the control group, whereas no improvement where seen for the altitude group.

Later on, Gough et al. (2012) compared changes in performance and hemoglobin mass following either LHTH or LTHL altitude training. Twenty-six elite swimmers were divided into two groups for 3 weeks of either LTHT or simulated LHTL altitude training in May 2009. LHTH trained at either 2320 meters or 2135 meters, while LHTL spent 14 hours per day at a simulated altitude of 3000 meters in normobaric hypoxia and trained in their normal environment. Swimming performance was measured via actual competitive performances, or via electronically timed time-trials if competitive data was not available. Performances were recorded in a designated swimming event (100 or 200-meters free or formstroke) 7 days before altitude, then 1,7,14,28 after the end of altitude exposure. Competitive performance data from eleven elite-swimmers not participating in altitude training were sourced from official race records to provide a control group. Additionally, a season-long comparison between altitude and non-altitude groups from March to August 2009 was undertaken to compare the progression of performances over the course of a competitive season.

Swimming performance was possibly slower in LHTH (-0.4 ± 0.4%, mean ± 90% confidence intervals), unclear in LHTL (-0.7 ± 1.1%), and substantially faster (0.9 ± 1.3%) in the control group 1-day post-altitude. At 7 days post-altitude performances where unclear in LHTH (0.2 ± 0.7%), likely slower in LHTL (-0.8 ± 0.9%) and very likely faster in the control group (1.1 ± 0.8%). Compared to the control group both LHTH and LHTL were substantially slower at both these time points. Measurements were not taken for the control group 14 and 28 days post altitude, although changes in performance were unclear for both LHTH (0.3% and -0.2%) and LHTL (-0.3% and -0.1%). From March to August, the altitude groups improved their performances by 0.8 ± 0.6%, while the control group improved by 1.1 ± 0.6%. However, the 0.3% difference between the groups were unclear.

Hemoglobin mass was measured in both LHTH and LTHL before the training camps plus one day, and two weeks after altitude exposure. One day after the training camps, the mean (± 90% confidence interval) change in hemoglobin mass was 3.8 ± 1.3% and 4.0 ± 1.1% in LHTH and LHTL respectively, compared to pre-measurements. Percentages were not reported by the authors for fourteen days post-altitude, albeit they mention that hemoglobin mass was reduced slightly in both LTHT and LHTL but remained “likely” higher than pre-measurements.

Bonne et al., (2014) subjected ten Danish Olympic swimming team to 3-4 weeks of altitude training (LHTH), while ten elite swimmers from a local swimming club were selected for a sea-level (SL) training camp. Differences in hemoglobin mass, swimming $VO2_{peak}$, 4x50-meter, 5x200-meter and 3000-meter swimming trials were measured before (1-2 weeks) and after (1-2 weeks) the intervention period. Seven swimmers from LHTH initially stayed at 3,094 m for one week, before travelling with the rest of the group to Flagstaff, AZ, USA, where they lived and trained at 2,130 meters above sea level for three weeks. To control for a possible training camp effect, the sea-level group stayed in Malaga, Spain, during the same period. The level of performance was not significantly ($p > 0.05$) different between groups, and the training volume and intensity were similar during the intervention period. After the intervention period, $Hb_{mass}$ improved by 6.2 ± 3.9% (mean ± standard deviation, $p < 0.05$) in LHTH, while no changes were observed for the sea-level group. $VO2_{peak}$ remained similar for both groups. Accumulated swim time in the 4x50 meter repeated sprint test was significantly faster, 3.9 ± 3.8 seconds ($P < 0.01$) and 2.1 ± 1.3 seconds ($P<0.001$), in both LHTH and SL respectively, after the intervention period, while no differences between groups at baseline or post-measurements was evident. Performance in the last 200 meters of a six-step step-test improved by 2.7 ± 3.6s ($P = 0.051$) in the LHTH, whereas it was similar before and after in the SL. However, no significant differences between the two groups could be detected. Time to completion of the 3,000m trial was reduced by 84 ± 34s in the LHTH group ($P < 0.01$) and 48 ± 37s in the SL group ($P < 0.01$), although the difference between groups did not reach significance ($P = 0.09$).

In probably the most comprehensive altitude study to date, Rodríguez et al. (2015) investigated the effects of four in-season training interventions on performance, $VO_2$ and hemoglobin mass. The four training interventions were as follows: living and training at high altitude (2320 meters above sea level) for 3 and 4 weeks ($LHTH^3$, $LHTH^4$), living high (2320 m) and training high and low (690 m) (LH-TH-TL), and living and training at sea-level (SL). Fifty-four elite swimmers participated in the study. All swimmers were international competitors and/or were preselected as a member of their national and/or Olympic teams. The interventions were conducted during the first macrocycle (short-course season) of the Olympic year before the London 2012 Olympic Games. This constituted a 3-4-week mesocycle during the general preparatory period.

Individualized training plans were developed by the swimmers' own coaches, adding to the relevance for real world application. Training load was measured as both session RPE and TRIMPc. Possible confounders due to iron deficiency was also controlled for, as ferritin levels were monitored weekly in all groups. All training camps were conducted in training centers of international standards, whether at sea-level or at altitude, mitigating possible differences in results due to a training camp effect. In addition, coaches were also encouraged to select swimmers who had positive or neutral expectations regarding the effects of the intervention. Lastly, to evaluate eventual placebo or nocebo effects, two ad hoc questionnaires were administered PRE-and POST testing, respectively, one for coaches and one for swimmers. On their questionnaire, coaches were asked to state whether (yes, no, or not sure) they believed that the chosen intervention would help (PRE) or had helped (POST) the swimmers improve their swimming performance and whether they would choose again the same intervention as that at the time of entering the study (POST). On their questionnaire, swimmers were asked to state whether they believed that their training camp would (PRE) or did (POST) help them improve their swimming performance.

To measure the effects on performance, all swimmers completed time-trials over 50- and 400-meter crawl, and 100 or 200 meters at best stroke, while $Hb_{mass}$ was measured during PRE- and once weekly during the camps (W1-W3/W4). Initial measures in time-trial performance were recorded during an initial 3-5-day lead-in period (PRE), and repeated immediately (POST), and once weekly on return to sea-level (PostW1 to PostW4).

50-meter time-trials performances remained stable immediately POST in all groups except Hi-Hi3. At PostW1 all groups improved their performance from PRE as follows (mean percentage change ± 90% confidence intervals): SL (2.0% ± 1.6%; P<0.001), LHTH$^4$ (4.0% ± 0.9%; P < 0.001), and LH-TH-TL (4.8% ± 0.4%; P<0.001). The greatest change in performance was seen in Hi-HiLo at PostW4, improving their performance by 5.5% ± 1.0%. Compared to SL (3.2% ± 1.1%) this effect was statistically significant (P<0.001). LHTH$^3$ and LHTH$^4$ stabilized their performances after PostW1, reaching equally significant changes from PRE as compared with SL (LHTH$^3$: 3.4% ± 4.0%, P<0.001; LHTH$^4$: 3.7% ± 1.2%, p<0.001).

Both LHTH$^3$, LHTH$^4$ and SL tended to decrease their 400-m time trial performance immediately POST, while LH-TH-TL tended to improve, swimming significantly faster compared to LHTH$^4$ (P=0.03). At PostW1 all groups experienced nearly identical improvement compared to PRE (~2%). At PostW2, the change from PRE in the LH-TH-TL group (4.2% ± 0.9%) was significantly greater compared to the other groups (P<0.001). Finally, at the end of the follow up period (PostW4), both the LH-TH-TL (4.7% ± 1.1%; P<0.001) and the LHTH$^4$ swimmers (3.3% ± 1.3%; P<0.001) had improved significantly more (P=0.001 and 0.03, respectively) than the SL controls (1.6% ± 1.0%; P<0.001). However, when adjusting for training load as a covariate, the differences between LHTH$^4$ and SL at PostW4 became not significant (P=0.08).

100 or 200-meter time trial performance improved similarly in all groups immediately POST, except in LHTH$^3$ (-1.9% ± 1.3%; P = 0.06), whose change was worse compared to both SL, LHTH$^4$, and LH-TH-TL (group-test interaction, P=0.006, 0.03, and <0.001, respectively). At PostW1, all group improved similarly (~2 to 3.5%), while LH-TH-TL improved more than LHTH$^3$ (group-test interaction, P=0.03). By far, the most significant changes could be seen in LH-TH-TL from PRE to PostW2 and onwards, improving by 5.3% ± 1.4% (P<0.001) at PostW2 and by 6.3% ± 1.2% (P<0.001) at PostW4. By the end of the follow up period, these improvements were substantially greater than SL (3.7% ± 1.0%), LHTH$^3$ (3.1% ± 0.9%), and LHTH$^4$ (3.4% ± 1.0%) (group-test interaction, P=0.02, 0.002, and <0.001, respectively).

Hemoglobin mass increased in both LHTH$^3$ and LHTH$^4$ but not in LH-TH-TL throughout the training camps. At W3, LHTH$^3$ increased their Hb$_{mass}$ by 3.8% ± 2.3% (P=0.08) while LHTH$^4$ increased their Hb$_{mass}$ by 6.2% ± 1.1% (P<0.001) by W4. Both these changes were significantly greater compared to LH-TH-TL (1.3% ± 1.8% group-test interaction, P<0.05).

Changes in swimming performance was only weakly associated with changes in swimming performance ($r < 0.2$)

In the only observational study, Robertson, Aughey, Anson, Hopkins, and Pyne (2010) evaluated a coach-prescribed altitude training program, quantifying changes in hemoglobin mass, along with training and competitive performance of elite swimmers. Eighteen swimmers were monitored over a 21-week preparatory period. The altitude group (n=9) completed up to four 2-week blocks of combined living and training at moderate altitude, LMTM (1350 meters), and simulated LTHL (2600-600 meters) between two national championships. Each 2-week altitude block in the produced the following improvements: a mean improvement of 0.9 ± 0.8% (±90% confidence intervals) in 200-meter step-test performance, a mean improvement in 2000-meter time-trial performance of 1.2 ± 1.6%, and a mean improvement in $Hb_{mass}$ of 0.9 ± 0.8%. The authors also found a moderate correlation between $Hb_{mass}$ and time-trial performance ($r = 0.47$), but an unclear correlation between $Hb_{mass}$ and step-test performance ($r = -0.23$). Additionally, competitive performance was evaluated using official race records from two Australian National Championships separated by one year, while a subgroup of altitude exposed swimmers (n = 6) and control (n = 5) competed at the Commonwealth Games, 6 weeks later. Interestingly, from one year to the next, the altitude group (n = 9) did not swim substantially faster (0.4 ± 0.9%) and swam even slower 6 weeks later (-0.6 ± 0.6%). In contrast, the control group swam substantially faster from year to year (0.9 ± 0.5%), but slower 6 weeks later (-1.2 ± 0.9%). There were however, no substantial differences in mean improvement between the groups from year to year (-0.5 ± 1.0%, altitude vs. control) or within the 6-week period (0.6 ± 0.9%).

Over a two-year period, Wachsmuth et al. (2013) followed 58 German national team swimmers during their preparation for the 2012 Beijing Olympics. The relationship between LHTH altitude training and hemoglobin mass was studied through five aspects. Firstly, they wanted to examine the normal oscillation of $Hb_{mass}$ at sea-level along with the time-course of adaption and de-adaption to altitude. Moreover, the group investigated whether there were any differences in the Hb-response to altitude between male and females, and whether injury and illness had any impact on the $Hb_{mass}$ at altitude. Finally, they examined the relationship between $Hb_{mass}$ and actual competitive performance.

$Hb_{mass}$ was measured approximately 6 times over the course of two years wherein 25 swimmers undertook four altitude camps. Performance was determined by analysing 726 competitions using the German point system (actual competition points = 1000 × $(wr/t)^3$). The normal oscillation of $Hb_{mass}$ at sea-level was 3.0% for males and 2.7% for females over the two-year period when altitude effects and effects of illness/injury were excluded. The mean ± SD increase in $Hb_{mass}$ at camps held at 2320 meters was 7.2 ± 3.3%, and the authors did not find any significant differences in the percentage increase between men and women. The group also demonstrated a lack of erythropoietic response in athletes that were sick during the altitude training, resulting in no increase in $Hb_{mass}$. However, in comparison to ill swimmers at sea-level, ill swimmers at altitude did not experience a decrease in either $Hb_{mass}$, suggesting that erythropoietic stimulation compensates for the inhibitory effects occurring at sea-level. $Hb_{mass}$ showed a slight dip after returning to sea-level, but was still increased 13 days post, and still elevated 24 days after return from altitude (4.0 ± 2.7%, $p < 0.05$). Finally, a non-significant drop in competitive performance by approximately -1% and -2% were seen 0-14 and 15-24 days after return from altitude, whilst an unclear improvement of 0.8% were seen 25-35 days after return in a small group of four athletes.

### 2.1.3 Uncontrolled studies

Roels et al. (2006) subjected one group of 9 swimmers to two training camps separated by six weeks. The first training camp was held at 1200 meters, while the second training camp was held at 1800 meters. During both camps the group both slept and trained at the same altitude. Hematological parameters and along with both step-test performance and 2000-meter time trials were measured 1-3 days before and after each camp. Although they didn’t measure hemoglobin mass directly, both mean cell volume and reticulocytes increased after training at 1800 meters, but not after training at 1200 meters. Neither of the training camps produced a significant increase in maximal velocity achieved during the incremental step-test. Time-trial performance however, was only significantly ($P < 0.01$) improved following training at 1200 meters but not after training at 1800 meters.

In an ingenious study, Friedmann et al. (2005) investigated whether the variability in hemoglobin mass following LHTH altitude training could be predicted by the erythropoietic response to acute normobaric hypoxia. This study was mainly inspired by the work of Chapman, Stray-Gundersen, and Levine (1998) who proposed that inter-individual variability in sea-level performances could be largely explained by individual variability in erythropoietic response to altitude. Friedmann et al. (2005) therefore measured erythropoietin (EPO) in sixteen (9 males, 7 females) junior elite swimmers prior to and after 4 hours of exposure normobaric hypoxia as well as repeatedly during LHTH (2100-2300 m) altitude training. Additionally, both $Hb_{mass}$ and incremental step test performance was tested before, and 10 days after return from altitude training. While the researchers did find a significant correlation ($r = 0.742$, $p < 0.001$) between EPO response to normobaric hypoxia and natural altitude, however neither responses where correlated with $Hb_{mass}$. The swimmers improved their performance in the incremental step test by 2-3% ($p < 0.001$), but this change was not correlated changes in $Hb_{mass}$. All in all, contrary to Chapman et al. (1998), this study found that EPO response could not predict which swimmers benefitted from altitude training.

Twenty elite Japanese swimmers (12 males, 8 female, age 13-19) conducted altitude camps at 2300 meters in a study reported by Miyashita, Mutoh, and Yamamoto (1988). Before the study the subjects were split into two groups. One group of 8 male swimmers (group 1) traveled to Mexico City to live and train at 2300 meters for three weeks. This same group participated in an international swim meet at sea-level just three days after return from altitude. The second group (group 2), consisting of 4 males and 8 female swimmers, travelled to the same place approximately one year after the first, spending the same amount of days, and competing within the same amount of days after altitude. Group 1 improved their performances by approximately 1.5% ($p < 0.05$) in the 200-meter events, although large inter-individual changes were seen ranging from -2.9 to 3.6%. Five out of twelve swimmers in group 2 performed exceptionally well, particularly in the longer distances. The largest individual improvement was seen in a male 1500-meter specialist who improved his performance by 3.6%. Among the women, the greatest improvement was seen in the 200 meter breaststroke, where one athlete set the yearly best record by improving her personal best by 2.1%. Miyashita et al. (1988) makes a note that 5 swimmers struggled with sickness during the camp and worsened their performance following altitude.

In a Korean study, Chung, Lee, Kim, Lee, and Lee (1995) investigated the effect of a 3 week altitude camp on blood cells, maximal oxygen uptake and swimming performance. Ten swimmers (4 males, 6 females) from the Korean national team trained at 1890 meters, while a group of seven swimmers (3 males, 4 females) from the Korean national junior team trained at sea-level. Blood parameters were taken one week before, and one and three weeks post-altitude. Swimming performance was measured one week before altitude training, and six weeks after. Compared to baseline measurements, hemoglobin concentration in the altitude group increased by 4% and 10% for male and female swimmers respectively, one week after altitude. After three weeks, this amount was reduced to 3% and 6% from baseline. No change was seen in the control group. No statistical analysis was reported, but a small mean increase in 100-meter (0.1 ± 0.7%, ±90% confidence intervals) and 200-meter (0.2 ± 0.7%) performances was seen.

### 2.1.4 Summary

To sum up, studies using sea-level control groups have not convincingly showed that altitude training leads to any greater increases in performance. The exception being the study by Rodríguez et al. (2015) showing that LH-TH-TL increases performance more so than both LHTH and LHTL. Although, LH-TH-TL did not produce a high increase in hemoglobin mass compared to the other models, and the small increase in hemoglobin mass was lower than the normal variation in hemoglobin mass at sea-level (~2.9%) found by Wachsmuth et al. (2013).

Table 2 shows mean percentage improvement in performance measures and hemoglobin mass. These values were either obtained from or calculated using data from the above studies.

*Table 2: Mean improvements in performance and $Hb_{mass}$ from the studies included in the review.*

| **Reference** | **Altitude model** | **Performance test(s)** | **Δ Performance (%)** | **Δ $Hb_{mass}$ (%)** |
|---|---|---|---|---|
| Rodriguez et al., 2015 | LHTHTL | 50-400m TT | ~6.2 | 1.3 |
| | LHTH | | ~3.5 | 3.8 |
| | LHTL | | ~3.5 | 6.2 |
| Bonne et al., 2014 | LHTH | 4x50m RS | 3.0 | 6.2 |
| | | 6x200m ST | 2.0 | |
| | | 3000m TT | 3.8 | |
| Gough et al., 2012 | LHTH | Race performance (100-200m) | 0.3 | 3.8 |
| | LHTL* | | -0.1 | 4.0 |
| Wachsmuth et al., 2013 | LHTH | Race performance | 0.8 | 7.2 |
| Robertson et al., 2010 | LHTL* + | 7x200m ST | 0.9 | 0.9 |
| | LMTM | 2000m TT | 1.2 | |
| | | Race performance | 0.4 | |
| Robach et al., 2006 | LHTL* | 2000m TT | -1.1 | 7.5 |
| Roels et al., 2006 | LHTH | 2000m TT | 0.5 | |
| | | 5x200m ST | -0.7 | |
| Friedmann et al., 2005 | LHTH | 5x100-400m ST | ~2-3 | ~6 |
| Chung et al., 1995 | LHTH | Race performance (100m, 200m) | 0.1, 0.7 | |
| Miyashita et al., 1988 | LHTH | Race performance (200m) | ~1.5 | |

*simulated LHTL. TT = time-trial. ST = incremental step test.

## 2.2 Interpreting changes in performance

Increasing the chances to win is of dire importance to coaches and athletes. Potential performance-enhancing strategies, like altitude training, should therefore be evaluate based on the chance to affect an athletes chance of winning. Two concepts have recently been expanded upon that can estimate such effects, the within-athlete variability of competitive performance (CV%) and the smallest worthwhile change or difference (SWC).

Hopkins, Hawley, and Burke (1999) was able to demonstrate that the variability in an athlete's performance from competition to competition could provide an estimate of the SWC. By using simulations of sports in which athletes compete as individuals for the best time, distance or performance score, Hopkins et al. (1999) derived that a change of 0.5 × the within athlete variability would result in one extra medal for every ten competitions. Estimates of the within-athlete variability between competitions are therefore crucial for identifying important changes in practical and research settings. In swimmers, Pyne, Trewin, and Hopkins (2004) reported a performance variation of 0.8% for international swimmers between national trials and Olympics. Swimmers whose main discipline was freestyle, and backstroke, showed greater consistency in performance (CV = 0.6%) in contrast to swimmers using breaststroke (CV = 0.8%) and butterfly (CV = 1.0%). There were also differences between distances, as the 50-400 distances saw greater consistencies (CV = 0.7%) compared to 800-1500 (CV = 1.0%). Pyne et al. (2004) also notes that to stay in contention for a medal, an Olympic swimmer should improve his or her performance by ~1% within the year leading up to the Olympics. Lastly, an much importantly in the context of altitude training, an additional enhancement of ~ 0.4% (0.5 × between competition variability) would substantially increase the swimmers chances of a medal (Pyne et al., 2004).

# 3 Methods

## 3.1 Study design

As showed in chapter 2, several studies found evidence for increases in hemoglobin mass and mixed improvements in several measures related to performance following altitude training. However, whether altitude training transfers into actual improved competitive performance remains an unexplored question as it has only been explored by Gough et al. (2012) to some degree. To provide a possible answer, an observational design was utilized to allow two seasons worth of competitive results to be evaluated using rigorous data analysis. By comparing the competitive results of two groups of elite swimmers: an altitude training group vs. a sea-level training group, an association could be made regarding the efficacy of altitude training. Efficacy meaning the ability of altitude training to produce the intended result, i.e. did the inclusion of altitude training improve performance more so than regular sea-level training.

Rather than randomly assigning swimmers to either one of the two groups, groups were naturally formed by factors outside the control of the investigator, closely resembling random assignment. Because some swimmers chose to train at altitude at specific times during the investigated period, while other swimmers chose not to, altitude and sea-level groups were naturally formed for the study purposes. In this respect, one group received a clearly defined exposure, while the other group did not. Additionally, since the study spanned two years, the reproducibility of altitude training could be investigated. By comparing two altitude camps exactly one year apart, using the same athletes, under the same conditions, inferences could be made whether the same group of athletes got the same results following each stay.

While altitude training has been showed to improve hemoglobin mass in swimmers, the relationship between change in hemoglobin mass following altitude training and change in performance has only been investigated by Friedmann et al. (2005) and Gough et al. (2012). Hemoglobin is strongly correlated with endurance performance (Calbet et al., 2006), however, evidence is bleak regarding its transfer to improved swimming performance. To add to the existing body of research, the effect of altitude training on hemoglobin mass and time-trial performance in elite swimmers was examined using data provided by Olympiatoppen. These measurements were taken before and after an altitude training camp in October-

November 2015. By examining the correlation between changes in time-trial performance and changes in hemoglobin mass, inferences could be made regarding the relationship between these two variables.

# 3.2 Subjects

## 3.2.1 Competitive performance

Race records of 44, 18 female and 26 male, elite swimmers competing at international level during the 2015 and 2016 where used in this study (table 1). Swimmers were of Norwegian (n=15), Swedish (n=14), Danish (n=14) or Faroese (n=1) nationality. Selection criteria were to have competed internationally and/or being preselected as a member of their national team. Exclusion criteria included altitude training in the previous four months before each camp, and not having recorded a comparable result before the investigative period. The whereabouts of each swimmers was verified by contacting each swimming federation.

Swimmers were allocated as follows:

**Altitude group** ← Swimmers participating at training camps with either the Norwegian, Swedish or Danish national team from the end of April – middle of May during the 2015 and/or 2016, were initially selected, including one Faroese swimmer training with the Danish national team. These swimmers had not undergone in the four months prior to the long course seasons. Four swimmers had to be excluded from this group due to not having comparable results before and after the altitude training camp. This resulted in two groups of 14 and 19 subjects.

**Sea-level group** ← Swimmers that were a part of the Norwegian, Swedish or Danish national team but who did not undergo altitude four months prior to, and during the long course seasons, where selected for the sea-level group. This resulted in two groups of 17 and 19 subjects.

### 3.2.2 Time-trial and hemoglobin mass

Time-trial performance and hemoglobin mass were measured in eight Norwegian swimmers before and after a three-week altitude camp during the late 2015 short course season. All swimmers had been selected to this camp by the Norwegian national team coach.

*Table 3: Subject characteristics and performance level*

| Group | | Male (n) | Female (n) | Total (n) | Age (years) | IPS (a.u) |
|---|---|---|---|---|---|---|
| Competitive performance | | | | | | |
| *2015* | | | | | | |
| | Altitude | 8 | 6 | 14 | 20.8 ± 3.0 | 854 ± 66 |
| | Sea-level | 7 | 10 | 17 | 22.3 ± 3.7 | 866 ± 55 |
| *2016* | | | | | | |
| | Altitude | 11 | 8 | 19 | 21.9 ± 3.9 | 875 ± 64 |
| | Sea-level | 9 | 10 | 19 | 23.2 ± 3.1 | 877 ± 60 |
| Time-trials and $Hb_{mass}$ | | | | | | |
| | Altitude | 5 | 3 | 8 | 19.8 ± 3.3 | 835 ± 56 |

Values are mean ± SD.
*IPS*, FINA Points Score 2015 of personal best time.

To quantify the competitive level of all subjects, the FINA Point Scoring system was used and a point range (0-1100) was ascribed to each swimmer according to their best time in their best event up until the April 2015, scaled up or down from 1000 points based on the global 2015 fastest performance in each event. An independent t-test was used to compare differences between groups in terms of age and performance level. There were no differences between groups (2015, P=0.62; 2016, P=0.32).

All race records were available through several public available databases and domains including octoopen.dk (Dansk Svømmeunion, 2018), octoopen.se (Svensk Simidrott, 2018), medley.no (Norges Svømmeforbund, 2018), and swimrankings.net (Swimrankings, 2018). Consent was therefore not needed. For the second study, all participants gave consent to be included in the study, and the thesis was approved by the NSD (The Norwegian Center for Research Data).

## 3.3 Selection of altitude training camps

Long course seasons were selected as the investigative period for two reasons. Firstly, long course swimming is characterized by more time spent swimming, and less time spent turning. Thus, if benefits of altitude training are primarily aerobic in nature differences between groups should be more easily seen in long course swimming, hence the selection of this specific period. Secondly, many international swimmers chose to sojourn to altitude at this specific time during the season. This was of great benefit as we wanted as many subjects as possible to inform the statistics. A common problem with altitude studies is the low sample size, however by opting for an observational design more swimmers could be identified as having had exposure to altitude, naturally increasing the sample size.

$Hb_{mass}$ and time-trial data was available from an altitude training camp conducted by the Norwegian national team during the late 2015 short course season (September-December). This was the only period in which data was available.

## 3.4 Description of altitude training camps

In terms of periodization, all training camps were placed during the early stages of a competitive season. In 2015, one group of seven swimmers trained for 18 days from 18$^{th}$ of April to 8$^{th}$ of May, while another group of seven trained 20 days from 25$^{th}$ of April to 15$^{th}$ of May. Both these camps were held High Performance Centre in Sierra Nevada, Spain, at 2320 meters above sea-level. Ten swimmers in the control group trained for 15 days from 10$^{th}$ of May to 25$^{th}$ of May at Tenerife Top Training, Mallorca, Spain, at sea-level.

In 2016, one group of nine swimmers trained in Sierra Nevada for 21 days, from 11$^{th}$ of April to 1$^{st}$ of May, while ten swimmers trained from 21$^{st}$ of April to 9$^{th}$ of May in Flagstaff, USA, 2100 meters above sea-level.

Later, eight swimmers trained at altitude for 20 days from 22$^{nd}$ of October to 10$^{th}$ of November.

All training sessions were conducted at high-altitude, and both the altitude (2100-2320 meters), length (18-20 days), and placement (preparation period) of the camps were well in line with the current recommendations regarding for LHTH (Tjelta et al., 2013).

## 3.5 Evaluation of performance

### 3.5.1 Competitive performance

Each long course season was separated into 2-4 periods based on the available data, and the performance of each swimmer was tracked in a designated swimming event across each season (100, 200, or 400-meter, freestyle or formstroke). For 2015, swimming performance was recorded at international swim meets 14-21 days before altitude $R_{pre}$, then 15-23 ($R_{15-23}$), 27-30 ($R_{25-32}$), 50-56 ($R_{50-56}$), and 70-76 ($R_{70-76}$) after the end of altitude exposure. For 2016, swimming performance was recorded 4-11 days before altitude $R_{pre}$, then 4-19 ($R_{4-19}$) and 85-99 ($R_{85-99}$) after altitude.

The 100,200, and 400-meter events were chosen for comparison because of the low coefficient of variation (CV%) associated with these events (Pyne et al., 2004). Consequently, race records for the 800 and 1500 events were not recorded because of their comparingly higher CV% (Pyne et al., 2004). This was done to increase the chances of detecting small but meaningful improvements in performance between races.

For each period, the best competitive result for each swimmer in his or her designated event was selected for comparison. If a swimmer participated in several competitions within a given period, the competition in which the majority of swimmers swam was used. An internationally accepted correction factor of 0.73 seconds was added to equate a relay leg (flying start) with an individual swim race (stationary dive start) (Skorski, Etxebarria, & Thompson, 2016). This adjustment was used for one swimmer in the altitude group at $R_{70-76}$, for three and two swimmers $R_{88-99,}$ in the altitude and sea level group, respectively.

The above-mentioned databases where used for cross-checking and collection of competitive data. Swimrankings.net bases its information on the European Swimming Federation (LEN) rankings database and the results and ranking database from 13 other federations. The Norwegian, Swedish and Danish databases contain information on all competitions held in these countries from 2005 and onwards, including results in the form of rankings and records. All recorded inputs in these databases are provided by the meet organizer for each event.

Recorded times for all competitions that were used in this study were under the strict rules for timing set by FINA.

### 3.5.2 Time-trials

Time-trial performance was measured 2-days before altitude ($Pre_{AT}$) and within 2-5 days after the end of altitude exposure ($Post_{AT}$), but only in the altitude group (LHTH). Trials were conducted in a 25-meter indoor pool (temperature 27-28 degrees Celsius), at the Norwegian School of Sports Sciences, Oslo, Norway, 2015. After a standard competition warm-up, swimmers were instructed to achieve the best possible time for one 100-meter trial in their prefered stroke. Time-trial performance was assessed only once, considering the high reliability of these measurements (typical error: 1.4 ± 1.5%, mean ± 90% confidence intervals) (Rodríguez et al., 2007), and to avoid the risk of underperformance. Swimmers swam alone, and start was given as in a competition. Time was manually recorded to the nearest 0.01 by three experienced timers, and the median values were used for analysis.

### 3.5.3 Hemoglobin mass

Hemoglobin mass was measured using the optimized carbon monoxide rebreathing technique (Schmidt & Prommer, 2005). Both pre and post measurements were taken at Olympiatoppen, Oslo, Norway, 2015.

The test was initiated by taking duplicate capillary blood samples from the fingertips, which were then analyzed for carboxyhemoglobin (HbCO%) on an AB 80 Series blood gas analyzer (Radiometer Medical, Copenhagen, Denmark). Each capillary sample contained enough blood for two analyses, giving four HbCO% measurements in total. The average value of these four measurements was used as the baseline value for HbCO%. The breathing procedure of the test was then initiated. After connecting the subjects to a spirometer via mouth piece, the subjects were instructed to exhale as much air as possible via their nose, which was closed immediately thereafter with a nose-clip. The subjects were then instructed to inhale deeply as the CO dose (1.5 ml per kilogram bodyweight) was administered to the spirometer via a pre-filled syringe. At the same time a valve between the subjects and an oxygen reservoir (a 3-liter anesthetic bag containing 100% oxygen) was opened. The subjects were then instructed to inhale as much oxygen from the bag as possible, hold their breath for 10 seconds, before breathing normally for 1 minute and 50 seconds. This was to ensure that all the CO was inhaled in the first part of the breath and subsequently distributed within the alveoli. To verify that no gas escaped during the rebreathing procedure a portable CO analyzer was placed beside the mouth piece and nose-clip. Before being disconnected from the spirometer the subjects were instructed to exhale as much air into the anesthetic bag as possible before closing the valve. This full exhalation was necessary to quantify the volume of CO which was not taken up by the body (lungs, spirometer, bag) in addition to the amount lost through respiration until the last blood sample was taken. The amount CO left in the system (lungs, spirometer, bag) was estimated by multiplying the volume of gas left in the system with the CO concentration as measured by the CO analyzer. To also quantify the CO volume that was exhaled after disconnecting from the spirometer until the last blood sample was taken (6 minutes), the end-tidal CO concentration was measured at the time of the last blood sample and multiplied by the alveolar ventilation (estimated to be 5-liter $min^{-1}$).

Capillary blood samples were taken 4 and 6 minutes after the subjects were disconnected from the spirometer. This yielded four measurements for each subject which were analyzed for HbCO%. The average value of these four measurements was used as the post-inhalation measurement. The change in in %HbCO (difference from baseline) was used to calculate total $Hb_{mass}$ (Schmidt & Prommer, 2005)[1].

## 3.6 Statistical analysis

### 3.6.1 Bayesian approach

A common challenge in sports science involves making accurate and relevant estimations of small effects that can be meaningful. In recent commentaries, both Batterham and Hopkins (2006), and Buchheit (2017), criticized the commonly used null-hypothesis testing (NHST) for its insufficiencies in dealing with such challenges. These critics cite the inability of NHST in dealing with small sample sizes and because significance testing doesn’t inform on the

[1] Calculations are shown in the appendix.

magnitude of an effect. Small sample sizes are common when dealing with elite level athletes, and small effects can be the difference between winning and losing. While NHST has been criticized, several papers have proposed Bayesian analysis as better approach to statistical analysis in sports science. In simple terms, Bayesian methods treats parameters as random variables that have a true, but unknown value Bernards, Sato, Haff, and Bazyler (2017). These values are described by a posterior distribution that reflects the uncertainty associated with how well they are known, based on the data (Mengersen, Drovandi, Robert, Pyne, & Gore, 2016). Notably, this approach was recently showed to provide a more direct probabilistic comparisons of altitude training interventions and able to identify small effects of interest, even with small sample sizes (Mengersen et al., 2016). Based on these recommendations, a Bayesian approach based on Kruschke (2013) was chosen for the present study to compare changes in competitive performance and hemoglobin mass.

To assess the effect of altitude and sea-level training over time, data was first log-transformed to account for non-uniformity of error, and the percent change in swimming performance and $Hb_{mass}$ from pre-altitude to each time point after altitude was calculated. Changes in performance were assessed in relation to the smallest worthwhile change (SWC) for swimming, estimated as one-half of the between subject standard deviation in swimming race time, 0.4% as showed by Pyne et al. (2004). Following the findings of Wachsmuth et al. (2013), the present study used a SWC for $Hb_{mass}$ of 2.9%, which is the typical variation in $Hb_{mass}$ in swimmers under sea-level conditions.

Descriptive data were shown as mean ± standard deviations, while observed effects were reported as percentage change ± 90% highest density interval (HDI). The HDI indicates that the true parameter value lies within the given interval with an estimated probability of 90%. Changes in performance or hemoglobin mass were termed faster/beneficial, similar/trivial, or slower/harmful based on the magnitude of change relative to the SWC. These effects were given a qualitative descriptor based on the probability of exceeding the SWC as follows: 50-74% “possible”, 75-94%” likely, 95-99% “very likely”. Changes were the posterior probability overlapped simultaneously both the substantially positive and negative thresholds (>5%) were deemed unclear.

### 3.6.2 True individual responses

As noted by Hopkins (2015) both inherited and acquired characteristics can modify the effects of a training intervention, making it more or less beneficial, harmful or ineffective in different individuals. In essence, individual responses are those that can be explained by differences between subjects in inherited and stable characteristics, whereas random responses can be attributed due to changes in subject characteristics or states between administration of a given treatment (Hopkins, 2015). Moreover, individual responses manifest themselves as larger standard deviation of the change score in the experimental group than in the control group (Hopkins, 2015). Therefore, individual responses in the present study were calculated from the square root of the square of the standard deviation of the change score in the altitude group minus the square of the standard deviation of the change score in the sea level group. This was only done for changes in competitive performance.

### 3.6.3 Correlations

To investigate the reproducibility of altitude training, the linear relationship between changes in performance following altitude training in 2015 and 2016 was examined using Pearson's correlation coefficient. The same procedure was done for the association between $Hb_{mass}$ and time-trial performance. Pearson's correlation were interpreted using a scale of magnitudes (Cohen, 1988) compromising of 0.1-0.3 (small), 0.3-0.5 (moderate), and >0.5 (large).

The Bayesian analysis were done using the statistical software R (R Development Core, 2013), with the package BEST, while all other measures were calculated using Microsoft Excel 2013, (USA).

## 3.7 Validity and reliability

Validity denotes the degree to which one can reasonably draw inferences from the results of a study. This means that what is measured must be relevant to the problem that is under investigation (Dalland, 2007).

Validity is usually broken up into internal and external validity, where external validity refers to the degree in which the findings of a study is generalizable, while internal validity denotes the success in which confounding variables are controlled for within the study (Jacobsen, 2005). In general, it is a way of describing the relationship between what has been studied, and whether it correspond to what was supposed to be studied. Another important question is whether the appropriate measurements methods were used.

Reliability refers to the stability of consecutive measurements (Hopkins, 2000). A measure is said to have high reliability if it produces similar results under consistent conditions, corollary, if a measurement produces different result under the same conditions, its reliability is low. Precision and thoroughness are deciding factors for whether a study is reliable or not. If the reliability of a study is high and the validity given, a study could be done producing the exact same results.

The validity of this study can be demonstrated in several ways. Firstly, our study sample consisted of all high-caliber elite swimmers, including several international gold medalists and both former and current world record holders. Secondly, this study set out to investigate the effects of altitude training on performance and hemoglobin mass. To that end the main measurement used was competitive performance itself, which is the most valid measure of performance there is. Time-trials should also be considered valid measures of performance, as these tests closely mimic actual competition standards. Additionally, the validity and reliability of the CO-rebreathing method for measuring $Hb_{mass}$ has been demonstrated by Schmidt and Prommer (2005), and this method has been used in several altitude training studies (Gore et al., 2013) . The present study can also be said to contain high degree of ecological validity as the study took place under real-world conditions, where the stakes were high and both athletes and coaches were expected to perform at their best.

Considering reliability, international swimming competitions are recorded using electronical timed equipment which records time down to the nearest 1/100 of a second. Variation in results between competitions can therefore solely be ascribed to biological variation in the subjects. Hand-timed time-trials are not as reliable as competitions, and some variation in results may be escribed to the nature of hand timing. However, such tests has been proven to be fairly reliable (TE: 1.4 ± 1.5%, mean ± 90% confidence intervals) as showed by Rodríguez et al. (2007).

# 4 Results

This chapter highlights the study findings. First, changes in performance during the both 2015 and 2016 seasons is presented, along with reproducibility of performance changes between these two seasons. The second part shows changes in time-trial performance and hemoglobin mass following an altitude camp held in October-November. The chapter ends with a summarization of the combined time-trial and competitive performances data, giving insight into the timing of return for competition.

## 4.1 Competitive performance

Descriptive data for each season is given in table 4.

*Table 4: Competitive performance (velocities) for the altitude and sea-level groups included in this study.*

| | | | **Days post-altitude** | | | |
|---|---|---|---|---|---|---|
| | | Pre | *15-23* | *27-30* | *50-56* | *70-76* |
| **2015** | Altitude | 1.69 ± 0.13 | 1.71 ± 0.11 | 1.69 ± 0.14 | 1.66 ± 0.13 | 1.70 ± 0.15 |
| | Sea-level | 1.63 ± 0.17 | 1.62 ± 0.19 | 1.60 ± 0.15 | 1.61 ± 0.18 | 1.64 ± 0.12 |
| **2016** | | Pre | *4-19* | *88-99* | | |
| | Altitude | 1.71 ± 0.16 | 1.69 ± 0.17 | 1.73 ± 0.14 | | |
| | Sea-level | 1.68 ± 0.18 | 1.67 ± 0.20 | 1.72 ± 0.15 | | |
| **2015 +2016** | | Pre | *4-23* | | | |
| | Altitude | 1.70 ± 0.14 | 1.70 ± 0.14 | | | |
| | Sea-level | 1.65 ± 0.19 | 1.65 ± 0.20 | | | |
| Number are mean ± SD | | | | | | |

### 4.1.1 2015 World championship season

Changes in competitive performance following three weeks of altitude or sea-level training is presented in table 5 and figure 2. Altitude camps were held in April-May, and the FINA World Championships in August. For the most part changes were unclear.

*Table 5: 2015 season. Percent changes in swimming performance within and between groups from PRE to 15-23, 27-30, 50-56 and 70-76 days after 3 weeks of altitude or sea-level training. (n) = participation rate. NC = National Championships, WC = FINA World Championships*

| Group | | Days post-altitude | | | |
|---|---|---|---|---|---|
| | | 15-23 | 27-30 | 50-56 NC | 70-76 WC |
| Altitude | Mean change, %, ± 90% HDI, (n) | 0.2 ± 1.0 (12) | -1.2 ± 1.8 (10) | 0.4 ± 1.0 (11) | 0.4 ± 1.4 (7) |
| | Probability for faster/similar/slower effect (%) | 38/48/14 | 6/14/80 | 47/40/13 | 51/35/14 |
| | Qualitative descriptor of change | Unclear | Unclear | Unclear | Unclear |
| Sea-level | Mean change, %, ± 90% HDI, (n) | -0.6 ± 1.1 (10) | 0.0 ± 0.3 (11) | -0.3 ± 0.7 (14) | 0.6 ± 0.6 (9) |
| | Probability for faster/similar/slower effect (%) | 7/32/61 | 3/96/1 | 6/56/38 | 71/28/1 |
| | Qualitative descriptor of change | Unclear | Very likely trivial | Unclear | Possibly faster |
| Altitude vs. Sea-level | Mean change, %, ± 90% HDI, | 0.8 ± 1.5 | -1.3 ± 1.8 | 0.8 ± 1.5 | -0.2 ± 1.5 |
| | Probability for faster/trivial/slower effect (%) | 68/23/9 | 6/13/81 | 63/28/8 | 26/35/40 |
| | Qualitative descriptor of change | Unclear | Unclear | Unclear | Unclear |

Starting off, there were no clear changes in either altitude (0.2 ± 1.0%) or sea-level (-0.6 ± 1.1%), 15-23 days post altitude. The small mean improvement in the altitude group was also unclear compared to sea-level (0.8 ± 1.5), despite a 68% probability of a change greater than the SWC. True individual responses, indicating the variability in response to altitude training, were similar to the mean difference between the groups (1.0%), meaning that the true individual response ranged from -0.2% to 1.8%. At 27-30 days, changes were clearly similar in the sea-level group (0.0 ± 0.3%) while the altitude group tended to be slower (-1.2 ± 1.8%, 80% probability). However, this change was still unclear. No clear changes in performance were seen around the National Championships, 50-56 days post-altitude, both within and between groups. Although, the posterior probability showed a tendency for both similar and faster (40% and 47%) performances in the altitude group, and similar and slower (45% and 49%) performances in the sea-level group. At the FINA World Championships, the sea-level group were likely faster (0.1 ± 0.3%) compared to baseline, while no clear changes were seen for the altitude group. A mean decrease in the change in performances between groups (altitude vs. sea-level) were observed (-0.2 ± 1.5), but this change was unclear.

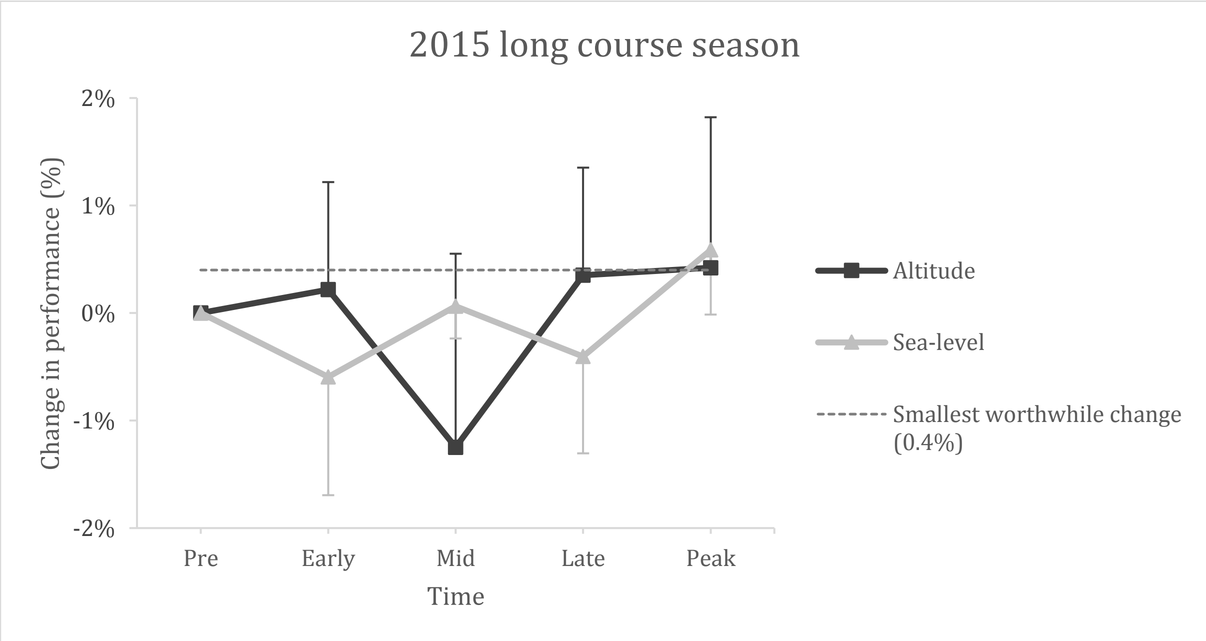



*Figure 2: Seasonal progression in performance as percentage change from Pre. Values are mean ± 90% HDI. Early = 15-23 days post altitude, Mid = 27-30 days post altitude, Late = 50-56 days post altitude, Peak = 70-76 days post altitude. The dashed line indicates the smallest worthwhile change (0.4%).*

### 4.1.2 2016 Olympic season

Seasonal progression in performance towards the 2016 Olympics is showed in table 6 and figure 3. Altitude camps were held in April-May, and the Olympics Games in August.

*Table 6: 2016 season. Percent changes in swimming performance within and between groups from PRE to 4-19, and 88-99 days after 3 weeks of altitude or sea-level training. (n) = participation rate. WC = FINA World Championships in Kazan*

| Group | | Days post-altitude | |
|---|---|---|---|
| | | 4-19 | 88-99 OL |
| Altitude | Mean change, %, ± 90% HDI, (n) | -0.3 ± 0.7 (14) | -0.3 ± 1.0 (10) |
| | Probability for faster/similar/slower effect (%) | 5/57/38 | 12/49/39 |
| | Qualitative descriptor of change | Possibly trivial | Unclear |
| Sea-level | Mean change, %, ± 90% HDI, (n) | 0.0 ± 0.6 (16) | 0.6 ± 0.4 (12) |
| | Probability for faster/similar/slower effect (%) | 16/72/12 | 76/24/0 |
| | Qualitative descriptor of change | Unclear | Likely faster |
| Altitude vs. Sea-level | Mean change, %, ± 90% HDI, | -0.3 ± 0.9 | -0.8 ± 1.0 |
| | Probability for faster/similar/slower effect (%) | 11/46/43 | 3/21/76 |
| | Qualitative descriptor of change | Unclear | Likely slower |

At 4-19 days post-altitude, performances were possibly similar in the altitude group (-0.3 ± 0.7%), while changes where unclear in sea-level (0.0 ± 0.6%). Neither group had increased their performance more than the other at this point. True individual responses could not be calculated. At the Olympic Games, the sea-level group saw a marked increase in performance (0.6 ± 0.4%) that was also likely faster compared to altitude group whose change was unclear (-0.3 ± 1.0%).

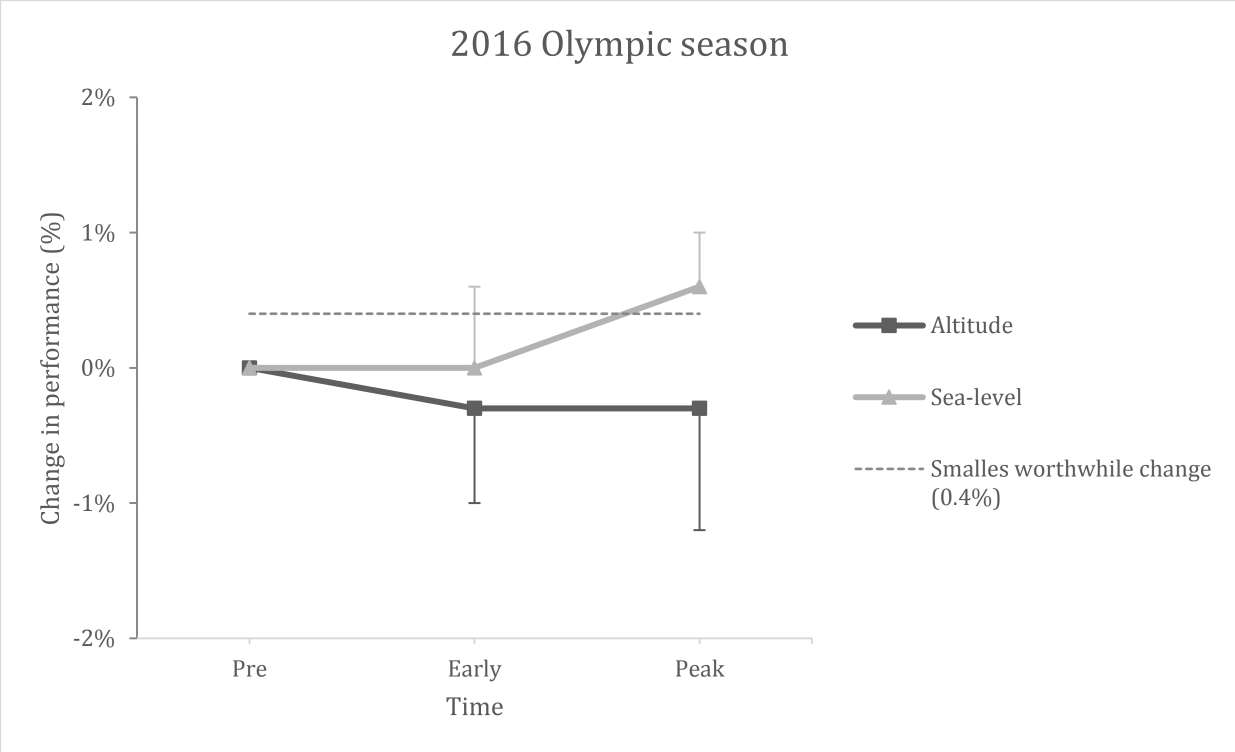



*Figure 3: 2016 seasonal progression in performance as percentage change from Pre. Values are mean ± 90% HDI. Early = 4-19 days post altitude, Peak = 88-99 days post altitude. The dashed line indicates the smallest worthwhile change (0.4%).*

### 4.1.3 Combined 2015 and 2016 seasonal data

The combined seasonal data for the closest time-points (15-23 and 4-19 days) post altitude is presented in table 7. As shown, changes were unclear for both groups (Altitude: -0.1 ± 0.5%; Sea-level: -0.3 ± 0.5%), even though the altitude group showed a small but unclear increase in performance compared to sea-level training (0.2 ± 0.7). The combined true individual response was 0.6%, giving a range of responses from -0.4% to 0.8%.

The posterior distribution gave a 57% and 38% probability for similar and slower performances following altitude training, while changes were probably 72% similar in the sea-level group. Between groups, altitude training was 33% more likely to improve performance compared to sea-level training, but also 58% likely to cause similar increases in performance.

*Table 7: Percent changes in swimming performance within and between groups from pre to 4-23 post altitude. (n) = participation rate.*

| Group | | Days post-altitude |
|---|---|---|
| | | 4-23 |
| Altitude | Mean change, %, ± 90% HDI, (n) | -0.1 ± 0.5 (26) |
| | Probability for faster/similar/slower effect (%) | 5/57/38 |
| | Qualitative descriptor of change | Unclear |
| Sea-level | Mean change, %, ± 90% HDI, (n) | -0.3 ± 0.5 (27) |
| | Probability for faster/similar/slower effect (%) | 16/72/12 |
| | Qualitative descriptor of change | Unclear |
| Altitude vs. Sea-level | Mean change, %, ± 90% HDI | 0.2 ± 0.7 |
| | Probability for faster/similar/slower effect (%) | 33/58/8 |
| | Qualitative descriptor of change | Unclear |

## Reproducibility

Each altitude training period produced a mean increase (0.2 ± 1.0%) and a mean decrease (-0.3 ± 0.7%) in performance, and there was a lack of association ($r = -0.06$, $P = 0.9$) between these changes as shown in figure 4. A similar trend was seen for the sea-level group wherein each period produced a mean decrease (-0.6 ± 1.1%) and a similar change (0.0 ± 0.6%) in performance, resulting in weak but insignificant correlation coefficient ($r = -0.2$, $P = 0.7$).

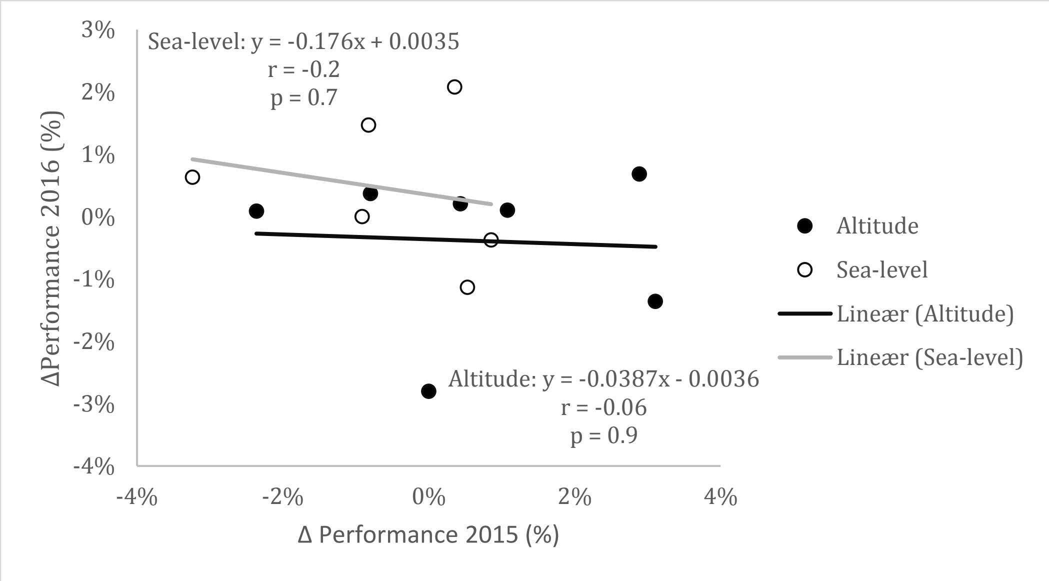



*Figure 4: Percent change in performance in 2015 vs. 2016. Measures are 15-23 vs. 4-19 days post altitude. Groups are altitude (n = 7; filled circles) and sea-level (n = 6; open circles). The regressions are the line of best fit.*

## 4.2 Time-trial performance and hemoglobin mass

The mean (± SD) hemoglobin mass showed a marked increase from 926 ± 198 grams to 980 ± 211 grams after the altitude training, a clear improvement of 5.8 ± 3.8%. In the same period the group increased their 100-meter time-trial performance by 0.5 ± 1.5%, although this effect was unclear. There was also wide heterogeneity in both $Hb_{mass}$ and time-trial responses as shown in figure 5. Despite a marked increase in $Hb_{mass}$, changes between $Hb_{mass}$ and changes in performance were small, but unclearly, correlated ($r = -0.3$, $P = 0.5$). Pre-versus post results are showed in table 8.

*Table 8: Changes in $Hb_{mass}$ and time-trial velocity before and after altitude training.*

| | | **Pre-altitude** | | **Post altitude** | | **ΔPre vs. Post** | |
|---|---|---|---|---|---|---|---|
| **Subject** | **Sex (M/F)** | **v100m (m/s)** | **Hb (g)** | **v100m (m/s)** | **Hb (g)** | **ΔHb (%)** | **Δ100m (%)** |
| 1 | M | 1.89 | 952 | 1.89 | 1057 | 11.0% | 0.4% |
| 2 | M | | 1004 | | 1024 | 2.0% | |
| 3 | F | 1.73 | 774 | 1.723 | 783 | 1.1% | -0.4% |
| 4 | M | 1.82 | 1117 | 1.854 | 1141 | 2.2% | 2.0% |
| 5 | M | 1.86 | 896 | 1.888 | 975 | 8.8% | 1.3% |
| 6 | F | 1.76 | 765 | 1.721 | 835 | 9.2% | -2.2% |
| 7 | F | 1.95 | 1251 | 1.961 | 1339 | 7.0% | 0.5% |
| 8 | M | 1.36 | 649 | 1.382 | 682 | 5.1% | 1.3% |
| **Mean** | | **1.7675884** | **925.9** | **1.775** | **979.5** | **5.8%** | **0.4%** |
| **SD** | | **0.19** | **198.4** | **0.20** | **210.9** | **3.8%** | **1.4%** |
| **90% HDI** | | | | | | **2.8%** | **1.0%** |
| **% for beneficial/trivial/harmful** | | | | | | **95/5/0** | **55/36/9** |
| **Qualitative descriptor** | | | | | | **Very likely beneficial** | **Unclear** |

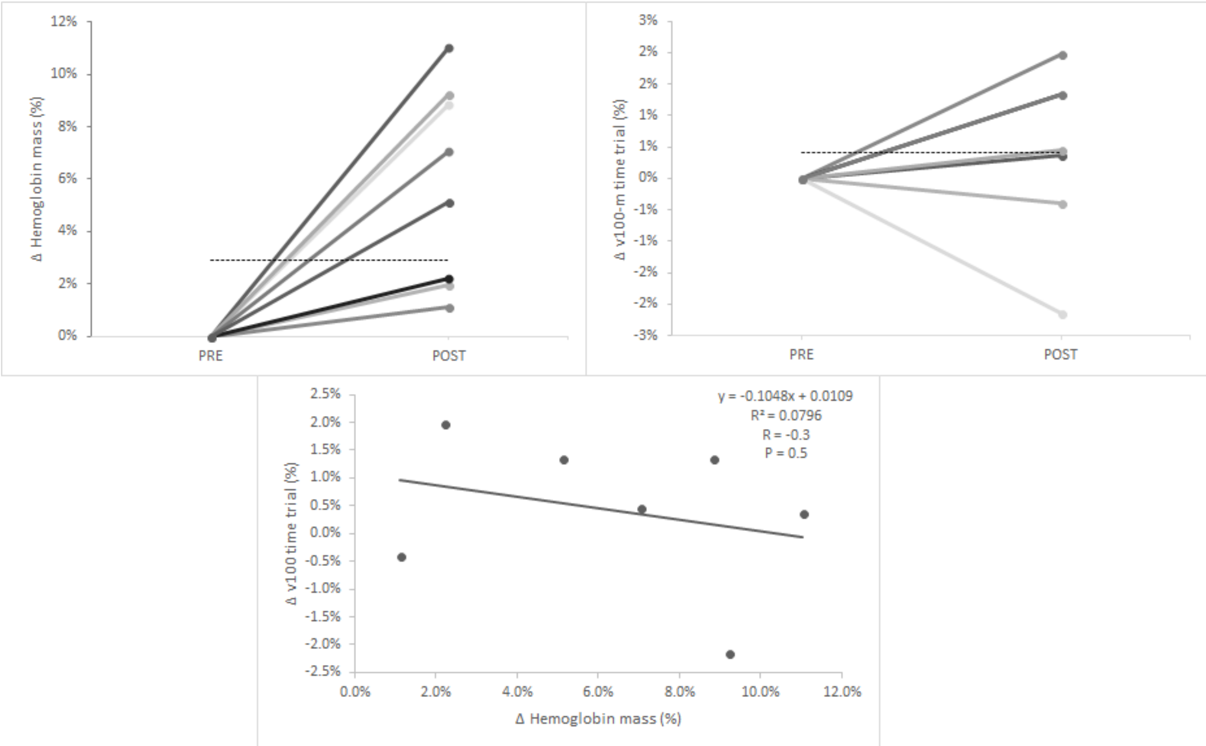



*Figure 5: Upper left and right: Changes in hemoglobin mass and time-trial performance from pre to post. Lower: Linear relationship between changes in hemoglobin mass and changes in time-trial performance.*

## 4.3 Combined performance data

A scatter plot of combined performances (time-trials and competitions) up to and including 30 days is shown in figure 6. The regression line shows a slight tendency towards better performances closer to return from altitude. Finally, the combined data in figure 7 shows wide heterogeneity in response following altitude training.

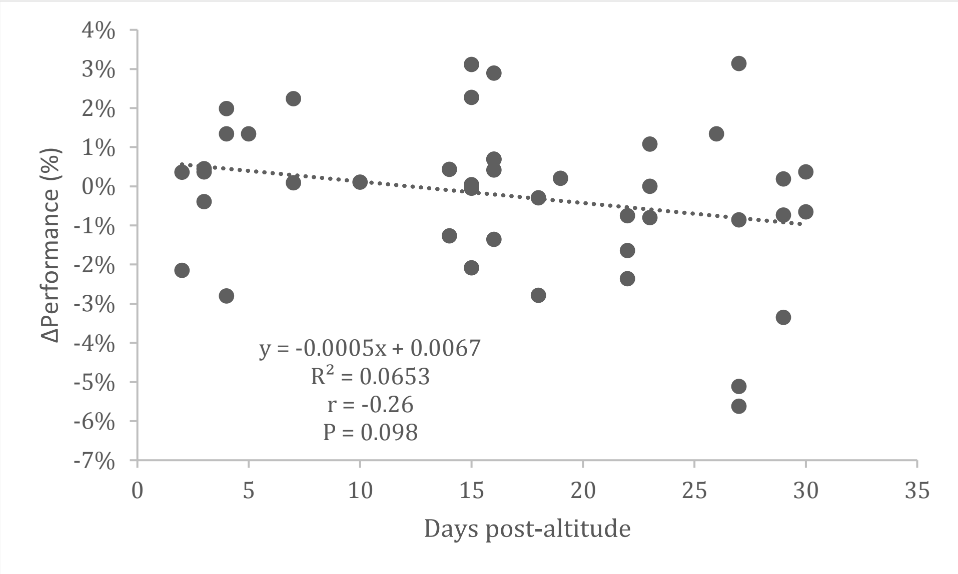



*Figure 6: Change in performance following altitude. Data are pooled time-trial and competitive performances for all altitude groups in this study. Regression line represents line of best fit.*

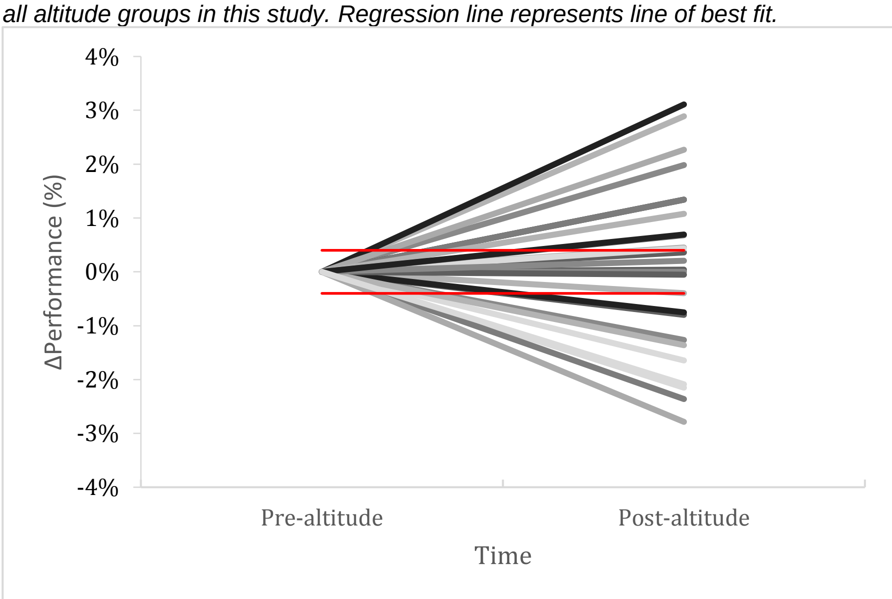



*Figure 7: Inter and intra-individual changes in performance from pre to post altitude (2-25 days). Data are pooled time-trial and competitive performances for all groups in this study. Red lines represent thresholds for positive (+0.4%) and negative changes (-0.4%)*

# 5 Discussion

## 5.1 Summary of findings

The main purpose of the present study was to investigate whether altitude training led to greater increases in performances compared to sea-level training, and the association between changes in time-trial performance and hemoglobin mass following altitude training.

No clear differences were seen between groups at either 4-19 and 15-23 days post-altitude, and these differences persisted even when results where pooled. However, the combined posterior distribution showed that altitude training was 33% more likely to produce a change greater than the smallest worthwhile difference (0.4%) compared to sea-level training, but also 58% likely to produce similar changes, and 8% more likely to decrease performance. In addition, the true individual response to altitude training were similar to the mean responses, meaning that the effect of altitude training was 0.8 ± 1.0% and 0.2 ± 0.6% (mean ± individual responses) for 2015, and 2015/2016 combined.

For the 2015 season, no differences were seen between groups at either at 27-30 and 50-56 days post-altitude. The sea-level group swam faster at the World Championships in Kazan compared to pre-training, however these changes were not different from the altitude group. During the 2016 season, the sea-level group swam faster at the Olympic Games compared to pre-training, and this change in performance was likely greater compared to the altitude group. Lastly, results from altitude training were not reproducible, meaning changes following one altitude camp showed no association with changes following the other.

Altitude training led to a marked increase in hemoglobin mass in a group of Norwegian swimmers. Although, despite this increase, an unclear change was seen in time-trail performance, and only a small, but unclear, association between these two variables could be detected.

When grouping both time-trial and competitive performances together, a slight tendency towards greater changes in performances where seen closer to altitude exposure, decreasing as time passes.

### 5.1.1 Changes in competitive performance

#### Short term changes (≤ 30 days post-altitude)

The present study did not find any clear evidence that the implementation of an early seasonal LHTH altitude camp causes greater increases in performance compared to sea-level training. However, considerable individual variation exists, and the present study cannot exclude the possibility that under certain context-specific scenarios, individuals may benefit from altitude training.

These results are pretty much in line with findings from other studies examining either time-trial or competitive performance. Gough et al. (2012) found an unclear increase (0.3 ± 0.8%, mean ± 90% confidence intervals) in competitive performance two weeks post-altitude in swimmers using LHTH, while Rodríguez et al. (2015) reported no significant differences in swimmers using LHTH for three weeks at 2-3 weeks post-altitude when using 100/200-meter time trials. Similarly, Wachsmuth et al. (2013) found a 0.4% and 0.1% decrease both 0-14 and 14-25 days post altitude. Only Miyashita et al. (1988) has noted a significant ~1.5% ($P < 0.05$) increase in the 200-meter events following three weeks of LHTH altitude training, however no sea-level control group was reported for this study. An unclear decrease in performance with large HDIs was seen 27-30 days for the altitude group in the present study, which is the same as Gough et al. (2012), but in slight contrast to Rodríguez et al. (2015) and Wachsmuth et al. (2013). Gough et al. (2012) reported an unclear decrease in performance (-0.2 ± 0.9%) at 28 days post, while Rodríguez et al. (2015) and Wachsmuth et al. (2013) found non-significant improvements of ~2% and 0.8%, respectively.

Why do we not see a clear increase in performance? The main reason swimmers sojourn to altitude is based on the prediction that physiological adaptions to hypoxia will transfer positively into improved performance (Truijens & Rodríguez, 2010). However, whether this prediction holds true turns out to be far from certain. Several notable studies have tried using protocols with different metabolic requirements to detect relevant performance effects. Two such protocols are the incremental step test, and over-distance time-trials. The first test is a crude measure of the velocity at peak oxygen uptake, while over-distance time-trials are basic measurements of the ability to maintain a high percentage of $VO_{2peak}$ over a longer period of time (Bonne et al., 2014). Bonne et al. (2014) reported that maximal speed reached in an incremental swimming step test ($P = 0.051$), and 3000-meter time-trial tended ($P = 0.09$) to be more improved after LHTH than sea-level training. However, neither of these findings were significantly different from the control group, despite a significant increase in hemoglobin mass. Step-test performance was also significantly improved by 2-3% ($P<0.001$) in the study by Friedmann et al. (2005), albeit the results were reported in an uncontrolled study on junior swimmers. Each 2-week altitude block in the study by Robertson, Aughey, et al. (2010) produced a mean improvement of 0.9 ± 0.8% (±90% confidence intervals) in step-test performance, and a mean improvement in 2000-meter time-trial performance of 1.2 ± 1.6%. Finally, Robach et al. (2006) found that 2000-meter time-trial performance was unchanged in swimmers living high-and training low (LHTL), while swimmers in a control group significantly improved their performance in the same test ($P<0.05$). In a follow-up study, the same authors found that living and training at 1200 meters was more effective in improving 2000-meter time trial performance compared to living and training at 1800 meters. Taken together, these studies do neither provide a convincing answer for improvements in performance measures following altitude training. Findings are either not significant or confounded because of a lack of control group.

Lastly, another possible reason for not seeing an increase in performance is that the underlying prediction behind altitude training is not sound to begin with. At least not when it comes to swimming. Firstly, swimming performance is highly dependent on economy of movement (Di Prampero, Pendergast, & Zamparo, 2011), and while oxygen transport to the muscles may increase following altitude training, the reduced training intensity may lead to impaired technique and economy (Mercade, Arellano, & Feriche, 2006). As shown by Mujika et al. (1995), training intensity is a key factor in improving swimming performance, more so than training volume and frequency, and it is questionable if the cost of sacrificing training intensity, as is often done during LHTH altitude training, pays of in the end. In fact, Truijens, Toussaint, Dow, and Levine (2003) demonstrated that swimmers doing high-intensity training in hypoxia actually trained at lower swimming speeds and lower power outputs compared to a group training in normoxia. This happened despite both groups training at the same relative intensities. Secondly, the benefits of altitude training might be more potent for swimmers of different events. For example, the energy percent share (phosphagenic-glycolytic-oxidative) at maximal competitive speed ranges from approximately 38%-58%-4% in 50-meters to 6%-21%-73% in 400-meter events (Rodríguez & Mader, 2011). Most of the events in the present study were 200-meter distances which has an approximately energy contribution of 13%-

29%-58%. Seeing as the benefits of altitude training are thought to be mostly aerobic in nature, it might be the case that events of 800-1500-meters are more suited to investigate the effect of altitude training in competitive performance. This could be the case seeing as greater increases in performance following LHTH are seen for tests of longer duration (Bonetti & Hopkins, 2009). Then again both Bonne et al. (2014), Robach et al. (2006), and (Roels et al., 2006) found that LHTH did not improve 3000 and 2000 meter time-trial performance, respectively. To summarize, the investment into LHTH altitude camps does not seem warranted.

### Time course of performance changes

Numerous reports based on coaches' experience have tried to pin point specific periods wherein athletes achieve peak condition following altitude training (Chapman, Laymon Stickford, Lundby, & Levine, 2013). While some suggest competing immediately upon return, others have reported better performances between 1-3 weeks post altitude (Chapman et al., 2013; Millet, Roels, Schmitt, Woorons, & Richalet, 2010; Tjelta et al., 2013).

One could suppose that the small ($r = -0.26$), but insignificant ($P = 0.098$) negative correlation could indicate that swimmers achieve their best performances closer to returning from altitude. It is known that neocytolysis rapidly kicks after return from altitude (Reynafarje, Lozano, & Valdivieso, 1959), causing a marked decrease in red cell survival time, which over time will decrease total $Hb_{mass}$. If one presupposes that performance enhancements following altitude are primarily mediated by hematological factors one could reasonable assume that performance would be more enhanced immediately following altitude exposure. However, the weak correlation ($r = -0.3$) between changes in $Hb_{mass}$ and changes in performance appear to oppose the notion that effects following altitude are primarily hematological in nature. Also, it's important to note that the reported regression line is based on the combined data from three altitude camps, meaning that the context-specific scenarios in each camp will have a large effect on the result. For example, it is common for swimmers to take a short break after the long course season, which would mean that they start from a lower performance baseline when returning to training. It is possible that the trend towards better performances immediately after altitude is confounded by the altitude camp held in October-November, as the effect of this camp might just be the result of swimmers getting back in shape. In other words, a regression towards the mean.

The trend towards better performances immediately post exposure is also not supported by previous studies. Both Gough et al. (2012), Rodríguez et al. (2015) and Wachsmuth et al. (2013) found that performance likely deteriorates immediately post-altitude and either increases or return to baseline 2-3 weeks after exposure. These studies were also much better controlled than the present study. In the most recent meta-analysis on altitude training, Bonetti and Hopkins (2009) found that the effects of LHTH were enhanced by 0.5±0.7% when adjusting for test day, indicating that changes in performance probably manifest themselves after a period of deacclimatization. The same authors also state that it may be better to implement LHTH altitude training 2-3 weeks before an important competition. Interestingly, for measurements taken 15-23 days post altitude during the 2015 season, the posterior distribution revealed a 68% probability for greater improvements following altitude training compared with sea-level training, which coincides with the recommendations of Bonetti and Hopkins (2009).

Taken together, it may be that benefits from LHTH altitude training are more likely to manifest themselves after a two-week period of proper training upon return from altitude.

## Reproducibility

The present study compared two altitude training periods placed approximately one year apart, with seven of the same participants, and found no association between changes in performance ($r = -0.016$). The sea-level group saw a weak negative correlation ($r = -0.2$) in the same period, a result of slightly faster performance in 2016 vs. 2015. It should be noted that the numbers of subjects in this investigation was low, as seen in by the considerable high sample dependent p-values ($P = 0.9$ and $P = 0.7$). As such, inferences hard to draw.

While no previous study has examined the reproducibility of LHTH in swimmers, one study examined the reproducibility of simulated LHTL in runners (Robertson, Saunders, et al., 2010). When examining percent changes in time-trial performance between two separate altitude training blocks, the altitude group were substantially faster (1.4%) after the first block, but trivially slower after the second block (-0.7%). This resulted in a correlation coefficient of $r = 0.10$, which is similar to the correlation coefficient noted in the present study.

The difference in settings between the 2015 and 2016 seasons could provide some insight into the reported findings. Mainly, the context pertaining to the races in which these two periods were sourced from was different. The immediate post altitude results in 2015 were sourced from races held in what would be considered regular international meets, while the immediate results in 2016 were primarily taken from the European Aquatic Championships (EC). It could be the case that the sea-level group were more motivated to perform at the latter championships, and so chose to stay at sea-level to taper their performance. However, this motivation could also be the case for the altitude group, seeing as LHTH has been recommended 2-3 weeks before a key competition (Bonetti & Hopkins, 2009). In the end, the poor correlations may indicate that there is no such thing as responder or non-responder to altitude training, or maybe any training intervention for that matter. Context is king, and the results from any training intervention is likely a combination of both inter-individual and intra-individual conditions.

### Individual responses

Estimates for true individual responses, indicating the typical variation in response to altitude training from individual to individual were 1.0% for 2015 and 0.6% when both years were combined. This means that if the mean response to altitude training in 2015 was 0.8%, most swimmers would have a true response somewhere in the region of -0.2% to 1.8%, which is a large range when considering the smallest worthwhile difference. True individual response couldn't be calculated for 2016, because the variance in the change scores was negative. As proposed by Hopkins (2003) this can likely be attributed to random sampling variation resulting in a negative difference purely by chance. Lastly, when seasons where combined the true individual response to altitude training became 0.2 ± 0.6% (mean ± SD) or between -0.4% to 0.8%. These findings are in line with Robertson, Saunders, et al. (2010) who reported large individual variation (1.4 ± 1.5% and 0.7 ± 1.6%) in running time-trial performance after two blocks of LHTL altitude training.

While one could speculate endlessly as to which factors could affect each individuals response, large individual responses to training are not a new phenomenon, and has been elaborated upon in great detail by Kiely (2012). As explained in his landmark paper, individual results can likely be attributed to complex interactions between a broad spectrum of inherited characteristics and varying biopsychosocial factors (Kiely, 2012). As a result, individual athletes will respond differently to one another to identical training sessions. It is therefore highly improbable that mean change in performance can be generalized to the individual swimmer.

### Long term changes (≥ 50 days)

An important thing to remember is that the further one gets away from altitude exposure, the more difficult it is to interpret results because several factors, other than the exposure itself, come in to play.

In the present study, the most apart differences between groups were seen during the 2016 season where the sea-level group improved their performance more than the altitude group from pre-altitude to the Olympics. Additionally, for the 2015 season, although differences between groups were unclear, the sea-level group were likely faster at the World Championship compared to baseline. Similar findings has been reported in other studies. Gough et al. (2012) showed that both LHTH and LHTL were likely faster (0.8%) at the 2009 FINA World Championship compared to pre-altitude, while the sea-level group was very likely (1.1%) faster. However, the -0.3% difference between groups were unclear. Similarly, Robertson, Aughey, et al. (2010) reported that swimmers incorporating altitude camps into their preparation did not perform substantially faster (0.4%), while a group receiving no altitude exposure swam substantially faster (0.9%) from year to year at a national championship. Likewise, the -0.5% differences between groups were unclear.

Again, the tendency towards greater long-term changes in performance with sea-level training is hard to interpret and can likely be attributed to other factors. A very simple explanation could be that groups differed in their tapering strategies towards these championships, and that the sea-level groups just managed to do it better. A well performed taper has been showed to drastically improve performance leading into important championships (Mujika, Padilla, & Pyne, 2002). For example, when investigating changes during the final 3 weeks leading into the Sydney Olympics, Mujika et al. (2002) found a 2.2% increase in performance, which is considerably larger than the seasonal progression in performance in the present study. Interestingly, they also found that the magnitude of change between the gold medalist and the fourth place was 1.6%, while 2.0% between 3rd and 8th place. These findings suggest that the final training phase, along with other possible factors contributing to performance gains (e.g. motivation), is important in the preparation of Olympic-level swimmers.

### 5.1.2 Hemoglobin mass

There should now be little doubt that altitude training can increase hemoglobin mass in swimmers when given adequate exposure. The present study found a clear 5.8% mean increase in hemoglobin mass, which is in accordance with similar studies. Both Gough et al. (2012), Wachsmuth et al. (2013), Friedmann et al. (2005), Robach et al. (2006) ,and Rodríguez et al. (2015) found mean increases of 3.8%, 7.2%, ~6%, 7.5%, and 3.8%, respectively, in swimmers using LHTH. The similarities between these findings are also supported by the fact that all of them used CO-rebreathing methods.

Although $Hb_{mass}$ increased significantly, only a small, unclear, correlation between changes in performance and changes in $Hb_{mass}$ could be detected. This finding is also shared by Gough et al. (2012) and Friedmann et al. (2005), who found small ($r = 0.2$) and no correlation at all, between these two variables, respectively.

There are several explanations as to why these two variables were only weakly correlated. First, like the investigation into competitive performance, the 100-meter distance might not be as dependent on oxygen transport as some of the longer distances. Thus, potential performance enhancing effects of hemoglobin mass might not have been detected. Using simulations, Rodríguez and Mader (2011) showed that the energy percent share (phosphagenic-glycolytic-oxidative) in 100-meter was approximately 20%-39%-41%, while the 1500-meter events, in contrast, was 3%-11%-86%. It may be the case that a stronger linear relationship could have been detected if the present study used 1500-meters instead of 100-meters. Secondly, fatigue and impaired technique could have played a confounding role during the post time-trial performances. These tests were performed within a relatively short time after altitude (2-5 days”), and athletes have reported feeling sluggish upon return to sea-level. For example, Martin (1994) reported that middle distance runner felt like they had lost “turnover”, that is, the sensation of feeling coordinated at faster running speeds. One could reasonably hypothesize that this sensation would also affect swimmers, and maybe even to a higher degree, seeing as a) swimming is highly dependent on economy (Di Prampero et al.,

2011) , and b) technique is altered when swimmers are exposed to acute hypoxia (Mercade et al., 2006). Therefore, the weak association between hemoglobin mass and 100-meter time trial performance could be explained by these factors.

## 5.2 Implications for coaches and athletes

### 5.2.1 Probability for improvements

The beauty of doing a Bayesian analysis is that it allows a direct probabilistic comparison of altitude and sea-level training to be made. This is in stark contrast to the commonly used null-hypothesis testing that makes a binomial decision of whether the intervention is significant or not. As noted by Buchheit (2017), coaches and athletes are first and foremost interested in knowing the magnitude of an effect, and how likely this magnitude is to be of practical importance. A Bayesian approach is therefore suitable to accommodate these needs.

The present study used an objectively derived measure, the smallest worthwhile change for swimming (0.4%), and presented the probabilities that altitude training produced better/similar/or lesser changes in performance compared to training at sea-level. These probabilistic statements can be used by coaches and athletes to inform decision making of whether one should sojourn to altitude. When looking at the 2015 season, altitude training was 68% probable of producing better results ~2-3 weeks after the camp compared to sea-level training, despite these differences being unclear. For some coaches and athletes, the 68% probability might be sufficient encouragement for the use altitude training, for others not. Also, it may be that altitude training is more appropriate in some contexts more than others. For example, altitude training was 46% probable of decreasing performance compared to sea-level within ~1-2 weeks post altitude during the 2016 season. It may very well be that LHTH altitude training is less appropriate before important races, seeing as the immediate post swimming meet in 2016 was the European Championships. LHTH is characterized by mostly low-intensity training and is probably more suited at the beginning of a swimming season to build a base and to prepare the body for higher intensities going forward. Finally, coaches should also consider using a “live high-train high-train low” (LH-TH-TL) since Rodríguez et al. (2015) showed it to be more effective in improving performance compared to both sea-level training and LHTH.

### 5.2.2 Rational for using altitude training

Based on the current literature, the notion that an increase in hemoglobin mass will automatically translate into improved performance cannot be supported. However, these studies have looked at shorter distances, and it is possible that distances that rely more on oxygen transport, such as the 800 and 1500-meters, may benefit from hematological adaptions following altitude training. For shorter distances, increases in performances might simply be the result of a training camp effect, in which case it might be a better idea to just train at sea-level.

Could other mechanisms besides the training camp effect and hematological adaptions cause improvements in performance following altitude training? Gore, Clark, and Saunders (2007) has suggested that non-hematological factors linked to improved exercise economy may explain some of the improvements in performance. This would mean that that the swimmer uses less oxygen at a given exercise intensity, and one could suspect that peripheral adaptions due to a shortage of oxygen in tissues would arise as a response to hypoxia. While prolonged hypoxia has been showed to improve skeletal muscle mitochondrial content and efficiency, notable studies have reported no changes in exercise economy nor alterations in skeletal muscle mitochondrial efficiency following altitude training. Moreover, Truijens et al. (2003) found that despite an increase in time-trial performance (100 and 400 meter freestyle) neither swimming economy nor anaerobic capacity improved in collegiate and master swimmers using high-intensity hypoxic training. Likewise, simulated altitude (4000-5500 meters) for 3 h/day, 5 days/week, for 4 weeks, did not improve submaximal economy in trained swimmers (Truijens et al., 2008). This seems to argue against the notion of improved swimming economy following altitude training.

Gore et al. (2007) has also suggested increased muscle buffering capacity as a possible benefit of altitude training and did find such an adaption in well-trained triathletes after living and training low for three weeks. Interestingly, Roels et al. (2006) reported that end exercise lactate concentration in an incremental step-test decreased significantly in swimmers living and training at 1850 meters, but not in swimmers living and training at 1200 meters. However, step-test performance remained unchanged, and only the 1200 group increased their performance in the 2000-meter time trial.

## 5.3 Limitations

The choice of using an observational design certainly had its limitations. Mainly, that only an association between the studied groups and changes in performance could be made. Because of a lack of experimental manipulation, many possible confounding factors could have influenced the results.

A considerable amount of time elapsed between pre-competition and altitude, and from altitude to post competition measurements. This meant that the effects of the altitude camps themselves were probably confounded by a large proportion of sea-level training. In this sense, it was not the effects of the camps that were studied, but rather training periods that included altitude training. Although, from a pragmatic view, this is how altitude training is integrated, and several authors has explained the importance of both the pre-and post-altitude training periods (Mujika, 2012; Tjelta et al., 2013).

The consequence of a possible training camp effect cannot be excluded. This effect has been proposed as being responsible for approximately half the effect of altitude training (Saunders et al., 2010; Tjelta et al., 2013). In an ideal setting, the subjects in the control groups should have undertaken their own training camp at sea-level for this effect to be fully controlled, preferably at the same time as the altitude group. No control group was used for the investigation of time-trial performance and hemoglobin mass following altitude training, and this makes the results harder to interpret. However, the change in hemoglobin mass that this group experience was much larger than the variation in $Hb_{mass}$ that occurs in swimmers training at sea-level, meaning that these results are probably true.

A key factor in the individual response to training, whether at altitude or sea-level, is the training load. This was not reported in the present study and thus the effect of the training could not be evaluated. Other factors such as injury and sickness could also have influenced the results for certain individuals. Both prolonged inflammatory responses associated with soft tissue injuries has been showed to interfere with altitude adaptions, as has low iron stores (Mazzeo, 2005), while Wachsmuth et al. (2013) showed a lack of erythropoietic response in both injured and sick athletes. Sleep disturbances and lower appetites are also association with altitude training and may also have influenced the results.

Another limitation is that a rather simple repeated-measure design was used. To detect possible differences, the percent change in each subjects score were calculated thereby taking into account the differences between the groups at baseline. Percent changes does, however, have some weaknesses. For one, they are sensitive to pre-training differences, meaning that if a swimmer decided to take a shorter break mid-season, the following increase in performance might just be a regression towards mean, and not an improvement because of the intervention. Although, at least for the investigation into competitive performance, groups were closely matched in terms performance level, and the baseline measures were taken during a period where brakes from training were less likely.

Finally, the sample sizes for the correlations were likely to low to detect any linear relationship between the investigated variables.

## 5.4 Future directions

The present study investigated the effects of altitude training on swimming performance and hemoglobin mass from an observational perspective, complementing the experimental studies that had already been done. Future studies should try to expand upon the work by Kiely (2012) and examine altitude training by regarding athletes as complex biological systems. In simple terms, complex systems are systems whose behavior is intrinsically hard to predict, because of the many interacting parts, dependencies and relationships (Bosch, 2015). As noted by Kiely (2012), the adaptive response to an intervention is predicated upon the complex interaction between inherited predispositions and chronically and acutely varying biopsychosocial factors. Hence the training effect from a given training intervention will vary from individual to individual and even from time to time. It is highly doubtful that the current paradigm in which sports science is situated in can capture this complexity.

An important realization is that sports science as a field is very much situated within a positivistic paradigm, and that this perspective has severe limits when it comes to predicting the outcomes of an intervention such as altitude training. Positivism has an ontological perspective based on the idea that reality is governed by abstract underlying principles that can be captured in physical and mathematical formulas (Sohlberg & Sohlberg, 2008). The belief is that the impact that numerous factors have on the training process can be captured accurately in such physical and mathematical principles, and hence is constant (Bosch, 2015). Since factors are constant, major factors would always have a major impact, while minor factors would always have minor impact. This consistency also provides predictive value because training effects are based on the assumed stable dominance of the underlying principles, and hence dependent on whether that theory is accurate and complete.

We see this line of thinking within the hematological paradigm of that has been the dominating rational behind the use of altitude training. The central notion is that positive effects of altitude are mediated primarily through an increase in hemoglobin mass (Levine & Stray-Gundersen, 2005). Levine and Stray-Gundersen (2005) support this position using three types of evidence: Firstly, an increase in hemoglobin mass has been showed increase both $VO_{2max}$ and performance, and corollary: when no increase in hemoglobin mass is present, there is no increase in $VO_{2max}$ and no increase in performance. Secondly, a sojourn to altitude is accompanied by an increase in hemoglobin mass and hemoglobin mass and is the only measured factor linked to improved performance that changes. Third and finally, when hemoglobin mass is manipulated independently through doping, the same improvements in physiological parameters occur. Corollary, in the presence of altitude exposure, when hemoglobin mass is inhibited, then the outcome is prevented. Here we see that hemoglobin is considered the major factor, and that increases in hemoglobin mass will lead to an increase in performance. However, recent findings do not support this notion (Robach et al., 2018; Siebenmann et al., 2011).

Although such a positivistic approach may claim a degree of predictability for the training effect, the large numbers of factors involved will produce a far more uncertain response. It is questionable if broad, generalized, and averaged answers can offer a solution to individual specific and context-specific problems. If athletes were linear systems, this approach would be valid, but as has been showed in several altitude studies, these predictions don't always hold up. This goes to show that we can measure many underlying factors and variables, but we cannot predict what happens to performance when these factors are perturbated. Under some circumstances both major and minor factors may have major impact, but in other circumstances little or no impact on what happens within the system. This looks to be the case with altitude training as sometimes an increase in hemoglobin mass does seem to play a major factor (Levine & Stray-Gundersen, 1997), while other times not (Robach et al., 2018). In practice, the way interventions lead to increases in performance turns out to differ greatly from individual to individual, and even from time to time within a single individual.

A suggestion going forward, is to focus less on searching for universal 'best' answers and more on exploring the emergence of context-specific training solutions. This can of course be done within then standard quantitative framework, but other research designs can also be useful. One such design is case-studies. Case studies are mostly used to acquire knowledge about the training programs of high caliber athletes and their physiological or psychological characteristics (Halperin, 2018). Due to the relative simplicity of collecting data on one or a few participants, case studies are more logistically suited for richer and more complex designs, such as longitudinal interventions. Case studies can also contribute to generating hypotheses for future research questions. A brilliant example of a good case study was recently written Solli, Tønnessen, and Sandbakk (2017) titled "The Training Characteristics of the World's Most Successful Female Cross-Country Skier". In it they describe a wide range of training characteristics for this specific athlete, including the training during several altitude camps. Interestingly, these camps were of a relative shorter duration (≤16 days) then what is currently recommended, characterized by higher volume of low intensity training, and living at 1800-2000 meters and training at 1000-3000 meters. Studies such as this provides valuable information regarding the nuances of training and how world class athletes and their coaches combine these intricacies into world class performances.

A possible way of conducting such a study in swimming could involve tracking a group of swimmers during an altitude camp using modern monitoring methods. To track recovery, subjective ratings of key indicators e.g. mood, sleep quality, readiness to train etc. could be used alongside objective measures such as morning heart rate or submaximal V4. Training could be recorded in numerical form such as sets, reps, volume, time in zone, along with subjective feel (e.g. athlete rating on a 1-10 scale) and technical quality (e.g. coach rating on 1-10 scale). Post-training measurements such as session RPE could be used calculate the training load (session time x subjective rating on a 1-10 scale), and long-term training load derivatives such as strain and monotony.

One can further add to this type of research by using qualitative methods such as interviews. Training and performance are complex phenomena, and our predictions based on loose theories are fragile as showed with the hematological paradigm. As noted by Taleb (2012), when dealing with complex systems, phenomenology, e.g. the observation of an empirical regularity without a theory for it, is more robust than theories. Many coaches and athletes has been using altitude training as a part of their preparation for decades, and it makes sense to listen to their thoughts and experiences. Interviews can therefore be a great way to further the knowledge around the use of altitude training for increased performance.

All in all, there is a great need for insight into which factors are crucial in a given training setting, and which are not. This calls for sound knowledge of training practice. As noted by Bosch (2015), with help from experienced coaches, who usually have better sense of what is actually going on, researchers can gain a somewhat better idea of the mechanisms that play a key part in the reality of training. In short, in order to deal with the complexity and unpredictability of training, research requires not only facts, but also thinking models based on practical experience that can provide a framework for gathering more evidence.

# 6 Conclusion

The implementation of early seasonal altitude training camps was not associated with any clear increases in performance when compared to sea-level training. When combining results from two seasons, altitude training was 33%-58%-8% likely to produce greater-similar-or worse results compared to sea-level training. However, large individual variation exists, and altitude training did not seem to produce reproducible results from season to season.

Swimmers experienced large increases in hemoglobin mass following altitude training. However, this change was only weakly correlated with 100-meter time-trial performance. Consequently, the notion of sojourning to altitude to reap the benefits of increased hemoglobin mass does not seem warranted. At least not for the shorter distances.

To conclude, swimmers sojourning to altitude will likely experience similar results compared to sea-level training, despite significant increases in hemoglobin mass.

# 7 References


Bailey, D. M., & Davies, B. (1997). Physiological implications of altitude training for endurance performance at sea level: a review. *British journal of sports medicine, 31*(3), 183-190.

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International journal of sports physiology and performance, 1*(1), 50-57.

Bernards, J. R., Sato, K., Haff, G. G., & Bazyler, C. D. (2017). Current Research and Statistical Practices in Sport Science and a Need for Change. *Sports, 5*(4), 87.

Bonetti, D. L., & Hopkins, W. G. (2009). Sea-level exercise performance following adaptation to hypoxia. *Sports Medicine, 39*(2), 107-127.

Bonne, T. C., Lundby, C., Jørgensen, S., Johansen, L., Mrgan, M., Bech, S. R., . . . Nordsborg, N. B. (2014). "Live High–Train High" increases hemoglobin mass in Olympic swimmers. *European journal of applied physiology, 114*(7), 1439-1449.

Bosch, F. (2015). *Strength training and coordination: An integrative approach*: 2010 Publishers ten Brink.

Buchheit, M. (2017). Want to see my report, coach. *Sport Science Reporting in the Real World. Aspetar Sports Med. J, 6*, 36-42.

Calbet, J. A., Lundby, C., Koskolou, M., & Boushel, R. (2006). Importance of hemoglobin concentration to exercise: acute manipulations. *Respiratory physiology & neurobiology, 151*(2-3), 132-140.

Chapman, R. F., Laymon Stickford, A. S., Lundby, C., & Levine, B. D. (2013). Timing of return from altitude training for optimal sea level performance. *Journal of applied physiology, 116*(7), 837-843.

Chapman, R. F., Stray-Gundersen, J., & Levine, B. D. (1998). Individual variation in response to altitude training. *Journal of applied physiology, 85*(4), 1448-1456.

Chung, D., Lee, J., Kim, E., Lee, C., & Lee, S. (1995). The effects of altitude training on blood cells, maximal oxygen uptake and swimming performance. *Korean J Sci, 7*, 35-46.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences 2nd edn: Erlbaum Associates, Hillsdale.

Dalland, O. (2007). *Metode og oppgaveskriving for studenter*: Gyldendal akademisk.

Dansk Svømmeunion. (2018). Retrieved from octoopen.dk

Di Prampero, P., Pendergast, D., & Zamparo, P. (2011). Swimming economy (energy cost) and efficiency. *World book of swimming: from science to performance*, 297-312.

Friedmann, B., Frese, F., Menold, E., Kauper, F., Jost, J., & Bärtsch, P. (2005). Individual variation in the erythropoietic response to altitude training in elite junior swimmers. *British journal of sports medicine, 39*(3), 148-153.

Gore, C. J., Clark, S. A., & Saunders, P. U. (2007). Nonhematological mechanisms of improved sea-level performance after hypoxic exposure. *Medicine & Science in Sports & Exercise*, *39*(9), 1600-1609.

Gore, C. J., Sharpe, K., Garvican-Lewis, L. A., Saunders, P. U., Humberstone, C. E., Robertson, E. Y., . . . Friedmann-Bette, B. (2013). Altitude training and haemoglobin mass from the optimised carbon monoxide rebreathing method determined by a meta-analysis. *Br J Sports Med, 47*(Suppl 1), i31-i39.

Gough, C. E., Saunders, P. U., Fowlie, J., Savage, B., Pyne, D. B., Anson, J. M., . . . Gore, C. J. (2012). Influence of altitude training modality on performance and total haemoglobin mass in elite swimmers. *European journal of applied physiology, 112*(9), 3275-3285.

Halperin, I. (2018). Case Studies in Exercise and Sport Sciences: A Powerful Tool to Bridge the Science-Practice Gap. *International journal of sports physiology and performance,* 1-9.

Heinicke, K., Wolfarth, B., Winchenbach, P., Biermann, B., Schmid, A., Huber, G., . . . Schmidt, W. (2001). Blood volume and hemoglobin mass in elite athletes of different disciplines. *International journal of sports medicine, 22*(07), 504-512.

Hopkins, Hawley, & Burke. (1999). Design and analysis of research on sport performance enhancement. *Medicine and science in sports and exercise, 31*(3), 472-485.

Hopkins, W. (2003). A spreadsheet for analysis of straightforward controlled trials. Sportscience 7. *Available from sportsci.org/jour/03/wghtrials.html.*

Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Medicine, 30*(1), 1-15.

Hopkins, W. G. (2015). Individual responses made easy: Am Physiological Soc.

Jacobsen, D. I. (2005). *Hvordan gjennomføre undersøkelser?: innføring i samfunnsvitenskapelig metode* (Vol. 2): Høyskoleforlaget Kristiansand.

Keith, B. (2016, 16. october). British Swimming Launches 1st of 10 Altitude Camps in Tokyo 2020 Prep. *SwimSwam*. Retrieved from https://swimswam.com/british-swimming-launches-1st-10-altitude-camps-tokyo-2020-prep/

Kiely, J. (2012). Periodization paradigms in the 21st century: evidence-led or tradition-driven? *International journal of sports physiology and performance, 7*(3), 242-250.

Kruschke, J. K. (2013). Bayesian estimation supersedes the t test. *Journal of Experimental Psychology: General*, *142*(2), 573.

Levine, B. D., & Stray-Gundersen, J. (1997). "Living high-training low": effect of moderate-altitude acclimatization with low-altitude training on performance. *Journal of applied physiology, 83*(1), 102-112.

Levine, B. D., & Stray-Gundersen, J. (2005). Point: positive effects of intermittent hypoxia (live high: train low) on exercise performance are mediated primarily by augmented red cell volume. *Journal of applied physiology, 99*(5), 2053-2055.

Lundby, C., Millet, G. P., Calbet, J. A., Bärtsch, P., & Subudhi, A. W. (2012). Does 'altitude training'increase exercise performance in elite athletes? *Br J Sports Med*, bjsports-2012-091231.

Martin, D. (1994). The challenge of using altitude to improve performance. *NSA, 9*, 51-57.

Mazzeo, R. S. (2005). Altitude, exercise and immune function. *Exerc Immunol Rev, 11*(6), 16.

Mengersen, K. L., Drovandi, C. C., Robert, C. P., Pyne, D. B., & Gore, C. J. (2016). Bayesian estimation of small effects in exercise and sports science. *PloS one, 11*(4), e0147311.

Mercade, J. J., Arellano, R., & Feriche, B. (2006). *Effects of acute moderate altitude exposure on physiological and technical performance in front crawl swimming* (Revista Portuguesa de Ciencias do Desporto ed. Vol. 6). Porto: Faculdade de Desporto da Universidade do Porto.

Millet, G. P., Roels, B., Schmitt, L., Woorons, X., & Richalet, J. (2010). Combining hypoxic methods for peak performance. *Sports Medicine, 40*(1), 1-25.

Miyashita, M., Mutoh, Y., & Yamamoto, Y. (1988). Altitude training for improving swimming performance at sea level. *Japanese Journal of Physical Fitness and Sports Medicine, 37*(2), 111-116.

Mujika, I. (2012). *Endurance training: science and practice*: Mujika.

Mujika, I., Chatard, J.-C., Busso, T., Geyssant, A., Barale, F., & Lacoste, L. (1995). Effects of training on performance in competitive swimming. *Canadian Journal of Applied Physiology, 20*(4), 395-406.

Mujika, I., Padilla, S., & Pyne, D. (2002). Swimming performance changes during the final 3 weeks of training leading to the Sydney 2000 Olympic Games. *Int J Sports Med, 23*(8), 582-587. doi:10.1055/s-2002-35526

Norges Svømmeforbund. (2018). Retrieved from medley.no

Penland, S. (2018, 01. february). Part of Spanish National Team on High Altitude Training Trip in France. *SwimSwam*.

Pyne, D. B., Trewin, C. B., & Hopkins, W. G. (2004). Progression and variability of competitive performance of Olympic swimmers. *Journal of sports sciences, 22*(7), 613-620.

Reynafarje, C., Lozano, R., & Valdivieso, J. (1959). The polycythemia of high altitudes: iron metabolism and related aspects. *Blood, 14*(4), 433-455.

Robach, P., Hansen, J., Pichon, A., Meinild Lundby, A. K., Dandanell, S., Slettaløkken Falch, G., . . . Keiser, S. (2018). Hypobaric live high-train low does not improve aerobic performance more than live low-train low in cross-country skiers. *Scandinavian journal of medicine & science in sports*.

Robach, P., & Lundby, C. (2012). Is live high–train low altitude training relevant for elite athletes with already high total hemoglobin mass? *Scandinavian journal of medicine & science in sports, 22*(3), 303-305.

Robach, P., Schmitt, L., Brugniaux, J. V., Roels, B., Millet, G., Hellard, P., . . . Moutereau, S. (2006). Living high–training low: effect on erythropoiesis and aerobic performance in highly-trained swimmers. *European journal of applied physiology, 96*(4), 423-433.

Robertson, E. Y., Aughey, R. J., Anson, J. M., Hopkins, W. G., & Pyne, D. B. (2010). Effects of simulated and real altitude exposure in elite swimmers. *The Journal of Strength & Conditioning Research, 24*(2), 487-493.

Robertson, E. Y., Saunders, P. U., Pyne, D. B., Aughey, R. J., Anson, J. M., & Gore, C. J. (2010). Reproducibility of performance changes to simulated live high/train low altitude. *Medicine & Science in Sports & Exercise, 42*(2), 394-401.

Rodríguez, F. (2002). Intermittent hypoxia: An alternative to acclimatization to high altitude and enhancement of athletic performance? *American Journal of Medicine and Sports, 4*, 385-385.

Rodríguez, F. A., Iglesias, X., Feriche, B., Calderón-Soto, C., Chaverri, D., Wachsmuth, N. B., . . . Levine, B. D. (2015). Altitude training in elite swimmers for sea level performance (Altitude project). *Med Sci Sports Exerc, 47*(9), 1965-1978.

Rodríguez, F. A., & Mader, A. (2011). Energy systems in swimming. *World Book of Swimming. From Science to Performance. New York: Nova*, 225-240.

Rodríguez, F. A., Truijens, M. J., Townsend, N. E., Stray-Gundersen, J., Gore, C. J., & Levine, B. D. (2007). Performance of runners and swimmers after four weeks of intermittent hypobaric hypoxic exposure plus sea level training. *Journal of applied physiology, 103*(5), 1523-1535.

Roels, B., Hellard, P., Schmitt, L., Robach, P., Richalet, J., & Millet, G. (2006). Is it more effective for highly trained swimmers to live and train at 1200 m than at 1850 m in terms of performance and haematological benefits? *British journal of sports medicine, 40*(2), e4-e4.

Saunders, P. U., Ahlgrim, C., Vallance, B., Green, D. J., Robertson, E. Y., Clark, S. A., . . . Gore, C. J. (2010). An attempt to quantify the placebo effect from a three-week simulated altitude training camp in elite race walkers. *International journal of sports physiology and performance, 5*(4), 521-534.

Schmidt, W., & Prommer, N. (2005). The optimised CO-rebreathing method: a new tool to determine total haemoglobin mass routinely. *European journal of applied physiology, 95*(5-6), 486-495.

Siebenmann, C., Robach, P., Jacobs, R. A., Rasmussen, P., Nordsborg, N., Diaz, V., . . . Lundby, C. (2011). "Live high–train low" using normobaric hypoxia: a double-blinded, placebo-controlled study. *Journal of applied physiology, 112*(1), 106-117.

Skorski, S., Etxebarria, N., & Thompson, K. G. (2016). Breaking the myth that relay swimming is faster than individual swimming. *International journal of sports physiology and performance, 11*(3), 410-413.

Sohlberg, P., & Sohlberg, B.-M. (2008). *Kunskapens former: vetenskapsteori och forskningsmetod*: Liber förlag, Malmö.

Solli, G. S., Tønnessen, E., & Sandbakk, Ø. (2017). The Training Characteristics of the World's Most Successful Female Cross-Country Skier. *Frontiers in physiology, 8*, 1069.

Svensk Simidrott. (2018). Retrieved from octoopen.se

Swimrankings. (2018). Retrieved from swimrankings.net

Taleb, N. N. (2012). *Antifragile: Things that gain from disorder* (Vol. 3): Random House Incorporated.

Team, R. C. (2013). R: A language and environment for statistical computing.

Tjelta, L., Enoksen, E., & Tønnessen, E. (2013). Utholdenhetstrening, Forskning og beste praksis. *Cappelen Damm AS*.

Truijens, M. J., & Rodríguez, F. A. (2010). Altitude and hypoxic training in swimming. *World book of swimming: from science to performance*.

Truijens, M. J., Rodríguez, F. A., Townsend, N. E., Stray-Gundersen, J., Gore, C. J., & Levine, B. D. (2008). The effect of intermittent hypobaric hypoxic exposure and sea level training on submaximal economy in well-trained swimmers and runners. *Journal of applied physiology, 104*(2), 328-337.

Truijens, M. J., Toussaint, H. M., Dow, J., & Levine, B. D. (2003). Effect of high-intensity hypoxic training on sea-level swimming performances. *Journal of applied physiology, 94*(2), 733-743.

Wachsmuth, N., Völzke, C., Prommer, N., Schmidt-Trucksäss, A., Frese, F., Spahl, O., . . . Schmidt, W. (2013). The effects of classic altitude training on hemoglobin mass in swimmers. *European journal of applied physiology, 113*(5), 1199-1211.

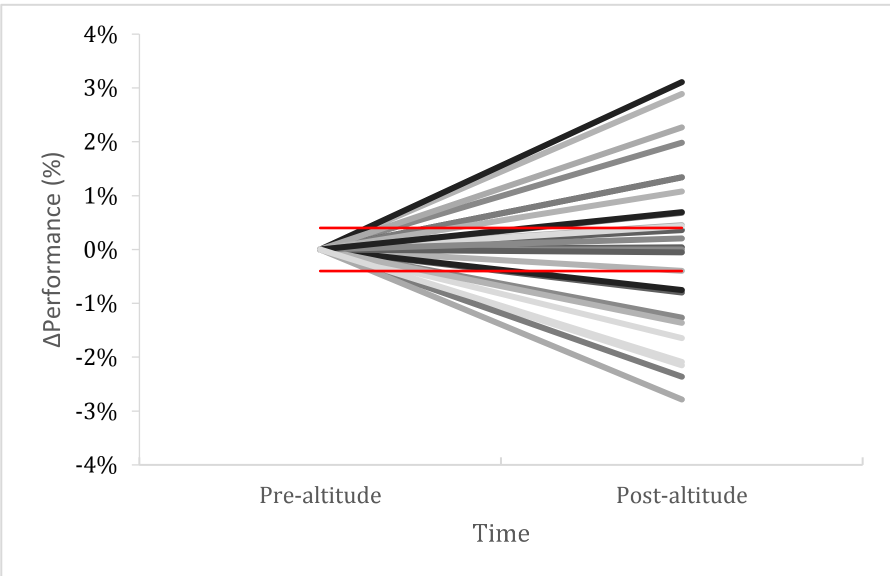
Wilber, R. L. (2004). *Altitude training and athletic performance*: Human Kinetics.

# 8 Tables and figures

## List of tables



## List of figures


4%
3%
2%
1%
0%
-1%
-2%
-3%
-4%
ΔPerformance (%)
Pre-altitude
Post-altitude
Time

# 9 Appendix

### Calculation of total hemoglobin mass (Schmidt & Prommer, 2005)

Total $Hb_{mass} = K \times MCO \times 100 \times (\Delta HbCO\% \times 1.39)^{-1}$

- $K$ = current barometric pressure × $760^{-1}$ × [1 + (0.003661 × current temperature)]
- $MCO = CO_{adm} - (CO_{system+lung\ (after\ disconnection)} + CO_{exhaled\ (after\ disconnection)})$
    - $CO_{adm}$ = CO volume administered into the system
    - $CO_{system+lung\ (after\ disconnection)}$ = CO concentration in spirometer × (spirometer volume + lung residual volume)
    - $CO_{exhaled\ (after\ disconnection)}$ = end-tidal CO concentration × alveolar ventilation × time
- ΔHbCO% = difference between basal HbCO and HbCO in the blood samples after CO administration
- 1.39 = Hüfners number (ml CO × g $Hb^{-1}$)

# MELDESKJEMA

Meldeskjema (versjon 1.6) for forsknings- og studentprosjekt som medfører meldeplikt eller konsesjonsplikt
(jf. personopplysningsloven og helseregisterloven med forskrifter).

## 1. Intro

| | | |
|---|---|---|
| Samles det inn direkte personidentifiserende opplysninger? | Ja ● Nei ○ | En person vil være direkte identifiserbar via navn, personnummer, eller andre personentydige kjennetegn.<br><br>Les mer om hva personopplysninger er.<br><br>NB! Selv om opplysningene skal anonymiseres i oppgave/rapport, må det krysses av dersom det skal innhentes/registreres personidentifiserende opplysninger i forbindelse med prosjektet.<br><br>Les mer om hva behandling av personopplysninger innebærer. |
| Hvis ja, hvilke? | ■ Navn<br>□ 11-sifret fødselsnummer<br>□ Adresse<br>□ E-post<br>□ Telefonnummer<br>□ Annet | |
| Annet, spesifiser hvilke | | |
| Skal direkte personidentifiserende opplysninger kobles til datamaterialet (koblingsnøkkel)? | Ja ○ Nei ● | Merk at meldeplikten utløses selv om du ikke får tilgang til koblingsnøkkel, slik fremgangsmåten ofte er når man benytter en databehandler. |
| Samles det inn bakgrunnsopplysninger som kan identifisere enkeltpersoner (indirekte personidentifiserende opplysninger)? | Ja ○ Nei ● | En person vil være indirekte identifiserbar dersom det er mulig å identifisere vedkommende gjennom bakgrunnsopplysninger som for eksempel bostedskommune eller arbeidsplass/skole kombinert med opplysninger som alder, kjønn, yrke, diagnose, etc.<br><br>NB! For at stemme skal regnes som personidentifiserende, må denne bli registrert i kombinasjon med andre opplysninger, slik at personer kan gjenkjennes. |
| Hvis ja, hvilke | | |
| Skal det registreres personopplysninger (direkte/indirekte/via IP-/epost adresse, etc) ved hjelp av nettbaserte spørreskjema? | Ja ○ Nei ● | Les mer om nettbaserte spørreskjema. |
| Blir det registrert personopplysninger på digitale bilde- eller videoopptak? | Ja ○ Nei ● | Bilde/videoopptak av ansikter vil regnes som personidentifiserende. |
| Søkes det vurdering fra REK om hvorvidt prosjektet er omfattet av helseforskningsloven? | Ja ○ Nei ● | NB! Dersom REK (Regional Komité for medisinsk og helsefaglig forskningsetikk) har vurdert prosjektet som helseforskning, er det ikke nødvendig å sende inn meldeskjema til personvernombudet (NB! Gjelder ikke prosjekter som skal benytte data fra pseudonyme helseregistre).<br><br>Les mer.<br><br>Dersom tilbakemelding fra REK ikke foreligger, anbefaler vi at du avventer videre utfylling til svar fra REK foreligger. |

## 2. Prosjekttittel

| | | |
|---|---|---|
| Prosjektittel | Sammenhengen mellom selvrapportert trening, hjertefrekvensdata og utvikling av test- og konkurranseresultater hos norske elitesvømmere under høydeleir | Oppgi prosjektets tittel. NB! Dette kan ikke være «Masteroppgave» eller liknende, navnet må beskrive prosjektets innhold. |

## 3. Behandlingsansvarlig institusjon

| | | |
|---|---|---|
| Institusjon | UiT Norges arktiske universitet | Velg den institusjonen du er tilknyttet. Alle nivå må oppgis. Ved studentprosjekt er det studentens tilknytning som er avgjørende. Dersom institusjonen ikke finnes på listen, har den ikke avtale med NSD som personvernombud. Vennligst ta kontakt med institusjonen.<br><br>Les mer om behandlingsansvarlig institusjon. |
| Avdeling/Fakultet | Fakultet for idrett, reiseliv og sosialfag | |
| Institutt | Idrettshøgskolen | |

## 4. Daglig ansvarlig (forsker, veileder, stipendiat)

| | | |
|---|---|---|
| Fornavn | Odd-Egil | Før opp navnet på den som har det daglige ansvaret for prosjektet. Veileder er vanligvis daglig ansvarlig ved studentprosjekt. Les mer om daglig ansvarlig.<br><br>Daglig ansvarlig og student må i utgangspunktet være tilknyttet samme institusjon. Dersom studenten har ekstern veileder, kan biveileder eller fagansvarlig ved studiestedet stå som daglig ansvarlig.<br><br>Arbeidssted må være tilknyttet behandlingsansvarlig institusjon, f.eks. underavdeling, institutt etc.<br><br>NB! Det er viktig at du oppgir en e-postadresse som brukes aktivt. Vennligst gi oss beskjed dersom den endres. |
| Etternavn | Olsen | |
| Stilling | 1. amanuensis | |
| Telefon | 78450173 | |
| Mobil | | |
| E-post | odd-egil.olsen@uit.no | |
| Alternativ e-post | odd-egil.olsen@uit.no | |
| Arbeidssted | Idrettshøgskolen | |
| Adresse (arb.) | Follumsvei 39 | |
| Postnr./sted (arb.sted) | 9510 Alta | |
| **5. Student (master, bachelor)** | | |
| Studentprosjekt | Ja ● Nei ○ | Dersom det er flere studenter som samarbeider om et prosjekt, skal det velges en kontaktperson som føres opp her. Øvrige studenter kan føres opp under pkt 10. |
| Fornavn | Andreas | |
| Etternavn | Winther | |
| Telefon | 93614466 | |
| Mobil | | |
| E-post | awi027@post.uit.no | |
| Alternativ e-post | awi027@post.uit.no | |
| Privatadresse | Evjenvegen 47 | |
| Postnr./sted (privatadr.) | 9024 Tomasjord | |
| Type oppgave | ● Masteroppgave<br>○ Bacheloroppgave<br>○ Semesteroppgave<br>○ Annet | |
| **6. Formålet med prosjektet** | | |
| Formål | Formålet med studien er å undersøke i hvilken grad det er sammenheng mellom registrert hjertefrekvens under trening og utøvernes selvrapporterte trening. Videre vil vi undersøke i hvilken grad treningstid i ulike intensitetssoner under høydetrening har betydning for utvikling av testresultater underveis på høydesamling. Til sist vil vi se på sammenhengen mellom utvikling i testresultater og prestasjonsutviklingen i konkurranser. Vi vil benytte data fra norske landslagsutøvere i svømming i perioden 2006 til 2016. | Redegjør kort for prosjektets formål, problemstilling, forskningsspørsmål e.l. |
| **7. Hvilke personer skal det innhentes personopplysninger om (utvalg)?** | | |
| Kryss av for utvalg | □ Barnehagebarn<br>□ Skoleelever<br>□ Pasienter<br>□ Brukere/klienter/kunder<br>□ Ansatte<br>□ Barnevernsbarn<br>□ Lærere<br>□ Helsepersonell<br>□ Asylsøkere<br>■ Andre | Les mer om forskjellige forskningstematikker og utvalg. |
| Beskriv utvalg/deltakere | Landslagsutøvere i svømming av begge kjønn I perioden 2006-2016. | Med utvalg menes dem som deltar i undersøkelsen eller dem det innhentes opplysninger om. |
| Rekruttering/trekking | Alle utøvere som har vært på landslag i disse årene vil bli forespurt. | Beskriv hvordan utvalget trekkes eller rekrutteres og oppgi hvem som foretar den. Et utvalg kan rekrutteres gjennom f.eks. en bedrift, skole, idrettsmiljø eller eget nettverk, eller trekkes fra registre som f.eks. Folkeregisteret, SSB-registre, pasientregistre. |

| | | |
|---|---|---|
| Førstegangskontakt | Førstegangskontakt opprettes gjennom landslagstrener Petter Løvberg. | Beskriv hvordan førsstegangskontakten opprettes og oppgi hvem som foretar den.<br><br>Les mer om førstegagskontakt og forskjellige utvalg på våre temasider. |
| Alder på utvalget | □ Barn (0-15 år)<br>□ Ungdom (16-17 år)<br>■ Voksne (over 18 år) | Les om forskning som involverer barn på våre nettsider. |
| Omtrentlig antall personer som inngår i utvalget | 15 | |
| Samles det inn sensitive personopplysninger? | Ja ○ Nei ● | Les mer om sensitive opplysninger. |
| Hvis ja, hvilke? | □ Rasemessig eller etnisk bakgrunn, eller politisk, filosofisk eller religiøs oppfatning<br>□ At en person har vært mistenkt, siktet, tiltalt eller dømt for en straffbar handling<br>□ Helseforhold<br>□ Seksuelle forhold<br>□ Medlemskap i fagforeninger | |
| Inkluderes det myndige personer med redusert eller manglende samtykkekompetanse? | Ja ○ Nei ● | Les mer om pasienter, brukere og personer med redusert eller manglende samtykkekompetanse. |
| Samles det inn personopplysninger om personer som selv ikke deltar (tredjepersoner)? | Ja ○ Nei ● | Med opplysninger om tredjeperson menes opplysninger som kan identifisere personer (direkte eller indirekte) som ikke inngår i utvalget. Eksempler på tredjeperson er kollega, elev, klient, familiemedlem, som identifiseres i datamaterialet. Les mer. |
| **8. Metode for innsamling av personopplysninger** | | |
| Kryss av for hvilke datainnsamlingsmetoder og datakilder som vil benyttes | □ Papirbasert spørreskjema<br>□ Elektronisk spørreskjema<br>□ Personlig intervju<br>□ Gruppeintervju<br>□ Observasjon<br>□ Deltakende observasjon<br>□ Blogg/sosiale medier/internett<br>□ Psykologiske/pedagogiske tester<br>□ Medisinske undersøkelser/tester<br>□ Journaldata (medisinske journaler) | Personopplysninger kan innhentes direkte fra den registrerte f.eks. gjennom spørreskjema,intervju, tester, og/eller ulike journaler (f.eks. elevmapper, NAV, PPT, sykehus) og/eller registre (f.eks.Statistisk sentralbyrå, sentrale helseregistre).<br><br>NB! Dersom personopplysninger innhentes fra forskjellige personer (utvalg) og med forskjellige metoder, må dette spesifiseres i kommentar-boksen. Husk også å legge ved relevante vedlegg til alle utvalgs-gruppene og metodene som skal benyttes.<br><br>Les mer om registerstudier. Dersom du skal anvende registerdata, må variabelliste lastes opp under pkt. 15<br><br>Les mer om forskningsmetoder. |
| | □ Registerdata | |
| | ■ Annen innsamlingsmetode | |
| Oppgi hvilken | Treningsdagbok fra Olympiatoppen, gjennomførte tester, målinger av hjertefrekvens, konkurranseresultater | |
| Tilleggsopplysninger | | |
| **9. Informasjon og samtykke** | | |
| Oppgi hvordan utvalget/deltakerne informeres | □ Skriftlig<br>■ Muntlig<br>□ Informeres ikke | Dersom utvalget ikke skal informeres om behandlingen av personopplysninger må det begrunnes.<br><br>Les mer.Vennligst send inn mal for skriftlig eller muntlig informasjon til deltakerne sammen med meldeskjema.<br><br>Last ned en veiledende mal her.<br><br>Les om krav til informasjon og samtykke.<br><br>NB! Vedlegg lastes opp til sist i meldeskjemaet, se punkt 15 Vedlegg. |
| Samtykker utvalget til deltakelse? | ● Ja<br>○ Nei<br>○ Flere utvalg, ikke samtykke fra alle | For at et samtykke til deltakelse i forskning skal være gyldig, må det være frivillig, uttrykkelig og informert.<br><br>Samtykke kan gis skriftlig, muntlig eller gjennom en aktiv handling. For eksempel vil et besvart spørreskjema være å regne som et aktivt samtykke.<br><br>Dersom det ikke skal innhentes samtykke, må det begrunnes. Les mer. |
| **10. Informasjonssikkerhet** | | |

| | | |
|---|---|---|
| Spesifiser | Ei navneliste med et forsøkspersonnummer oppbevares for seg selv. | NB! Som hovedregel bør ikke direkte personidentifiserende opplysninger registreres sammen med det øvrige datamaterialet. Vi anbefaler koblingsnøkkel. |
| Hvordan registreres og oppbevares personopplysningene? | □ På server i virksomhetens nettverk<br>■ Fysisk isolert PC tilhørende virksomheten (dvs. ingen tilknytning til andre datamaskiner eller nettverk, interne eller eksterne)<br>□ Datamaskin i nettverkssystem tilknyttet Internett tilhørende virksomheten<br>■ Privat datamaskin<br>□ Videoopptak/fotografi<br>□ Lydopptak<br>□ Notater/papir<br>□ Mobile lagringsenheter (bærbar datamaskin, minnepenn, minnekort, cd, ekstern harddisk, mobiltelefon)<br>□ Annen registreringsmetode | Merk av for hvilke hjelpemidler som benyttes for registrering og analyse av opplysninger.<br><br>Sett flere kryss dersom opplysningene registreres på flere måter.<br><br>Med «virksomhet» menes her behandlingsansvarlig institusjon.<br><br>NB! Som hovedregel bør data som inneholder personopplysninger lagres på behandlingsansvarlig sin forskningsserver.<br><br>Lagring på andre medier - som privat pc, mobiltelefon, minnepinne, server på annet arbeidssted - er mindre sikkert, og må derfor begrunnes. Slik lagring må avklares med behandlingsansvarlig institusjon, og personopplysningene bør krypteres. |
| Annen registreringsmetode beskriv | | |
| Hvordan er datamaterialet beskyttet mot at uvedkommende får innsyn? | Datamaskin har password og brukernavn | Er f.eks. datamaskintilgangen beskyttet med brukernavn og passord, står datamaskinen i et låsbart rom, og hvordan sikres bærbare enheter, utskrifter og opptak? |
| Samles opplysningene inn/behandles av en databehandler (ekstern aktør)? | Ja ○ Nei ● | Dersom det benyttes eksterne til helt eller delvis å behandle personopplysninger, f.eks. Questback, transkriberingsassistent eller tolk, er dette å betrakte som en databehandler. Slike oppdrag må kontraktsreguleres. |
| Hvis ja, hvilken | | |
| Overføres personopplysninger ved hjelp av e-post/Internett? | Ja ○ Nei ● | F.eks. ved overføring av data til samarbeidspartner, databehandler mm.<br><br>Dersom personopplysninger skal sendes via internett, bør de krypteres tilstrekkelig.<br><br>Vi anbefaler ikke lagring av personopplysninger på nettskytjenester. Bruk av nettskytjenester må avklares med behandlingsansvarlig institusjon.<br><br>Dersom nettskytjeneste benyttes, skal det inngås skriftlig databehandleravtale med leverandøren av tjenesten. Les mer. |
| Hvis ja, beskriv? | | |
| Skal andre personer enn daglig ansvarlig/student ha tilgang til datamaterialet med personopplysninger? | Ja ● Nei ○ | |
| Hvis ja, hvem (oppgi navn og arbeidssted)? | Landslagssjefen vet hvem utøverne er | |
| Utleveres/deles personopplysninger med andre institusjoner eller land? | ● Nei<br>○ Andre institusjoner<br>○ Institusjoner i andre land | F.eks. ved nasjonale samarbeidsprosjekter der personopplysninger utveksles eller ved internasjonale samarbeidsprosjekter der personopplysninger utveksles. |

## 11. Vurdering/godkjenning fra andre instanser

| | | |
|---|---|---|
| Søkes det om dispensasjon fra taushetsplikten for å få tilgang til data? | Ja ○ Nei ● | For å få tilgang til taushetsbelagte opplysninger fra f.eks. NAV, PPT, sykehus, må det søkes om dispensasjon fra taushetsplikten. Dispensasjon søkes vanligvis fra aktuelt departement. |
| Hvis ja, hvilke | | |
| Søkes det godkjenning fra andre instanser? | Ja ○ Nei ● | I noen forskningsprosjekter kan det være nødvendig å søke flere tillatelser. Søkes det f.eks. om tilgang til data fra en registereier? Søkes det om tillatelse til forskning i en virksomhet eller en skole? Les mer om andre godkjenninger. |
| Hvis ja, hvilken | | |

## 12. Periode for behandling av personopplysninger

| | | |
|---|---|---|
| Prosjektstart<br><br>Planlagt dato for prosjektslutt | 01.06.2017<br><br>30.06.2018 | Prosjektstart Vennligst oppgi tidspunktet for når kontakt med utvalget skal gjøres/datainnsamlingen starter.<br><br>Prosjektslutt: Vennligst oppgi tidspunktet for når datamaterialet enten skalanonymiseres/slettes, eller arkiveres i påvente av oppfølgingsstudier eller annet. |
| Skal personopplysninger publiseres (direkte eller indirekte)? | □ Ja, direkte (navn e.l.)<br>■ Ja, indirekte (identifiserende bakgrunnsopplysninger)<br>□ Nei, publiseres anonymt | Les mer om direkte og indirekte personidentifiserende opplysninger.<br><br>NB! Dersom personopplysninger skal publiseres, må det vanligvis innhentes eksplisitt samtykke til dette fra den enkelte, og deltakere bør gis anledning til å lese gjennom og godkjenne sitater. |

| | | |
|---|---|---|
| Hva skal skje med datamaterialet ved prosjektslutt? | ■ Datamaterialet anonymiseres<br>□ Datamaterialet oppbevares med personidentifikasjon | NB! Her menes datamaterialet, ikke publikasjon. Selv om data publiseres med personidentifikasjon skal som regel øvrig data anonymiseres.Med anonymisering menes at datamaterialet bearbeides slik at det ikke lenger er mulig å føre opplysningene tilbake til enkeltpersoner.<br><br>Les mer om anonymisering av data. |
| **13. Finansiering** | | |
| Hvordan finansieres prosjektet? | Støtte fra Norges Olympiske Komite | Fylles ut ved eventuell ekstern finansiering (oppdragsforskning, annet). |
| **14. Tilleggsopplysninger** | | |
| Tilleggsopplysninger | | Dersom prosjektet er del av et prosjekt (eller skal ha data fra et prosjekt) som allerede har tilrådning fra personvernombudet og/eller konsesjon fra Datatilsynet, beskriv dette her og oppgi navn på prosjektleder, prosjekttittel og/eller prosjektnummer. |
| **15. Vedlegg** | | |
| Vedlegg | Antall vedlegg: 1.<br><br>● veiledende_mal_for_informasjonsskriv.doc | |

Odd-Egil Olsen
Idrettshøgskolen UiT Norges arktiske universitet
Follumsvei 31
9510 ALTA

| | | | |
|---|---|---|---|
| Vår dato: 30.06.2017 | Vår ref: 54533 / 3 / BGH | Deres dato: | Deres ref: |

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 26.05.2017. Meldingen gjelder prosjektet:

| | |
|---|---|
| *54533* | *Sammenhengen mellom selvrapportert trening, hjertefrekvensdata og utvikling av test- og konkurranseresultater hos norske elitesvømmere under høydeleir* |
| *Behandlingsansvarlig* | *UiT Norges arktiske universitet, ved institusjonens øverste leder* |
| *Daglig ansvarlig* | *Odd-Egil Olsen* |
| *Student* | *Andreas Winther* |

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

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

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

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

Personvernombudet vil ved prosjektets avslutning, 30.06.2018, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Katrine Utaaker Segadal

Belinda Gloppen Helle

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

Kontaktperson: Belinda Gloppen Helle tlf: 55 58 28 74
Vedlegg: Prosjektvurdering
Kopi: Andreas Winther awi027@post.uit.no

# Personvernombudet for forskning

## Prosjektvurdering - Kommentar

Prosjektnr: 54533

SAMARBEIDSSTUDIE
Personvernombudet forstår det slik at prosjektet er et samarbeid mellom UiT Norges arktiske universitet, Universitetet i Tromsø og Olympiatoppen. UiT Norges arktiske universitet er behandlingsansvarlig institusjon. Ombudet forutsetter at ansvarsforhold, sikring og evt. eierskap av data er avklart mellom de institusjonene, og anbefaler at forholdet formaliseres.

FORMÅL
Formålet med studien er å undersøke i hvilken grad det er sammenheng mellom registrert hjertefrekvens under trening og utøvernes selvrapporterte trening. Videre vil vi undersøke i hvilken grad treningstid i ulike intensitetssoner under høydetrening har betydning for utvikling av testresultater underveis på høydesamling. Til sist vil vi se på sammenhengen mellom utvikling i testresultater og prestasjonsutviklingen i konkurranser. Vi vil benytte data fra norske landslagsutøvere i svømming i perioden 2006 til 2016.

INFORMASJON OG SAMTYKKE
Utvalget informeres skriftlig og muntlig om prosjektet og samtykker til deltakelse. Informasjonsskrivet er godt utformet.

UTVALG OG DATAINNSAMLING
Utvalget er landslagsutøvere i svømming i perioden 2006-2016. Utvalget består av begge kjønn. Datamaterialet består av opplysninger fra Olympiatoppens dagbok, opplysninger fra treningsøkter som utøverne har gjennomført med pulsklokke. I tillegg skal det samles inn opplysninger fra tester under høydeopphold og utøvernes prestasjon i konkurranser. Personvernombudet forutsetter at det ikke samles inn flere opplysninger om utøverne enn dem de har samtykket til å dele med studenten.

SENSITIVE PERSONOPPLYSNINGER
Personvernombudet vurderer at det kan fremkommer sensitive personopplysninger om helseforhold.

INFORMASJONSSIKKERHET
Personvernombudet legger til grunn at forsker etterfølger UiT Norges arktiske universitet sine interne rutiner for datasikkerhet. Dersom personopplysninger skal lagres på privat pc, bør opplysningene krypteres tilstrekkelig.

PUBLISERING
I meldeskjemaet har dere krysset av for at dere skal publisere indirekte personopplysninger i oppgaven. Dersom personopplysninger skal publiseres, må det innhentes et eksplisitt samtykke til dette. Vi kan imidlertid ikke finne informasjon om dette i informasjonsskrivet. Personvernombudet legger derfor til grunn at dette er feil, og har endret dette punktet til at dere skal publisere anonymt og at ingen informanter vil kunne gjenkjennes i publikasjonen.

PROSJEKTSLUTT OG ANONYMISERING

Forventet prosjektslutt er 30.06.2018. Ifølge prosjektmeldingen skal innsamlede opplysninger da anonymiseres. Anonymisering innebærer å bearbeide datamaterialet slik at ingen enkeltpersoner kan gjenkjennes. Det gjøres ved å:

- slette direkte personopplysninger (som navn/koblingsnøkkel)
- slette/omskrive indirekte personopplysninger (identifiserende sammenstilling av bakgrunnsopplysninger som f.eks. bosted/arbeidssted, alder og kjønn)