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Continuous sport competitions lasting three to seven days

A comparative study between the biking race OffroadFinmark and the dogsled races Finnmarksløpet

Andi Weydahl og Giovanna Calogiuri

HØGSKOLEN I FINNMARK

Høgskolen i Finnmark

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"Heart rates were monitored male mushers during a continuous dogsled races five in a 1000km race, and five in a 500km race as well as in six male off road bikers in 700km continuous off road race using Polar ® HR recording systems, RS 400 (dog sled) and Polar Team2 (off road bikers). Activity levels where recorded using Actiwatch AW4, three days before and three days after the races, to evaluate and analyse rest-activity circadian rhythm and sleep qualtity.

Examples of individual heart rate profiles during different phases of each race are shown, as well as the amount of time used on legs and checkpoints.

Comparisons between activity, circadian rhythm parameters and sleep parameters before and after the race and between the three races are shown both as bar graphs and as numbers in tables, with statistical analyses."

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CONTINUOUS SPORT COMPETITIONS LASTING THREE TO SEVEN DAYS

A comparative study between the biking race OffroadFinnmark and the dogsled races Finnmarksløpet.

Heart rates during the competitions and sleep and rest-activity circadian rhythm after the competitions.

Andi Weydahl, Giovanna Calogiuri
Finnmark University College, Alta, Norway

FORORD

Denne rapporten gir i tillegg til resultatene fra analysene og våre konklusjoner en utførlig beskrivelse av hvordan vi behandlet rådata for å kunne gjennomføre analysene. Vi mener det er viktig å publisere det, inkludert filnavn for de lagrede data, slik at det skal være mulig for interesserte å kunne kontrollere våre vurderinger og eventuelt bruke en annen tilnærming for å undersøke problemstillingen.

Rapporten er satt opp på en litt uvanlig måte, der vi først gir informasjon om de tre konkurransene og en introduksjon om hvile-aktivitets døgnrytmer (rest-activity circadian rhythm) og søvn. Vi gir en oversikt over datainnsamling og behandling, men vi tar en mer utdypende beskrivelse av databearbeiding og analyser sammen med resultatene for hver del: Heart rate analysis, Activity analysis, Non Parametric Circadian Rhythm Analysis (NPRCA), Sleep Analysis. Til slutt gir vi en generell konklusjon.

Vi takker utøverne for godt samarbeid, stor innsats og nøyaktighet i alle pålagte oppgaver. Uten dem hadde det ikke blitt noen rapport.

Vi håper rapporten kan gi deltakerne noen tips til fremtidige konkurranser ved opplegg av strategi og taktikk. Vi håper også at kunnskapen og erfaringen vi har fått, vil motivere til videre arbeid med hensyn til arbeid, søvn og hvile og så i hverdagen for yrkesutøvere med stressende og langvarige arbeidsøkter.

Alta 12.januar 2011

Andi Weydahl Giovanna Galogiuri

PREFACE

In addition to the results from the analyses and our conclusions, this report gives an extended overview of how we treated the raw data to be able to run the analyses. We think it is important to publish this, including the file names, so that it will be possible for others to control our conclusions, and to look at the data from different perspectives.

The report is set up in a little unusual way: First we give some short information about each of the three involved competitions and an introduction about rest-activity circadian rhythm and sleep. Then we give an overview of the material and methods, but the extensive explanation about the method and results are treated in separate chapters: 1. Heart rate analysis 2. Activity analysis 3.Non Parametric Circadian Rhythm Analysis (NPRCA), 4. Sleep Analysis. At the end there is a chapter called 5. General Conclusions.

We thank the athletes for good cooperation, great effort and accuracy in all the tasks. Without this commitment there would have been no data and no project.

We hope this report will give athletes as well as readers, some advice for tactics, strategies and planning for future competitions and training. We also hope this knowledge and experience will motivate to further work in the field of activity, sleep and rest for everyday life for workers in stressful and unknown duration of workloads i.e. relief workers.

Alta January 12th 2011

Andi Weydahl Giovanna Galogiuri

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INTRODUCTION

Finnmarksløpet[1] is the world's northernmost and Europe's longest sled-dog race covering 1044km using up to fourteen dogs. It starts at 70 degrees north, (Alta, Norway) in March every year. Throughout the race the participants have to check into several checkpoints every 4 to 10 hours. During the race there are two compulsory stops and a minimum resting time. The race takes between five and ten days to complete and has twelve checkpoints. There is also a shorter trail, 500km, taking about three days to complete with six checkpoints and using up to eight dogs. The races go through varied terrain, over hills and steep downward slopes, over lakes and rivers. The snow condition might vary from icy to sugar-like snow. The musher is often very active by kicking with one leg or running beside the sled. In that way the musher helps the dogs moving the sled. The trail is marked with sticks, but the musher might have to navigate due to the weather conditions. In the 2006 and 2007 Finnmark dog sled race, we studied male mushers' physical fitness (direct measured VO_{2max}) and their workload based on heart rate recordings during the race (Weydahl, 2007). This descriptive study showed that Finnmarksløpet is a very demanding competition. The participants are physically active most of the time, with few and fragmented rests.

Offroad**Finnmark** is a team mountain bike race, with two or three bikers in the team. As the dog sled race it starts in Alta, Norway. It takes place during the daylight period of the Finnmark summer, with 24 hours daylight a day. The race lasts between three and four days and has thirteen checkpoints 60-99 km apart. During the race there are three compulsory stops, each at a minimum of 3hrs. The race course is largely on cart roads and single-track mountain paths across Finnmark's mountain plateau. The topography is challenging and the average pace is approximately 12 km/h. The bikers need to cross hundreds of brooks, creeks and a few large rivers. They have to get across wild, pathless terrain, where technical challenges are frequent and the bikes often need to be carried. During the test race in 2008, we found that the mean heart rate (HR) during the race varied between 53-74% of the bikers peak heart rate obtained during VO_{2max} testing (HR_{peak}). The HR was highest on the first leg with a tendency to fall throughout the race.

Finnmarksløpet and Offroad**Finnmark** show continuous physical effort which induce a state of prolonged fatigue, and it is expected that non-photic synchronizers, like sleep habits, would be modified. This expectation makes these two events interesting situations for investigating the effects of prolonged fatigue and sleep loss. Since the circadian system is strongly linked to a properly function of the organism. Circadian disorders can affect the state of health on several levels, both physiological and neuro-behavioural (Sack et al., 2007).

The purpose of this project was to study the intensity of the competitions and the effects of the strenuous, long lasting physical activity and prolonged sleep deprivation upon the rest-activity rhythm and sleep quality in male athletes after they have participated in continuous sport competitions lasting three to seven days.

Like most physiological functions, rest-activity rhythms and sleep-wake cycles show a rhythmical periodicity in the 24-hour cycle, and they are also strongly related to *circadian structure* (Halberg, Carandente, Cornelissen, & Katinas, 1977). Circadian rhythms are *endogenous*, intrinsic to the organism, with the supra-chiasmatic nucleus (SCN) superintending as the main inner modulator of physiologic periodicity (Boivin, Duffy, Kronauer, & Czeisler,

[1] Finnmark is the northern county in Norway.

1994; Buijs, van Eden, Goncharuk, & Kalsbeek, 2003; Dijk & Lockley, 2002). In humans, the period of intrinsic rhythm is slightly longer than an exact period of 24 hours (Dijk & Lockley, 2002), so environmental time signals called *synchronizers* determine a precise synchronization with the 24-hour day (*entrainment*). Sunlight exposure has been shown to be fundamental for entrainment (Buijs, et al., 2003; Delaunay, Thisse, Marchand, Laudet, & Thisse, 2000; Hsu et al., 1996; Jin et al., 1999; Lee, Loros, & Dunlap, 2000; Plautz, Kaneko, Hall, & Kay, 1997; van der Horst et al.; Whitmore, 2001), but several non-photic synchronizers, like social factors and sleep-wake routines, contribute to modulating the circadian system. However, their power compared to the solar light/darkness cycle remains to be defined (Sack, et al., 2007). For example, Burgess and Eastman have shown that manipulations of sleep duration can produce phase shift (Burgess & Eastman, 2006) as well as fatigue, and night work shifts are causes of disturbances in entrainment (Sack, et al., 2007). Physical activity is also a factor that can influence circadian rhythms, such as inducing phase shift (Atkinson, Edwards, Reilly, & Waterhouse, 2007; Barger, Wright, Hughes, & Czeisler, 2004; Buxton, Lee, L'Hermite-Baleriaux, Turek, & Van Cauter, 2003; Carandente F, 2006; Halberg et al.; Miyazaki, Hashimoto, Masubuchi, Honma, & Honma, 2001; Montaruli, 2005; Reebs, Lavery, & Mrosovsky, 1989; Reebs & Mrosovsky, 1989a, 1989b; Van Reeth et al., 1994). The effects of physical activity on entrainment depend on the intensity and length of exercise, and on the time of the day the physical activity is carried out (Carandente F, 2006; Montaruli, 2005).

Sleep loss is known to induce deleterious effects on the state of health of the individuals (Gay, Lee, & Lee, 2004; Knutsson, 2003; Santhi, Horowitz, Duffy, & Czeisler, 2007; Totterdell, Reynolds, Parkinson, & Briner, 1994). The circadian system generates a time-dependent alert process during the waking period. Consequently, attempting sleep at the “wrong circadian phase” undermines sleep quality and shortens its duration (Edgar, Dement, & Fuller, 1993). Sarthe et al. found that visual selective attention decreases considerably after staying awake for 24-hour periods, thus increasing the risk of occupational errors, accidents and injuries in shift workers (Santhi, et al., 2007). Van Dongen et al. found that chronic reduction of sleep to 6 hours or less per night, over a period of at least one week, produced cognitive performance deficits equivalent up to 2 nights of total sleep deprivation (Van Dongen, Maislin, Mullington, & Dinges, 2003). Because of its modulating effects on the circadian system, physical activity might influence sleep patterns. However, few data are available concerning how the exercise-induced modifications of the circadian structure influence the nocturnal sleep (Calogiuri et al., 2009; Mischler et al., 2003).

Elmenhorst et al (Elmenhorst et al., 2008) looked at partial sleep deprivation and the impact on the architecture and quality of sleep. If time in bed was reduced from 8 to 5 hrs per night during four consecutive nights, the EEG showed a reduction in the S1 and S2 (amount of slow wave sleep stage 1 and 2) and increase in S3, S4 and REM sleep. Subjective sleep quality improved.

The objects of this work was to see: How is the intensity during the three continuous races 500km dogsled, 1000km dogsled and 700km off-road biking, expressed from the heart rates? What happen to the participants’ rest-activity rhythm and sleep quality after the race?

MATERIAL AND METHODS

Subjects

Ten male mushers in the dogsled race Finnmarksløpet 2009, five in the 500km race and five in the 1000km race, and six male bikers in the 700km off road biking race Offroad**Finnmark** 2010, volunteered to participate in the study. Prior to participating in the study they all signed a written consent and had an interview with the researchers, in order to evaluate their past and present state of health and the presence of pre-existent sleep disorders, which would have caused exclusion from the study. All of the requited subjects were healthy and none of the requited subjects were excluded.

Data Gathering

About a week before the competition all participants performed an incremental maximal cardio-pulmonary test, during which respiratory gasses were analyzed by automatic metabolimeter (Vmax 29, Sensormedics ®) to find their maximum oxygen uptake (VO_{2max}). Heart rates (HR) were measured by HR-monitor, epoch length set to 5 sec (Polar RS400, Polar Electro®) to determine their peak HR during the test (HR_{peak}).

The participants did two continuous monitoring sessions of activity levels for three consecutive days, wearing an actigraph (Actiwatch AW4, Cambridge Neurotechnology) on the non-dominant wrist. One monitoring was done before the race (PRE) and the second monitoring after the race (POST). In the periods when the subjects wore the actigraph, they kept a record (sleep log), reporting bed- and wake-up times, nap times and other information concerning the monitoring (e.g. taking the monitor off). The participants did not wear an actigraph during the race, therefore actigraphy data related to the race are not considered. After the competition, all of the subjects had a week off from work, so they were free to choose their own activity, and to sleep on a "free schedule".

The actigraph is a small device, at the size of a watch. It uses an accelerometer, which produces voltage when the device is moved. In the sensor, the degree and force of any movement are processed in activity counts, which are then recorded every 30 seconds. Recordings from acticraphs have been shown to be very good for identifying circadian rhythms and recording sleep disturbances (Ancoli-Israel et al., 2003; Littner et al., 2003).

To be able to evaluate the degree of physical strain, the mushers and bikers wore a heart rate recording system consisting of a chest band including a recorder, that monitored every heart beat (Polar Team2 (bikers), or RS 400 (mushers) Polar Electro, Kempele ®) during the competitions.

Data Processing

<u>HR data processing</u> - The HR data collected during the races were transferred to Microsoft Excel files, creating temporal series that was compared with the competitors' personal race report from the official race logs (http://www.Finnmarksløpet.no/ and http://www.offroadfinnmark.no/). This procedure allowed us to study the HR values collected during the legs and those collected in the check-points separately. In order to estimate the competitors' workload from start to finish, while on the legs and at the check-points, we converted the HR absolute values into percentages of the single subject's HR_{peak}.

<u>Actigraphy data processing</u> - The data collected by the actigraphs were uploaded to a PC and analyzed by the program *Actiwatch Activity and Sleep Analysis* (Cambridge Neurotechnology),

which makes it possible to study the activity data from several points of view. The actigraph collects the data in a length of time which is pre-set through a PC. Sleep log and diary are fundamental tools when processing the actigraphy data. At first, *actogram* (graphs reporting the activity levels recorded during the monitoring) were macroscopically studied and compared with the diary data, in order to verify the absence of anomalies and the success of the monitoring. Then, on the basis of the sleep log data, bed-time and wake-up-time were determined for further analysis.

<u>Non-Parametric Circadian Rhythm Analysis</u> In order to evaluate the rest-activity circadian rhythm, the data were analyzed using the Non-Parametric Circadian Rhythm Analysis (NPCRA) function. This analysis process is founded on the assumption that the rest-activity rhythm does not fit in a cosine-like wave shape (van Someren et al., 1996; Van Someren, Lijzenga, Mirmiran, & Swaab, 1997). NPCRA elaborates the data collected by continuous monitoring, and returns parameters which describe a situation of stability or instability that develops during the length of the monitoring. We used values for a typical healthy adult population (van Someren, et al., 1996; Van Someren, et al., 1997) when discussing the NPCRA results and comparing the PRE and POST profiles.

<u>Activity Analysis</u> - Basic activity analysis (*Actogram* function), which provides a day-by-day "overview" with several parameters describing the distribution of the activity values in the 24-hour cycle. Default L/D Ratio periodicity (06:00-18:00) were used.

<u>Sleep Analysis</u> - In order to study the subject's sleep quality, the *Sleep Analysis* function in the *Actiwatch Activity and Sleep Analysis* software were used. This elaborates the activity data relative to single nights, providing parameters which describe the characteristics of nocturnal sleep. Sleep logs data were used to determine the bedtime and the wake up time.

Activity and Sleep analysis provide parameter values for day-by-day and a night-by-night. Therefore we got three values for each activity- and sleep-parameter for the PRE-monitoring and POST-monitoring (Activity Analysis: day1, day2, day3; Sleep Analysis: night1, night2, night3).

A description of all the parameters that were studied and discussed is summarized in table 1.

Statistical analysis
A 2-way ANOVA were used to test for overall interaction between PRE-POST and the three categories for each variable. If significance was reached, Student t-test on paired samples was used for post hoc analysis. Before t-test was applied, variables were tested for homogeneity of variances with Bartletts's F-test. Level of significance was set to $p<0.05$. Significance is most likely affected by the small sample size in this study, therefore comparisons with a marginal significance ($p \leq {}^{4}/_{5}$ 0.10) will also be shown and discussed.

Ethical considerations
This study was approved by the regional Committee for Medical and Health Ethics, Northern Norway project 5.2008.1056 and 5.2006.3353 and carried out in accordance with the Declaration of Helsinki.

1. HEARTH RATE ANALYSIS

Data processing

The data for the single subjects have been grouped in an xls file (e.g "legs+CP-OF2010.xls"), where the HR data have been organized for legs and check points. Also, xls files containing data referring to only legs and only check-point have been created (e.g "Legs-OF2010.xls" and "CP-OF2010.xls" respectively). In these files the bikers' HR values have been averaged per legs and check-points. The absolute HR values have been converted in % of the single subjects HRpeak during the test.

In the above reported files, the average time for each leg/check-point and the average HR (in terms of % of the HRpeak) have been calculated and summarized in graphs. The HR SDs have been considered as "HR range", which should describe the degree of intermittence of the physical effort during the legs (HR range in legs) and how much active the competitors were in the check-points (HR range in check-points)

In another xls file ("HR_OF2010 vs. FL2009.xls") comparisons with the race-timing and the HR values from the Finnmarksløpet 2009 (500km ad 1000km) have been made.

To obtain the graphs reported at the end (examples of HR profile; "HRexamples_RACE.xls") for the bikers, the original HR data (with epoch length 5sec.) have been averaged for an epoch length of 1min., in order to have a lower amount of data and to have the same epoch length we had for the mushers.

Calculated resting time

It cannot be assumed that the total time spent in the check-points is pure resting/sleeping time. The resting (we cannot be sure they actually slept, within this period) time was calculated as follow:

OffroadFinnmark: total time in the check-point longer than 1-h (Kaut., Sous., Karas. and Skogan.) MINUS average time of all the check-point wherein they stayed for less than 1-h (supposing it was not a time long enough for sleeping and the minimum time to register and getting ready for the next leg)

Finnmarksløpet-500km: total time in the check-point longer than 3-h (Skog., Levajok, Karas. and Jergul),MINUS 3-h for each of these check-points (assuming that the mushers need about 3-h in a check-point for taking care of the dogs and themselves and getting ready for the next leg).

Finnmarksløpet-1000km: total time in the check-point longer than 3-h (Skog., Levajok, Tana, Kirk., Varang. and Karasjok), MINUS 3-h for each of these check-points (assuming that the mushers need about 3-h in a check-point for taking care of the dogs and themselves and getting ready for the next leg). Karas. and Neiden (compulsory 16-h and 8-h respectively), were singularly studied through the HR profile.

Statistic analysis

Statistics was made by 2-tailed t-tests comparing the different competitions with each other (bikers vs. 500km-mushers; bikers vs. 1000km-mushers; 500-km mushers vs. 1000km-mushers) in order to study possible differences of average HR profile and race-timing. Before t-test was applied, the data were tested for homogeneity by f-test: if f-test was significant, the t-test was set as a comparison between two non-homogeneous groups.

Results

Table 1 - Heart Rate (HR) values*

Mushers participating at the Finnmarksløpet in 2009 (500km and 1000km) and bikers participating at the Offroad-Finnmark in 2010.

	OF2010-700km	FL2009-500km	FL2009-1000km
HR mean values during legs **t-test** OF-700 vs. FL-500: n.s OF-700 vs. FL-1000: *0,039* FL-1000 vs. FL-500: *0,008*	62,42 ±10,34	60,36 ±5,47	50,78 ±2,67
HR mean values during Check-Points **t-test** OF-700 vs. FL-500: n.s. OF-700 vs. FL-1000: n.s. FL-1000 vs. FL-500: n.s.	47,84 ±8,01	48,96 ±6,09	48,23 ±3,96
HR range during legs **t-test** OF-700 vs. FL-500: *0,002* OF-700 vs. FL-1000: n.s. FL-1000 vs. FL-500: n.s.	5,92 ±1,22	8,61 ±0,66	9,08 ±3,80
HR range during check-points **t-test** OF-700 vs. FL-500: *<0,001* OF-700 vs. FL-1000: *0,012* FL-1000 vs. FL-500: n.s.	4,42 ±0,77	9,36 ±0,77	9,31 ±2,61

*(MEAN±SD)
OF-700 = OffroadFinnmark, 700km category (data from 2010); FL-500 = Finnmarksløpet, 500km category (data from 2009); FL-1000 = Finnmarksløpet, 1000km category (data from 2009).
HR values are expressed as % of the HR peak recorded during preliminary maximal test (HRpeak).

Table 2 – Time for completion and percentage spent in legs and check-points*

Mushers participating in Finnmarksløpet in 2009 (500km and 1000km) and bikers in OffroadFinnmark in 2010.

	OF2010-700km	FL2009-500km	FL2009-1000km
Total Race Time (Time±SD) **t-test** OF-700 vs. FL-500: *0,002* OF-700 vs. FL-1000: *<0,001* FL-1000 vs. FL-500: *<0,001*	93:26:40 ±3:23:17	64:31:12 ±2:14:24	135:51:12 ±3:17:07
% time in Legs (Time%±SD) **t-test** OF-700 vs. FL-500: *<0,001* OF-700 vs. FL-1000: *<0,001* FL-1000 vs. FL-500: n.s.	77,98 ±3,92	59,90 ±4,69	59,86 ±4,10
% time in Check-Points (Time%±SD) **t-test** OF-700 vs. FL-500: *<0,001* OF-700 vs. FL-1000: *<0,001* FL-1000 vs. FL-500: n.s.	22,02 ±3,92	40,10 ±4,69	40,14 ±4,10

*(MEAN±SD)
OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009).

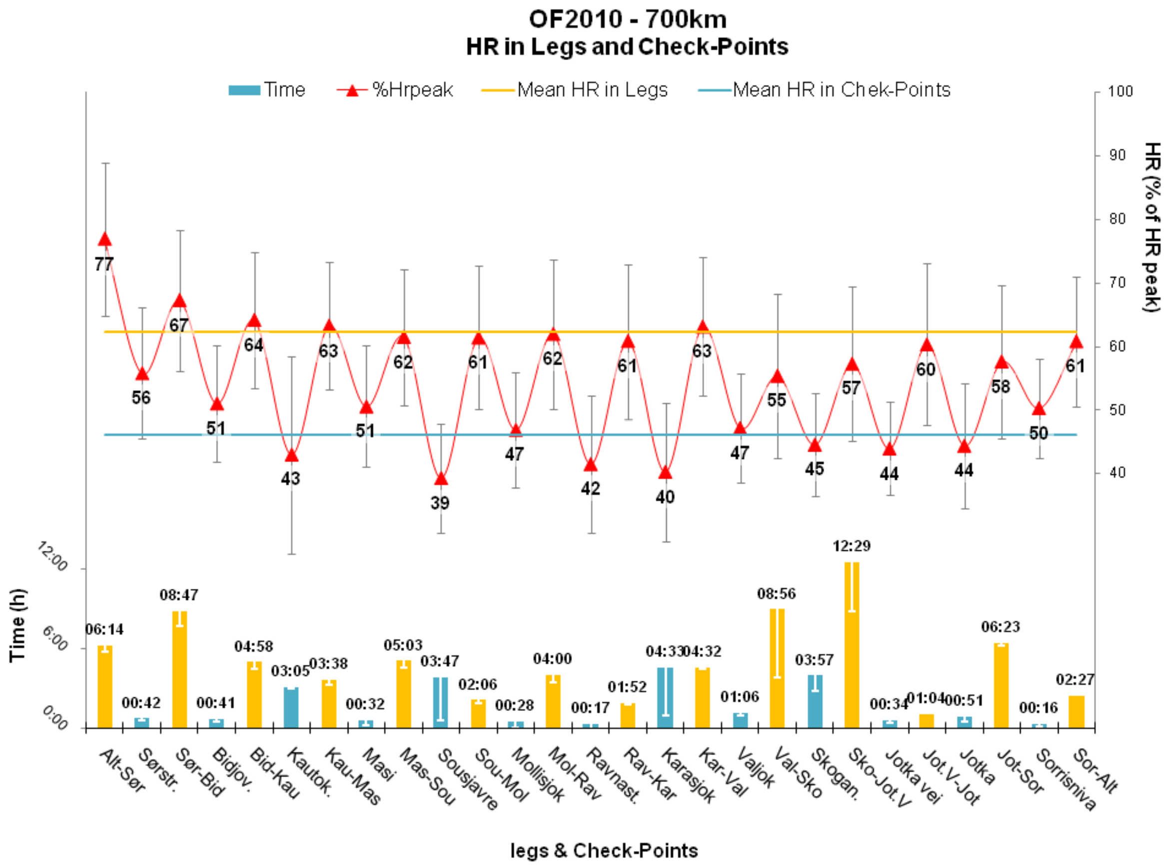
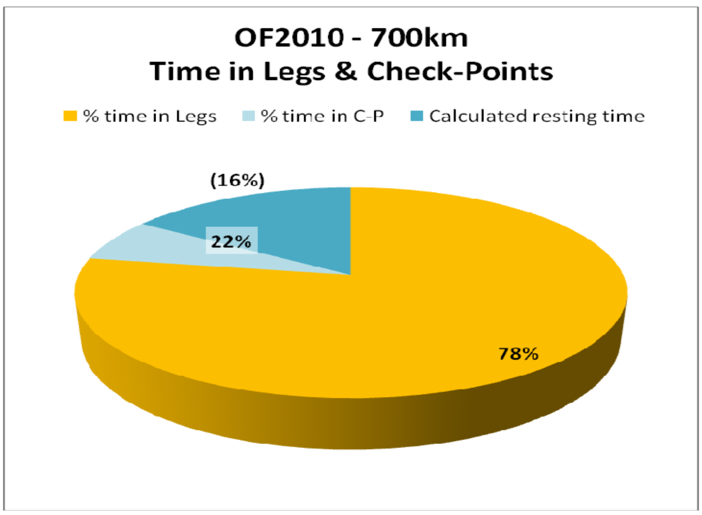


Fig 1. Offroad 700km HR in Legs and Check-points
The yellow and blue colums in the lower part of the graph represent the time spent in the legs and check-points respectively; the red tringles in the upper part of the graph represent the average HR (%of the HRpeak); the horizontal yellow and blue lines in the upper part of the graph represent the mean HR calculated for the legs and the check-points respectively.



The yellow slice (78% of total race time) is the average time spent in the legs, according with the official report.

The light blue + darker blue slice is the time spent in the check-points, according with the official report (22% of total race time).

The darker blue slice is the "calculate resting time" (16% of total race-time).

Fig 2. Offroad 700km time spent in Legs and Check-points

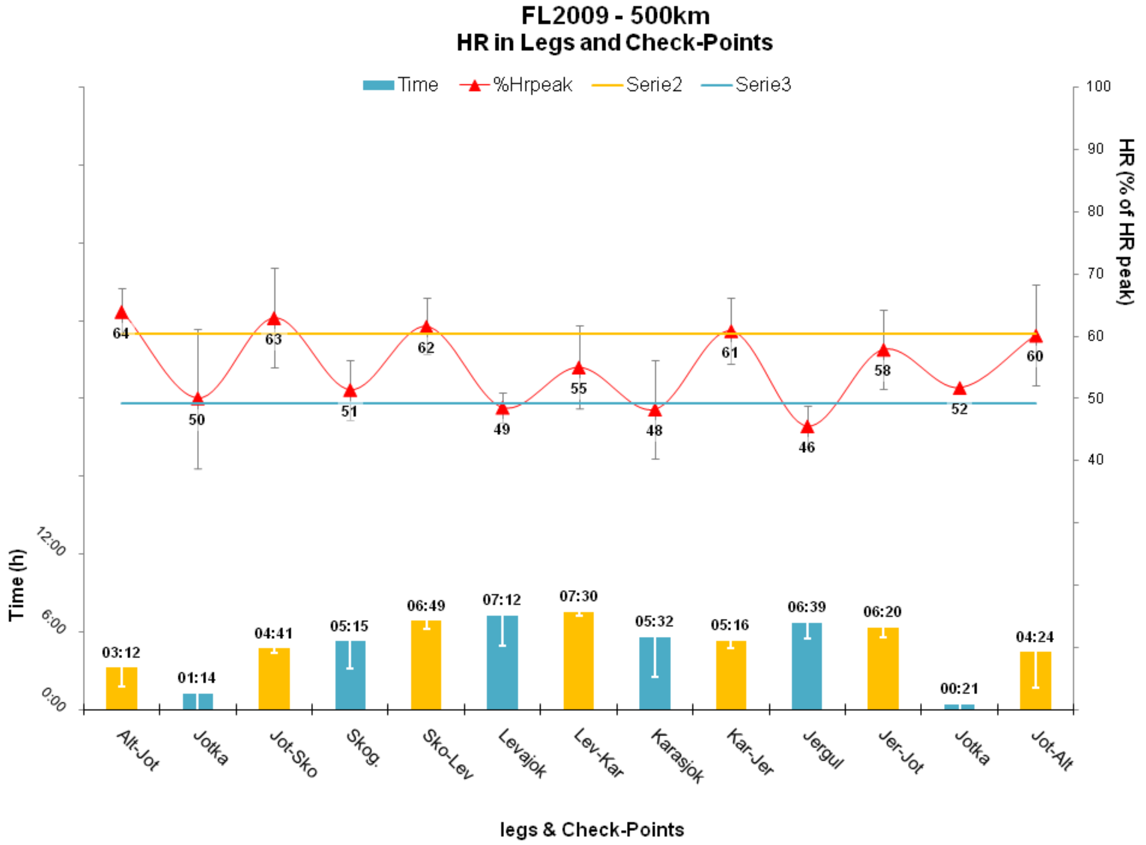


Fig 3. Finnmarksløpet 500km HR in Legs and Check-points.
The yellow and blue colums in the lower part of the graph represent the time spent in the legs and check-points respectively; the red tringles in the upper part of the graph represent the average HR (%of the HRpeak); the horizontal yellow and blue lines in the upper part of the graph represent the mean HR calculated for the legs and the check-points respectively.

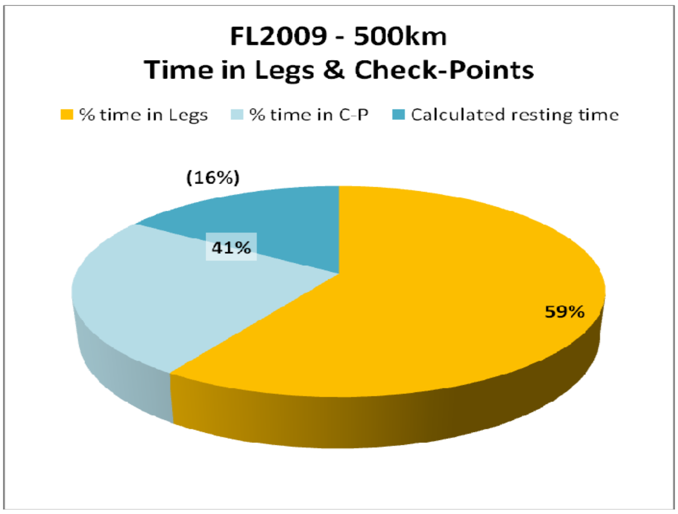


Fig 4. Finnmarksløpet 500km time in Legs and Check-points.

The yellow slice (59% of total race time) is the average time spent in the legs, according with the official report;

The light blue + darker blue slice is the time spent in the check-points, according with the official report (41% of total race time);

The darker blue slice is the "calculate resting time" (16% of total race-time).

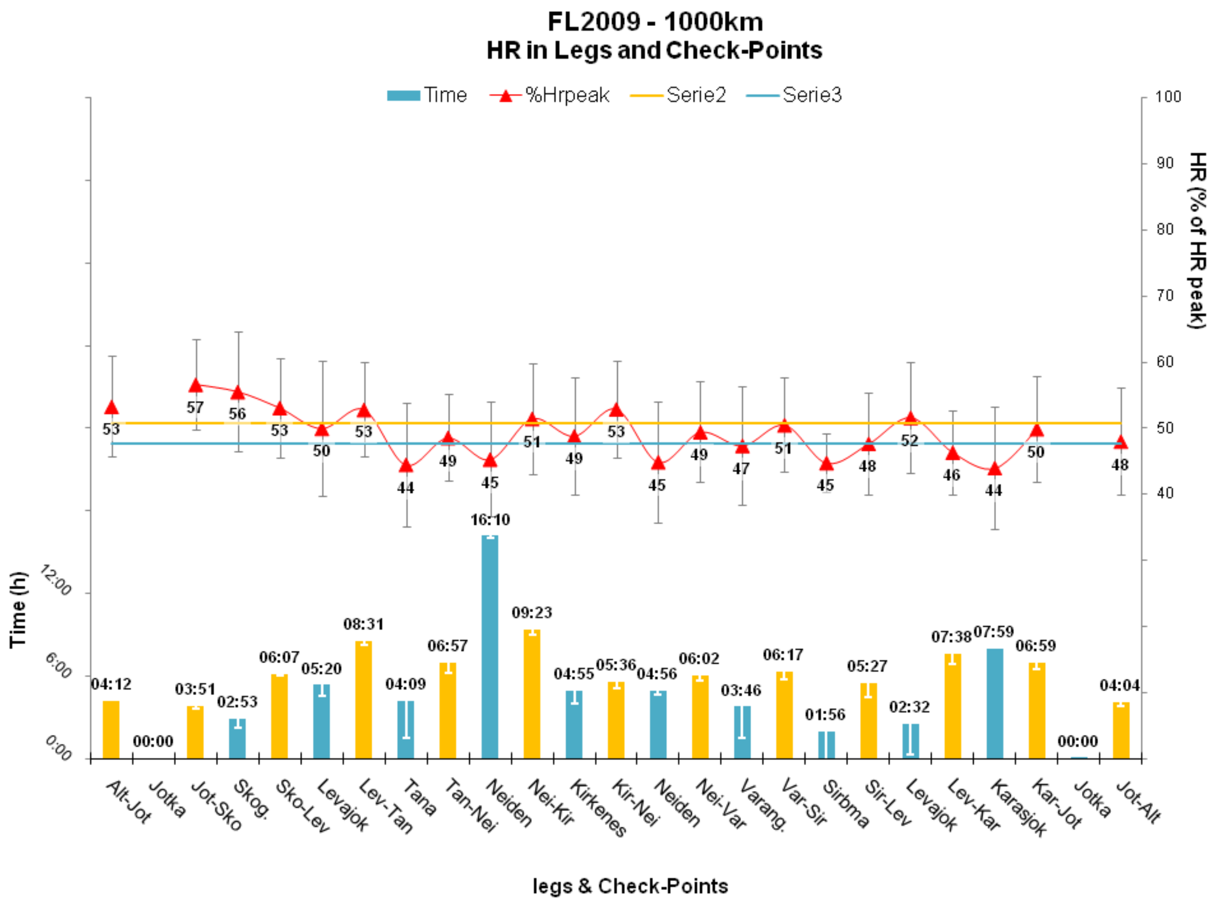


Fig 5. Finnmarksløpet 1000km HR in Legs and Check-points.
The yellow and blue colums in the lower part of the graph represent the time spent in the legs and check-points respectively; the red tringles in the upper part of the graph represent the average HR (%of the HRpeak); the horizontal yellow and blue lines in the upper part of the graph represent the mean HR calculated for the legs and the check-points respectively.

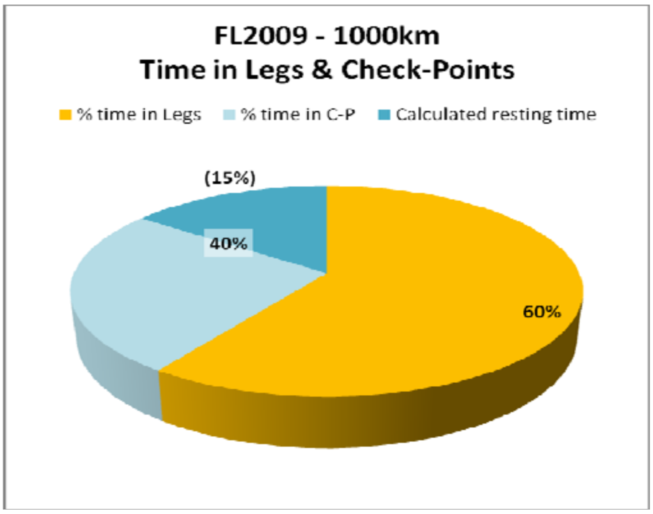


Fig. 6 Finnmarksløpet 1000km time in legs and check-points

The yellow slice (60% of total race time) is the average time spent in the legs, according with the official report;

The light blue + darker blue slice is the time spent in the check-points, according with the official report (40% of total race time);

The darker blue slice is the "calculate resting time" (15% of total race-time).

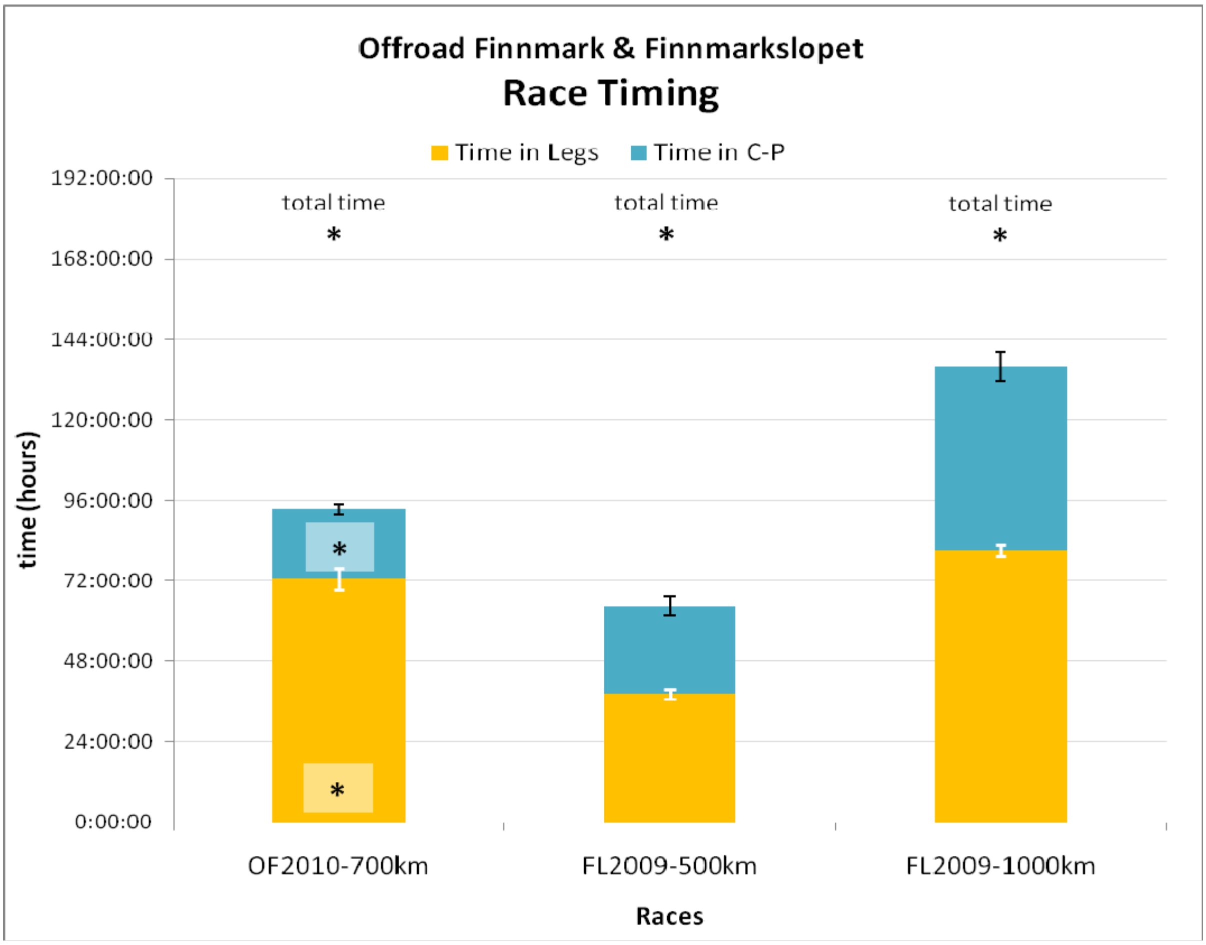


Fig 7. Total race time, time in legs and in check-points.
Bikers who participated at the OffroadFinnmark in 2010 and mushers participating at the Finnmarksløpet in 2009 (500km and 1000km category).(MEANS±SD), OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). * = t-test statistically significant ($p<0,05$) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

The t-test found statistically significant differences in total time for completion across all the competitions (OF-700 vs. FL-500 p=*0,002;* OF-700 vs. FL-1000 p*<0,001;* FL-1000 vs. FL-500 p*<0,001*). Also statistically significant differences between OffroadFinnmark bikers and Finnmarksløpet mushers (both 500km and 1000km) were found for % time in check-point and % time in legs, showing that the bikers spent a minor part of the race in the check-points. Anyway, one should consider the "calculated resting time": despite the mushers spent more time in the check-points (in terms of % of the total race-time), they had to dedicate more time for the dogs' care. We found that the "calculated resting time" was totally alike across the races (OffroadFinnmark: 16%; Finnmarksløpet-500km: 15%; Finnmarksløpet-1000km: 15%).

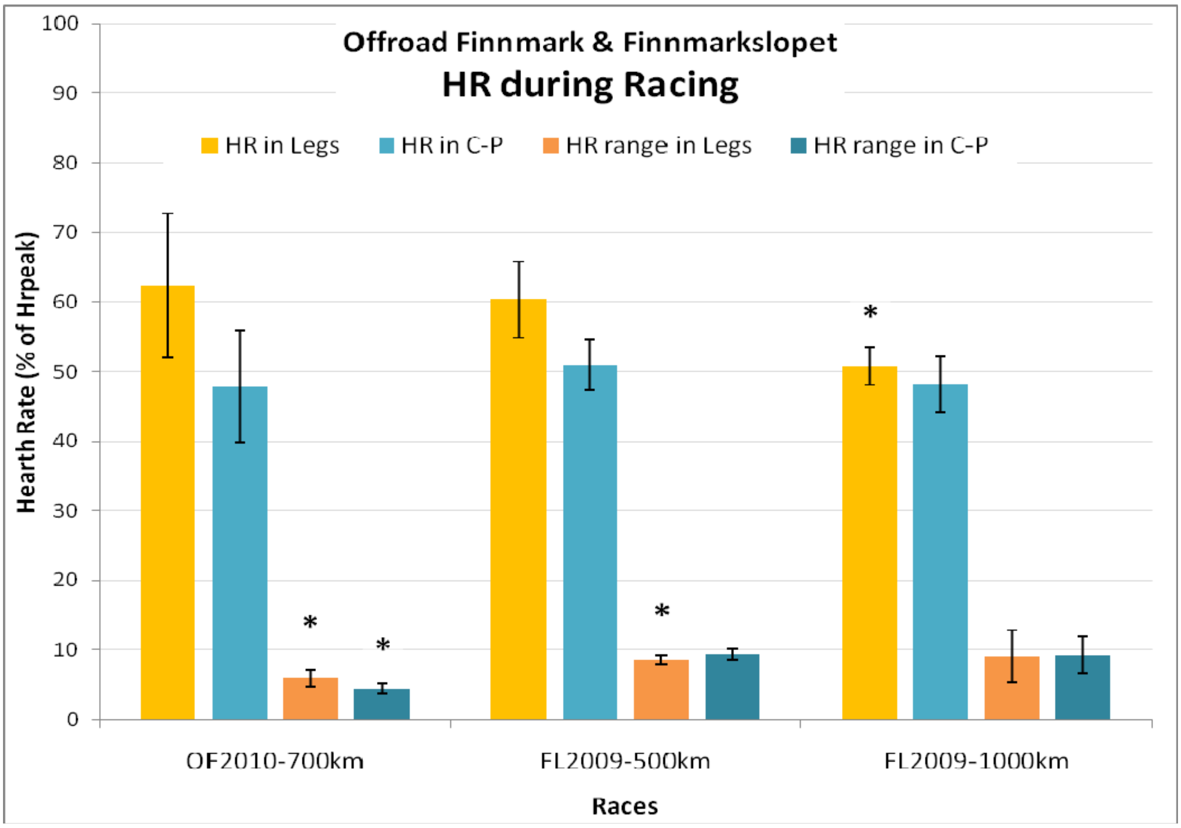
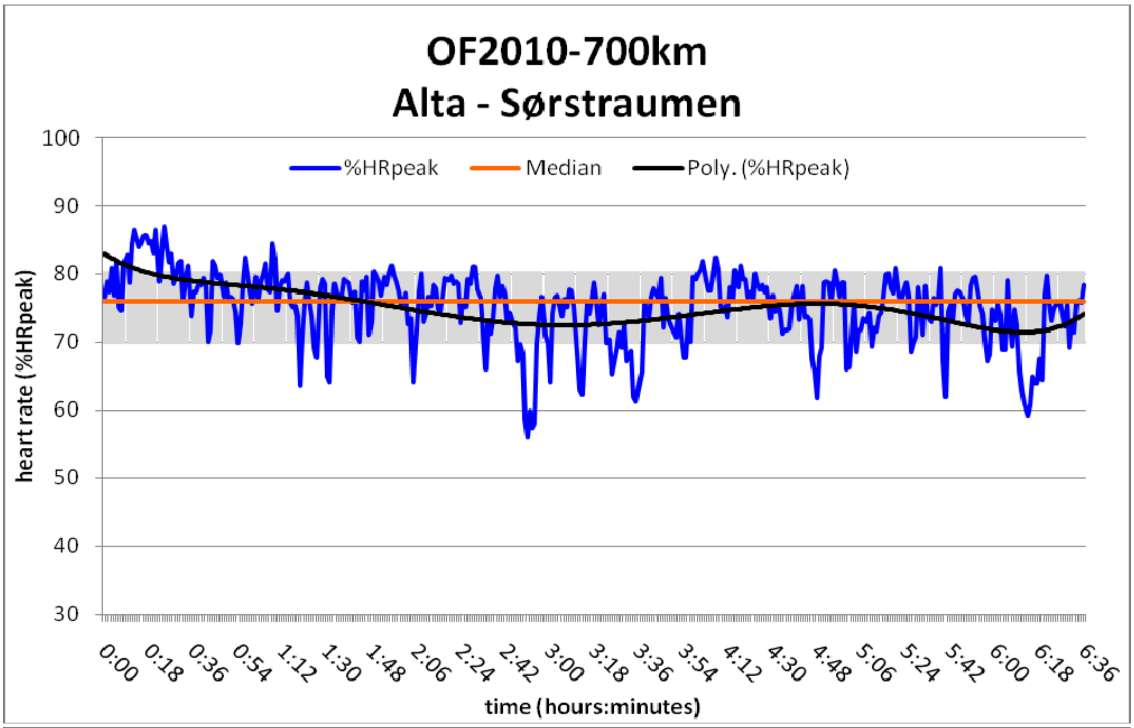


Fig 8. Heart rate during racing.
Mean HR and HR range in legs and check-pints for bikers who participated at the OffroadFinnmark in 2010 and mushers participating at the Finnmarksløpet in 2009 (500km and 1000km category).
(MEANS±SD), OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). * = t-test statistically significant ($p<0,05$) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

T-test found statistically significant differences in HR in legs between 1000km-mushers and both 500km-mushers and bikers, showing that the 1000km-mushers' workload was less intensive compared with the bikers and the 500km-mushers. No differences were found between bikers and 500km-mushers.
The HR range in legs is significantly lower for the bikers against the 500km-mushers. There is a quite large interindividual variability within 1000km-mushers (notice the SD). This evidence indicate that the mushers participating at the Finnmarksløpet-500km go through a more intermittent workload, while the 1000km-mushers and, especially, the bikers keep the HR more constatnt among the legs. It would be interesting to understand if a higher degree of intermittance of workload (that means more physical participation by the 1000km-mushers) would be beneficial for competing the Finnmarksløpet-1000km.
The average HR in the check point does not show statistically significant differences across the different races, but the HR range in the check point is sisgnificantly lower for the bikers compared with both the categories of mushers. This shows that the mushers are more active while they are in the check-points.

HR profiles during the competitions.
In the following figures we show the heart rate profiles for one athlete in each of the competitions at four different stages: The first leg (a), a leg in the middle of the race (b), the last leg (c) and at a checkpoint at the mid way of the race. The HR range (SD of the HR) is shown as a grey band, and the epoch length is 1 minute.



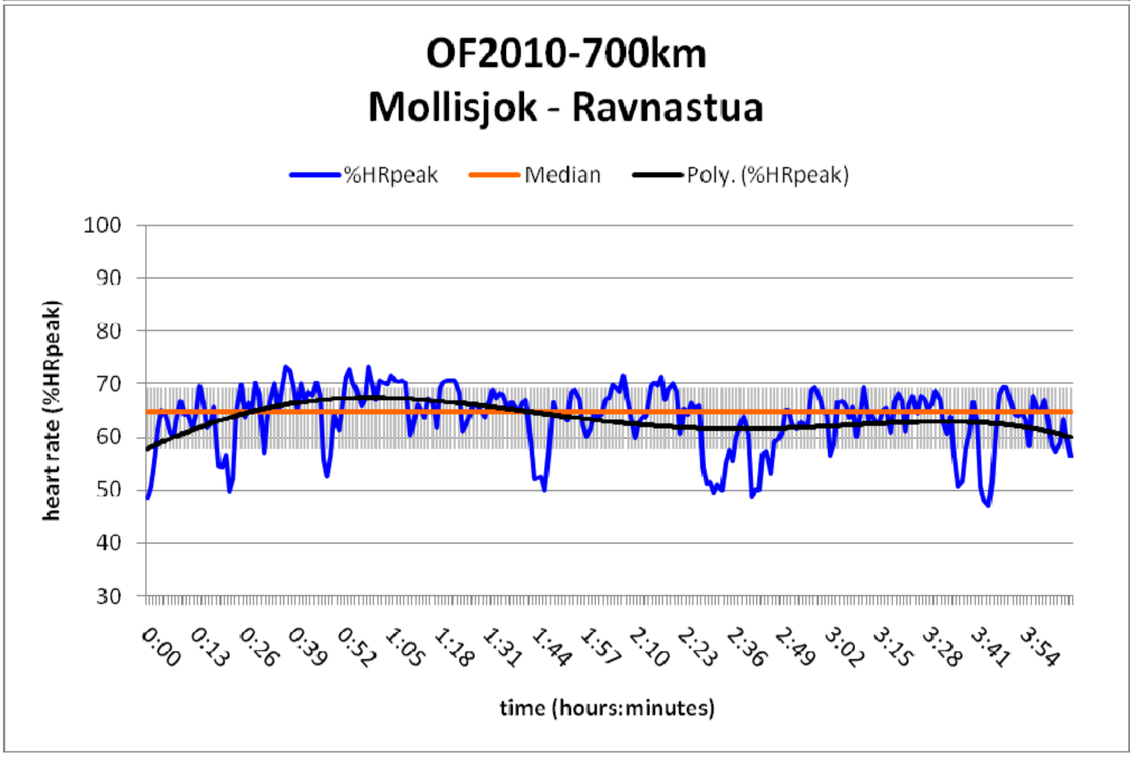
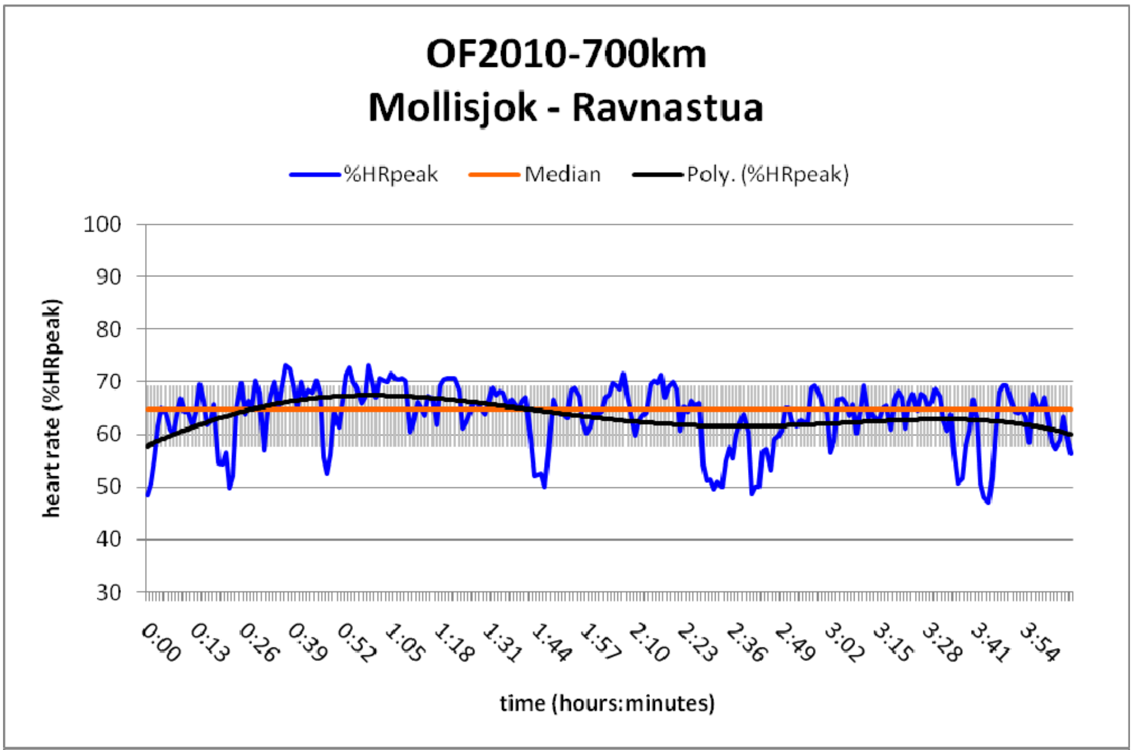


Fig 9. Offroad biker HR profile first and middle leg.
The first leg (top) and a leg in the middle of the race (bottom). The gray band represent the HR range (DS of the HR during the leg/check-point)



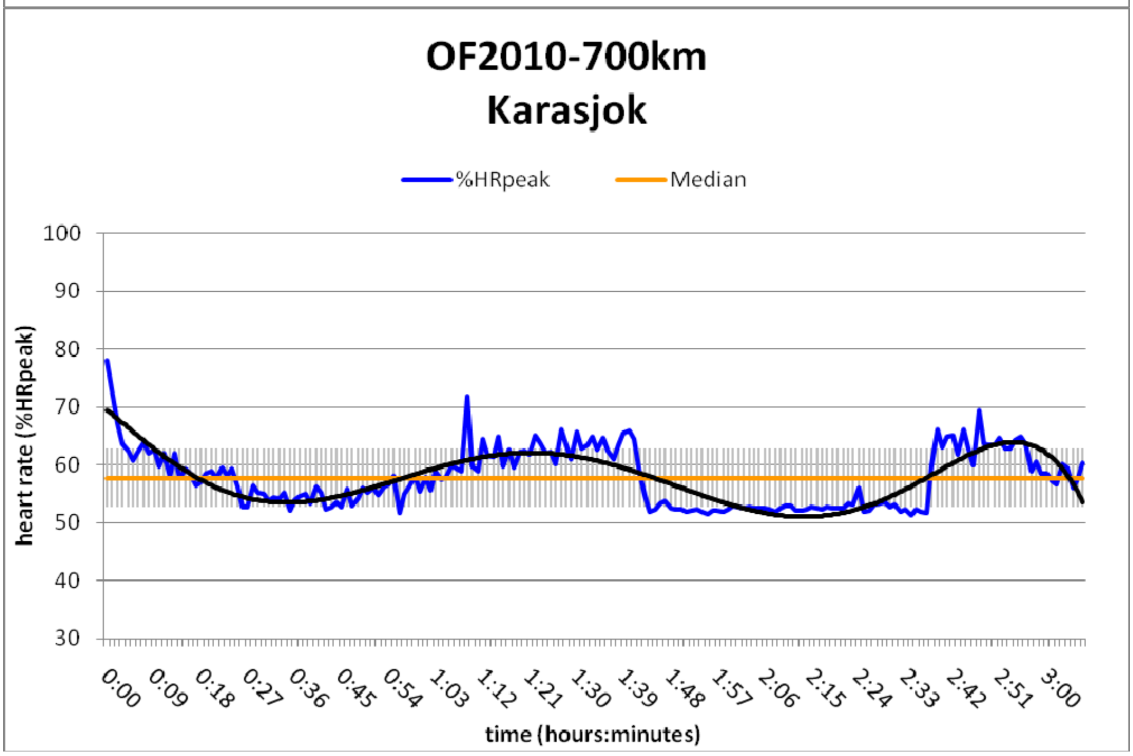
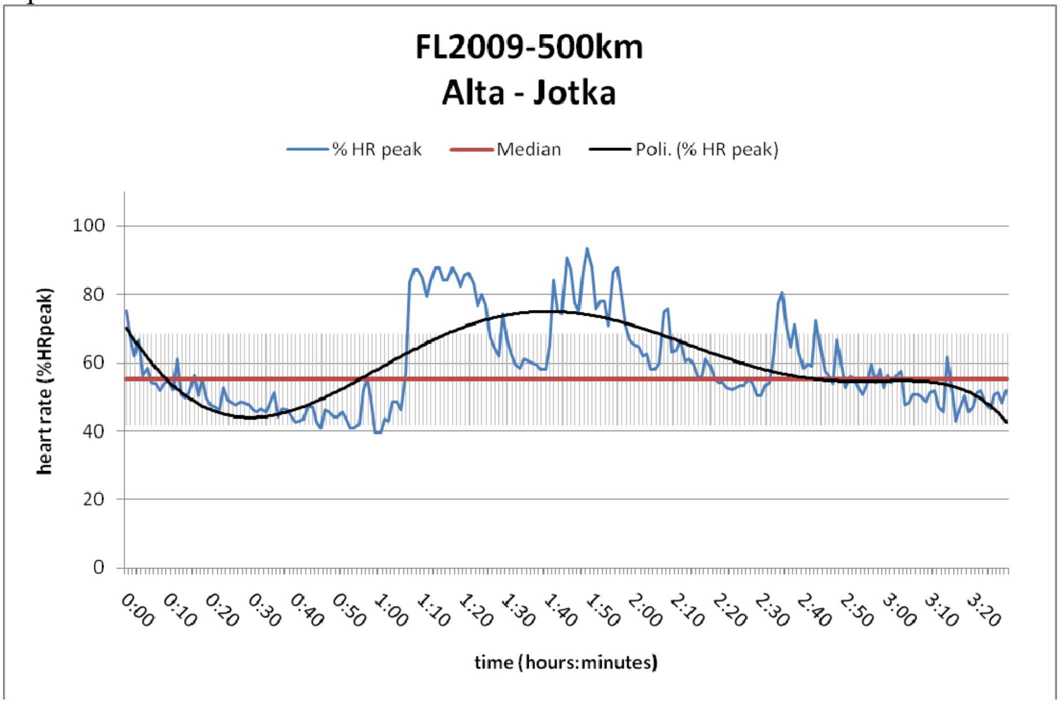


Fig 10. Offroad biker HR profile last leg and checkpoint mid way.
The last leg (top) and a checkpoint in the middle of the race (bottom). The gray band represent the HR range (DS of the HR during the leg/check-point)

Examples of HR profile of a musher competing for the Finnmarksløpet-500km in 2009. Following, the HR profile of a single 500km-musher during 3 legs (the first one, one at the middle way of the race and the last one) and a check-point (at the middle way of the race) are reported.



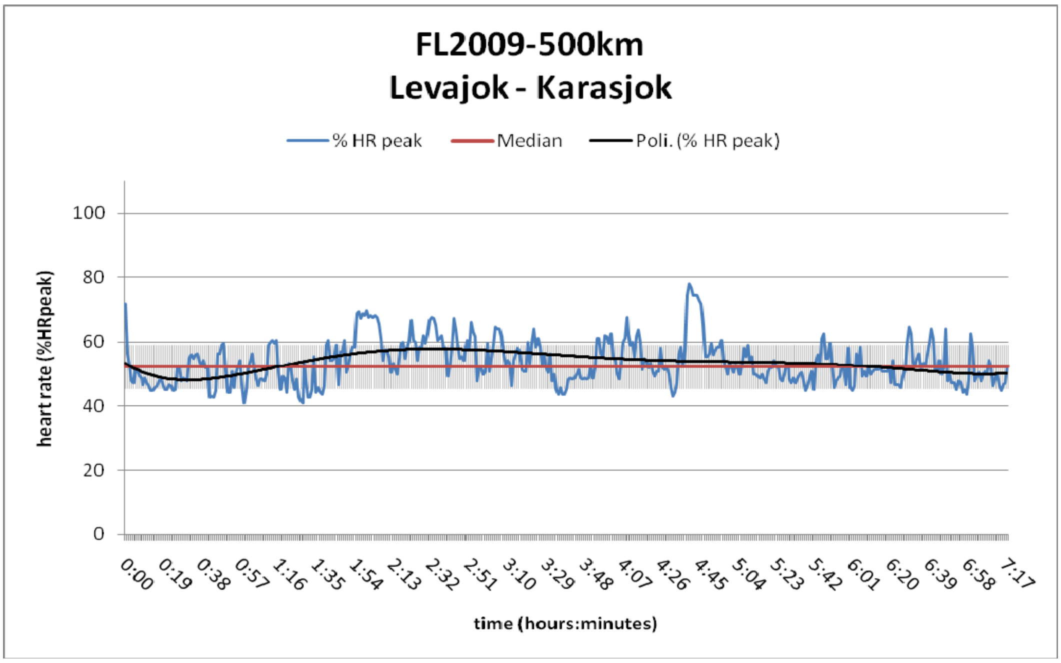
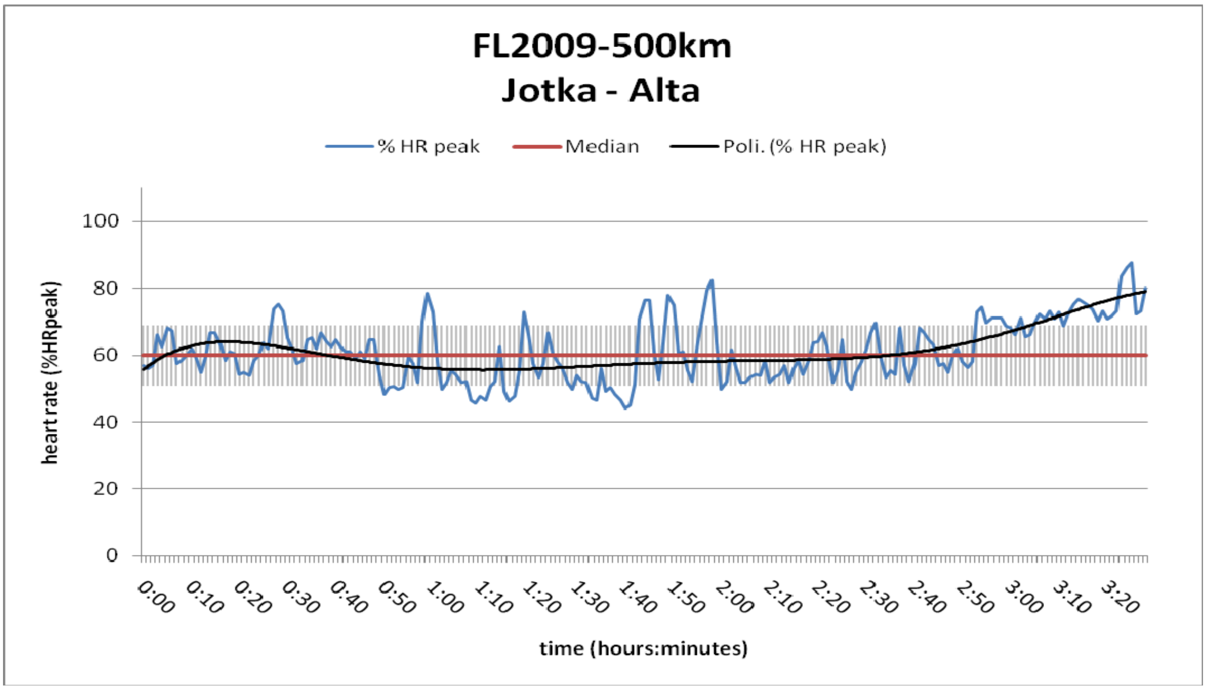


Fig 11. Musher in Finnmarksløpet 500km HR profile first and middle leg
The first leg (top) and a leg in the middle of the race (bottom). The gray band represent the HR range (SD of the HR during the leg/check-point)



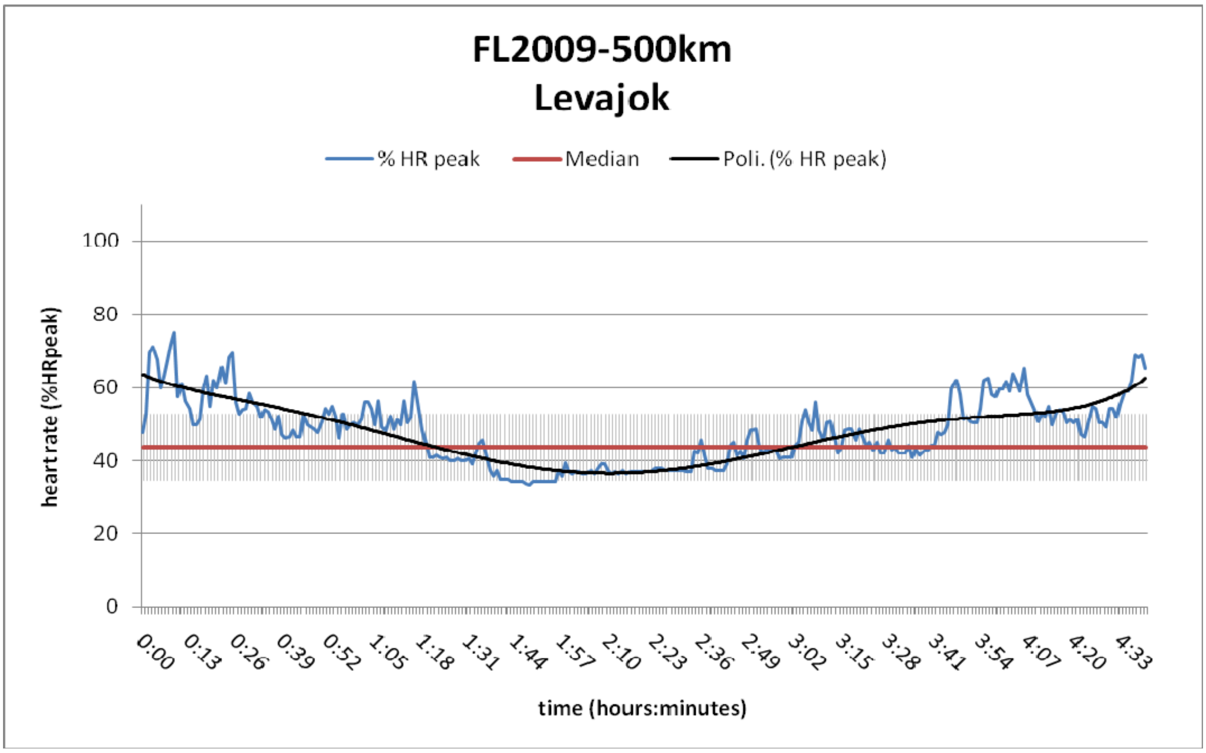
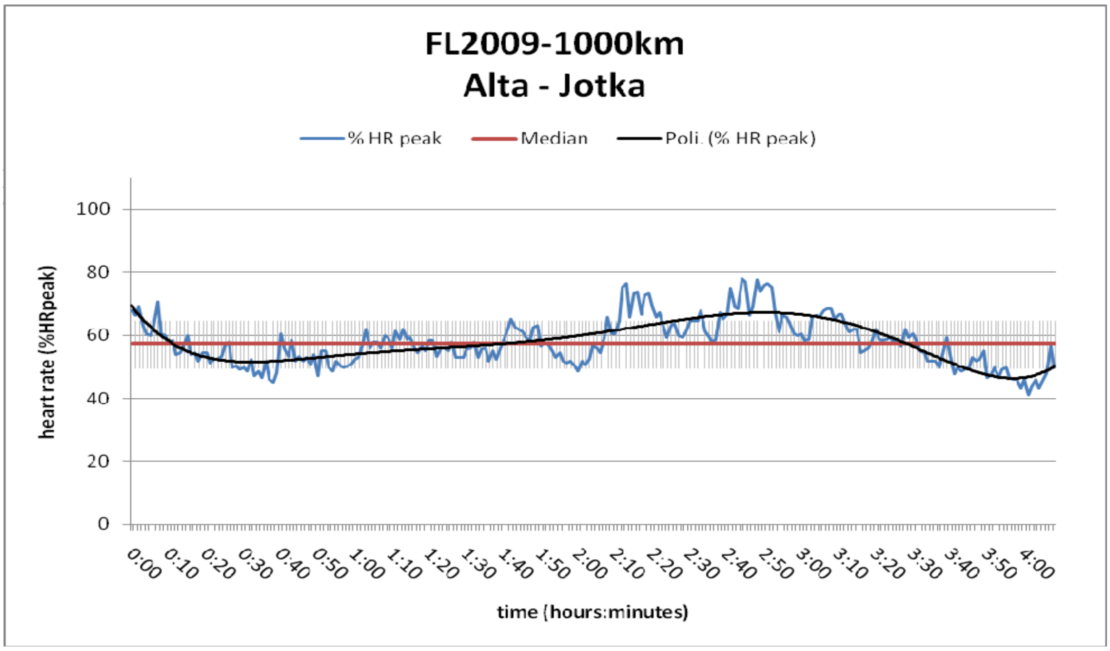


Fig 12. Musher in Finnmarksløpet 500km HR profiles, last leg and checkpoint.
Last leg (top) and a checkpoint in the middle of the race (bottom). The gray band represent the HR range (SD of the HR during the leg/check-point).
HR epoch length= 1min

Examples of HR profile of a musher competing for the Finnmarksløpet-1000km in 2009. Following the HR profile of a single 1000km-musher during 3 legs (the first one, one at the middle way of the race and the lastone) and a check-point (at the middle way of the race) are reported.



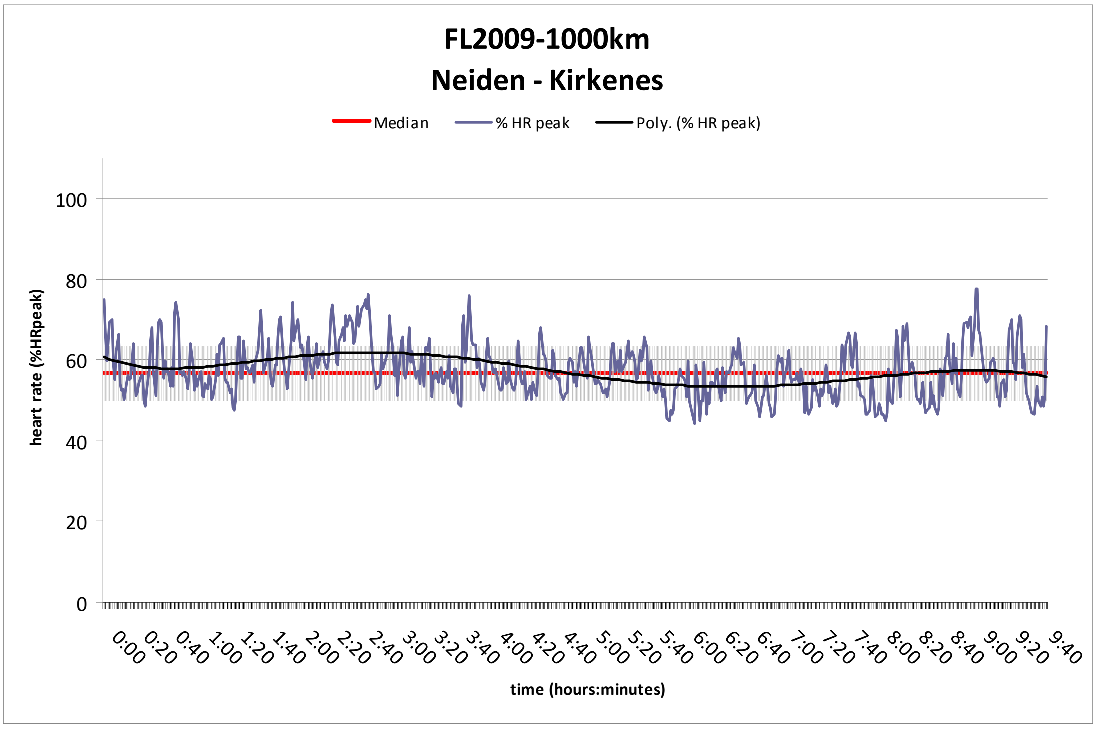
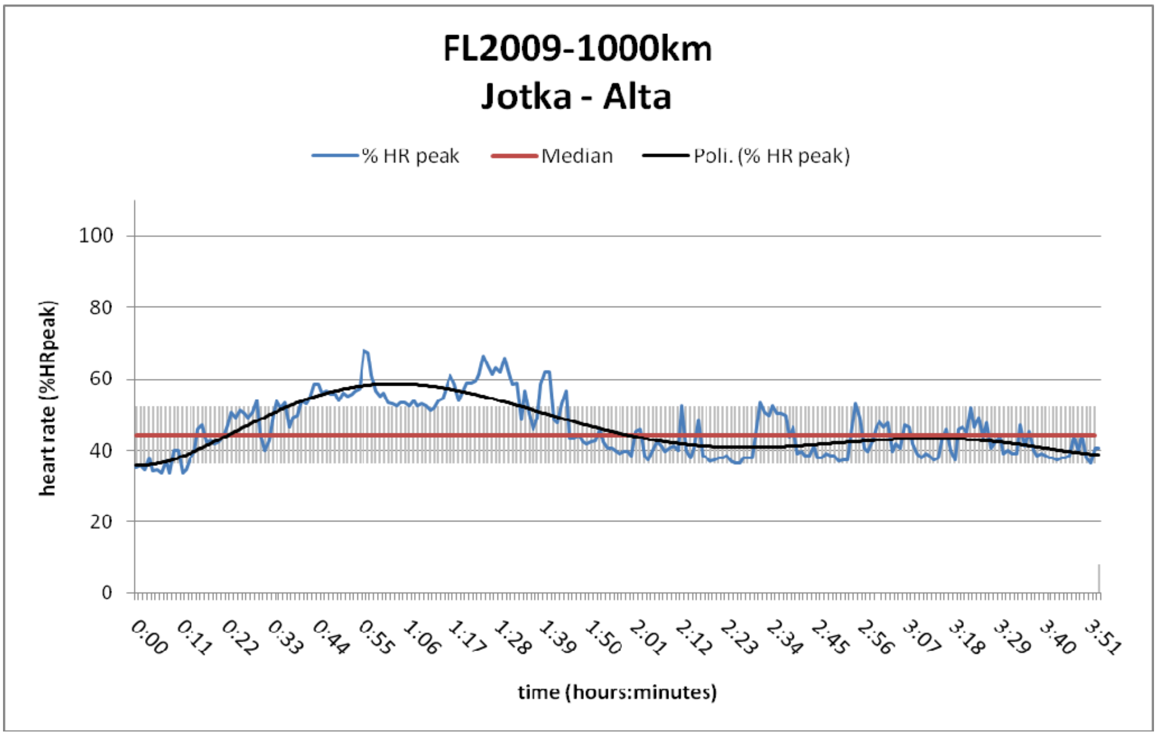


Fig 13. Musher in Finnmarksløpet 1000km HR profile first and middle leg
The first leg (top) and a leg in the middle of the race (bottom). The gray band represent the HR range (SD of the HR during the leg/check-point)



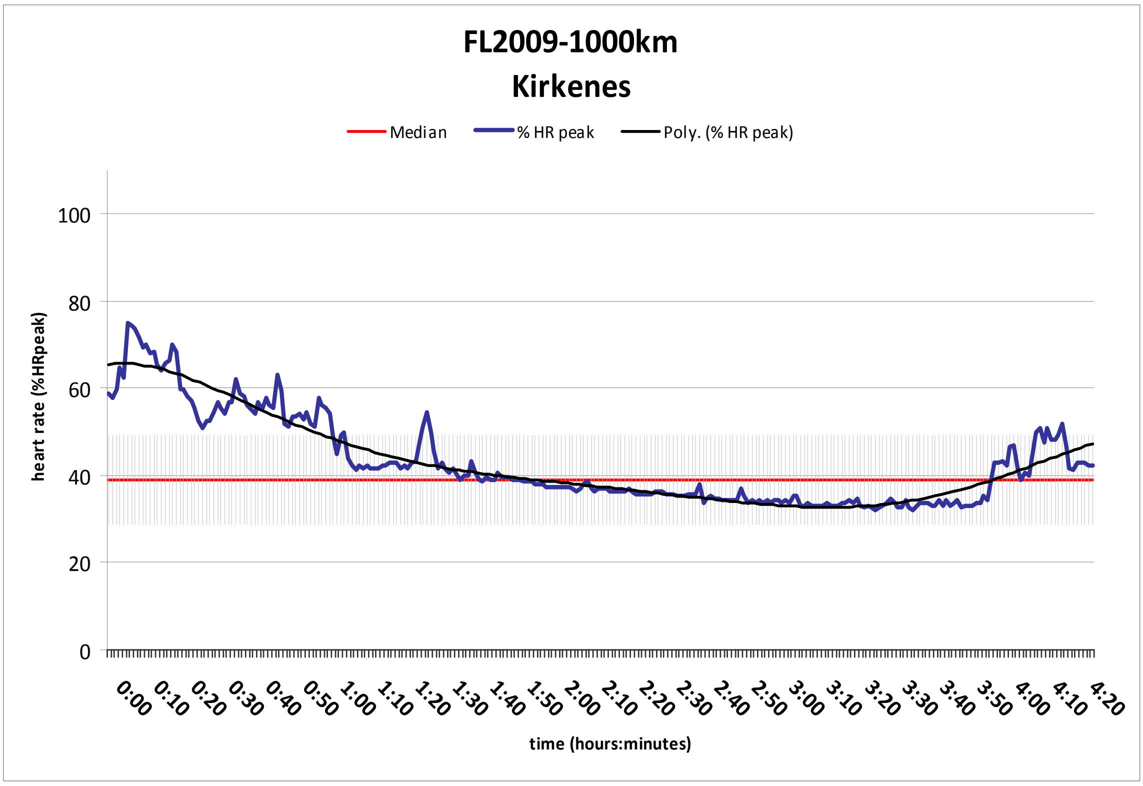


Fig 14. Musher in Finnmarksløpet 1000km HR profiles, last leg and checkpoint.
Last leg (top) and a checkpoint in the middle of the race (bottom). The gray band represent the HR range (SD of the HR during the leg/check-point). HR epoch length= 1min

2. ACTIVITY ANALYSIS

Data Processing

The actigraphy data for the bikers participating at the OffroadFinnmark 2010 (OF2010-700km) consisted in a single file, which was loaded into the *Sleep & Activity Analysis* software for processing.

1) Half of the bikers had just a 3-days long POST-monitoring (3 of them had a 4-days and only 2 had a 5-days), while for the mushers had a 5-days long POST-monitoring.
2) Most of the mushers cut the arrival at night or early morning. This made the mushers' POST-monitoring composed by data series which can be fairly considered full days. Most of the bikers cut the arrival around noon or even later, so this makes the first POST-day just a "half day" of monitoring (or even less). This makes the first POST-day not reliable for the activity analysis.

Because of the problems reported above, we repeated the analysis on the mushers considering only the 3 days following the arrival, so that the results were comparable with the bikers from the OffroadFinnmark.

We also "meshed up" (as possible by the software) the values of the PRE and the POST monitoring, in order to avoid possible interferences due to the long data-holes. As a result, for the activity analysis we won't have a day-by-day comparison (e.g. PRE vs. DAY1, PRE vs. DAY2, etc.) but just a PRE-POST comparison.

So, in conclusion, the following values, for both mushers and bikers, refer to PRE and POST monitoring that were 3-days long and that have been "meshed-up" for the analysis.

Data Analysis

2-way ANOVA was performed with SPSS 17.00. The meshed-up PRE and POST values were run as follow:

- dependent variable = Activity Analysis parameters: Activity Average, Cosine Peak and L/D ratio (a 2-way ANOVA was performed for each parameter).
- independent variables = PRE/POST and race: OffroadFinnmark-700km, Finnmarksløpet-500km, Finnmarksløpet-1000km).

Post-hoc analysis:

- PRE vs. POST comparisons for each group were performed by a paired 2 tailed t-test.
- Cross-comparisons were performed for all the possible combinations by 2 tailed t-test; before t-test was applied, the data were tested for homogeneity by f-test: if f-test was significant, the t-test was set as a comparison between two non-homogeneous groups.

Because of the little sample size, which is also dissimilar between bikers and mushers (6 vs. 5), marginally significant results (*0,05<p<0,08*) have been reported and discussed.

All the analysis results and graphs are collected in the file "ActAnalysis-OF2010.xls", while the ANOVA results are collected in doc. files in folder named "ANOVA_Activity Analysis".

Results

Table 3 Activity Analysis

Activity Analysis parameters* of mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark in 2010. The data are relative to 3-days before (PRE) and 3-days after (POST) the competition**.**

	OF2010-700km (N=6)			**FL2009-500km (N=5)**			**FL2009-1000km N=5)**		
	PRE		**POST**	**PRE**		**POST**	**PRE**		**POST**
Activity Average **2way-ANOVA** Across Races: n.s. Pre-Post: *0,017* Interaction: n.s.	83,0 ±67,8	§	38,0 ±27,0	96,0 ±32,7	*	66,8 ±12,7	86,8 ±37,9	.	55,2 ±21,0
Cosine Peak **2way-ANOVA** Across Races: n.s. Pre-Post: *0,005* Interaction: n.s.	15:02 ±02:06	.	16:39 ±01:12	13:27 ±01:53	*	16:14 ±01:30	14:44 ±01:40	.	16:21 ±02:28
Light/Darkness Ratio **2way-ANOVA** Across Races: n.s. Pre-Post: n.s. Interaction: n.s.	1,8 ±0,5	.	1,5 ±0,9	1,9 ±0,3	*	1,5 ±0,4	1,9 ±0,6	.	1,5 ±0,8

(MEANS±SD)

OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009).

§ = PRE/POST t-test marginally significant ($0,05<p<0,08$).

* = PRE/POST t-test statistically significant ($p<0,05$)

Table 4 Activity Analysis - Post-hoc Analysis*

	ACT.AVERAGE *p*	**COSINE PEAK** *p*	**L/D RATIO** *p*
t-test PRE			
OF-700 vs. FL-500	n.s.	n.s.	n.s.
OF-700 sv. FL-1000	n.s.	n.s.	n.s.
FL-500 vs. FL-1000	n.s.	n.s.	n.s.
t-test POST			
OF-700 vs. FL-500	*0,057*	n.s.	n.s.
OF-700 sv. FL-1000	n.s.	n.s.	n.s.
FL-500 vs. FL-1000	n.s.	n.s.	n.s.

* 2 tailed t-test, after the data have been tested for homogeneity by f-test

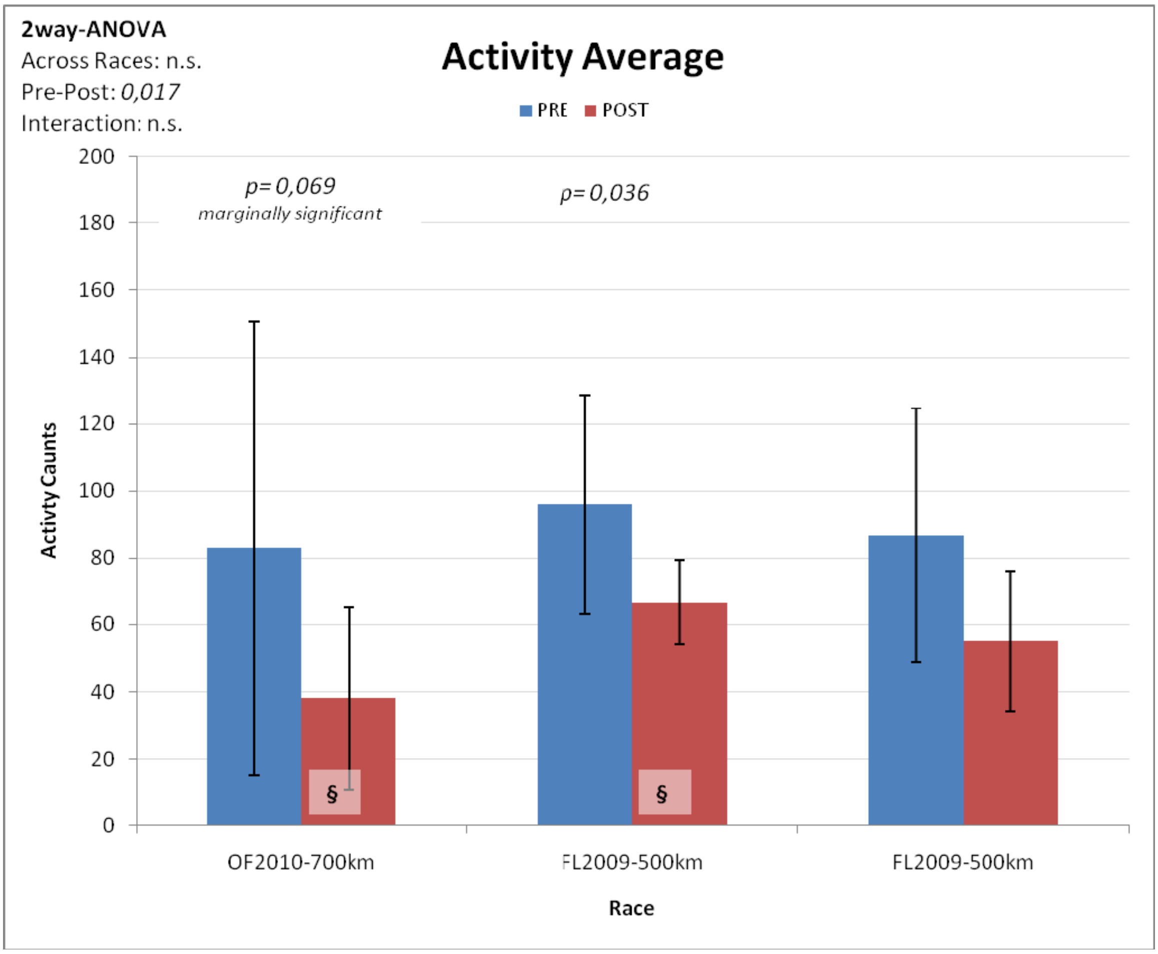


Fig 15 Activity Average
Activity Average values* of mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. Data relative to 3-days before (PRE) and 3-days after (POST) the competition. (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). § = t-test marginally significant (*0,05<p<0,08*).

One can notice the very large SDs values. This is because of there is a large inter-individual variability of the Activity Average values, since some individuals show low activity level during the day, while other individuals looked generally more active, at least for what concern the activity of the upper arms, where the Actigraph was placed. The large inter-individual variability, beside the small number of subjects, might affect the statistic results. Observing the values it is possible to notice a general trend in reducing the Activity Average values during the three days following the competition and the 2-way ANOVA found a statistically significant PRE/POST variation, with no significant interaction. Anyway, when performing a post-hoc comparison by paired t-test, significant PRE/POST difference was achieved only for the 500km-mushers, while significance was only marginal for the OffroadFinnmark bikers and it is not achieved for the 1000km-mushers. A marginally significant difference (p=0,057) was found between the 500km-mushers and the bikers in POST, indicating lower activity levels for the bikers after the competition.

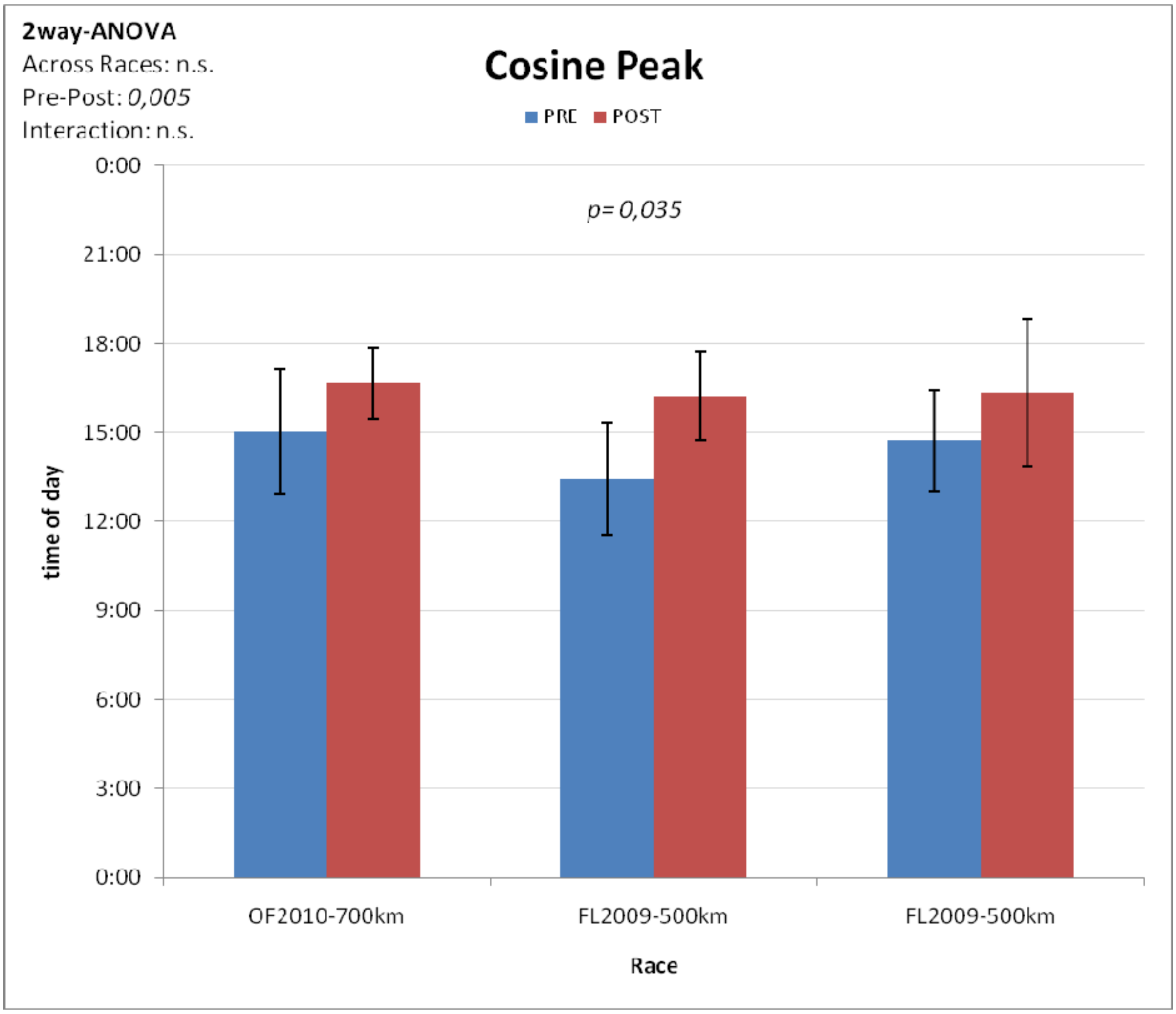


Fig 16 Cosine peaks before and after participation in the different competitions.
(MEANS±SD) , OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009).

It seems that the Cosine Peak generally leads to be delayed after all the different competitions. 2-way ANOVA found a significant PRE/POST variation, with no significant interaction. This result seems to confirm the general delay of cosine peak. When performing the PRE/POST post-hoc analysis, statistical significance was achieved only for the 500km-mushers (mean delay of about 1,5h). The cross-post-hoc analysis did not find any significant difference across the different groups (races).

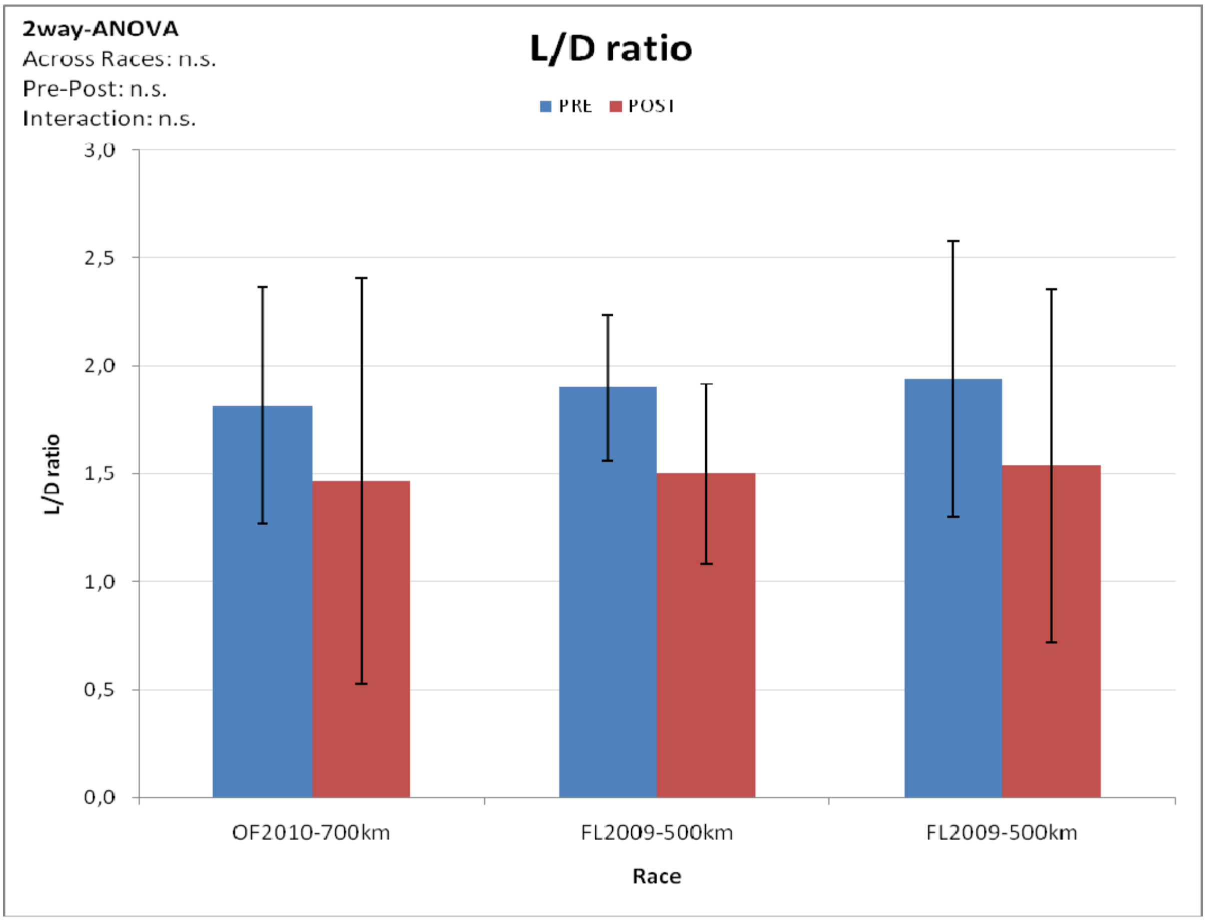


Fig 17 - Light/Darkness (L/D) ratio values
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The data are relative to 3-days before (PRE) and 3-days after (POST) the competition**.** (MEANS±SD) . OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009).

Similarly than the Activity Average values, the L/D ratio shows a large inter-individual variability. It seems the L/D values lead to diminish for the participants of all the races: this suggest the presence higher activity levels during the nocturnal hours for the participants. Anyway, neither the 2-way ANOVA, nor the post-hoc analysis found statistically significant differences.

3. NON PARAMETRIC CIRCADIAN RHYTHM ANALYSIS (NPCRA)

Data Processing

The actigraphy data for the bikers participating at the OffroadFinnmark 2010 (OF2010-700km) consisted in a single file, which was loaded into the *Sleep & Activity Analysis* software for processing.

In a previous work were we studied 10 mushers (Calogiuri, Weydahl, & Roveda, 2011), the POST monitoring was 5-days long. The bikers had shorter POST monitoring, less than 4 complete days, just enough for covering a 3x24h period.

Therefore we have repeated the NPCRA on the mushers considering only the 3 days following the arrival, so that the results were comparable with the bikers from the OffroadFinnmark.

<u>Data Analysis</u>

2-way ANOVA was performed with SPSS 17.00. The values were run as follow:

- dependent variable = NPCRA parameters: IS, IV, L5, L5onset, M10, M10onset, Amplitude and Relative Amplitude (a 2-way ANOVA was performed for each parameter).
- independent variables = PRE/POST and race (OffroadFinnmark-700km, Finnmarksløpet-500km, Finnmarksløpet-1000km).

Post-hoc analysis:

- PRE vs. POST comparisons for each group were performed by a paired 2 tailed t-test.
- Cross-comparisons were performed for all the possible combinations by 2 tailed t-test; before t-test was applied, the data were tested for homogeneity by f-test: if f-test was significant, the t-test was set as a comparison between two non-homogeneous groups.

Because of the little sample size, which is also dissimilar between bikers and mushers (6 vs. 5), marginally significant results ($0,05<p<0,08$) have been reported and discussed.

All the analysis results and graphs are collected in the file “NPCRA-OF2010.xls”, while the ANOVA results are collected in doc. files in folder named “ANOVA_NPCRA”.

Results

Table 5 Non Parametric Circadian Rhythm Analysis.
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark in 2010. The values refer to 3 continuous periods of 24-h before (PRE) and after (POST) the competition**.**

	OF2010-700km (N=6)			**FL2009-500km** (N=5)			**FL2009-1000km** (N=5)		
	PRE		**POST**	**PRE**		**POST**	**PRE**		**POST**
IS **2way-ANOVA** Across Races: *0,001* Pre-Post: n.s. Interaction:.*0,002*	0,30 ±0,15		0,51 ±0,23	0,57 ±0,10		0,58 ±0,15	0,88 ±0,12	*	0,54 ±0,12
IV **2way-ANOVA** Across Races: n.s.. Pre-Post: *0,002* Interaction: § *0,066*	0,69 ±0,26		0,94 ±0,17	0,61 ±0,07	*	0,99 ±0,17	0,73 ±0,14	.	0,74 ±0,14
L5 **2way-ANOVA** Across Races: *0.001* Pre-Post: § *0,077* Interaction: n.s.	468 ±382	§	691 ±478	2285 ±1456		2324 ±1173	1242 ±749		3105 ±1767
L5 onset **2way-ANOVA** Across Races: § *0,082* Pre-Post: *0,014* Interaction: n.s.	01:50 ±01:10	*	03:10 ±00:58	01:24 ±00:32		01:36 ±00:32	1,03 ±0,05	*	1,10 ±0,08
M10 **2way-ANOVA** Across Races: *<0,001* Pre-Post: *0,003* Interaction: n.s.	17984 ±13625	*	10377 ±7956	41151 ±15246	§	27122 ±3378	36620 ±6507	*	25085 ±3108
M10 onset **2way-ANOVA** Across Races: n.s. Pre-Post: n.s. Interaction: n.s.	09:50 ±02:02		10:10 ±02:08	11:00 ±03:40		10:36 ±01:49	0,45 ±0,17		0,39 ±0,06
Amplitude **2way-ANOVA** Across Races: *<0,001* Pre-Post: *<0,001* Interaction: n.s.	17516 ±13280	§	8903 ±8110	38866 ±14341	§	24799 ±3118	35377 ±5956	*	21980 ±4697
Relative Amplitude **2way-ANOVA** Across Races: n.s. Pre-Post: *0,001* Interaction: n.s.	0,94 ±0,02	*	0,86 ±0,06	0,90 ±0,05		0,85 ±0,07	0,94 ±0,03	§	0,78 ±0,14

(MEANS±SD)
OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009).
§ = PRE/POST t-test marginally significant (*0,05<p<0,08*). * = PRE/POST t-test statistically significant (*p<0,05*)

Table 6 Non Parametric Circadian Rhythm Analysis - Post-hoc Analysis*

	IS	IV	L5	L5onset	M10	M10onset	Amp.	Rel. Amp.
	p	*p*	*p*	*p*	*p*	*p*	*p*	*p*
t-test PRE								
OF-700 vs. FL-500	0,009	n.s.	0,047	n.s.	0,026	n.s.	0,031	n.s.
OF-700 sv. FL-1000	0,000	n.s.	*§0,053*	n.s.	0,021	n.s.	0,022	n.s.
FL-500 vs. FL-1000	0,002	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
t-test POST								
OF-700 vs. FL-500	n.s.	n.s.	0,012	0,012	0,002	n.s.	0,003	n.s.
OF-700 sv. FL-1000	n.s.	*§ 0,057*	0,036	n.s.	0,004	n.s.	0,014	n.s.
FL-500 vs. FL-1000	n.s.	0,032	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* 2 tailed t-test, after the data have been tested for homogeneity by f-test
§ marginally significant (*0,05<p<0,08*).

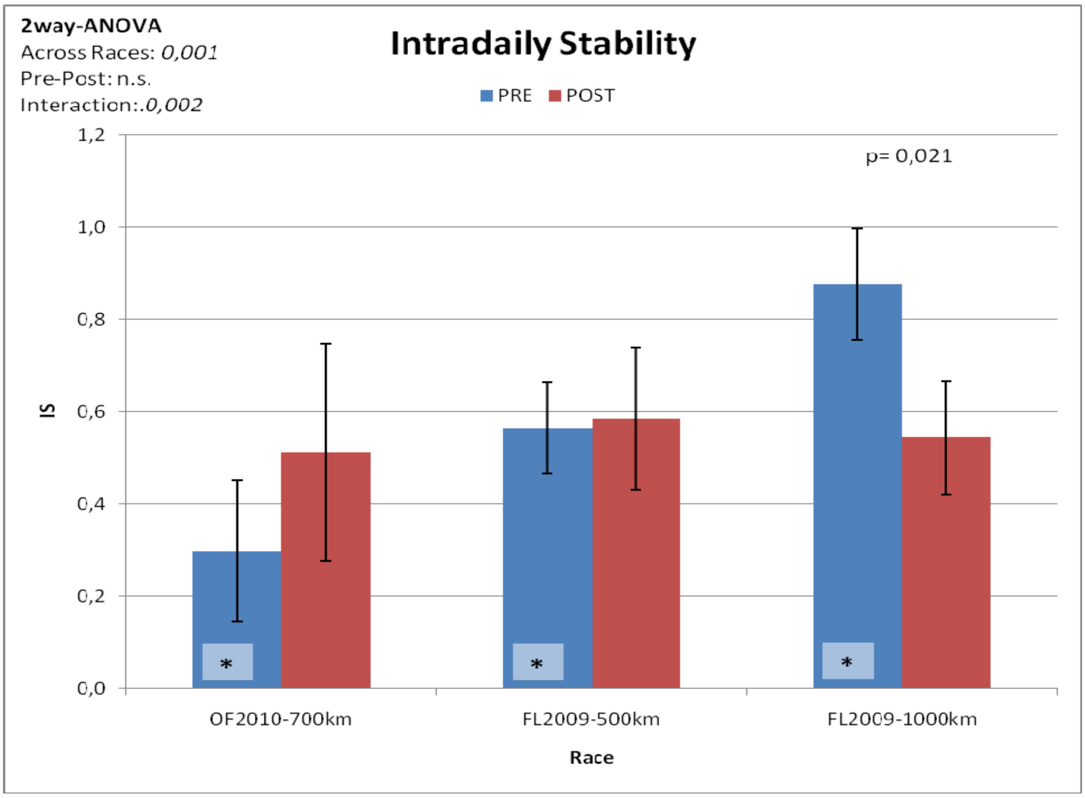


Fig 18 Interdaily Stability (IS)
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The values refer to 3 continuous periods of 24-h before (PRE) and after (POST) the competition**.**
(MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). * = t-test statistically significant (*p<0,05*) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

2-way ANOVA found statistically significant differences for IS across races and a significant interaction. The cross-post-hoc analysis shows significant differences across all the groups within the PRE condition, with very low levels for the OffroadFinnmark bikers (healthy adult population average = 0,6). 500km-mushers show lower IS values compared with 1000km-mushers, but their IS is yet pretty close to the healthy adult population reference. The PRE/POST post-hoc analysis by paired t-test achieved significance only for the 1000km-mushers, showing that they worsen relevantly there is after the competition.

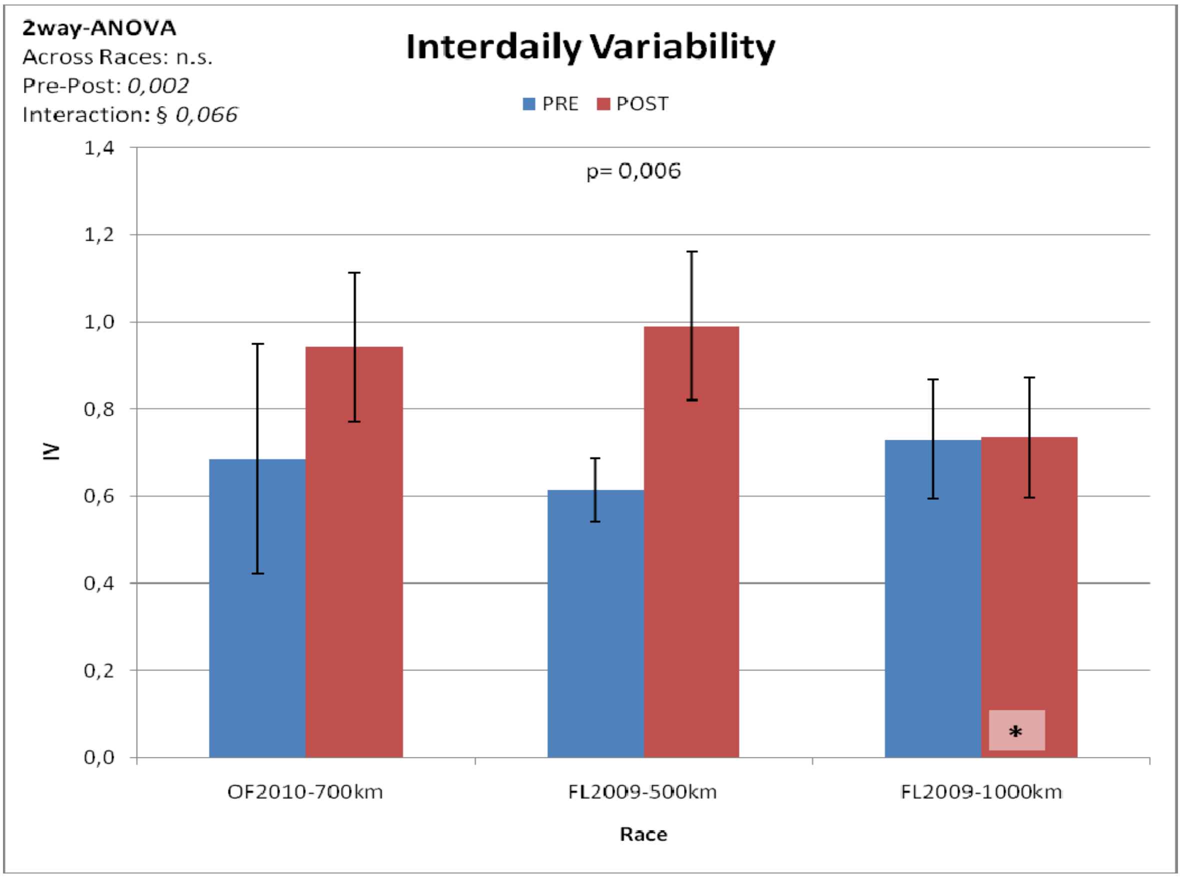


Fig 19 Intradaily Variability (IV)
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The values refer to 3 continuous periods of 24-h before (PRE) and after (POST) the competition**.**
(MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). * = t-test statistically significant ($p<0,05$) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

The 2-way ANOVA found a statistically significant PRE/POST variation for IV, with a marginally significant interaction. The post-hoc analysis found only a significant differences for the 500-km-mushers, with higher IV values in POST compared with PRE. Looking at the values, it seems that IV increases also for the OffroadFinnmark bikers, but the post-hoc analysis did not find statistical significance. The 1000km-mushers do not show any alteration of the IV values in POST conditions compared with PRE. Also, the cross-post-hoc analysis found statistically significant difference between 1000km-mushers and both 500km-mushers and OffroadFinnmark bikers in POST, with lower IV values for the 1000km-mushers after the competition.

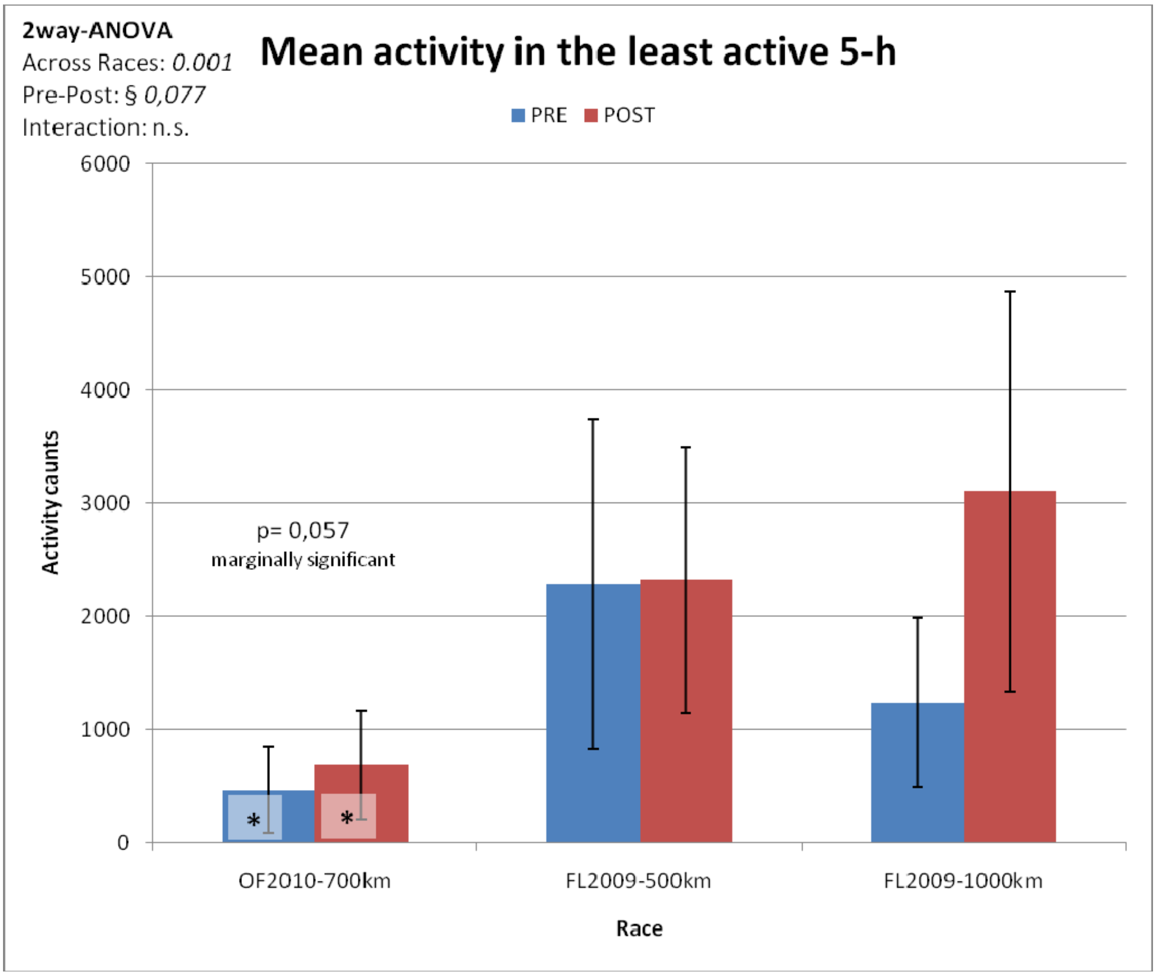


Fig 20 Mean activity during the five least active hours (L5)
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The values refer to 3 continuous periods of 24-h before (PRE) and after (POST) the competition**.**
(MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). * = t-test statistically significant (*p<0,05*) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

2-way ANOVA found statistically significant differences across races and the post-hoc analysis show that the OffroadFinnmark bikers recorded lower L5 values in both PRE and POST conditions, compared with the 500km- and 1000km mushers. Again, this evidence might be related with the midnight-sun period, during which the bikers have been monitored. Also, the 2-way ANOVA found a marginally significant PRE/POST variation, which is not really confirmed by the post-hoc analysis despite an apparent tendency in increasing the L5 values after the competition for bikers and 1000km-mushers.

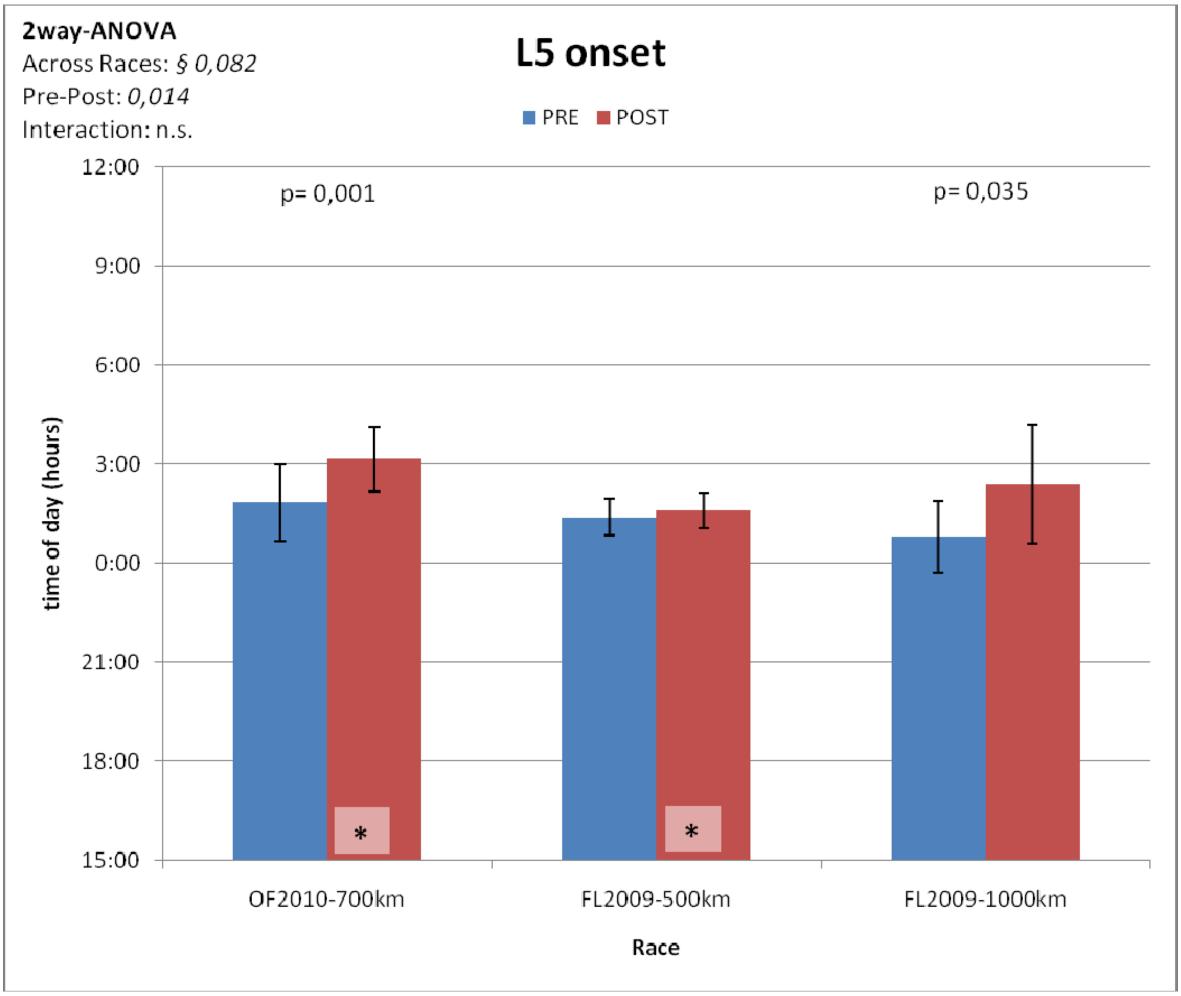


Fig 21 L5 onset
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The values refer to 3 continuous periods of 24-h before (PRE) and after (POST) the competition**.** (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). * = t-test statistically significant ($p<0,05$) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

2-way ANOVA found a merginally significant variation across races and a statistically significant PRE/POST variation. The post-hoc analysis shows statistically significant differences between 500km-mushers and OffroadFinnmark bikers in POST, with an earlier L5onset for the 500km-mushers. Also, statistically significant PRE/POST differences were found for bikers and 1000km-mushers, with a delayed L5onset after the competition. These results indicate that the L5onset was delayed for all the different competitors, but it was not significant for the 500km-mushers.

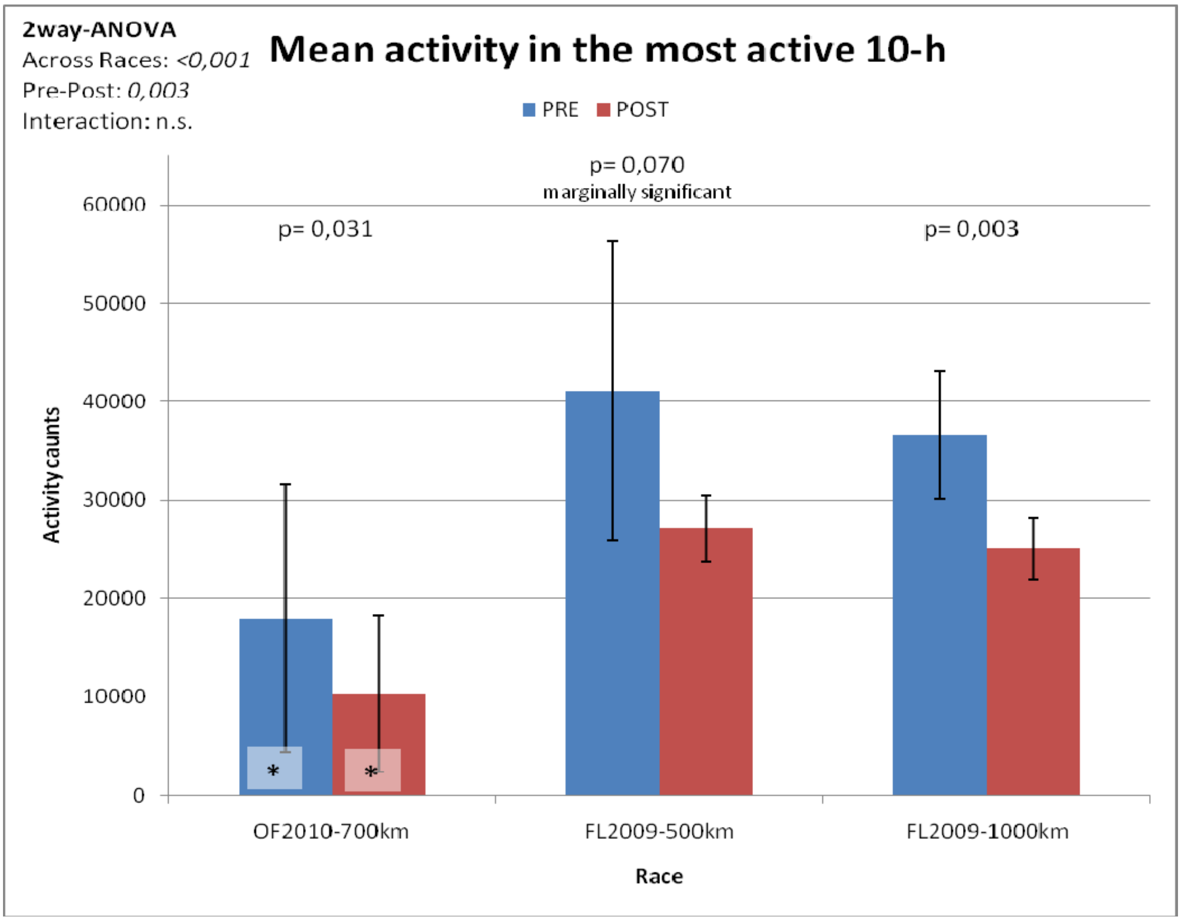


Fig 22 Mean activity during the ten most active hours (M10)
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The values refer to 3 continuous periods of 24-h before (PRE) and after (POST) the competition**.** (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009).* = t-test statistically significant (*p<0,05*) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

2-way ANOVA found a statistically significant variation across races and between PRE and POST. The post-hoc analysis shows that all the races' competitors lead to decrease their M10 after the competition, even if such a decrease is anly marginally significant for the 500km-mushers. Moreover, the post-hoc analysis found statistically significant differences between the OffroadFinnmark bikers and both 500km- and 1000km mushers, in both PRE and POST conditions. These lower activity levels might be related to the midnight-sun period, during which the bikers have been monitored. A possible influence of the daylight condition could be an interesting topic of future research.

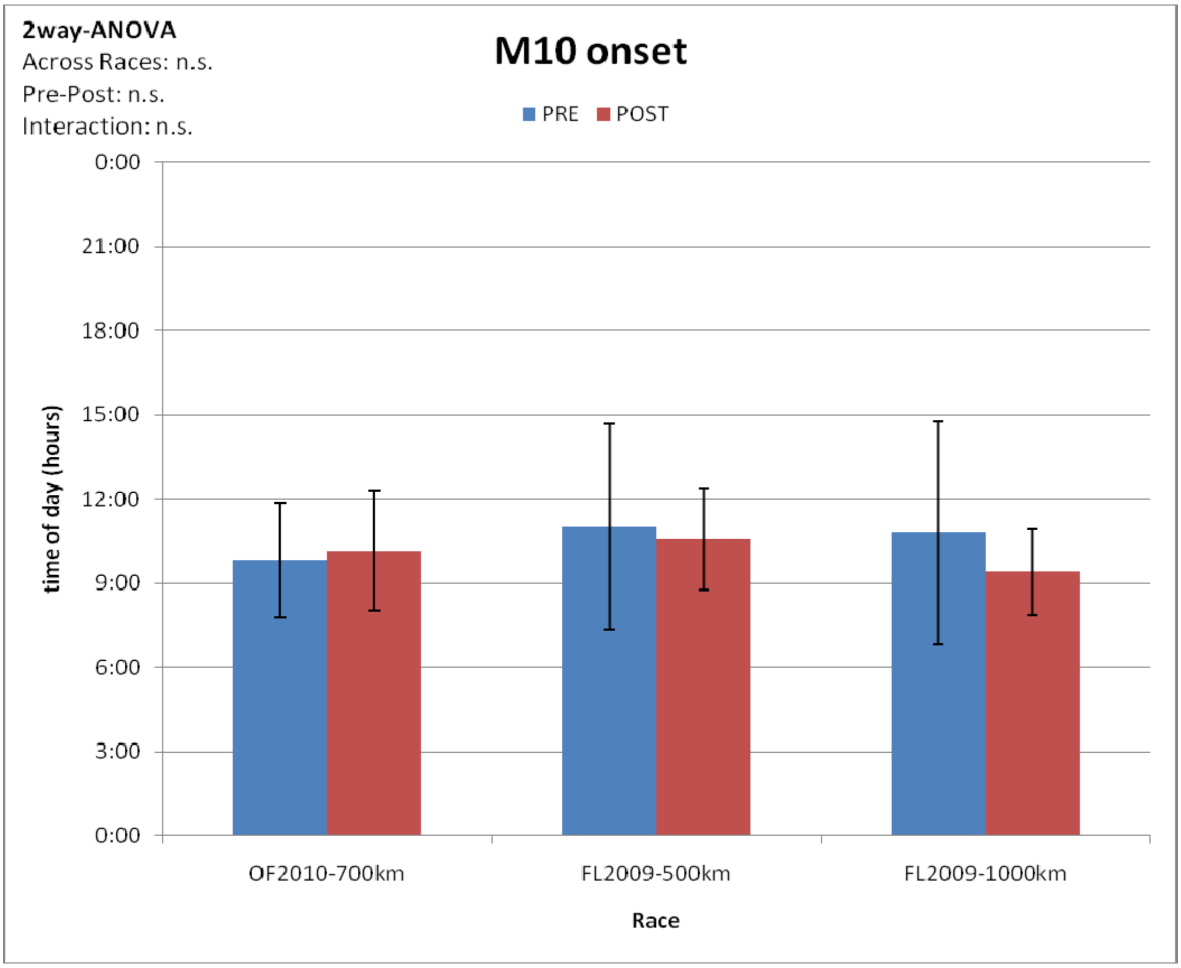


Fig 23 M10 onset (M10)
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The values refer to 3 continuous periods of 24-h before (PRE) and after (POST) the competition**.** (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). * = t-test statistically significant (*p<0,05*) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

No statistically significant variations of the M10 onset were found by 2-way ANOVA. Looking at the M10onset values, no relevant differences across races and between PRE and POST are evident.

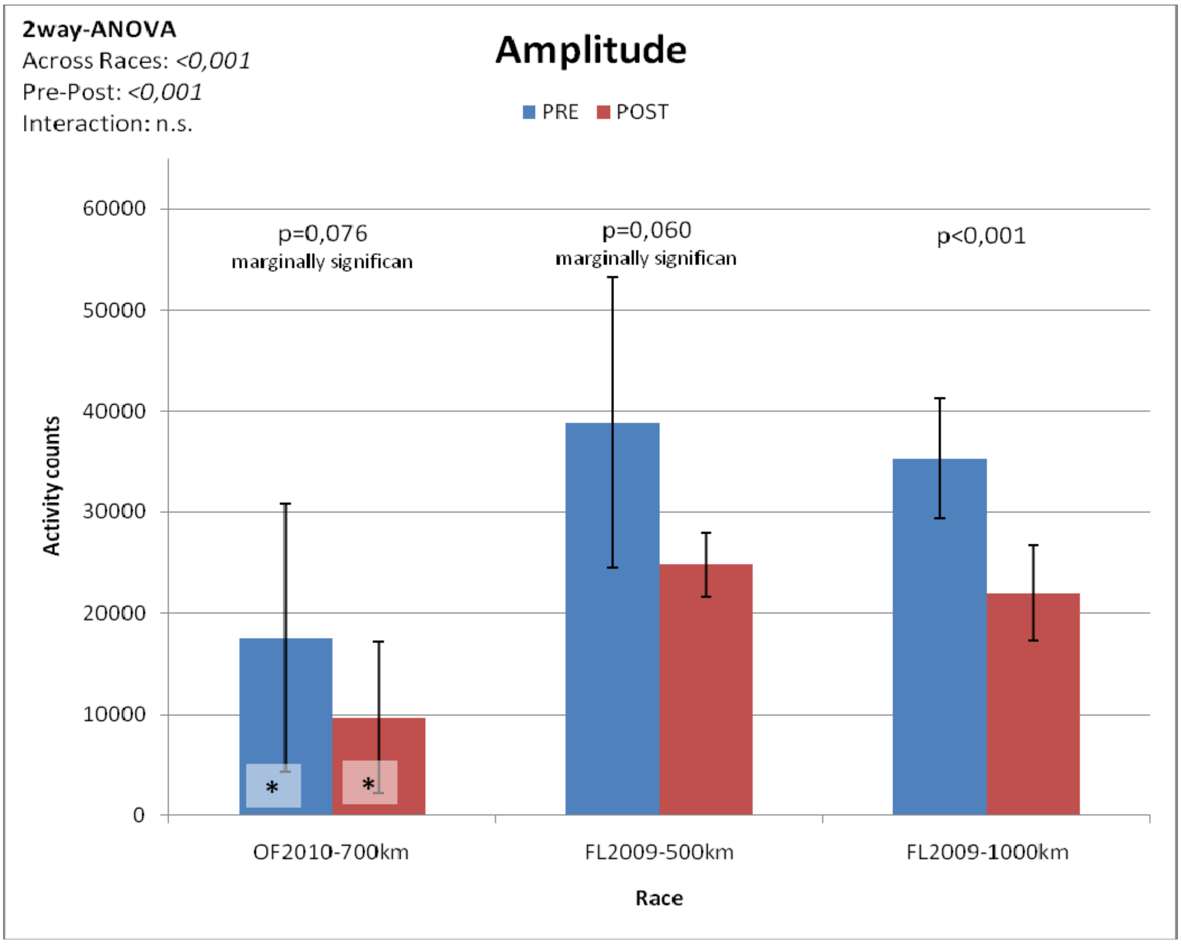


Fig 24 Amplitude (Amp)
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The values refer to 3 continuous periods of 24-h before (PRE) and after (POST) the competition**.** (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). * = t-test statistically significant ($p<0,05$) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

2-way ANOVA found strong statistically signifant differences of Amplitude across both races and PRE/POST. Looking at the values, it seems that the Amplitude values lead to decrease after the competition for all the races' competitors. Anyway, as shown by the post-hoc analysis, for bikers and 500km-mushers such reduction is only marginally significant, while statistical significance is chieved for 1000km-mushers. Moreover, the bikers' Amplitude values are significantly lower compared with the 500km- and 1000km-mushers, in both PRE and POST. This seems quite natural, since bikers had also low L5 and M10 values.

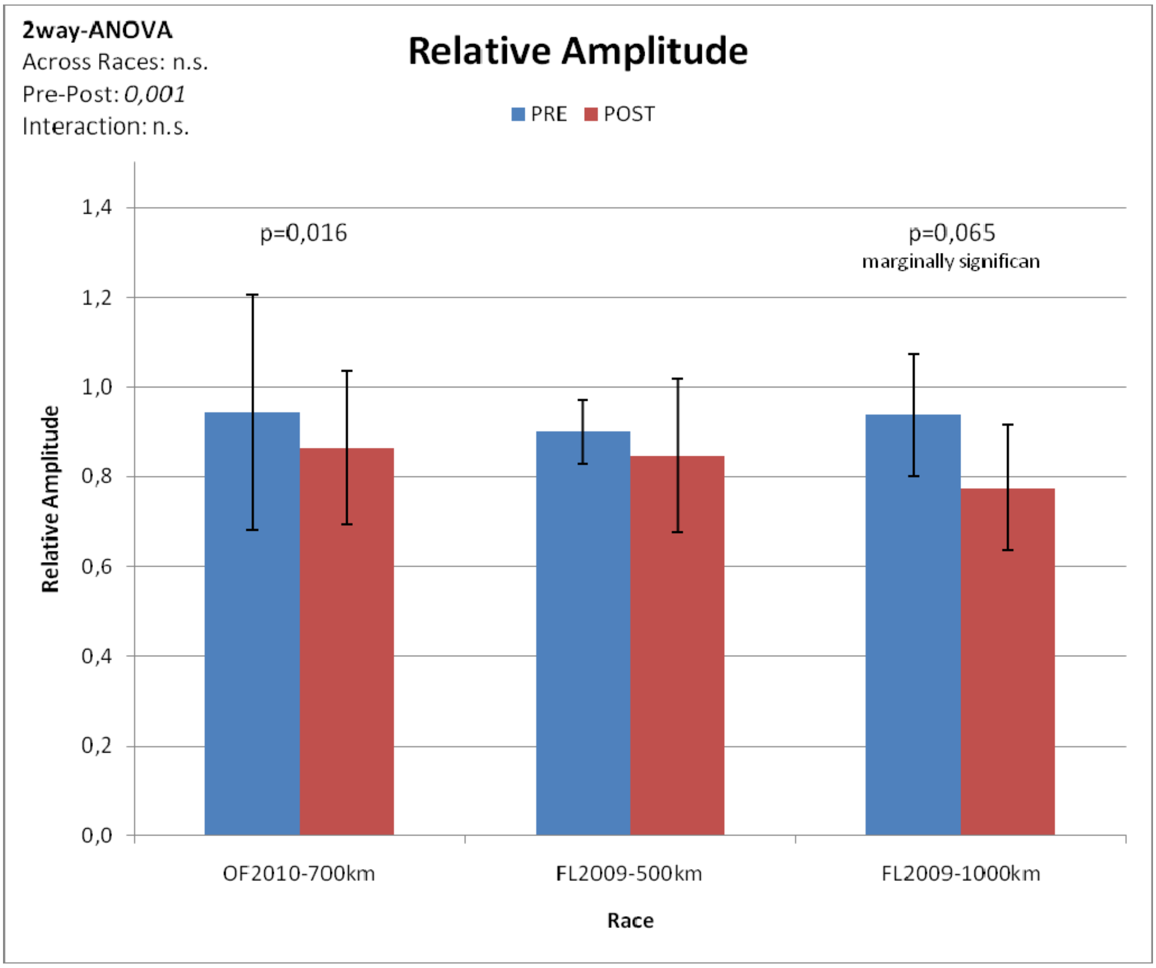


Fig 25 Relative Amplitude
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The values refer to 3 continuous periods of 24-h before (PRE) and after (POST) the competition**.** (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). * = t-test statistically significant (*p<0,05*) when the * is on a single column, it means that value is significantly different compared with the other two races; when the * is on two or more columns, it means that those values are different with each other.

2-way ANOVA found statistically a significant PRE/POST variation of Relative Amplitude. Looking at the data, there is apparently a tendency towards a reduction of the Relative Amplitude values after all the competitions, even if there are quite large inter-individual differences (SDs). The post-hoc analysis found statistically and marginally significant differences for bikers and 1000km-mushers, respectivelly, while significance is not achieved for 500km-mushers.

4. SLEEP ANALYSIS

Data Processing

The actigraphy data were run into the Sleep Analysis function of the CNT software. For each subject, the Sleep analysis for each single night was performed (6 nights for each subject: 3 nights PRE and 3 night POST).

In our previous work (Calogiuri, et al., 2011), we used 5 nights after the race in the analyses. The bikers had a shorter POST-monitoring compared with the mushers, so in this report only the first 3 night following the arrival have been used for the mushers as well, in order to make it comparable with the bikers.

Data Analysis

2-way ANOVA was performed with SPSS 17.00. The single values for the different night, for both PRE and POST, were run into the analyses (bikers N=18; mushers-500km N=15; mushers-1000km N=15). The values were run as follow:

- Dependent variable = NPCRA parameters: IS, IV, L5, L5onset, M10, M10onset, Amplitude and Relative Amplitude (a 2-way ANOVA was performed for each parameter).
- Independent variables = PRE/POST (3 nights for each subject for both PRE and POST); RACE (OffroadFinnmark-700km, Finnmarksløpet-500km, Finnmarksløpet-1000km).

Post-hoc analysis:

- OVERALL PRE vs. POST comparisons were performed by a paired 2 tailed t-test. PRE and POST values were not averaged, but 3 nights for each subject for both PRE and POST were used (bikers N=18; mushers-500km N=15; mushers-1000km N=15).
- Night-by-Night PRE/POST comparisons were performed by 2 tailed t-test (assuming identical variance) comparing all the PRE nights (3 nights for each subject all together) with the single POST nights (Night 1, Night 2 and Night 3)
- Cross-comparisons were performed for all the possible combinations by 2 tailed t-test; before t-test was applied, the data were tested for homogeneity by f-test: if f-test was significant, the t-test was set as a comparison between two non-homogeneous groups.

Because of the little sample size, which is also dissimilar between bikers and mushers (6 vs. 5), marginally significant results ($0,05<p<0,08$) have been reported and discussed.

All the analysis results and graphs are collected in the file “Sleep Analysis-OF2010.xls” and “Sleep Analysis-OF2010_post-hoc.xls, while the ANOVA results are collected in doc. files in folder named “ANOVA_Sleep Analysis”.

Results

Table 7 Sleep Analysis
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010 are shown. The values refer to 3 nights before and after the competition for each group (mean values for 3 nights).

	OF2010-700km (N=18)			**FL2009-500km (N=15)**			**FL2009-1000km (N=15)**		
	PRE		**POST**	**PRE**		**POST**	**PRE**		**POST**
Sleep Start **2way-ANOVA** Across Races: n.s. Pre-Post: 0,001 Interaction: n.s.	0:22 ±28’	*	1:42 ±1h 8’	0:37 ±56’		0:55 ±1h 25’	0:16 ±74’		1:42 ±2h 36’
Sleep End **2way-ANOVA** Across Races: 0,003 Pre-Post: <0,001 Interaction: n.s.	8:02 ±53’	*	9:10 ±1h 35’	7:04 ±46’	§	8:01 ±1h 42’	6:59 ±42’	*	8:26 ±1h 32’
Actual Sleep time **2way-ANOVA** Across Races: 0,003 Pre-Post: n.s. Interaction: n.s.	7h 09’ ±36’		6h 54’ ±1h 48’	5h 48’ ±1h 4’		6h 19’ ±1h 49’	6h 3’ ±1h 16’		5h 32’ ±1h 34’
SE **2way-ANOVA** Across Races: 0,002 Pre-Post: *0,054* Interaction: 0,032	90,8 ±5,3		90,5 ±5,8	87,8 ±5,8		87,1 ±6,4	88,8 ±2,9	*	80,4 ±10,8
SL **2way-ANOVA** Across Races: 0,012 Pre-Post: n.s. Interaction: n.s.	15’ ±16’		11’ ±11’	9’ ±15’		5’ ±13’	4’ ±7’		01’ ±02’
MAS **2way-ANOVA** Across Races: 0,003 Pre-Post: 0,047 Interaction: *0,070*	4,16 ±3,1		5,42 ±4,5	6,50 ±5,1		6,03 ±3,6	6,58 ±3,1	§	12,80 ±9,7
M&F index **2way-ANOVA** Across Races: n.s. Pre-Post: <0,001 Interaction: 0,031	27,1 ±8,8		32,7 ±13,0	30,0 ±10,7		37,6 ±13,6	21,3 ±8,2	*	45,4 ±23,4

(MEANS±SD)
OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009).
§ = overall PRE/POST t-test marginally significant (*0,05<p<0,08*).
* = overall PRE/POST t-test statistically significant (*p<0,05*)

Table 8 Sleep Analysis - Post-hoc Analysis*

The values refer to 3 nights before and 3 night after the competition for each group (OffroadFinnmark N=18; Finnmarksløpet-500km N=15; Finnmarksløpet-1000km N=15).

	S start *p*	S end *p*	AS time *p*	SE *p*	SL *p*	MAS *p*	M&F index *p*
t-test PRE							
OF-700 vs. FL-500	n.s.	*0,003*	*<0,001*	n.s.	n.s.	n.s.	n.s.
OF-700 sv. FL-1000	n.s.	*0,003*	*0,019*	n.s.	*0,029*	*§ 0,053*	n.s.
FL-500 vs. FL-1000	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*0,032*
t-test POST							
OF-700 vs. FL-500	n.s.	*§ 0,70*	n.s.	n.s.	n.s.	n.s.	n.s.
OF-700 sv. FL-1000	n.s.	n.s.	*0,034*	*0,005*	*0,005*	*0,017*	*0,085*
FL-500 vs. FL-1000	n.s.	n.s.	n.s.	*§ 0,063*	n.s.	*0,026*	n.s.

* 2 tailed t-test, after the data have been tested for homogeneity by f-test § marginally significant (*0,05<p<0,08*).

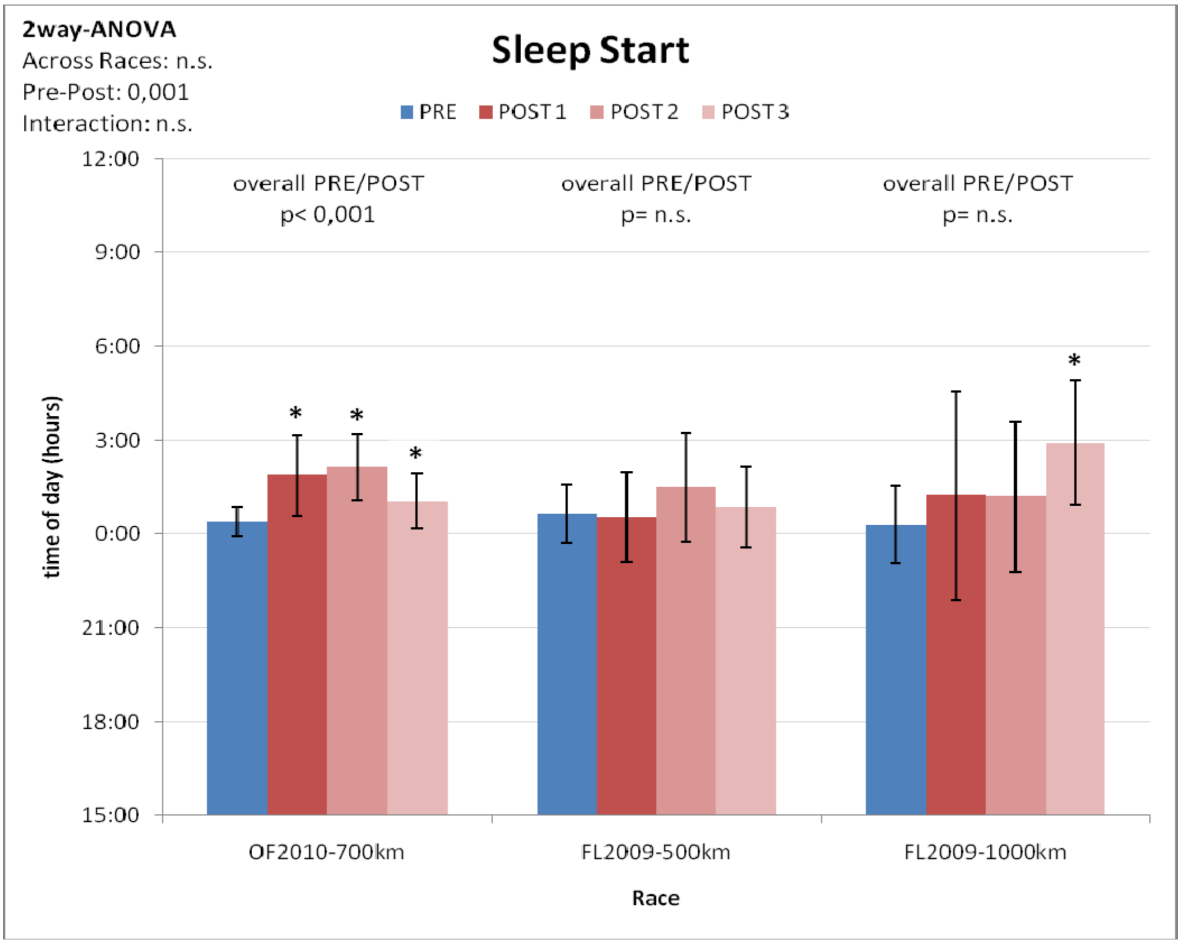


Fig 26 Sleep Start
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The PRE values are means of the 3 nights before the race, while the POST values refer to the single night after the competition. (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). overall PRE/POST = PRE/POST analysis (2 tailed t-test) comparing the PRE values (3 nights before the race-start) with POST values (3 night following the arrival) for each group. * above the columns = night-by-night PRE/POST analysis comparing the PRE values (3 nights) with POST 1, POST 2 and POST 3 (1th, 2th and 3th night after the arrival, respectively).

2-way ANOVA found a significant PRE/POST variation, with no interaction. Looking at the data it seems that there is a generale trend to have a delayed Sleep Start after all the competitions (moslty for the bikers and the 1000km-mushers). Anyway, the post-hoc analysis found significant differences only for the O.F. bikers (overall PRE/POST and all the night after the race), while for the 1000km-mushers the delay was significant only the 3th night (POST 3)

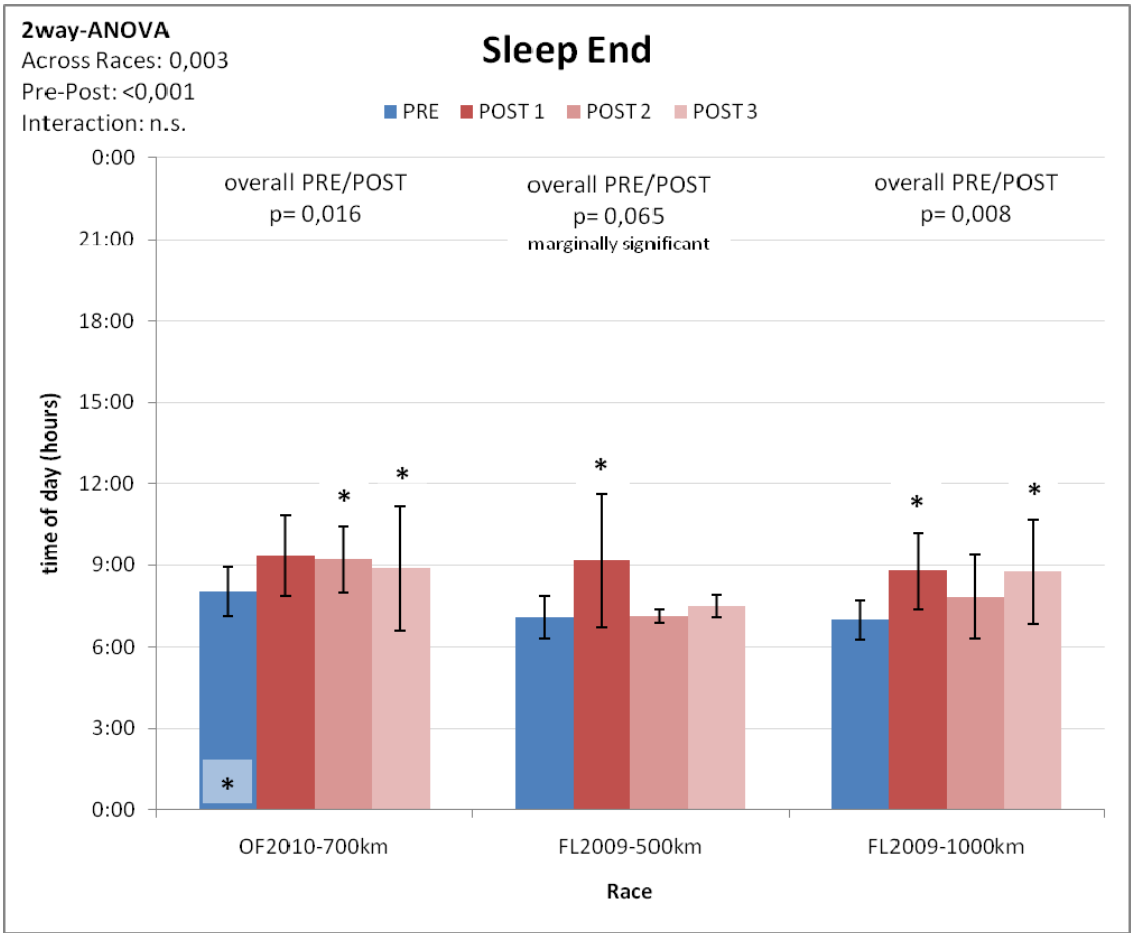


Fig 27 Sleep End
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The PRE values are means of the 3 nights before the race, while the POST values refer to the single night after the competition.(MEANS±SD) . OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). overall PRE/POST = PRE/POST analysis (2 tailed t-test) comparing the PRE values (3 nights before the race-start) with POST values (3 night following the arrival) for each group. * above the columns = night-by-night PRE/POST analysis comparing the PRE values (3 nights) with POST 1, POST 2 and POST 3 (1th, 2th and 3th night after the arrival, respectively).
colums marked by * = the value is stastistically significant different from the others. If only one column/group of colums is marked, it means that the value/values is/are different compared with both the others values; if two colums are marked (separatelly) it means that the difference was found just between those two values.

2-way ANOVA found significant variation across races and across PRE/POST. The post-hoc analysis moslty show a significant delay of S End among all the 3 POST-nights for bikers and 1000km-mushers, while 500km-mushers had a significant delay of S End only the first night after the arrival (POST 1). Also, the bikers were found having a sligthly later Sleep End in PRE, compared with the mushers.

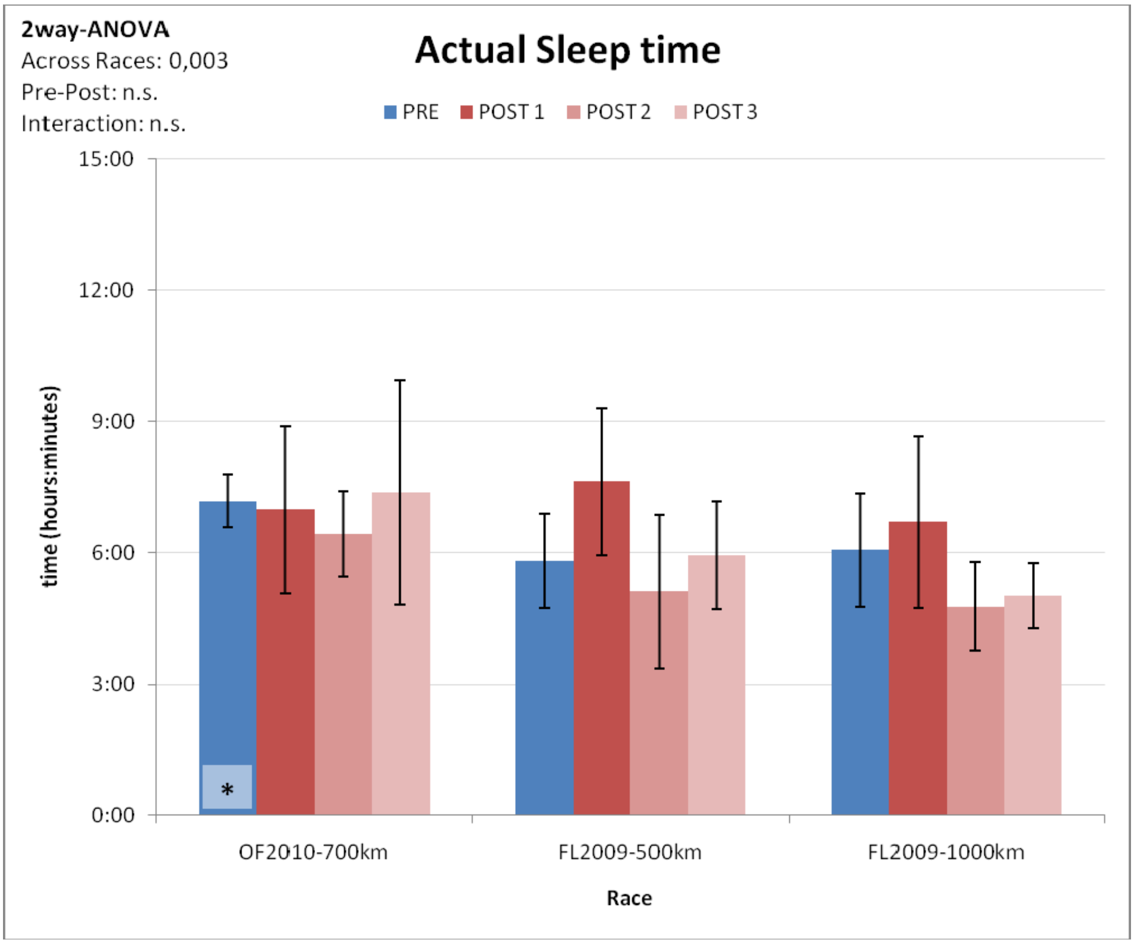


Fig 28 Actual Sleep time
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The PRE values are means of the 3 nights before the race, while the POST values refer to the single night after the competition. (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). colums marked by * = the value is stastistically significant different from the others. If only one column is marked, it means that the value is different compared with both the others values; if two colums are marked (separatelly) it means that the difference was found just between those two values.

2-way ANOVA found a significant variation across races. The post-hoc analysis found that the source of the variation was a longer AS-time for the bikers in PRE, compated with both the categories of mushers. No significant PRE/POST variation were found.

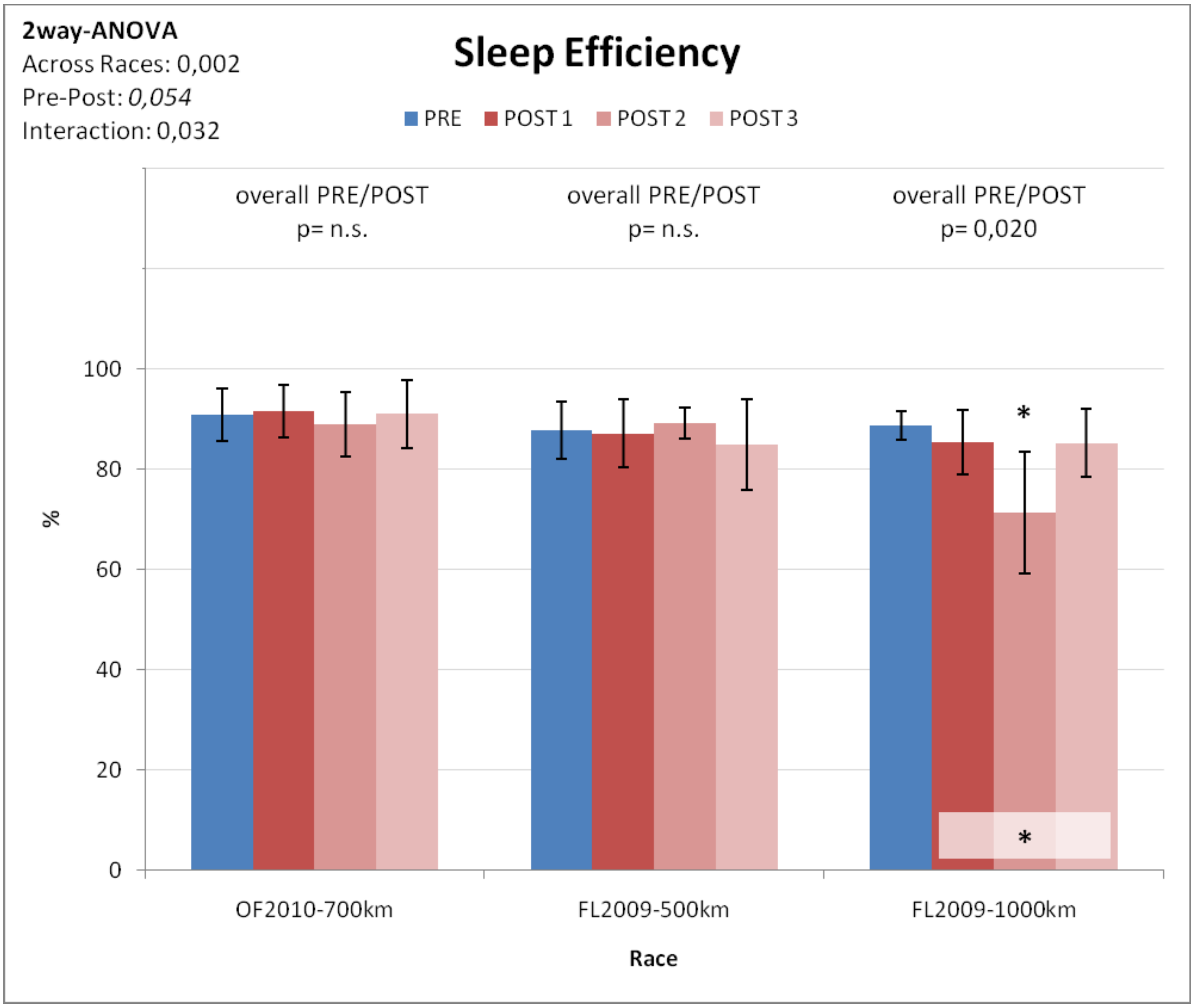


Fig 29 Sleep Efficiency
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The PRE values are means of the 3 nights before the race, while the POST values refer to the single night after the competition. (MEANS±SD) . OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). overall PRE/POST = PRE/POST analysis (2 tailed t-test) comparing the PRE values (3 nights before the race-start) with POST values (3 night following the arrival) for each group. * above the columns = night-by-night PRE/POST analysis comparing the PRE values (3 nights) with POST 1, POST 2 and POST 3 (1th, 2th and 3th night after the arrival, respectively). colums marked by * = the value is stastistically significant different from the others. If only one group of colums is marked, it means that the values are different compared with both the others values; if two colums are marked (separatelly) it means that the difference was found just between those two values.

2-way ANOVA found significant and marginally significant (p= 0,054) variation across races and PRE/POST, respectively. Also a statistically significant inteaction was found. The post-hoc analysis clearly indicates that SE reduced after the race only for the 1000km mushers, as a significant overall PRE/POST difference was found for the 1000km-mushers only and that their SE in POST is significantly lower compared with the bikers and the 500km-mushers.

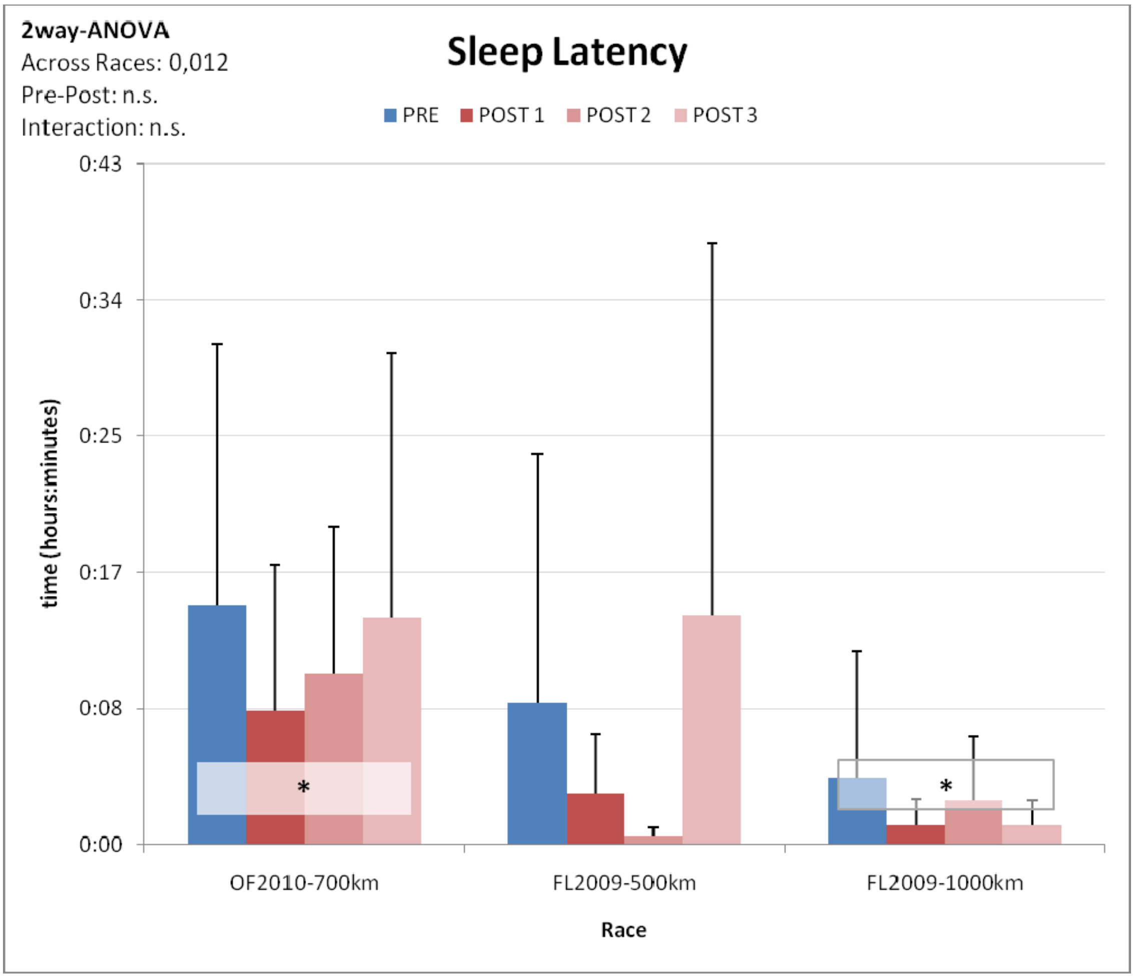


Fig 30 Sleep Latency
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The PRE values are means of the 3 nights before the race, while the POST values refer to the single night after the competition. (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). Colums marked by * = the value is stastistically significant different from the others. If only one group of colums is marked, it means that the values are different compared with both the others values; if two colums are marked (separatelly) it means that the difference was found just between those two values.

2-way ANOVA found significant variation across races and no significant PRE/POST variation, nor significant interaction. Looking at the data and the results from the post-hoc analysis, it seems that the bikers have generally higher SL values. Anyway the large SDs, due by a large inter-individual variability, have to be taken into account.
(N.B. the negative SD lines were removed because made the graph quite messy)

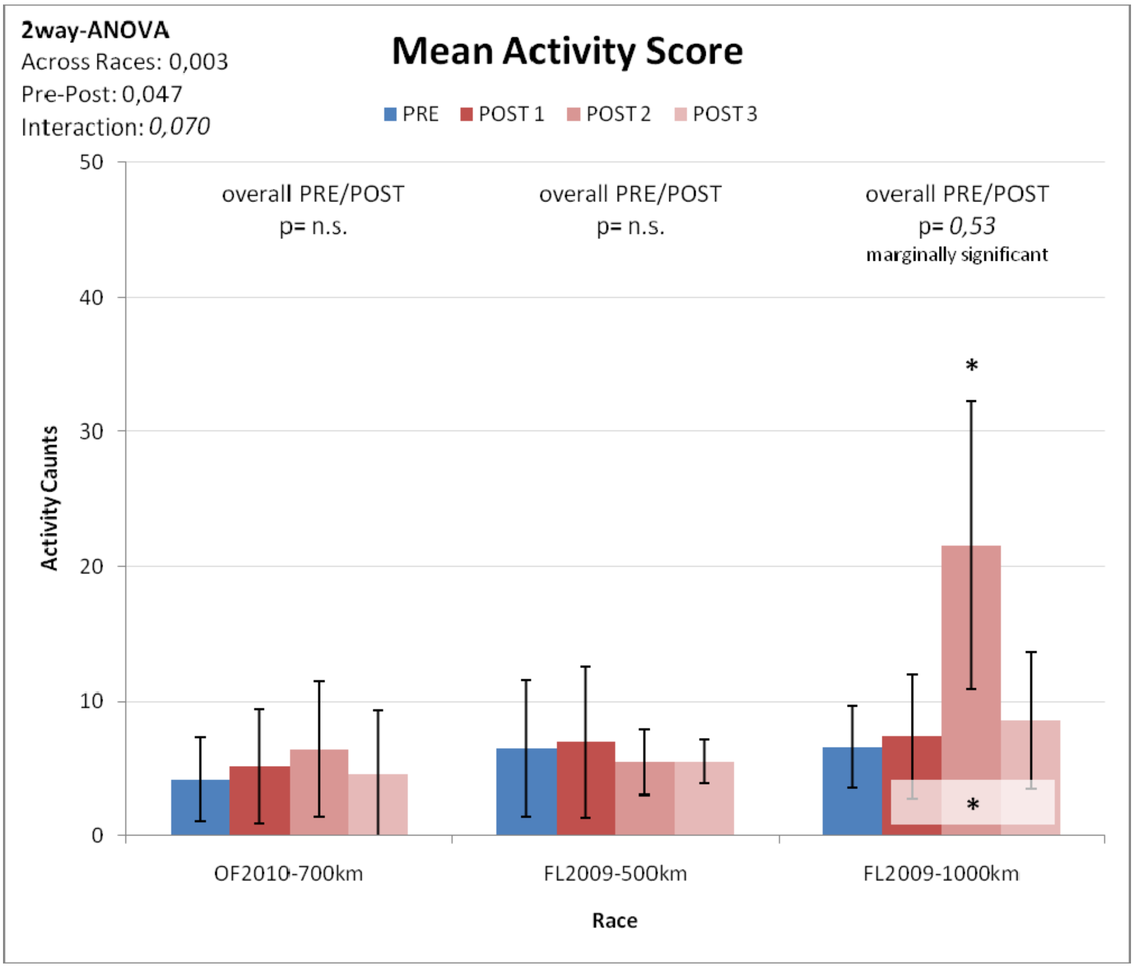


Fig 31 Mean Activity Score
Mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The PRE values are means of the 3 nights before the race, while the POST values refer to the single night after the competition. (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). overall PRE/POST = PRE/POST analysis (2 tailed t-test) comparing the PRE values (3 nights before the race-start) with POST values (3 night following the arrival) for each group.* above the columns = night-by-night PRE/POST analysis comparing the PRE values (3 nights) with POST 1, POST 2 and POST 3 (1th, 2th and 3th night after the arrival, respectively).
colums marked by * = the value is stastistically significant different from the others. If only one group of colums is marked, it means that the values are different compared with both the others values; if two colums are marked (separatelly) it means that the difference was found just between those two values.

2-way ANOVA found significant variation across races and PRE/POST, and a marginally significant interaction. The post-hoc analysis (overall PRE/POST, night-by-night and cross comparisons) seems to indicate that the MAS values were worsened only for the 1000km-mushers after the competition, mostly within the second night after the arrival (POST 2).

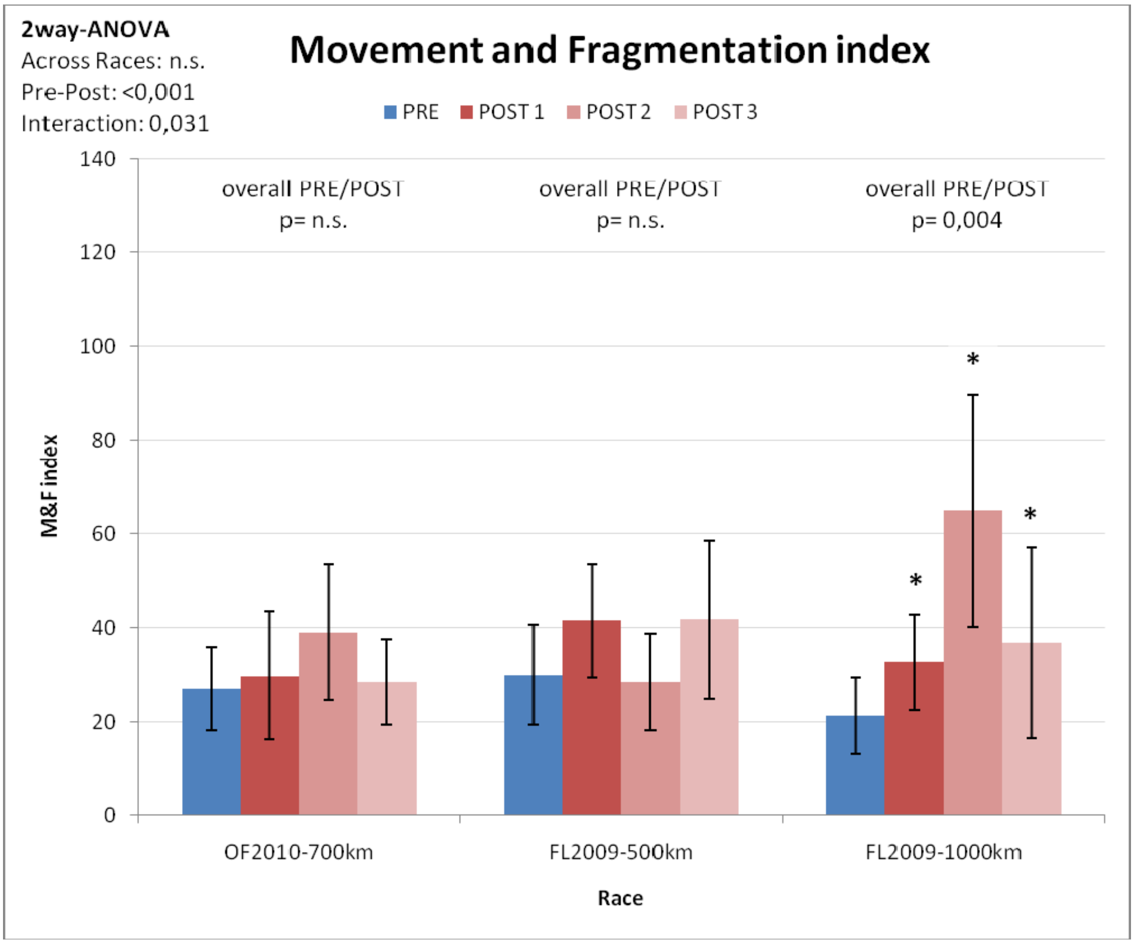


Fig 32 Movement and Fragmentation index
Movement and Fragmentation index (M&Fi) values* of mushers participating at the Finnmarksløpet in 2009 and bikers participating at the OffroadFinnmark 2010. The PRE values are means of the 3 nights before the race, while the POST values refer to the single night after the competition. (MEANS±SD) OF2010-700km = OffroadFinnmark, 700km category (data from 2010); FL2009-500km = Finnmarksløpet, 500km category (data from 2009); FL2009-1000km = Finnmarksløpet, 1000km category (data from 2009). overall PRE/POST = PRE/POST analysis (2 tailed t-test) comparing the PRE values (3 nights before the race-start) with POST values (3 night following the arrival) for each group. * above the columns = night-by-night PRE/POST analysis comparing the PRE values (3 nights) with POST 1, POST 2 and POST 3 (1th, 2th and 3th night after the arrival, respectively).

2-way ANOVA foun significant variation across PRE/POST and a significant interaction. Looking at the data, it seems that the competitors of all the races lead to increase their M&Fi after the competition, expecially for the 1000km-muahers. The post.hoc analysis actually show significant PRE/POST difference only for the 1000km-mushers, with a significant higher M&Fi during all the 3 nights after the race.

5. GENERAL CONCLUSIONS

Rhythm stability (IS and IV)

IS represents the stability of the rest-activity rhythm across the days. IS decreases after the competition only for the 1000km mushers. This suggests that the interdaily stability might be altered more by a longer period of irregularity of the sleep-wake patterns, rather than intensive physical activity.

IV represents the stability of the monophasic pattern that typically characterize the adults' sleep-wake cycle. Differently than IS, IV seems to be more influenced after those competitions with high intensity workloads, such the 500km Finnmarksløpet and the OffroadFinnmark.

Activity levels (Activity Average, L/D ratio, L5, M10 and Amplitude)

The Activity Average seems to decrease after all the races.

M10, which represent the activity values during the daytime, reduce after the race among all the competitors, but the degree of the reduction seems to be related with the race length: it is definitively relevant for the 1000km-mushers, quite relevant but smaller for the bikers, and only marginally significant for the 500km-mushers.

L5, which represent the amount of movement during the nocturnal hours, lead to increase after the race for bikers and 1000km-mushers, even if full significance is not achieved, while it does not seem altered for the 500km mushers.

No significant differences were found for L/D ratio, while Amplitude (as both "absolute" and relative Amplitude), which represent the degree of the activity levels' periodicity, lead to decrease after the race among all the competitors, with an apparent major effect related to the length of the race.

Summarizing, the daytime activity levels seem to decrease after the race while the night-time activity levels seem to increase, with an apparent effect related to the length of the race (the longer is the race, the more the rhythm amplitude is affected).

Rhythm Phase (Cosine Peak, L5onset, M10onset, S start and S end)

Cosine Peak seems to be slightly delayed after all the competitions, especially for the 500km-mushers. Also L5onset seems to be slightly delayed after all the competitions, while no relevant variations are evident for M10onset.

S-start leads to delay within all the groups, especially for the bikers and the 1000km-mushers (500km-mushers show quite weak delay of S start). S-end, which represent the wake-up time, is significantly delayed after all the competitions as well, even if the 500km mushers show a significant delay only the first day, returning to PRE wake-up time the following two days. These evidences indicate the presence of a mild (about 1-2 hours) forward phase shift induced by the competitions.

Sleep Quality (SE, MAS and M&Findex)

The analysis show that SE, MAS and M&Findex worsened after the competition only for the 1000km-mushers. This might assume that the quality of the sleep is mostly negatively influenced by a long period of sleep deprivation and disruption of the sleep-wake patterns, rather than a shorter period with intensive physical activity (OffroadFinnmark bikers). The 500km-mushers and the OffroadFinnmark bikers went through a period of sleep deprivation and disruption of the sleep-wake patterns which was about 3-day and 4-day long respectively, while the 1000km-mushers competed for about 6 days. We can therefore suppose that it is after such a length of time with sleep deprivation and disruption of the sleep-wake patters that the sleep quality will be seriously altered.

Characteristic of the different races - type of work and time of year

OffroadFinnmark, 500km Finnmarksløpet and 1000km Finnmarksløpet are competitions which are all extremely physically demanding, but the different competitions make the participats facing different challenges. All of these competition, which last from 3 up to 6 days, induce a state of sleep deprivation and disruption of the sleep-wake patterns, with in average 4-5 hours of rest/sleep per day.

The OffroadFinnmark requires a very high intensity of physical workload, as the bikers recorded an average HR that was a little more that 60% of their HRpeak. Some of the bikers, in some of the legs, even kept for long time up to 80-85% of their HRpeak. Therefore this competition require a long-term resistance to high intensity workloads.

The Finnmarksløpet-1000km seems to require a lower intensity of physical worklad, as the mushers recorded an average HR that was about 50% of their HRpeak during the legs. On the other hand, this is the longest competition and the study on the HR profile during the check-point shows that the mushers are physically active for most of the time they spent in the the check points. Therefore, the Finnmarksløpet-1000km is definetly the competition which induce the highest degree of sleep deprivation and sleep-wake patterns. Also, the extreme environmental condition during which the Finnmarksløpet takes place (e.g. very low temperature, risk of snow-storms, etc.) represent a big challenge that must to be taken into

account. Strategy and psychological factors (such as determination) are fundamental issues for participating at this competition.
The Finnmarksløpet-500km is the shortest within these three competition, nevertheless it is not the “easiest”. It seems The Finnmarksløpet-500km can be comparable to the OffroadFinnmark in terms of physical worload. Differently than the OffroadFinnmark and the Finnmarksløpet-1000km, the workload during the Finnmarksløpet-500km seems to have an higher degree of intermittance, requiring form the mushers a good resistance to intermittant workloads. This has to be combined with the challenging environmental conditions that characterize the Finnmarksløpet-1000km.
The statistics on the actigraphy data indicats that the rest-activity rhythm is differently influenced by the different competitions. Could there be an influence from the different light conditions? The Offroad Finnemark takes place during the midnight sun period, where there is no darkness during the night.
In their PRE values the OffroadFinnmark bikers show significantly lower levels of IS, even below the healthy adult population reference (around 0.6), and general lower levels of activity (L5 and M10) compared with the mushers, whom were monitored during the regular daylight-darkness periodicity (March). The bikers’ Amplitude values are also significantly lower compared with the mushers; anyway, when considering amplitude in terms of Relative Amplitude, there are no statistically significant differences between bikers and mushers.
Concerning the bikers quality of sleep, the sleep analysis found only a slightly longer AS time and SL, compared with the mushers. Bikers’ average AS time in PRE was about 8-hours, while mushers’ AS was about 6-hours. The experts recommend sleeping at least 7-8 hours per night, therefore it might be said that actually the bikers had a healthier duration of sleep, compared with the mushers. SL should be within the 15 minutes. The bikers’ SL in PRE showed a very large interindividual variability, with values ranging between 5 and 50 minutes. Mushers’ SL seems to be generally lower, with less and apparently isolated cases of SL longer than 10-15 minutes. A longer SL is likely to be related with the midnight-sun period, since the exposure to daylight up to the late hours of the day might inhibit the melatonin secretion.
Anyway, these assumptions need to be confirmed by a specific research aiming to look at seasonal variations of the rest-activity rhythm, possibly comparing populations living below and above the circumpolar.

CONCLUSIONS

The long lasting physical activity with fragmented sleep showed that

1) There is a mild phase delay for all athletes: bikers in the 700km off-road biking as well as mushers in the 500km and 1000km dogsled races, and no free-running.
2) There are changes in the rhythm's structure, shown as reduced amplitude. There are significant differences between the races and the reduction seems to be greatest in the race with the largest sleep loss (1000km).
3) An increased fragmentation of the sleep circadian pattern is shown only for the mushers participating in the shortest dogsled race (500km), a tendency is shown for the bikers in the 700km off road biking race.
4) Reduced sleep quality is shown only for the longest competition the 1000km dogsled race.

Appendix 1

Non-Parametric Circadian Rhythm Analysis (NPCRA)
Parameters and Relative Description.

Parameter	Abbrev.	Description
Interdaily Stability	IS	quantifies the degree of resemblance between the activity patterns on individual days; ranges from 0 to 1 and may typically be about 0.6
Intradaily Variability	IV	quantifies the fragmentation of periods of rest and activity; ranges from 0 to 2 and typically is below 1, with higher values indicating a more fragmented rhythm
L5	L5	the five least active hours in the 24-hour cycle (average of the activity values)
L5 onset	L5 onset	onset time of the five most restful hours
M10	M10	the ten most active hours in the 24-hour cycle (average of the activity values)
M10 onset	M10 onset	onset time of the ten most active hours
Amplitude	AMP	difference between M10 and L5
Relative Amplitude	RA	calculated by dividing AMP by the sum of L5 and M10; ranges from 0 to 1, with higher values indicating higher amplitude of the rhythm
Activity Analysis		
Activity Average	Act Ave	average of the activity values in the 24-hour cycle
Darkness/Light ratio	D/L ratio	ratio between the activity values in periods of light and darkness (default light/darkness periodicity: 6.00-18.00)
Cosine Peak	CP	time of day in which the peak of the activity values is identified
Sleep Analysis		
Sleep Start, **Sleep End**	S start S end	identified by the program in relation to the bed-time and wake-time provided by the subjects
Actual Sleep Time	AS time	total amount of effective sleep time
Sleep Efficiency	SE	percentage of effective sleep during time in bed
Mean Activity Score	MAS	average score of movements during sleep length
Movement and Fragmentation Index	M&Fi	index indicating the level of restlessness during sleep, based on movements and calculated fragmentation of sleep

REFERENCES

Ancoli-Israel, S., Cole, R., Alessi, C., Chambers, M., Moorcroft, W., & Pollak, C. P. (2003). The role of actigraphy in the study of sleep and circadian rhythms. *Sleep, 26*(3), 342-392.

Atkinson, G., Edwards, B., Reilly, T., & Waterhouse, J. (2007). Exercise as a synchroniser of human circadian rhythms: an update and discussion of the methodological problems. *Eur J Appl Physiol, 99*(4), 331-341.

Barger, L. K., Wright, K. P., Jr., Hughes, R. J., & Czeisler, C. A. (2004). Daily exercise facilitates phase delays of circadian melatonin rhythm in very dim light. *Am J Physiol Regul Integr Comp Physiol, 286*(6), R1077-1084.

Boivin, D. B., Duffy, J. F., Kronauer, R. E., & Czeisler, C. A. (1994). Sensitivity of the human circadian pacemaker to moderately bright light. *J Biol Rhythms, 9*(3-4), 315-331.

Buijs, R. M., van Eden, C. G., Goncharuk, V. D., & Kalsbeek, A. (2003). The biological clock tunes the organs of the body: timing by hormones and the autonomic nervous system. *J Endocrinol, 177*(1), 17-26.

Burgess, H. J., & Eastman, C. I. (2006). A late wake time phase delays the human dim light melatonin rhythm. *Neurosci Lett, 395*(3), 191-195.

Buxton, O. M., Lee, C. W., L'Hermite-Baleriaux, M., Turek, F. W., & Van Cauter, E. (2003). Exercise elicits phase shifts and acute alterations of melatonin that vary with circadian phase. *Am J Physiol Regul Integr Comp Physiol, 284*(3), R714-724.

Calogiuri, G., Beldo, S., Roveda, E., Montaruli, A., Carandente, F., & Weydahl, A. (2009). Training time and adaptation to lack of daylight: a case report. *Sport Science for Health, 5*(1).

Calogiuri, G., Weydahl, A., & Roveda, E. (2011). Effects of sleep loss and strenuous physical activity on the rest-activity circadian rhythm: a study on 500km and 1000km sled-dog racers. *Biological Research for Nursing., Accepted for publication*

Carandente F, M. A., Roveda E, Calogiuri G, Michielon G, La Torre A (2006). Morning or evening training: effect on heart rate circadian rhythm. *Sport Science for Heath, 1*(3), 113-117.

Delaunay, F., Thisse, C., Marchand, O., Laudet, V., & Thisse, B. (2000). An inherited functional circadian clock in zebrafish embryos. *Science, 289*(5477), 297-300.

Dijk, D. J., & Lockley, S. W. (2002). Integration of human sleep-wake regulation and circadian rhythmicity. *J Appl Physiol, 92*(2), 852-862.

Edgar, D. M., Dement, W. C., & Fuller, C. A. (1993). Effect of SCN lesions on sleep in squirrel monkeys: evidence for opponent processes in sleep-wake regulation. *J Neurosci, 13*(3), 1065-1079.

Elmenhorst, E.-M., Elmenhorst, D., Luks, N., Maass, H., Vejvoda, M., & Samel, A. (2008). Partial sleep deprivation: Impact on the architecture and quality of sleep. *Sleep Medicine, 9*(8), 840-850.

Gay, C. L., Lee, K. A., & Lee, S. Y. (2004). Sleep patterns and fatigue in new mothers and fathers. *Biol Res Nurs, 5*(4), 311-318.

Halberg, F., Carandente, F., Cornelissen, G., & Katinas, G. S. (1977). [Glossary of chronobiology (author's transl)]. *Chronobiologia, 4 Suppl 1*, 1-189.

Halberg, F., Vallbona, C., Dietlein, L. F., Rummel, J. A., Berry, C. A., Pitts, G. C., et al. (1970). Human circadian circulatory rhythms during weightlessness in extraterrestrial flight or bedrest with and without exercise. *Space Life Sci, 2*(1), 18-32.

Hsu, D. S., Zhao, X., Zhao, S., Kazantsev, A., Wang, R. P., Todo, T., et al. (1996). Putative human blue-light photoreceptors hCRY1 and hCRY2 are flavoproteins. *Biochemistry, 35*(44), 13871-13877.

Jin, X., Shearman, L. P., Weaver, D. R., Zylka, M. J., de Vries, G. J., & Reppert, S. M. (1999). A molecular mechanism regulating rhythmic output from the suprachiasmatic circadian clock. *Cell, 96*(1), 57-68.

Knutsson, A. (2003). Health disorders of shift workers. *Occup Med (Lond), 53*(2), 103-108.

Lee, K., Loros, J. J., & Dunlap, J. C. (2000). Interconnected feedback loops in the Neurospora circadian system. *Science, 289*(5476), 107-110.

Littner, M., Kushida, C. A., Anderson, W. M., Bailey, D., Berry, R. B., Davila, D. G., et al. (2003). Practice parameters for the role of actigraphy in the study of sleep and circadian rhythms: an update for 2002. *Sleep, 26*(3), 337-341.

Mischler, I., Vermorel, M., Montaurier, C., Mounier, R., Pialoux, V., Pequignot, J. M., et al. (2003). Prolonged daytime exercise repeated over 4 days increases sleeping heart rate and metabolic rate. *Can J Appl Physiol, 28*(4), 616-629.

Miyazaki, T., Hashimoto, S., Masubuchi, S., Honma, S., & Honma, K. I. (2001). Phase-advance shifts of human circadian pacemaker are accelerated by daytime physical exercise. *Am J Physiol Regul Integr Comp Physiol, 281*(1), R197-205.

Montaruli, A. (2005). *A short program of moderate physical activity don't modify the heart rate circadian synchronization*. Paper presented at the AIESEP World Congress

Plautz, J. D., Kaneko, M., Hall, J. C., & Kay, S. A. (1997). Independent photoreceptive circadian clocks throughout Drosophila. *Science, 278*(5343), 1632-1635.

Reebs, S. G., Lavery, R. J., & Mrosovsky, N. (1989). Running activity mediates the phase-advancing effects of dark pulses on hamster circadian rhythms. *J Comp Physiol A, 165*(6), 811-818.

Reebs, S. G., & Mrosovsky, N. (1989a). Effects of induced wheel running on the circadian activity rhythms of Syrian hamsters: entrainment and phase response curve. *J Biol Rhythms, 4*(1), 39-48.

Reebs, S. G., & Mrosovsky, N. (1989b). Large phase-shifts of circadian rhythms caused by induced running in a re-entrainment paradigm: the role of pulse duration and light. *J Comp Physiol A, 165*(6), 819-825.

Sack, R. L., Auckley, D., Auger, R. R., Carskadon, M. A., Wright, K. P., Jr., Vitiello, M. V., et al. (2007). Circadian rhythm sleep disorders: part I, basic principles, shift work and jet lag disorders. An American Academy of Sleep Medicine review. *Sleep, 30*(11), 1460-1483.

Santhi, N., Horowitz, T. S., Duffy, J. F., & Czeisler, C. A. (2007). Acute sleep deprivation and circadian misalignment associated with transition onto the first night of work impairs visual selective attention. *PLoS One, 2*(11), e1233.

Totterdell, P., Reynolds, S., Parkinson, B., & Briner, R. B. (1994). Associations of sleep with everyday mood, minor symptoms and social interaction experience. *Sleep, 17*(5), 466-475.

van der Horst, G. T., Muijtjens, M., Kobayashi, K., Takano, R., Kanno, S., Takao, M., et al. (1999). Mammalian Cry1 and Cry2 are essential for maintenance of circadian rhythms. *Nature, 398*(6728), 627-630.

Van Dongen, H. P., Maislin, G., Mullington, J. M., & Dinges, D. F. (2003). The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep, 26*(2), 117-126.

Van Reeth, O., Sturis, J., Byrne, M. M., Blackman, J. D., L'Hermite-Baleriaux, M., Leproult, R., et al. (1994). Nocturnal exercise phase delays circadian rhythms of melatonin and thyrotropin secretion in normal men. *Am J Physiol, 266*(6 Pt 1), E964-974.

van Someren, E. J., Hagebeuk, E. E., Lijzenga, C., Scheltens, P., de Rooij, S. E., Jonker, C., et al. (1996). Circadian rest-activity rhythm disturbances in Alzheimer's disease. *Biol Psychiatry, 40*(4), 259-270.

Van Someren, E. J., Lijzenga, C., Mirmiran, M., & Swaab, D. F. (1997). Long-term fitness training improves the circadian rest-activity rhythm in healthy elderly males. *J Biol Rhythms, 12*(2), 146-156.

Weydahl, A. (2007). *Forskningsprosjektet: Hundekjørerne under Finnmarksløpet; Available from: <http://www.finnmarkslopet.no/autoweb/fl/dok/Artikkel1.pdf>* Alta, Norway: Finnmark University College.

Whitmore, T. C. (2001). Drug test warning. *Nature, 411*(6838), 633.