Physiological Changes During a 20-Day Winter Military Training Course and its Subsequent 10-Day Recovery Period Among Finnish Paratroopers

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ABSTRACT

Purpose: *To investigate physiological changes in Finnish paratroopers during a 20-day winter military training course and the following 10-day recovery period.*

Methods*: Fifty-eight (age 19±1 years, height 182±6 cm, body mass 78.5±7.2 kg) male soldiers participated in a 20-day military field training course with two phases. The first phase consisted of basic skills training (skiing, shooting etc.) lasting 10 days in winter conditions, while the second phase started with a parajump with equipment into the arctic wilderness and continued with reconnaissance and other military tasks lasting 10 days. The training course ended with survival training and a strenuous ski march (24 h). During the training course, the subjects practiced and applied their military and survival skills in the cold environment and were exposed to strenuous physical and psychological stress. Body composition, shooting and performance tests were measured as well as serum biomarker levels (testosterone, TES; cortisol, COR; sex-hormone binding globulin, SHBG; insulin-like growth factor-1, IGF-1; creatine kinase, CK; and C-reactive protein; CRP). were analyzed four times (PRE=day 0; MID=day 10; POST=day 20; RECO=day 30) during the study) In addition, questionnaires were collected daily for subjective sleep amount and rate of perceived exertion.*

Results: *The course induced significant declines in body (-3.9%, $p<0.05$) and fat mass (31.6 %, $p<0.05$) as well as in all assessed physical performance variables (-9.2 - -20,2 %, $p<0.05$), and TES (-73.7 %, $p<0.001$) and IGF-1 concentrations (-43.6, $p<0.001$). At the same time, the SHBG, CK, CRP values increased significantly (46.3 - 1952.7 %, $p<0.05$) After the 10 - day recovery period, body composition and hormonal* *values returned to the baseline ($p<0.05$), but physical performance variables, such as explosive force production for the upper and lower body remained unrecovered. Contrary, 2-min sit-ups and the evacuation test were recovered during the 10-day recovery period ($p<0.05$).*

Conclusion: *The 20-day strenuous winter military training caused drastic decline in physical performance even for highly physically fit soldiers, and the 10-day recovery period did not establish full recovery. Explosive force production remained unrecovered, whereas hormone concentrations and body composition recovered fully.*

Operational relevance: *When planning field training exercises or operational missions, it is important to know how long it takes soldiers to recover from different kinds of strains. Even though the body is fully recovered in terms of body composition or hormonal concentrations, physical performance can still be under recovered, especially the nervous system and the capability to produce power. If this trend continues, symptoms of overtraining and risk of injury may increase.*

1.0 INTRODUCTION

Military operations are performed in climatic environments ranging from extreme hot (40°C) to extreme cold (-40°C) conditions. The weather (cold or hot) is not a barrier to perform physical activity. Today´s battlefield requires soldiers to have appropriate strength and anaerobic capacity to fulfil the occupational requirements of high intensity movements with heavy load carriage in various environments (Kraemer & Szivak 2012, Friedl et al. 2015).

As seen in Figure 1, operations in arctic environment place soldiers even higher psychological and physiological stressors and can include also drastic energy deficit and sleep restriction as well as extreme weather conditions. When operating in cold environment these stressors can have even a bigger role, due to the weight of cold protective clothes and other equipment or decreased dexterity caused by gloves. Although the soldiers are exposed to cold air, critical decrease in core temperature can be avoided with appropriate winter clothing (Castellani & Tipton 2015). Downside to this is increased total weight carried, every extra kilogram increases energy expenditure by 3 % and every extra layer of clothes by 4 % (Rintamäki 2007).

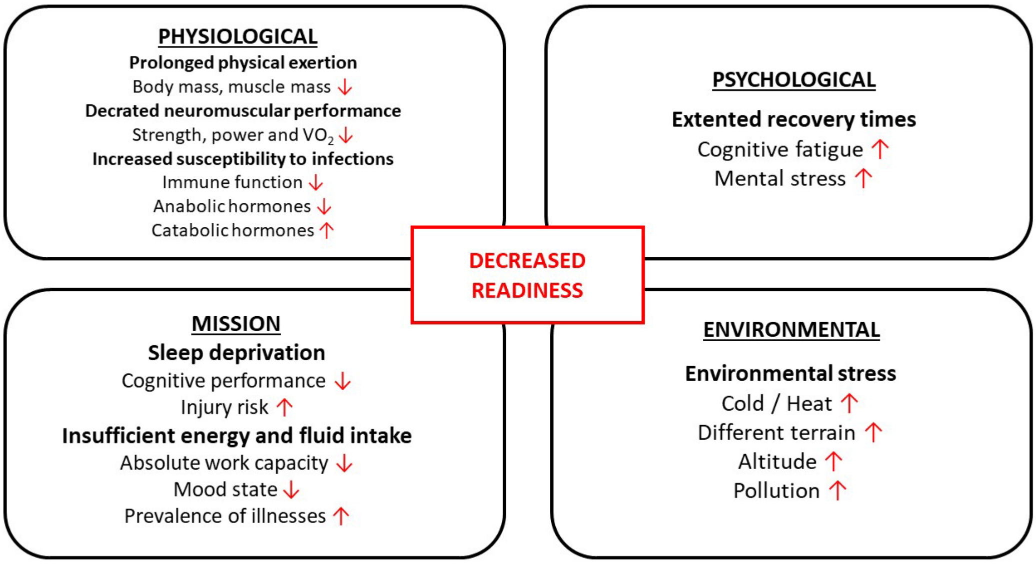

Figure 1: Physiological, Psychological, Mission, and Environmental factors affecting soldier's readiness (Church et al. 2019; Henning et al. 2011; Nindl et al., 2013; Pihlainen 2022).

Hackney et al. (1991) found that four-day military field training both in hot and cold environment had a negative effect on anaerobic performance measured with Wingate-test. Although cold environment caused larger changes in all measured variable, especially when compared to relative body weight. Also, creatine kinase and lactate values were higher after military training in the cold. Cold environment impacts physical performance in several ways. For example, it causes changes in cardiovascular function, nerve conduction, and skeletal muscle contraction. These changes can be seen as a degreed aerobic, anaerobic, and strength / power performance, although the impact of cold exposure on physical performance has not been studied thoroughly. (Castellani & Tipton 2015).

Cahill et al. (2011) have reported that decline in core temperature decreased the ability to produce maximal force, but on the other hand slowed down the fatigue caused by repeated contraction. Galloway and Maughan (1997) studied the effect of temperature on aerobic performance and found that the best performance was achieved at 11° C. Higher and lower temperatures resulted a shorter time to exhaustion in bike test. Similar drop in aerobic performance was observed by Sandsund et al. (2012), although in their studies the highest time to exhaustion was performed at -4° C. The difference in Galloway and Maughan (1997) and Sandsund et al. (2012) studies can be at least partly explained by clothing. In Galloway and Maughan (1997) the subjects wore shorts and t-shirts as in Sandsund et al. (2012) the subjects wore cross-country skiing clothes, which have offered an insulating layer against cold weather. Cold environment has also been found to lower maximal oxygen uptake (VO_2 max). Oksa (2002) reported, that oxygen consumption was higher in submaximal treadmill running in the cold air, and also VO_2 max was lower in maximal test.

When thinking about the mechanisms that limit aerobic exercise performance and maximal oxygen uptake in the cold Castellani & Tipton (2015) have listed the following:

1) Temperature (lower deep body temperature, decreased muscle temperature, reduced skin temperature).
2) Metabolism (increased lactate, low glucose levels, fasting, increased VO2 / reduced economy).
3) Central / peripheral circulation (reduced maximal HR => 10 to 30 beats, when body temp is 0.5-2.0 lower, lower cardiac output, reduced muscle blood flow => 30 to 40 % reduction after cold-water immersion).

Similar performance reductions in cold exposure are found for anaerobic, strength, and power performance. Cold affects significantly strength performance and the ability to produce power by decreased contraction speed, decreased nerve conduction velocity, increased joint velocity, increased co-activation of agonist-antagonist muscle pairs, increased EMG activity, and enhanced fatigue (Castellani & Tipton 2015). Giesbrecht et al. (1995) showed that local muscle temperature is the driver for decreased strength. Oksa et al. (1997) found that the flight time in rebound jump declined after 60-min exposure to 27, 20, 15, and 10 ° C air. Davies & Young (1983) studied the effect of cold on the force-velocity curve, and found leftward shift in the curve, demonstrating that with colder muscles any given force output the velocity is less during cycling exercise. Cold exposure also seems to degrade the ability to maintain both static and dynamic balance (Castellani & Tipton 2015).

2.0 METHODS AND DESIGN

The study was conducted during a winter military exercise in northern Finland above the Arctic circle. The exercise consisted of two phases (Figure 2); the first phase included basic skills training (skiing, shooting etc.) lasting 10 days in winter conditions, while the second phase started with a parajump with all their equipment into the arctic wilderness and continued with reconnaissance and other military tasks lasting 10 days. At the end of the training course participants performed a strenuous ski march (24 h). During the MFT, the subjects practiced and applied their military and survival skills in the cold environment and were exposed to strenuous physical and psychological stress. The aim of the study was to investigate physiological changes in Finnish paratroopers during a 20-day winter military training course and the following 10-day recovery period.

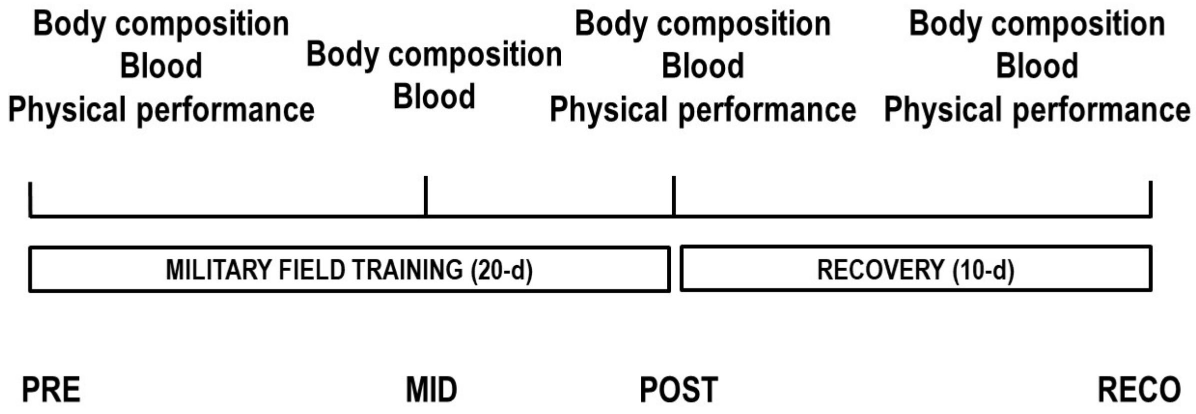

Figure 2: Study design and measurement points.

The weather data during the exercise was collected from the Finnish Meteorological Institute (https://en.ilmatieteenlaitos.fi/download-observations) and are shown in Table 1 for the beginning of exercise (0 – 10 d), the later part of the exercise (11 – 20 d), and for the whole exercise (0 – 20 d).

Table 1: Weather details during the exercise.

	0 - 10 d	11 - 20 d	0 - 20 d
Average snow depth (cm)	92	79	85
Average daily temp (°C)	-14.5	-5.2	-9.6
Average daily min temp (°C)	-6.5	-0.7	-3.5
Average daily max temp (°C)	-22.6	-12.8	-17.5

2.1 Participants and Questionnaires

Total of fifty-eight (age 19±1 years, height 182±6 cm, body mass 78.5±7.2 kg) male soldiers voluntary participated in a 20-day military field training course (MFT).

2.2 Anthropometrics

Body composition and serum hormone concentrations were measured before the MFT, before the most demanding part of the MFT, after the MFT, and 10 days after the MFT (PRE=day 0; MID=day 10; POST=day 20; RECO=day 30). Body composition was assessed via bioimpedance analysis (InBody 720/770, Inbody Company Ltd, Soul, South-Korea) in the morning before breakfast.

2.3 Physical Performance

The subjects also performed a series of physical performance tests including standing and prone shooting (EcoAims Ltd, Ylämylly, Finland), countermovement jump, medicine ball throw, standing broad jump, weighted chin-ups, 2 min sit-ups, and casualty evacuation test (Angeltveit et al. 2016) three times during the study (PRE, POST, and RECO). The tests were performed in a same order in all measurement points.

2.4 Serum Biomarker Levels

Venous blood samples were drawn from the antecubital vein after an overnight fast before breakfast. Serum biomarker levels (testosterone, TES; cortisol, COR; sex-hormone binding globulin, SHBG; insulin-like growth factor-1, IGF-1; creatine kinase, CK; and C-reactive protein; CRP) were measured and analysed four times (PRE, MID, POST, and RECO) during the study).

2.5 Statistics

Statistical analysis were conducted in R v 4.1.2 (R Core Team, 2021) with packages rstatix (CRAN - Package lmerTest (r-project.org)) for ANOVA, and with ggpubr (CRAN - Package ggpubr (r-project.org)) for correlations. All data were checked quantitively and visually for normality and logarithmic transformation were performed for skewed, not-normal variables. Data are presented as means with standard deviation and confidence intervals (95 % CI) when appropriate. The level of significance was set 95 % confidence ($p < 0.05$). Repeated measures analysis of variance was performed for inspecting dependency between measured (logarithmically transformed) test result values on different timepoints. Variances were equal (Levene’s test) on different timepoints (PRE, MID, POST, RECO). All data were examined quantitively and graphically.

3.0 RESULTS

Rate of perceived exertion, sleep time, and NASA-TLX questionnaire were used to evaluate daily subjective physical strain. As you see for Figure 3 the participants felt that the winter military exercise was quite demanding, both physically and mentally.

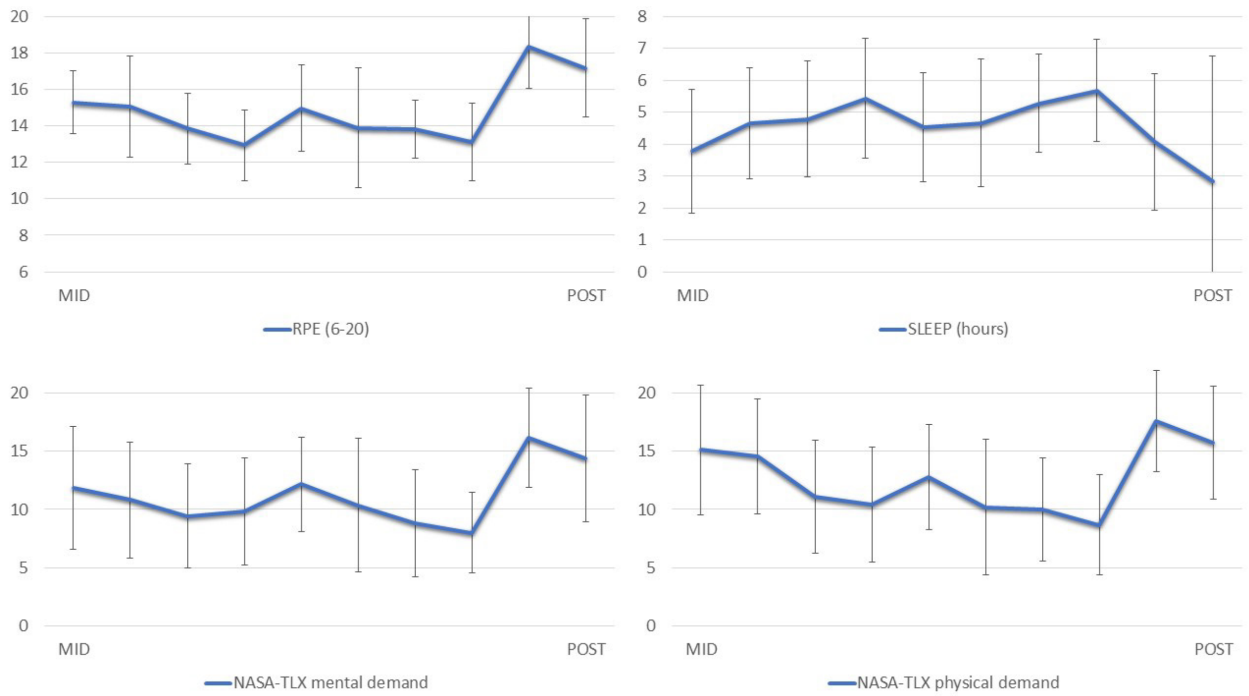

Figure 3: Subjective rating of perceived exertion (RPE), sleep, mental, and physical demand during the last part of the military exercise.

Participants' body weight and fat mass declined during the field training, but recovered to PRE – values after a 10 – day recovery period (Figure 4).

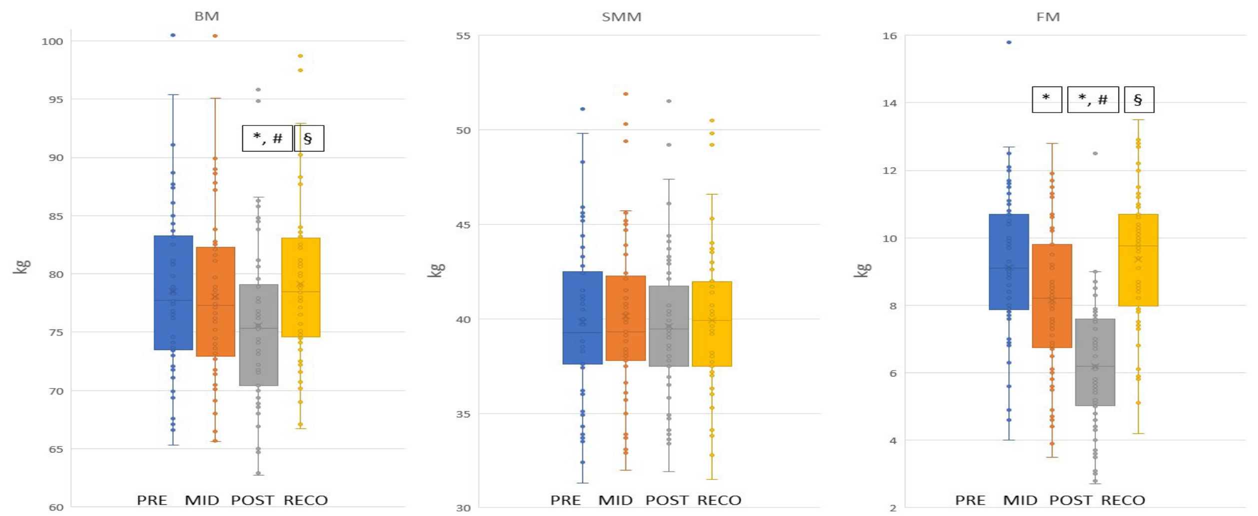

Figure 4: Anthropometric changes during the military exercise. BM=body mass, SMM=skeletal muscle mass, FM=fat mass. * = compared to PRE-value, *=p<0.05; # = compared to MID-value, #=p<0.05; § = compared to POST-value, §=p<0.05.

When looking at the changes in physical performance, there was a significant decline in performance in all measured variables. Sit-ups and evacuation test seemed to recover after 10 – days recovery period, but medicine ball throw, standing long jump, and counter movement jump did not recover to PRE-values after the 10 – day recovery period (Figure 5).

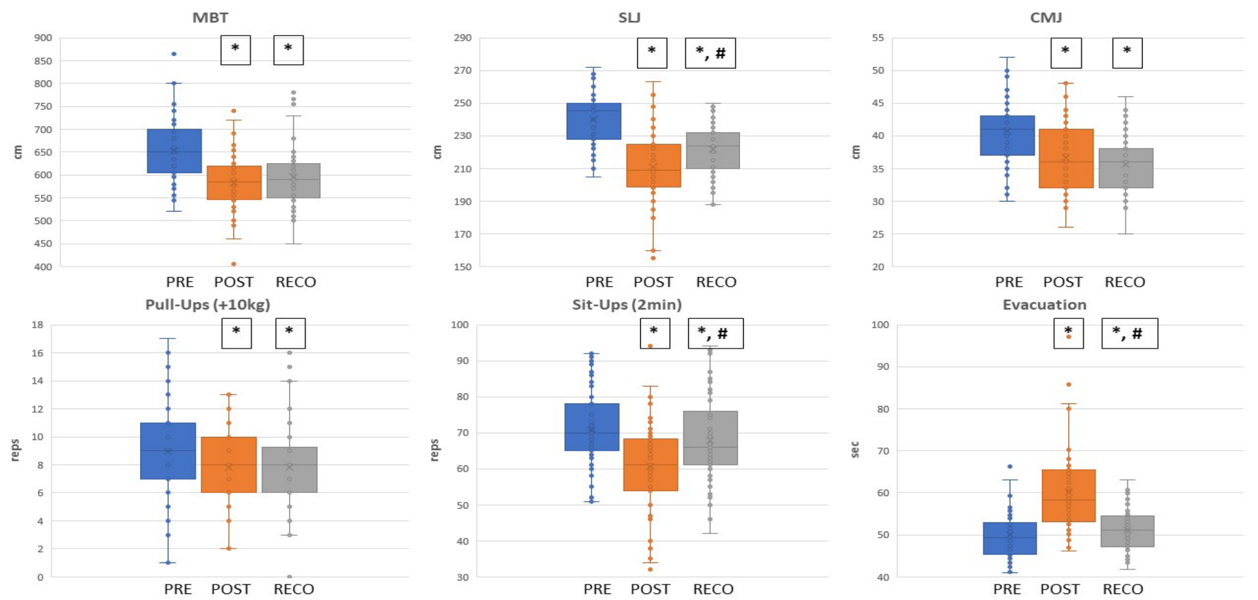

Figure 5: Physical performance changes during the military exercise. MBT=medicine ball throw, SLJ=standing long jump, CMJ=counter movement jump. * = compared to PRE-value, *=p<0.05; # = compared to MID-value, #=p<0.05.

There was significant decline in TES (PRE-POST -72%), and IGF-1 (PRE-POST -43%) values during the winter military exercise and significant increase in SHBG (PRE-POST 45%), CK (PRE-POST 2045 %), CRP (PRE-POST 2408 %). All the measured values returned to PRE-level after a 10 – day recovery period (Figure 6).

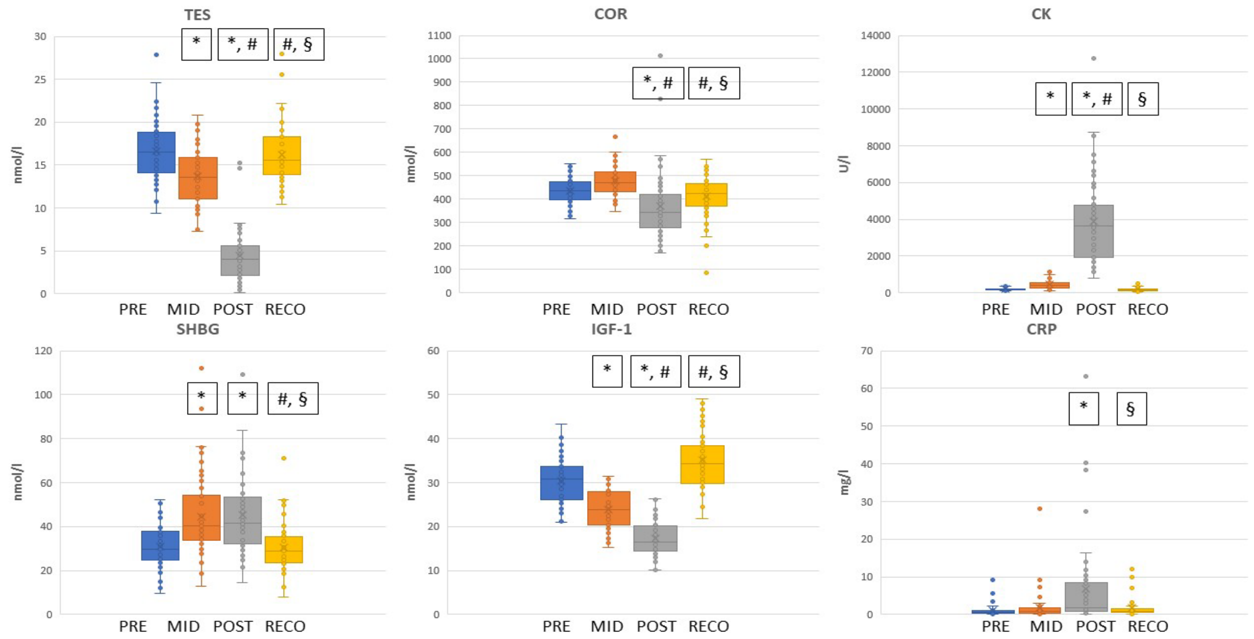

Figure 6: Biochemical changes during the military exercise. TES=testosterone, COR=cortisol, CK=creatine kinase, SHBG=sex hormone binding globulin, IGF-1=insulin like growth factor-1, CRP=c-reactive protein. * = compared to PRE-value, *=p<0.05; # = compared to MID-value, #=p<0.05; § = compared to POST-value, §=p<0.05.

4.0 DISCUSSION

The 20-day strenuous winter military training caused drastic decline in physical performance even for highly physically fit soldiers, and the 10-day recovery period did not establish full recovery in all measured variables. Explosive force production remained unrecovered, whereas hormone concentrations and body composition recovered fully. Previously it has been reported that full hormonal recovery after a strenuous winter expedition to North Pole (Gagnon et al. 2011) occurred after 2 weeks (of recovery). Also, after a 20-day military training in summer conditions, 4 – day recovery period was adequate for return of hormone concentrations to baseline (Ojanen et al. 2018). On the other hand, this kind of physiological stress influences also the circadian cycles of hormones. Although the hormone values may return to baseline quite fast, Opstad (1994) found that after a short but demanding 5–day military training including severe sleep and energy deprivation, the circadian rhythm of different hormones did not return to baseline within 5–day recovery period. This homeostatic disturbance is an important point for future studies to focus on.

In the present study, the decline in physical performance (Figure 6) in POST measurement point was quite drastic in several variables measured. The last part of winter military exercise was very demanding, with a 24-hour ski march at the end. The physical demands of the exercise had negative impact especially to explosive force production in both upper and lower body. Standing long jump declined 12.3%, counter movement jump 9.6%, and medicine ball throw 10.5%. Even the 10–day recovery period could not return these values to PRE-measurement levels. Actually, counter movement jump still declined 2.5% between the POST and RECO measurements. Also, casualty evacuation test time increased by 21.2 % in POST measurement point, but recovered quite close to PRE-value in RECO test (49.7±5.6 s vs. 51.5±5.5 s). Sit-ups and push-ups recovered quite well in 10 days. One reason for this might be the arduous ski march at the end of the winter military training, which might have caused significant muscle damage, that requires weeks of regeneration (Hamarsland et al. 2018). This is an important point to consider when planning for future studies.

When planning field training exercises or operational missions, it is important to know how long it takes that the soldiers to recover from different kinds of strains. Even though the body is fully recovered in terms of body composition or hormonal concentrations, physical performance can still be unrecovered, especially the nervous system and the capability of explosive force production. If this type of high operative stress continues for a longer period of time, symptoms of overtraining and risk of injury may increase and lead to decreased readiness of soldiers. Cold environment increases decline in strength and power performance, and can have a greater effect on soldiers' performance in the battlefield. Also, extreme cold can lead to cold weather injuries, which can decrease soldier's performance even more. These observations of prolonged reductions on physical performance should be considered when planning operational missions and following recovery periods and strategies.

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