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**Title:** Effect of Prolonged Military Field Training on Neuromuscular and Hormonal Responses and Shooting Performance in Warfighters

**Year:** 2018

**Version:** Accepted version (Final draft)

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**Please cite the original version:**

Ojanen, T., Kyröläinen, H., Igendia, M., & Häkkinen, K. (2018). Effect of Prolonged Military Field Training on Neuromuscular and Hormonal Responses and Shooting Performance in Warfighters. *Military Medicine*, 183(11-12), Article e705. <https://doi.org/10.1093/milmed/usy122>

Pages: 23

Words: 3779

Tables: 2

Figures: 1

References: 40

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12 **Effect of prolonged military field training on neuromuscular and hormonal responses and**  
13 **shooting performance in warfighters**  
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45 **KEYWORDS:** Physiology, Endocrinology, Training, Strength, Performance  
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52 **Conflicts of interest:** none  
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55 **Funding:** The study was funded by the Finnish Defence Forces.  
56  
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59 **Acknowledgements:** The authors thank Mrs. Elina Vaara, MSc, for statistical support.  
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## STRUCTURED SUMMARY

### Introduction

Previous studies have shown that Military Field Training (MFT) has effects on warfighters' hormonal responses, neuromuscular performance and shooting accuracy. The aim of the present study was to investigate the changes in body composition, upper and lower body strength, serum hormone concentrations of testosterone (TES) and cortisol (COR), insulin-like growth factor – 1 (IGF-1) and sex hormone binding globulin (SHBG) and shooting accuracy during prolonged MFT.

### Methods

Serum hormone concentrations, isometric strength of the upper and lower extremities and shooting performance were measured four times during the study: before MFT (PRE), after 12 days (MID), at the end of MFT (POST) and after four days recovery (RECO). The study was approved by the Finnish Defence Forces and was granted ethical approval by the Ethical Committee of the University of Jyväskylä.

### Results

There was no change in prone shooting score between the measuring points. In the standing position, however, there was a significant ( $p \leq 0.001$ ) decrease from PRE  $58.2 \pm 12.3$  points to MID  $45.2 \pm 10.4$  points. Also POST  $61.4 \pm 10.8$  points and RECO  $56.8 \pm 13.6$  points were significantly ( $p \leq 0.001$ ) higher than MID  $45.2 \pm 10.4$  points. Serum hormone concentrations of TES and IGF-1 decreased significantly during MFT. In COR and SHBG concentrations significant increases were observed during MFT. Individual changes in lower body strength and changes in shooting standing score between the measurement points (PRE - MID / POST / RECO) correlated significantly ( $r=0.332$ ,  $p=0.031$ ;  $r=0.335$ ,  $p=0.025$ ;  $r=0.489$ ,  $p=0.001$ , respectively). The similar finding was observed with changes in upper body strength and changes in standing shooting between the PRE

1 and RECO measurement points (0.339,  $p=0.010$ ). The changes in COR and the changes in prone  
2 shooting showed a positive correlation in all measurement points ( $r=0.531$ ,  $p\leq 0.001$ ;  $r=0.337$ ,  
3  $p=0.024$ ;  $r=0.572$ ,  $p\leq 0.001$ ). The changes in IGF-1 correlated negatively ( $r=-0.325$ ,  $p=0.038$ ) with  
4 shooting prone between the PRE and MID measurement points. The changes in shooting standing  
5 and the changes in TES between PRE and POST correlated negatively ( $r=-0.378$ ,  $p=0.010$ ).  
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## 10 **Conclusion**

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18 In this study we observed a decrease in leg strength from the PRE to MID measurements. When the  
19 physical load requirements during the MFT decreased after the MID measurements, leg strength  
20 increased. In addition, the shooting score from the standing position decreased from the PRE to MID  
21 measurements and improved significantly from the MID to POST measurements. The prone shooting  
22 score did not show any significant changes during the study period. Significant positive correlations  
23 were found between the changes in standing shooting score and the changes in strength for the legs  
24 and upper body. There was a positive correlation between the changes in serum COR concentrations  
25 and changes in standing shooting score.  
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40 Altogether, the present study showed that the prolonged MFT has adverse effect on the strength levels  
41 and the shooting ability in warfighters. This shows that ensuring warfighters get an appropriate  
42 amount of rest while performing their duties is important. Shooting from a prone position was not  
43 affected by the changing workloads and this result indicated that soldiers should shoot from a prone  
44 position, whenever possible, especially when fatigued.  
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## INTRODUCTION

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4 Warfighters are exposed to physical, environmental and mental stressors when training for military  
5 operations. These stressors include factors such as physical and cognitive fatigue caused as a  
6 consequence of prolonged physical exertion and/or sleep deprivation and insufficient energy and fluid  
7 intake. During military field training (MFT) these factors have shown to cause disruptions in  
8 hormonal balance<sup>1,2,3,4</sup>, leading to reduced physical and cognitive performance<sup>5,6,7,8,9</sup>, extended  
9 recovery times<sup>10</sup> and increased susceptibility to infections<sup>11</sup>. How this kind of environment effects  
10 on warfighters' hormonal responses, neuromuscular performance and shooting accuracy and the  
11 consequences of these stressors and their influence on health, physical performance level and work  
12 capacity of a warfighter are of vital importance to commanders.  
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29 Previous studies have examined various biomarkers in warfighters in relation to nutrition status, fluid  
30 intake, body composition<sup>5,12</sup>, prolonged physical exertion, neuromuscular performance<sup>6,13</sup> and sleep  
31 deprivation<sup>14,15</sup>. Decrements in lower and upper body strength have been demonstrated after a  
32 prolonged MFT. The type of loading is a key determinant to which part of the body becomes fatigued  
33 <sup>2,6,7,13</sup>. In order to carry out daily duties, warfighters must have good muscle strength capability<sup>16</sup>.  
34 Even in the face of technological developments in the military field, the modern warfighters tasks  
35 are, however, physically very demanding. Both lower and upper body strength must be considered:  
36 marching long distances require a warfighter to have a strong lower body, while for lifting and  
37 carrying heavy equipment, a warfighter must have good upper body strength<sup>7,17</sup>. The modern  
38 warfighter needs power and strength as well as aerobic capacity and muscular endurance. The optimal  
39 level of either one is dependent on occupational tasks of a warfighter<sup>18</sup>. Multiple studies have also  
40 demonstrated that strength training and higher strength levels coincide with lower injury levels,  
41 particularly in the lower extremities<sup>19,20</sup>.  
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2 The impact of MFT on hormonal changes is well demonstrated. Cortisol (COR) and sex hormone  
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4 binding globulin (SHBG) concentrations have been shown to increase during prolonged  
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6 MFT<sup>1,3,7,21,22,23</sup>, whereas testosterone (TES) and insulin-like growth factor - 1 (IGF-1) concentrations  
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8 have been shown to decrease<sup>1,6,21,24,25,26,27,28</sup> Friedl et al. (2000) found that during US Army Ranger  
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10 training a warfighter lost 15 % in body mass, 7 % in fat free mass and 65 % of their fat mass. Nindl  
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12 et al. (2006) studied the effects of short term MFT on hormonal responses. The study showed that  
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14 there was a 3 % loss in body mass and 24 to 30 % loss in free TES levels. Kyröläinen et al. (2008)  
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16 found that during the first couple of days of strenuous MFT there was a significant increase in COR  
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18 levels (32 %) and a decrease in TES levels (27 %). Also, SHBG levels have been found to increase  
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20 during basic military training<sup>23</sup> and during heavy and strenuous MFT<sup>26</sup>.

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29 Shooting is one of the most important occupational skills for a warfighter. There is limited  
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31 information regarding shooting performance and how it is affected by prolonged MFT. It has been  
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33 shown that shooting performance differs as a result of different loading intensities<sup>29,30,31,32,33</sup>.  
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35 Warfighters are required to move on the battlefield, and maximizing shot accuracy in a state of  
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37 increased heart rate and fatigue<sup>31</sup>. Several factors affect the accuracy of shooting in warfighters.  
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39 Anxiety has been shown to decrease the accuracy of shooting as well as a negatively impact on  
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41 decision making<sup>34</sup>. Fatigue is also a significant factor affecting marksmanship, especially after  
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43 anaerobic physical strain<sup>30,31,32</sup>. In addition to anxiety and fatigue, sleep deprivation has shown a  
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45 detrimental effect on the shooting accuracy. Research on how prolonged MFT in a multistressor  
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47 environment affects the warfighters shooting performance is lacking<sup>33</sup>.

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56 The aim of the present study was to investigate the changes in body composition, upper and lower  
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58 body strength, serum hormone (TES, COR, SHBG, IGF-1) concentrations and shooting accuracy

during a prolonged MFT. We hypothesized that we would observe declines in all measured variables and the study would provide better understanding of the associations between warfighters physical performance and shooting capability during MFT.

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## **METHODS**

### **Subjects**

Sixty-one (n=61) male subjects volunteered for the present study. Each subject (conscript) was a Finnish Army member conducting infantry training, performed during their six-month mandatory service in the Finnish Defence Forces. Based on exit interviews, twelve individuals dropped out due to discomfort of having to give blood samples and unsustained motivation to participate in the study. Forty-nine subjects between 19 to 22 years of age completed the study. The mean ( $\pm$  standard deviation) age was  $20 \pm 1$  years, height of  $179 \pm 6$  cm, body mass  $73.5 \pm 8.7$  kg and body fat  $12.6 \pm 5.0$  %.

All subjects were fully informed of the experimental design and possible risks, and every subject signed an informed consent before the study commenced. The subjects were informed that they could cancel their participation in the present study at any stage if they so wished without any consequences. This study was conducted according to the provisions of the Declaration of Helsinki and was granted ethical approval by the Ethical Committee of the University of Jyväskylä. The study was also approved by the Finnish Defence Forces.

### **Experimental Design**

A week before MFT, all the subjects were tested for their baseline values. The same tests were also performed on the day 12 of MFT, at the end of MFT and after a recovery period of four days. Blood samples, isometric strength of the upper and lower extremities and shooting performance were recorded during the measurement days.



1 The PRE measurement week was a normal training week for the study participants. Duties included  
2 lectures in the classroom, rifle maintenance and preparation for MFT. The entire 21-day MFT period,  
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4 which was divided into three phases, was performed in field conditions. During the first phase (ST)  
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6 the subjects performed combat drills and live-fire shooting exercises. The goal for each conscript was  
7  
8 to improve their combat and shooting skills and advance their weapon handling abilities. In this phase,  
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10 the aim was not to physically exhaust the conscripts but rather to ensure that each of them maintained  
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12 a high level of performance by ensuring that they had an appropriate amount of rest and sleep. The  
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14 normal training day started at 07:00 hours and ended not later than 19:00 hours.  
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21 In the second phase (MFT), they practiced moving from their base to their attacking positions. The  
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23 tasks performed included reconnaissance, combat maneuvers, patrolling and tactical road marches.  
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26 In the last phase (MFT) they executed combat mission as a part of larger military exercise. The tasks  
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28 were the same as in the second phase. After the prolonged MFT, the subjects had four days of  
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30 recovery, two at home and two at the garrison before the final study measurements were taken.  
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## 36 **Measurements**

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### 41 *Neuromuscular performance*

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43 Maximal isometric strength of the upper and lower extremities was measured with dynamometers.  
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45 The measurements were conducted using a leg and bench press dynamometer manufactured by the  
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47 University of Jyväskylä, Department of Biology of Physical Activity, Finland. The knee angle was  
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49 set to 107 degrees<sup>35</sup>. During the maximal strength test for upper extremities the equipment was  
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51 adjusted for each subject so that when in sitting position with their feet flat on the floor their arms  
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53 were parallel to the floor and the elbow angle was 90 degrees. The test was performed by pushing the  
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55 bar horizontally. The subjects were given one trial attempt before the two actual test trials were  
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conducted on both leg extension and bench press. The subjects were instructed to produce maximal force as fast as possible in both leg extension and bench press. On all trials, the testing personnel encouraged them vocally during the maximal effort. The best performance was selected for analysis.

### *Serum Hormone concentrations*

Venous blood samples were drawn four times from the antecubital vein after an overnight fast between 0630 - 0730 to analyze TES, COR, SHBG and IGF-1 (Siemens Immulite 2000 XPI, Siemens Healthcare, USA). Interassay coefficients of variance were 9.4% for TES, 7,6% for COR, 5.6% for SHBG and 6.7% for IGF-1. The samples were centrifuged (Megafire 1.0 R Heraeus, DJB Lab Care, Germany) at 3500 rpm for 10 minutes and frozen and transported to the laboratory for later analysis.

### *Shooting*

The shooting test was performed from both prone and standing positions. First, the conscripts fired ten shots at the target from a prone position and then ten shots from a standing position. The best possible score was 100 points, and the result for each person was given at an accuracy of 0.1 points. The shooting test was performed indoors and the target was ten meters away in both prone and standing positions. The weapon system used (Eko-Aims Oy, Ylämylly, Finland) was similar to the Army assault rifle (RK95, Finland) which the conscripts handled daily. Because the tests were performed indoors the conditions were the same in all measurement periods. The sum of ten shots from both positions was recorded for analysis.

### *Statistical Analysis*

The data was analyzed using IBM SPSS Statistics 22.0 (IBM Corporation, Armonk, NY). Statistical analysis included descriptive statistics, Pearson correlation, and multivariate analysis of variance with repeated measures. Probability adjusted *t* tests were used for pairwise comparisons. A general linear

1 model, with repeated measures ANOVA was used to analyze the differences between the different  
2 measuring points. Bivariate correlation was used for correlation analysis where the changes in the  
3 variables between the different time points were tested. The  $p < 0.05$  criterion was used for  
4 establishing the statistical significance.  
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## RESULTS

### Neuromuscular performance

There was a significant increase ( $p \leq 0.05$ ) in isometric leg press force from MID of  $3406 \pm 923$  N to POST  $3532 \pm 1011$  N measurement. No other significant changes were found in leg press. Force of upper body isometric bench press increased significantly ( $p \leq 0.001$ ) from PRE of  $890 \pm 181$  N to MID  $929 \pm 179$  N. There was a decline in POST of  $900 \pm 179$  N ( $p \leq 0.05$ ) and RECO  $873 \pm 178$  N ( $p \leq 0.001$ ) measurements when compared to MID  $929 \pm 179$  N. RECO  $873 \pm 178$  N ( $p \leq 0.001$ ) was also significantly lower than POST of  $900 \pm 179$  N measurement. (Table 1)

### Shooting

There was no change in prone shooting score between the measuring points. In the standing position however there was significant ( $p \leq 0.001$ ) decrease from PRE  $58.2 \pm 12.3$  points to MID  $45.2 \pm 10.4$  points. Also POST of  $61.4 \pm 10.8$  points and RECO of  $56.8 \pm 13.6$  points were significantly ( $p \leq 0.001$ ) higher than MID of  $45.2 \pm 10.4$  points. (Table 1)

### Serum hormone concentrations

#### *Testosterone*

Serum TES concentrations decreased significantly ( $p \leq 0.001$ ) from PRE  $18.5 \pm 4.5$  nmol/l to MID  $13.8 \pm 4.9$  nmol/l (-25.0%) and POST  $16.0 \pm 4.2$  nmol/l (-13.0%). The POST value was also significantly ( $p \leq 0.01$ ) higher (15.9%) than the MID. RECO  $19.9 \pm 3.7$  nmol/l was significantly ( $p \leq 0.001$ ) higher (44.2 %) than MID and POST (24.4 %) and also higher than PRE ( $p \leq 0.05$ ) (8.2 %). (Table 2)

#### *Cortisol*

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There was a significant increase in serum COR concentrations between PRE  $301 \pm 86$  nmol/l and MID  $355 \pm 76$  nmol/l ( $p \leq 0.05$ ) (17.8 %), POST  $396 \pm 69$  nmol/l ( $p \leq 0.001$ ) (31.3 %) and RECO  $385 \pm 85$  nmol/l ( $p \leq 0.001$ ) (27.8 %). Also POST cortisol was significantly ( $p \leq 0.001$ ) higher than that of MID (15.9%). (Table 2)

### *Insulin-like Growth Factor-1*

IGF-1 showed a significant ( $p \leq 0.001$ ) reduction from PRE of  $40.6 \pm 7.7$  nmol/l to MID  $32.5 \pm 8.9$  nmol/l (-20.0 %) and POST  $32.5 \pm 7.7$  nmol/l (-20.0 %). Also a significant increase of the same magnitude ( $p \leq 0.001$ ) was observed between RECO of  $39.4 \pm 7.8$  nmol/l and MID (21.2 %) and POST (21.2 %). (Table 2)

### *Sex Hormone Binding Globulin*

There was a significant increase in SHBG from PRE of  $30.1 \pm 7.6$  nmol/l to MID  $32.8 \pm 7.9$  nmol/l ( $p \leq 0.01$ ) (9.0 %) and POST of  $34.3 \pm 9.1$  nmol/l ( $p \leq 0.001$ ) (14.0 %). A significant ( $p \leq 0.001$ ) decline was observed between POST and RECO  $31.5 \pm 8.1$  nmol/l (-8.2 %). (Table 2)

### **Associations between strength, shooting and serum concentrations**

In the present study individual changes in lower body strength and changes in shooting standing score between the measurement points (PRE - MID / POST / RECO) correlated significantly ( $r = 0.332$ ,  $p = 0.031$ ;  $r = 0.335$ ,  $p = 0.025$ ;  $r = 0.489$ ,  $p = 0.001$ ). The same effect was found with changes in upper body strength and changes in shooting standing between PRE and RECO measurement points ( $r = 0.339$ ,  $p = 0.010$ ). With regard to serum concentrations a negative correlation was observed between the changes in SHBG and changes in IGF-1 in all measurement points ( $r = -0.310$ ,  $p = 0.043$ ;  $r = -0.482$ ,  $p = 0.001$ ;  $r = -0.382$ ,  $p = 0.010$ ). There was also a positive correlation between the changes in SHBG and the change in TES ( $r = -0.330$ ,  $p = 0.027$ ) when comparing the PRE and RECO measurement points.

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The changes in COR correlated negatively with the changes in TES ( $r=-0.341$ ,  $p=0.025$ ) and the changes in IGF-1 ( $r=-0.346$ ,  $p=0.023$ ) between the PRE and MID measurement points. The changes in COR and the changes in shooting prone showed a positive correlation in all measurement points ( $r=0.531$ ,  $p\leq 0.001$ ;  $r=0.337$ ,  $p=0.024$ ;  $r=0.572$ ,  $p\leq 0.001$ ). The changes in IGF-1 correlated negatively ( $r=-0.325$ ,  $p=0.038$ ) with shooting prone between the PRE and MID measurement points. The changes in shooting standing and the changes in TES between PRE and POST correlated negatively ( $r=-0.378$ ,  $p=0.010$ ).

## DISCUSSION

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5 Our study supports previous investigations and adds to the existing literature on stressors and key  
6 military performance measures. The present study showed the decrease in leg strength from the PRE  
7 to MID measurements. When the physical load decreased after the MID measurements, the leg  
8 strength increased. In addition, the shooting score from the standing position decreased from the PRE  
9 to MID measurements and improved significantly from the MID to POST measurements. The  
10 shooting prone score did not show any significant changes during the study period. Serum COR and  
11 SHBG concentrations increased from PRE to MID and POST. SHBG increased in RECO  
12 measurements, but COR did not change. Serum TES and IGF-1 concentrations decreased during MFT  
13 and increased in RECO measurements. Significant positive correlations were found between the  
14 changes in standing shooting score and the changes in strength for the legs and upper body. There  
15 was a positive correlation between the changes in serum cortisol concentrations and changes in  
16 standing shooting score. All the measured variables except cortisol returned close to the baseline level  
17 after the recovery period.  
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39 Previous military field exercise studies<sup>2,6,7,13</sup> have shown that prolonged physical activity and  
40 negative energy balance combined with sleep deprivation have negative impact on neuromuscular  
41 performance and hormonal balance of a warfighter. In the present study, maximal upper body strength  
42 increased significantly from the PRE to MID measurements, but decreased back to PRE levels in the  
43 POST and RECO measurements. This was probably partly due to learning, but indicated that upper  
44 body strength was not affected by prolonged MFT.  
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56 It has been shown that lower body strength is an important factor for warfighters to be successful in  
57 their duties<sup>16,17</sup>. In the previous studies the lower body power has been reported both to either decrease  
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or increase<sup>2</sup> after MFT. In the present study, a slight, but not significant, decrease in leg extension values in the MID measurements. This was probably due to the higher loading of the first part of MFT as the four days before the MID measurements were physically the most demanding part of MFT. These findings suggest that lower body strength levels are related to the loads of MFT. There were no further declines after the loading was reduced. This indicates that it is possible to recover physically during the present type of MFT. Kyröläinen et al. (2008) had similar findings with reduced load during prolonged MFT. They showed that a lighter period between two intensive MFT parts can allow strength and hormone levels to recover before the commencing of the second intensive training period.

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Serum TES concentration decreased significantly from the PRE to MID (-25.0%) and PRE to POST (-13.0%) measurement. Similar findings have been reported earlier<sup>1,3,21</sup>. A significant increase was observed between MID to POST (15.9%) and POST to RECO (24.4%) measurements. This was probably due to the amount of physical load during MFT, as it was physically harder in the beginning of MFT.

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Serum COR concentration on the other hand, increased during MFT (31.3%) and did not return back to resting levels during the recovery period (27.8%). Friedl et al. (2000) and Nindl et al. (2007) found similar effect with US Army Rangers. Cortisol concentration increased significantly during the study period, but no recovery period was included. Kyröläinen et al. (2008) found that during a 20 day MFT cortisol levels increased by 32 %. COR, unlike TES and strength values did not begin to increase after the MID measurements. The present results showed that despite the loading was reduced in the latter part of MFT, the stress levels were at highest at the end of MFT, when the warfighters' training reached its capstone exercise.

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Previous studies have shown that SHBG concentration has increased during strenuous physical training<sup>22</sup>. In a study with Finnish conscripts, Tanskanen et al. (2011) showed that SHBG values were



1 elevated during eight weeks of military training. Accordingly, Alemany et al. (2008) have shown an  
2 increase in SHBG during MFT. In the present study, SHBG concentrations increased significantly  
3 from the PRE values in the MID (9.0%) and POST (14.0%) measurement points, but returned back  
4 to the PRE values in the RECO measurements.  
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10 IGF-I is one particular biomarker that has demonstrated a positive relationship between circulating  
11 levels and aerobic fitness<sup>36</sup>. Additional biomarkers (e.g. COR, TES, SHBG) have also shown to  
12 predict excessive rates of physical performance change. In addition to the ability of biomarkers to  
13 predict fitness measures, certain biomarkers that are sensitive to changes in homeostasis may serve  
14 as early indicators of stress or overreaching<sup>3,23,26</sup>. Rosendahl et al. (2002) reported a significant  
15 decline in total IGF-1 values after 11 weeks of garrison training. There have also been decreases in  
16 IGF-1 values after MFT<sup>37</sup> and longer special force training<sup>6</sup>.  
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31 In the present study IGF-1 concentration decreased from the PRE to MID measurements by 20.0%.  
32 The values stayed the same from MID to POST and returned back to resting levels in the RECO  
33 measurements. Similar findings have been reported in earlier studies<sup>7,28,38</sup>. Even more drastic changes  
34 (-62.0%) have been found during special force training<sup>6</sup>. The decrease in IGF-1 concentration is  
35 mainly due to physical strain and energy deficit, which has been shown to decrease IGF-1  
36 concentration<sup>21</sup>. This decrease in IGF-1 concentration indicates that warfighters' ability to recovery  
37 from physical strain and to repair muscle damage is weakened and can lead to decrease in physical  
38 performance. IGF-1 concentration seems to be a good marker to evaluate warfighters' recovery and  
39 physical performance.  
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54 In previous studies soldiers' shooting performance has mainly been measured after different  
55 simulations of military work. These studies have shown that drastic anaerobic work periods can  
56 decrease shooting accuracy, but it has been shown to recover quickly<sup>33</sup>. Evans et al. (2003) observed  
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1 the fatiguing upper body obstacle course decreased shooting accuracy significantly, but it recovered  
2 quickly. Load carriage has also been shown to decrease shooting accuracy<sup>40</sup>, although it seems that  
3 there is no change before the carried loads of 45% of body weight<sup>34</sup>. In a study of Tenan et al. (2017)  
4 shooting performance was studied during a loaded march with live-fire shooting in the field. They  
5 found that load carriage and marching did not affect shooting accuracy, actually the shooting  
6 improved with lighter load. In the present study we found that shooting from the prone position did  
7 not alter during MFT. Standing shooting was more sensitive to fatigue, but it seemed to decrease only  
8 after the first and most physically demanding part of MFT. Declines in lower body strength and  
9 hormonal concentrations have been shown to occur during MFT<sup>6,7</sup>. This might explain the decline in  
10 standing shooting score as physical exhaustion causes the heart rate to elevate and influence the  
11 shooting mechanisms<sup>33</sup>. More research should be done in the future to investigate the interaction  
12 between mechanical and physiological effects and differences in the standing and prone shooting  
13 positions in soldiers.  
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31 The change in standing shooting score correlated positively with the change in lower body strength.  
32 The similar correlation was observed between the change in upper body strength and the change in  
33 standing shooting only between the PRE and RECO measurements. It seems that muscular strength,  
34 especially in the lower body seems to be important for the standing shooting accuracy of a warfighter  
35 during MFT. Both lower and upper body strength seems to be important for enhancing the recovery  
36 process and thus the standing shooting accuracy in the recovery phase.  
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47 In the RECO measurements almost all the measured values were recovered to the PRE measurement  
48 values. Serum COR concentration was significantly higher than in the PRE measurements. Also, body  
49 weight (BW) and skeletal muscle mass (SMM) were significantly lower than in the PRE  
50 measurements, but had almost recovered to the PRE values. It seems like four days is adequate for  
51 the warfighter to recover from the physical strain of the present prolonged MFT in all measured  
52 variables except for COR concentration.  
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1 The present study had some limitations. Participants were representatives of the larger population  
2 doing their military service. A number of the subjects in the study represents only a small fraction of  
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4 the total number of service members. Thus, some caution should be used when extrapolating the  
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6 physiological data to the general population. Also, the number of dropped subjects in the study might  
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8 have had an influence on the results, because most of the dropped subjects were among the poorest  
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10 half with regard to physical fitness. On the other hand, this might also decrease the motivational effect  
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12 of the results, when the least motivated subjects were dropped out of the study. The present subjects  
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14 were familiarized with most of the physical tests, but some new tests were implemented (maximal  
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16 isometric tests), which could have had some influence in the results due to learning effect.  
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18 Nevertheless, all the measurements were carefully controlled by the trained researchers, and the tests  
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20 were completed in the same order and same time of day in all the measurement points.  
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27 The strength of the present study was that the conscripts performed similar duties during the study  
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29 period. In addition, there was a daily control of the subjects and the researchers were able to monitor  
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31 the loading during the whole study period. The MFT lasted for 21 days, which made it more realistic  
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33 when compared to short (three to five days) MFTs. The physical loading in the latter part of MFT  
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35 was lower than expected. This may have influenced the observed measures as they (shooting and  
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37 isometric maximal strength) did not decline after the MID measurements as expected based on prior  
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39 studies.  
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45 The present study showed that the prolonged MFT has adverse effect on the strength levels and the  
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47 shooting ability in warfighters. Therefore, to ensure that warfighters get an appropriate amount of  
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49 rest, while performing their duties is important. Shooting from a prone position was not affected by  
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51 the changing loads and this result indicated that soldiers should shoot from a prone position, whenever  
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53 possible, especially when fatigued.  
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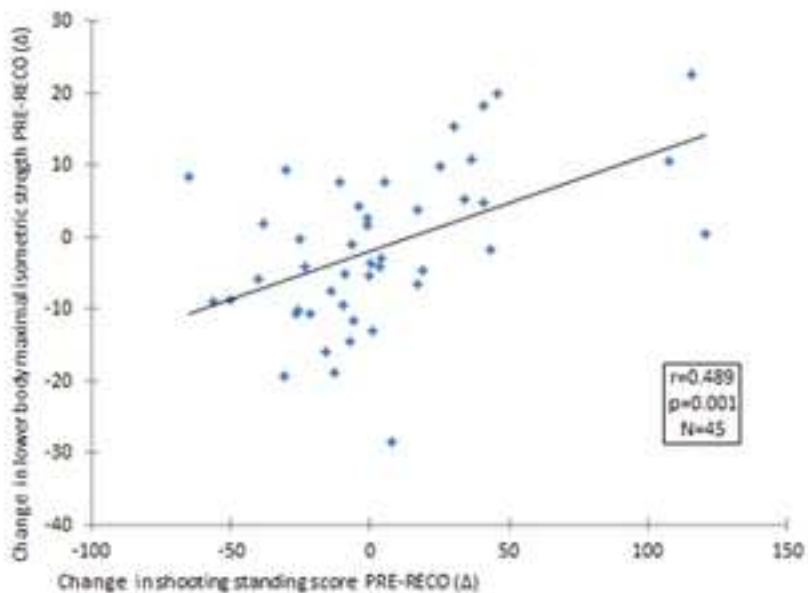
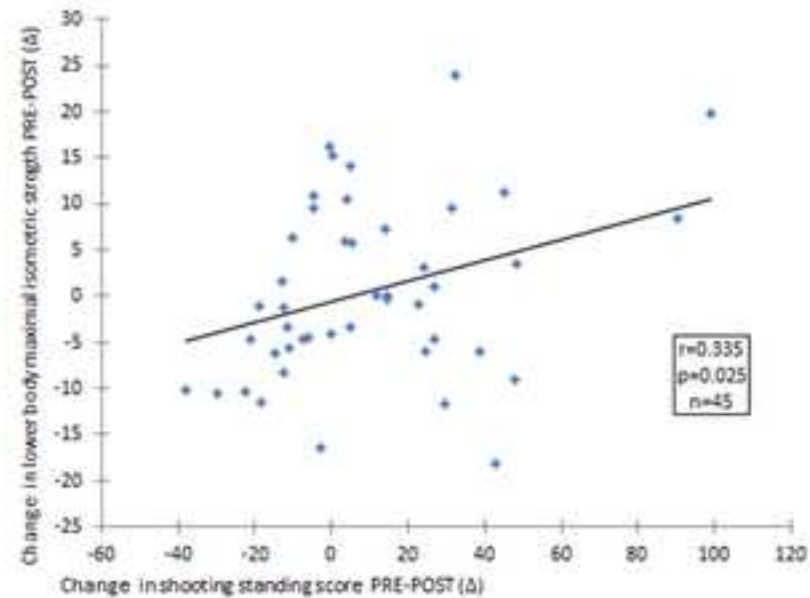
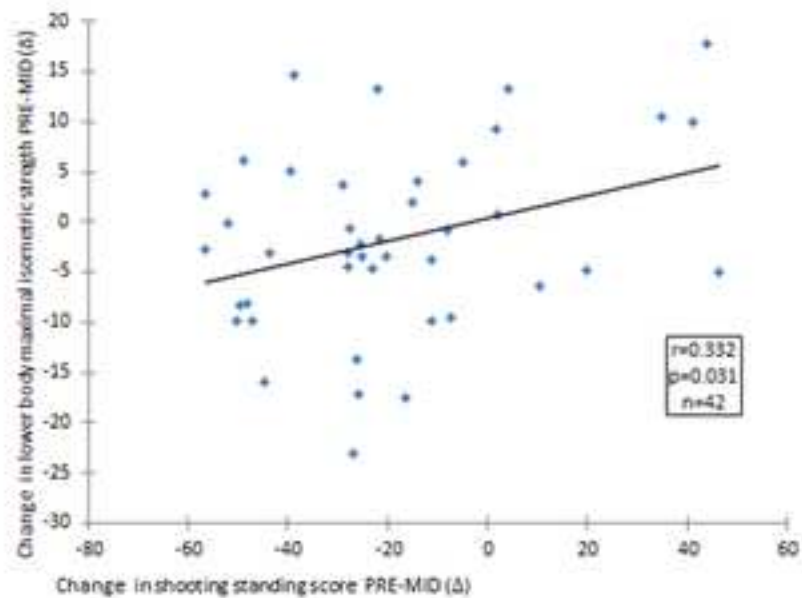


Figure 1. Correlations between the lower body maximal isometric strength and shooting standing score between the PRE-MID, PRE-POST and PRE-RECO measurement points

Abbreviations: PRE, Before training measurements; POST, Post training measurements; RECO, Recovery measurements

<b>Isometric strength</b>	<b>PRE</b>	<b>MID</b>		<b>POST</b>		<b>RECO</b>	
Bench Press (N)	890±181	929±179	***	900±179	†	873±178	*†††‡‡‡‡
Leg Press (N)	3495±931	3406±923	-	3532±1011	†	3424±913	-

<b>Shooting</b>	<b>PRE</b>	<b>MID</b>		<b>POST</b>		<b>RECO</b>	
Prone (Points)	84.3±11.7	85.5±9.1	-	84.8±11.5	-	87.2±11.0	-
Standing (Points)	58.2±12.3	45.2±10.4	***	61.4±10.8	†††	56.8±13.6	†††‡

Table 1. Mean ( $\pm$ SD) values of isometric strength and shooting tests during MFT (\*, †, ‡ =  $p < 0.05$ , \*\*\*, †††, ‡‡‡ =  $p < 0.001$ ; \*, \*\*\*, ††† = compared to PRE values, ††† = compared to MID values, ‡, ‡‡‡ = compared to POST values)

Abbreviations: PRE, Before training measurements; POST, Post training measurements; RECO, Recovery measurements

<b>Hormones</b>	<b>PRE</b>	<b>MID</b>		<b>POST</b>		<b>RECO</b>	
TES (nmol/l)	18.4±4.5	13.8±4.9	***	16.0±4.2	***††	19.9±3.7	*†††††††
COR (nmol/l)	301±86	355±76	*	396±69	***††	385±85	***
IGF-1 (nmol/l)	40.6±7.7	32.5±8.9	***	32.5±7.7	***	39.4±7.8	†††††††
SHBG (pmol/l)	30.1±7.6	32.8±7.9	**	34.3±9.1	***	31.5±8.1	†††

Table 2. Mean ( $\pm$ SD) serum hormone concentrations and SHBG concentrations during MFT (\* =  $p < 0.05$ , \*\*, †† =  $p < 0.01$ , \*\*\*, ††††, ††††† =  $p < 0.001$ ; \*, \*\*, \*\*\* = compared to PRE values, †, ††, ††† = compared to MID values, †, ††, ††† = compared to POST values)

Abbreviations: PRE, Before training measurements; POST, Post training measurements; RECO, Recovery measurements; TES, Testosterone; COR, Cortisol; IGF-1, Insulin-like growth factor 1; SHBG, Sex hormone-binding globulin