

## Physical Performance Capacity during 12 Days Military Manoeuvre in Winter Conditions

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### ABSTRACT

*Twelve days winter manoeuvre had minor effect on soldiers' physical performance capacity. It seems that the motorized infantry soldiers were not engaged in sustained overexertion during the manoeuvre. In fact, heart rate measurements in the field indicated that the mean workload varied between light and moderate. However, signs of fatigue were observed in the rate of force production and in the task that recruits small muscle groups. Similarly, winter time military manoeuvre had no effect on soldiers' maximal oxygen consumption, ventilation and ergometer work load. This also refers to that the manoeuvre was not strenuous enough to produce long term fatigue. Heart rate during maximal oxygen uptake test in the middle and in the end of the manoeuvre was significantly lower in relation heart rate measured before the manoeuvre, while significant change was not observed in other parameters. This may reflect increased efficiency of cardiac function (e.g. reduced end systolic volume) or increased plasma volume possibly due to training effect induced by the manoeuvre. In conclusion, soldiers were predominantly able to maintain their physical performance capacity during a long-term military manoeuvre in the cold.*

### 1.0 INTRODUCTION

The knowledge regarding the changes in soldiers' physical performance capacity, physical strain, fatigue and recovery during long term field operations in cold is quite sparse. So far, literature report results from operations lasting few hours or few days or report results focusing on one of the above mentioned components of physical function. For example, Hackney et al. (1) found that 4.5 days combat training in cold (-2 - -22 °C) decreased anaerobic capacity of the soldiers by ca. 9 % whereas similar operation in a warm environment (10 - 32 °C) reduced anaerobic capacity by ca. 3 %. Hodgdon et al. (2) found that endurance, measured as snowshoeing time, was reduced in soldiers living in tents in the field in comparison to soldiers living in the barracks. However, as the operations may last for several days or even weeks it is essential to know what effect long term military operation may have on individual or troop of soldiers' physical ability to function. Therefore, this study was designed to evaluate the effect of 12 days military manoeuvre in cold environment on physical performance capacity, physical strain, fatigue and recovery of participating soldiers. In addition, the aim was to find out how was the physical strain subjectively evaluated.

## **2.0 METHODS**

The 12 twelve day military manoeuvre consisted of 5 day combat training and 6 day combat shooting training with one day (day 6) for transportation in between. This study was divided into laboratory and field measurements.

### **2.1 Laboratory measurements**

There were 22 voluntary male conscripts participating the laboratory measurements. Their mean $\pm$ SD age was 20 $\pm$ 1 years, height 177.1 $\pm$ 6.8 cm, weight 71.4 $\pm$ 9.5 kg, subcutaneous fat 14.0 $\pm$ 2.8 and body mass index 22.8 $\pm$ 2.2 kg/m<sup>2</sup>. The subjects were tested on three occasions: just before (BF) the start of the manoeuvre, in the midst of the manoeuvre (day 6, MID) and after (AF) the manoeuvre. In the laboratory physical performance capacity was tested with six different tests:

1. Maximal oxygen consumption (MaxVO<sub>2</sub>) test was performed with a bicycle ergometer (Ergoline 100k, Fysioline Oy, Finland or Monark 839E, Monark Ab, Sweden). The test started with the load of 75 W and was increased by 25 W increments every 2 minutes until exhaustion. During the test oxygen consumption (Metamax 3B, Cortex Biophysik GmbH, Germany, Medikro 901, Medikro Oy, Finland and Oxygen Mobile, Cardinal Health Ltd, Canada) and heart rate (Polar S610i, Polar Electro Oy, Finland) were measured continuously. In each testing occasion the subjects were tested by using the same devices. Aerobic and anaerobic threshold levels were defined from changes in ventilatory equivalents (VE/VO<sub>2</sub> and VE/VCO<sub>2</sub>), ventilation and trueO<sub>2</sub> (3).

2. Maximal isometric knee extension (MVCknee) force was measured with a leg extension/flexion dynamometer (Legcurl, HUR Oy, Finland). The subjects were seated in the dynamometer with 110° knee and hip angle and were fixed to the seat and back support with a strap around their hip and chest in order to avoid movement during the test. When asked the subjects extended their knee maximally as fast as possible. From the data maximal force and force - time curve were analysed.

3. Maximal isometric wrist rotational (MVCwrist) force was measured using a rotation dynamometer (Newtest strain gauge 200, Newtest Oy, Finland). The dynamometer was fixed to a table adjustable to the waist height for each subject. With a pinch grip with three fingers on a key (2 cm diameter) attached to the dynamometer the subjects were asked to rotate their wrist clockwise as forcefully as possible. Maximal rotation force was measured.

4. Maximal static jump (SJ) was performed on a contact mat (Newtest Powertimer, Newtest Oy, Finland). The subjects started from a 90° knee angle squatting position with their hands on their waist and performed a maximal upward jump without any countermovement. The flight time of the jump was measured and jump height was calculated (4).

5. Maximal countermovement jump (CMJ) was performed on a contact mat (Newtest Powertimer, Newtest Oy, Finland). The subjects started from a standing position with their hands on their waist and squatted to their preferred depth and performed a maximal upward jump. The flight time of the jump was measured and jump height was calculated (4).

6. Anaerobic power (AP) of the lower extremities was determined by performing five consecutive CMJ's on a contact mat (Newtest Powertimer, Newtest Oy, Finland). The flight time of each jump was measured and anaerobic power was calculated (4).

In addition to physical performance capacity tests in every test occasion also body weight was measured and the amount subcutaneous fat (F%) was estimated by measuring skinfold thickness from four different sites: above *m. biceps* and *m. triceps*, below *os. scapula* and above *os. crista iliaca* (5).

## 2.2 Field measurements

Ten subjects out of the 22 participating in the laboratory measurements volunteered for the field measurements. Their mean±SD age was 20±1 years, height 177.4±8.1 cm, weight 71.5±7.7 kg, subcutaneous fat 13.8±3.1 and body mass index 22.7±2.3 kg/m<sup>2</sup>. On seven days during the manoeuvre (day 1 AM and PM, days 2, 3, 4, 8, 9 and 10 PM) the subjects performed four tests in the field: MVCwrist, SJ, CMJ and AP. Cardiac strain was monitored continuously throughout the manoeuvre by measuring heart rate (Polar S610i and S810i, Polar Electro Oy, Finland). The data was collected at 60 s intervals. The analysis of cardiovascular strain was performed concerning the whole manoeuvre and a block of selected tasks (see below). In addition, individual subjective evaluation of the experienced physical strain of the tasks and physical performance capacity were asked from each subject daily on 10 point scale: 1 = maximal strain/minimum performance capacity, 10 = minimum strain/maximum performance capacity (6). Also the amount of sleep, rest and ability to perform the required tasks were asked.

**Table 1. The list of selected tasks**

1	Attack, no engagement
2	Counter-attack exercise
3a	Attack
3b	Effect deployment according to mission plan, counter attack, interception
4a	Early dismounting and 7 km foot march
4b	Attack, objective attained
4c	Effect deployment
6	Firing attack
7	Unit raid
8	Urban warfare, attack. Exercise using blanks. Several 1 km trips from base to combat area and back.
9	Urban warfare, attack. Live rounds. Includes a 1 km trip from the base to the combat area and back.
10	Defensive action exercise
11	Defensive action during the day time
12	Defensive action during the night time

## 2.3 Statistics

Analysis of variance with repeated measures was used. When a significant F-ratio was obtained, one way analysis of variance with Duncan's post hoc test was applied and significance was accepted at  $p < 0.05$ .

### 3.0 RESULTS

#### 3.1 Laboratory measurements

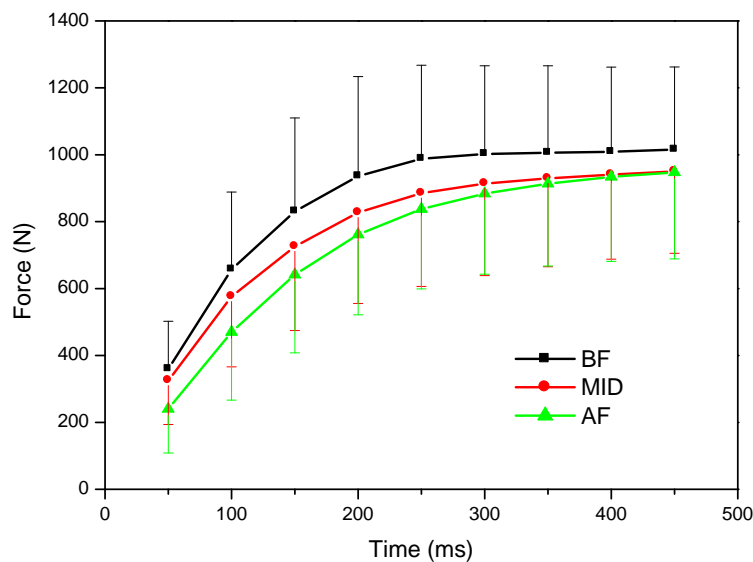
##### 3.1.1 Muscular performance

The manoeuvre did not induce any systematic changes in the maximal force levels. The height of the SJ increased ca. 3 cm in MID and AF in relation BF and MVCwrist decreased in MID ca. 6 N (Table 2).

**Table 2: Results from muscle force tests. \* =  $p < 0.05$  in relation to BF. Values are mean  $\pm$  SE, n = 22.**

Parameter	BF	MID	AF
MVCknee (N)	1233 $\pm$ 52	1204 $\pm$ 60	1210 $\pm$ 52
MVCwrist (N)	48.1 $\pm$ 2.2	42.5 $\pm$ 1.3*	45.8 $\pm$ 2.1
SJ (cm)	29.0 $\pm$ 0.7	32.1 $\pm$ 1.0*	31.8 $\pm$ 0.7*
CMJ (cm)	35.2 $\pm$ 0.9	35.1 $\pm$ 1.0	34.3 $\pm$ 0.9
AP ( $W \cdot kg^{-1}$ )	25.7 $\pm$ 0.8	25.9 $\pm$ 0.9	25.5 $\pm$ 0.7

However, the manoeuvre did induce a downward shift in the force - time curve indicating slowing of force production in a given time (Figure 1).



**Figure 1: Maximal isometric knee extension force - time curve.**

### 3.1.2 Cardiovascular performance

Average ( $\pm$ SE) maximal oxygen consumption at BF was  $3.17 \pm 0.11$  liters  $\cdot$  min<sup>-1</sup> ( $45.1 \pm 1.1$  ml $\cdot$ kg $\cdot$ min<sup>-1</sup>). The cardiovascular performance level depicted by oxygen consumption or bicycle ergometer workload did not significantly change in MID or AF in any exercise intensity level (aerobic/anaerobic/maximal). However, heart rate response with each exercise intensity was lower during MID and AF in relation to BF (Table 3).

**Table 3: Workload (WL), heart rate (HR) and oxygen consumption (O<sub>2</sub>) at aerobic threshold (AerT), anaerobic threshold (AnT) and at maximal (Max) exercise intensity during BF, MID and AF. \* = p<0.05 in relation to BF and # = p<0.05 in relation to AF and BF. Values are mean $\pm$ SE, n = 22.**

	Parameter	BF	MID	AF
AerT	WL (W)	126 $\pm$ 7	121 $\pm$ 6	123 $\pm$ 5
	HR (beats $\cdot$ min <sup>-1</sup> )	136 $\pm$ 3	133 $\pm$ 3*	128 $\pm$ 3*
	O <sub>2</sub> (liters $\cdot$ min <sup>-1</sup> )	1.66 $\pm$ 0.09	1.81 $\pm$ 0.07	1.71 $\pm$ 0.06
AnT	WL (W)	195 $\pm$ 9	193 $\pm$ 96	195 $\pm$ 9
	HR (beats $\cdot$ min <sup>-1</sup> )	165 $\pm$ 3	162 $\pm$ 3	156 $\pm$ 3*
	O <sub>2</sub> (liters $\cdot$ min <sup>-1</sup> )	2.44 $\pm$ 0.11	2.61 $\pm$ 0.13#	2.44 $\pm$ 0.10
Max	WL (W)	257 $\pm$ 8	256 $\pm$ 10	249 $\pm$ 8
	HR (beats $\cdot$ min <sup>-1</sup> )	188 $\pm$ 2	181 $\pm$ 3*	178 $\pm$ 3*
	O <sub>2</sub> (liters $\cdot$ min <sup>-1</sup> )	3.17 $\pm$ 0.11	3.26 $\pm$ 0.13	3.08 $\pm$ 0.10

### 3.1.3 Anthropometric changes

During the manoeuvre the weight of the subjects decreased significantly already at MID and continued to decrease towards AF. Similar significant changes could be observed also in the amount of subcutaneous fat and in the skinfold thicknesses (Table 4). Calculated from the changes in weight and subcutaneous fat the subjects lost approximately 857 g of fat (443 g weight loss due to other reasons), which corresponds to 7713 kcal of energy (32.3 MJ).

**Table 4: Weight, subcutaneous fat and skinfold thicknesses during BF, MID and AF. Values are mean $\pm$ SE, n = 22, \* = p<0.05 in relation to BF and # = p<0.05 in relation to MID.**

Parameter	BF	MID	AF
Weight (kg)	71.4 $\pm$ 2.0	70.6 $\pm$ 1.9*	70.1 $\pm$ 1.9*
Subcutaneous fat (%)	14.0 $\pm$ 0.5	13.4 $\pm$ 0.5*	12.8 $\pm$ 0.5
Biceps (mm)	4.1 $\pm$ 0.2	3.8 $\pm$ 0.2*	3.6 $\pm$ 0.2*
Triceps (mm)	8.4 $\pm$ 0.5	8.3 $\pm$ 0.5	8.3 $\pm$ 0.5
Scapula (mm)	10.2 $\pm$ 0.5	9.6 $\pm$ 0.4*	9.3 $\pm$ 0.4*#
Iliaca (mm)	9.2 $\pm$ 0.6	8.5 $\pm$ 0.5	7.9 $\pm$ 0.5*#

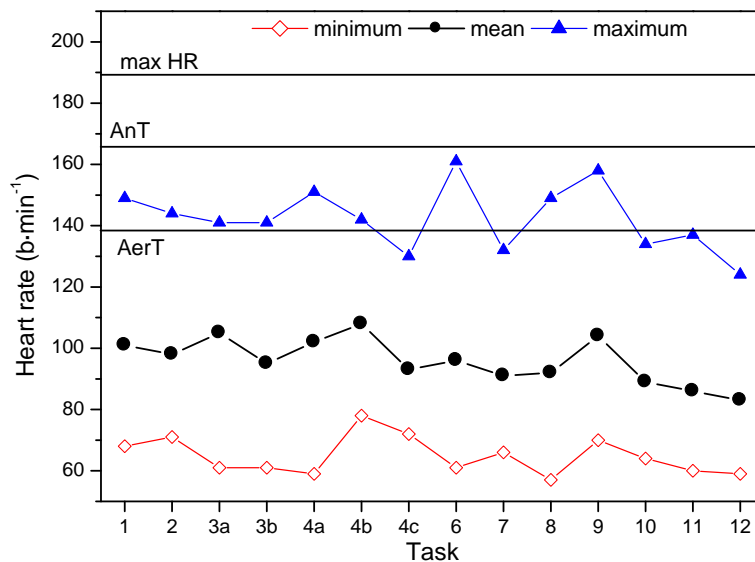
### 3.2 Field measurements

Heart rate measured during the selected tasks showed that average cardiovascular strain remained clearly on the level of aerobic exercise intensity. The average maximal heart rate was higher than aerobic threshold in 9 tasks out of 14 but never reached the level of anaerobic threshold (Figure 2).

There were only small differences in the cardiovascular strain between the selected tasks and the whole manoeuvre. The time spent between AerT and Ant was ca. 1% more in selected tasks in relation to whole manoeuvre (Table 5).

**Table 5: The time related percentual distribution of heart rate below AerT, between AerT - AnT and above AnT during whole operation and selected tasks. \* = p<0.05 in relation to whole operation. Values are mean±SE, n = 10.**

	Below AerT (%)	Between AerT - AnT (%)	Above AnT (%)
Whole manoeuvre	96.6±1.2	2.9±1.1	0.5±0.2
Selected tasks	95.4±1.6	4.0±1.4*	0.5±0.3



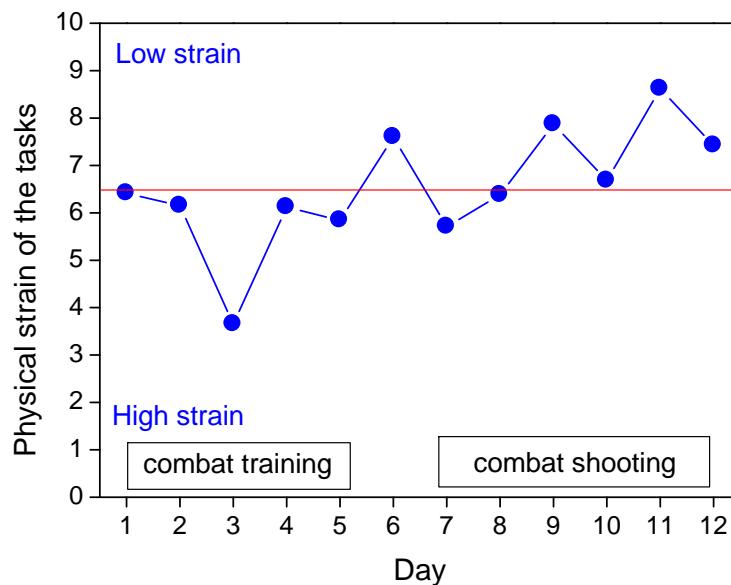
**Figure 2. Average heart rate with minimum and maximum average during selected tasks in the field. AnT and AerT definitions are from BF measurement.**

The daily performance capacity tests showed that MVCwrist was significantly decreased on day 3 and 4 i.e close to the end of combat training (Table 5). In the following combat shooting training the MVCwrist fully recovered. In the performance of the legs a similar pattern of change was observed; performance decreased the most on day 3 after which it started to recover and was fully recovered in the end of combat shooting training (Table 6).

**Table 6: Static jump, countermovement jump, anaerobic power and wrist rotation force during different days of the manoeuvre. \* =  $p < 0.05$  in relation to whole operation, # = differential measuring condition. Values are mean $\pm$ SE, n = 10.**

Day	SJ (cm)	CMJ (cm)	AP (W kg <sup>-1</sup> )	MVCwrist (N)
1 AM	26.4 $\pm$ 1.1	30.2 $\pm$ 1.5	23.4 $\pm$ 1.3	48.8 $\pm$ 3.1
1 PM	25.4 $\pm$ 0.9	28.6 $\pm$ 1.3*	22.4 $\pm$ 1.2*	44.0 $\pm$ 2.9
2	25.2 $\pm$ 1.1	29.0 $\pm$ 1.5	22.2 $\pm$ 1.2*	48.3 $\pm$ 2.8
3	23.5 $\pm$ 1.3*	26.7 $\pm$ 1.3*	19.9 $\pm$ 0.9*	43.2 $\pm$ 2.9*
4	24.1 $\pm$ 1.0	27.0 $\pm$ 1.2*	20.6 $\pm$ 1.2*	42.1 $\pm$ 2.7*
5	24.6 $\pm$ 0.6	27.6 $\pm$ 0.9*	21.0 $\pm$ 0.9*	44.5 $\pm$ 2.7
6	25.6 $\pm$ 1.1	27.8 $\pm$ 1.5*	22.1 $\pm$ 1.5	37.1 $\pm$ 2.5*#
7	25.7 $\pm$ 0.8	29.0 $\pm$ 1.3	22.4 $\pm$ 1.3	44.1 $\pm$ 2.9

According to subjective evaluation the physical performance capacity was voted fairly good being on average 6.8 in the beginning of operation and remained between 6.6-7.1 during rest of the operation. The experienced physical strain of the tasks was on average 6.5 $\pm$ 1.2 which supports heart rate responses so that the tasks were not experienced to be strenuous. The variation in experienced physical strain varied between 3.7-8.6 (Figure 3).



**Figure 3. Daily subjective evaluation of experienced physical strain.**

Physical performance capacity correlated positively with the amount of sleep ( $r = 0.399$ ,  $p < 0.01$ ) and rest ( $r = 0.549$ ,  $p < 0.01$ ). Similarly, the ability to perform the required tasks correlated positively with the amount of sleep and rest ( $r = 0.497$ ,  $p < 0.01$ ).

## **4.0 DISCUSSION**

The results of this study indicate that the physical fitness level of the group of subjects was sufficient to meet the demands set by the 12 days military manoeuvre. In addition, the physical strain induced by the manoeuvre did not cause changes in the fitness level (no long lasting fatigue).

### **4.1 Laboratory measurements**

The 12 days military manoeuvre in winter conditions induced a significant reduction in weight and in the amount of subcutaneous fat. The reduction in F% was mainly because of decreased skinfold thickness above *m. biceps*, below *os scapula* and above *crista iliaca*. These changes indicate that energy balance during the manoeuvre was negative: the need for energy exceeded the amount received. It may be argued that this level of energy deficit is able to induce only unpleasant sensations rather than changes in physical performance capacity. This argument is supported by the results showing that the average level of physical strain remained in the aerobic intensity zone and that there was no consistent reduction in physical performance capacity. However, should this kind of negative balance continue for longer periods it would inevitably induce reduction in individual and therefore also in troop performance capacity.

In maximal muscle force values measured in BF, MID and AF only changes were observed in static jump and wrist rotation force. The increase in jump height of SJ can most probably be explained by learning effect. The jump is technically demanding since no countermovement is allowed before actually performing the jump. In natural human locomotion this kind of muscle functioning does not exist rather every movement is preceded by a short countermovement (stretch) which is then followed by actual movement. It has been shown that motor performance improves already after few training sessions (7) which in this case is the most likely explanation for the increased jump height in SJ.

A reduction in the level of maximal muscle force can be regarded as a traditional indicator of muscle fatigue (8). The wrist rotation force was the lowest in MID indicating that the combat training was strenuous enough for small upper extremity muscles to induce fatigue. However, towards the end of the manoeuvre MVCwrist returned almost to BF level, indicating that combat shooting training was less strenuous and recovery of the upper arm muscles could take place.

Although the maximal isometric force level of the legs did not change significantly, the rate of force production did decline which was seen as a downward shift in the force-time curve. The change was not statistically significant but it still has a clear effect on momentary explosive performance; in a given time less force can be produced. The reduction in rate of force production may be e.g. due to slowed ATP hydrolysis, slowed calcium release and uptake in the sarcoplasmic reticulum and reduced binding affinity in the actomyosin complex (9, 10).

In cardiovascular performance ( $\max VO_2$ -test) two changes were observed: heart rate decreased in relation to workload in all exercise intensity levels and in MID anaerobic threshold was reached with higher  $VO_2$  though workload was the same as in BF and AF. The latter implies that there was a transient decrease in the efficiency of muscular work possibly due to inadequate recovery of energy reserves or decreased endurance capacity of the lower extremities. Together with the notion that force - time curve shifted downwards these may refer to that the lower extremities were to some extent fatigued due to physically more demanding start of the manoeuvre.



The systematic lowering of the heart rate in all exercise intensities refers to that the efficiency of cardiac function was enhanced and this may increase absolute working time in a given work level. It is also possible that general improvement in working economy due to long lasting aerobic exercise has taken place thus resulting in lower heart rate observed in all exercise intensities. The results of this study may not explain where the change originates but it can be argued that endurance type of training involved in the manoeuvre has induced a training effect leading to enhanced cardiac filling and/or reduced end systolic volume thus increasing the efficiency of cardiac function (11).

### **4.2 Field measurements**

During the manoeuvre in the daily measured performance tests no systematic changes were observed. Day to day variation, even statistically significant, could be observed in some tests however, these changes recovered. These results indicate that the daily physical strain has induced momentary fatigue which however, was recoverable to the forthcoming day or days. On the other hand, some of the changes were to that extent small that they could be explained by normal variation in performance capability and may not reflect actual muscle fatigue.

The average cardiovascular strain induced by the manoeuvre was fairly low. During the selected tasks average heart rate was below aerobic threshold and even average maximal heart rate did not exceed anaerobic threshold. Thus, majority of the measured heart rates were below aerobic threshold during the manoeuvre and the selected tasks analysis revealed that only 1 % more of the heart rates were in between AerT - AnT as compared to whole manoeuvre. These results indicate that the physical fitness level of the conscripts is sufficient for this kind of military manoeuvre used in the study. On the other hand, there might have been unintentional selection of the subjects. Their average cardiovascular fitness was clearly higher than that of an average conscript (in Cooper test 2700 meters in relation to an average of 2350 meters) and therefore, these results may not reflect the average strain experienced by a total population of conscripts. However, it can be argued that with physical fitness level estimated as "average" the 12 days military manoeuvre is not too strenuous and excessive fatigue can not be found. Therefore, it is concluded that average fitness level is sufficient to meet the demands of a 12 day military manoeuvre in winter conditions.

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