ORIGINAL RESEARCH PAPER

QUALITY EVALUTATION OF THE COMBAT INDIVIDUAL PROTECTION SYSTEM BY EUROFIT PHYSICAL FITNESS TESTING

Igors Šitvjenkins[1], Ausma Viļumsone[2], Viesturs Lāriņš[3], Iveta Ābele[4], Hanna Torbicka[5], Zane Pavāre[6]

[1] National Armed Forces Republic of Latvia
Defence Science Research Center
Address: 8 Ezermalas Street, Riga, LV 1014 Latvia
Phone: + 371 67076881, Fax + 371 670768888
E-mail: igors.sitvjenkins@mil.lv

[2,4] Riga Technical University
Textile Material Design and Technology Institute
Address: 14/24 – 319Āzenes Street, Riga, LV 1048 Latvia,
Phone: + 371 67089565, Fax: + 371 67089349
E-mail: ausma.vilumsone@rtu.lv, iveta.abele@rtu.lv

[3,6] Latvian Academy of Sport Education
Address: 333 Brivibas Street, Riga, LV 1006, Latvia
Phone: +371 67543444, Fax: +371 67543480
E-mail: viesturs.larins@lspa.lv, zane.pavare@lspa.lv

[5] NFM Group
Address: 5Targowa, Potegowo, PL-76230, Poland
Phone: +48 (59) 848 41 41, Fax +48 (59) 848 41 40
E-mail: hanna@nfm.no

Abstract

Researchers from the National Armed Forces (NAF) Republic of Latvia in cooperation with researchers from Riga Technical University (RTU) and Latvian Academy of Sport Education (LASE) carried out a quality evaluation of the combat individual protection system (CIPS) of the NAF by the EUROFIT physical fitness testing complex and Harvard step testing, covering flexibility, speed, endurance and strength. Experiments were split into five days. Five different sets in total have been evaluated during the experiments with the following loads – 1,7 kg (light clothing mode), 11,0 kg (light armour mode), 20,2 kg (heavy armour mode), 19,6 kg (heavy armour mode without combat jacket), 11,8 kg (backpack mode). Six NAF soldiers were involved in the experiments. Results of the experiments show up to 43% of muscular endurance decrease, cardiorespiratory endurance decreased by 35%, trunk strength decreased by 22%, explosive *leg power decreased by 26%, flexibility was lost to an amount of 18%, sweating during maximum load increased by 47%, with the combat jacket removed sweating was decreased by 29%. The Harvard step testing results identify the adaptation of the muscle groups to the specific load type and did not show significant changes in strength. The 10×5 m shuttle run (running speed and agility) demonstrated the high quality of the light armour load mode 18:16 sec. (1.7 kg) versus 18:30 sec. (11.0 kg), meaning a high level of modularity of the CIPS. The Flamingo balance test, plate tapping (speed of limb movement) and the handgrip test (static arm strength) showed no influence of the CIPS onto the soldiers' physical conditions.*

Keywords: *CIPS, combat clothing, load bearing, EUROFIT tests, Harvard step test, anthropometry, spirometry, endurance, cardiorespiratory system*

Introduction

The state defence concept of the Republic of Latvia (State Defence Concept, 2008) defines initiating operationally tactical requirements of the combat capabilities of the NAF for the protection of the Latvian national interests worldwide. Considering the Latvian membership in NATO and the European Union, as well as the involvement in strengthening international security, Latvian soldiers should be prepared to participate in international operations in geographically distant regions from Latvia and the unusual climate patterns that affect the materials soldiers have to carry to fulfil the tasks on ensuring the national interests of the Republic of Latvia. The soldiers are exposed of artificial threat from hostile forces and operate in an environment where risks, natural or artificial, are connected. The combination of risks influences the architecture of the protection system, the number of elements and their possible combinations. Artificial and natural threats can affect a soldier's life and health from all possible directions, namely, it is isotropic in nature.

The parts of the body of a soldier have to be protected basing on the priority principle of protection. The National Armed Forces have developed an combat individual protection system (Šitvjenkins, 2008) based on a number of operational, technical, political, economical sets of requirements, according to the current global geopolitical situation (Šitvjenkins, Viļumsone, 2009). Currently, the newly created combat individual protection system technological material components protect soldiers from artificial and natural threats only to a certain level. But soldiers could face the modern war. The new system is based on layering of the protection. Depending on the task, a soldier puts on or removes, as well as modulates the equipment to achieve the most effective combination of layers for a particular task, providing themselves the comfort and sense of security about their equipment, allowing them to focus on tasks.

The combat equipment of soldiers to carry will grow in future as command and control system soldier outfits complemented with a variety of electronic devices and systems for military operations, surveillance, communication, reconnaissance and tracking are developing rapidly. There are a series of solutions for further improvement the future soldier's personal equipment and personal protection system to deal with the increasing weight problem. The solutions mainly show two directions: increasing the soldier's physical ability by applying biotechnologies and textile technologies and combining electronic and information technologies. Currently, these two areas are the main points of interest for military researchers. The NAF and RTU continue to improve the combat individual protection systems on the basis of future developments of material technologies. Currently the RTU based scientific group 1DP/1.1.1.2.0./09/APIA/VIAA/148 “Multi industry scientific group establishing for the purpose of developing new functions of e-textiles and its implementation in innovative products” continue working in the direction of applying new developments in different clothing systems, including military. The implementation of new quality evaluation methodologies to be applied for the analysis of CIPS, is one of the group tasks. One such new quality evaluation technique is the physical fitness testing in the analysis of CIPS influence on the physical condition of the soldiers during different loads.

Materials and methods

In general five different sets of CIPS have been evaluated during the experiments (Table 1). Load types were chosen to modulate CIPS wearing in warm weather condition since testing was carried out in-house with the average temperature 20^0C and air humidity 60%. The main purpose of the research was to evaluate the combat clothing system and load bearing armour system influence on a soldier’s physical condition depending on different loads. Combat boots were exchanged with sport shoes, otherwise it would not be possible to identify the individual influence of both types of loads.

Six NAF soldiers were involved in the experiment. Results of the experiments were evaluated as an average score of the unit, consisting of the six soldiers. Two soldiers were from the NAF Joint Headquarters battalion and four soldiers from the NAF Special Task unit. The EUROFIT physical fitness testing (Lāriņš, 2004; EUROFIT) complex covering flexibility, speed, endurance and strength as well as the Harvard step test (Lāriņš, 2004;

The Harvard Step test) were used during the evaluation of the CIPS influence on soldiers.

Table 1

Load modes for CIPS evaluation by EUROFIT and Harvard step testing

Load	20.03.12	21.03.12	22.03.12	23.03.12	24.03.12
	weight, kg	weight, kg	weight, kg	weight, kg	weight, kg
combat underwear (1.level)	0,2100	0,2100	0,2100	0,2100	0,2100
combat jacket	NA	0,5980	0,5980	NA	0,5980
combat pants	0,6160	0,6160	0,6160	0,6160	0,6160
combat pants belt	0,1500	0,1500	0,1500	0,1500	0,1500
combat socks (summer)	0,0480	0,0480	0,0480	0,0480	0,0480
ID-combat patch "LATVIJA and flag"	NA	0,0040	0,0040	0,0040	0,0040
ID-combat patch "Name and last name"	NA	0,0040	0,0040	0,0040	0,0040
ID-combat patch "Rank"	NA	0,0030	0,0030	0,0030	0,0030
ID-combat patch "Unit logotype"	NA	0,0070	0,0070	0,0070	0,0070
BEAR II-combat load bearing vest	NA	1,5250	1,5250	1,5250	NA
pocket set	NA	1,8000	1,8000	1,8000	NA
BEAR II-armour plate 25×30 cm pair	NA	5,3400	5,3400	5,3400	NA
BEAR II-armour vest	NA	NA	2,3550	2,3550	2,3550
BEAR II-armour plate 15×20 cm pair	NA	NA	2,2100	2,2100	2,2100
BEAR II-armour plate 14×20 cm pair	NA	NA	1,4100	1,4100	NA
BEAR II-upper arm protector (right)	NA	NA	0,3900	0,3900	0,3900
BEAR II-upper arm protector (left)	NA	NA	0,3900	0,3900	0,3900
BEAR II-shoulder protector	NA	NA	0,7550	0,7550	0,7550
BEAR II-neck protector	NA	NA	0,2200	0,2200	0,2200
BEAR II-groin protector	NA	NA	0,5950	0,5950	0,5950
BEAR II-groin protector extender	NA	NA	0,2850	0,2850	0,2850
BEAR II-coccyx protector	NA	NA	0,5500	0,5500	0,5500
MMS-assault/3 day backpack	NA	NA	NA	NA	1,7000
sport shoes	0,7100	0,7100	0,7100	0,7100	0,7100
total, kg:	***1,7***	***11,0***	***20,2***	***19,6***	***11,8***

NA – not applicable this testing day

Anthropometric data of the soldiers is reflected in Table 2. The unit's average Body mass index (BMI) is 24,70 kg/m^2, which is considered to be a normal BMI (Lāriņš, 2004; Sauka et al., 2011), and is calculated as a proportion between body weight and height in square.

Table 2

Anthropometric data of the soldiers

N.	*Name*	*Age*	*Height (cm)*	*Weight (kg)*	*BMI (kg/m²)*	*FVC (l)*	*LI (ml/kg)*	*Chest girth (cm)*
1.	Soldier 1	23	176,00	68,90	22,24	5,55	80,60	102
2.	Soldier 2	30	184,50	92,80	27,26	6,10	65,73	110
3.	Soldier 3	27	178,50	77,40	24,29	5,70	73,64	102
4.	Soldier 4	21	174,50	73,50	24,14	5,90	80,27	98
5.	Soldier 5	20	186,50	84,30	24,24	5,30	62,87	100
6.	Soldier 6	20	188,50	92,50	26,03	6,00	64,86	107
	Average:	***23,5***	***181,40***	***81,60***	***24,70***	***5,76***	***71,33***	***103***

Forced vital capacity (FVC) is the amount of air which can be forcibly exhaled from the lungs after taking the deepest breath possible, measured with a spirometer. Average FVC of the unit is 5,67 l. Average life index is 71,33 ml/kg (considered as normal). LI of and average person is within a range of 65 – 70 ml/kg, for sportsman 75 – 80 ml/kg, for women 55 – 60 ml/kg. The life index is calculated as a proportion between FVC (ml) and body weight (kg) (Lāriņš, 2004; Sauka et al., 2011). According to the anthropometric data the physical condition of the soldiers is appropriate for the EUROFIT physical testing and Harvard step testing.

Anthropometric data of the soldiers chosen for the CIPS evaluation fully complies with the anthropometric data of the main ground combat unit of NAF – Special Force, Infantry Brigade and HQ battalion see Table 3.

Table 3

Anthropometric data of the HQ battalion, Infantry brigade and Special Force

	HQ battalion		Infantry brigade		Special Force	
	heigh, cm	chest, cm	heigh, cm	chest, cm	heigh, cm	chest, cm
Mean	180,55	101,37	179,22	103,88	177,40	104,20
Standard Error	0,44	0,55	0,31	0,38	0,69	0,84
Median	180,00	100,00	180,00	103,00	178,00	105,00
Mode	180,00	96,00	180,00	110,00	176,00	100,00
Standard Deviation	7,01	8,66	7,32	9,01	7,29	8,91
Sample Variance	49,16	75,03	53,57	81,15	53,19	79,47
Kurtosis	0,65	1,71	0,14	1,45	-0,01	0,09
Skewness	-0,05	0,76	-0,06	0,79	-0,18	-0,15
Range	45,00	57,00	40,00	64,00	36,00	45,00
Minimum	162,00	80,00	160,00	80,00	158,00	80,00
Maximum	207,00	137,00	200,00	144,00	194,00	125,00
Sum	45137,00	25139,00	100362,00	58278,00	20046,00	11775,00
Count	250	248	560	561	113	113
Confidence Level (95,0%)	0,87	1,08	0,61	0,75	1,36	1,66

The average height of the CIPS evaluators is 181 cm. The average height of the HQ battalion is 181 cm, Infantry brigade 179 cm, Special Force 177 cm. The average chest girth of the CIPS evaluators is 103 cm. The average chest girth of the HQ Battalion is 101 cm, Infantry Brigade - 104 cm and Special Force - 104 cm. Anthropometric data is reflected basing on the passive experiment made by NAF according to the source [7].

Average results of the EUROFIT physical testing **Table 4**

Loading / Date	*Nr.*	Right hand grip test (kg)	Left hand grip test (kg)	Flamingo balance test	Sit-Ups in 1 min	Flexibility (cm)	Plate tapping (sek.)	Bent arm hang (sek.)	Standing broad jump (m)	Shuttle run (10x5m) sek.	Endurance shuttle run (20 m) min	Sweating (kg)
20.03.12.	*1.*	64	56	6	54	18,50	12	38	2,28	19	7,41	0,40
	2.	50	76	9	54	6,00	10	47	2,38	19	5,50	0,40
	3.	63	64	10	60	3,00	9	43	2,35	18	8,36	0,70
	4.	66	58	8	59	9,00	10	50	2,37	18	7,23	0,40
	5.	72	70	6	56	12,00	9	48	2,32	17	9,15	0,40
1,7	*6.*	76	75	8	64	5,00	10	54	2,50	18	8,38	1,00
Mean		65,17	66,50	7,83	57,83	8,92	10,00	46,67	2,37	18,17	7,67	0,55
Standard deviation		8,95	8,53	1,60	3,92	5,66	1,10	5,57	0,07	0,75	1,28	0,25
Standard error of mean		3,66	3,48	0,65	1,60	2,31	0,45	2,28	0,03	0,31	0,52	0,10
Coefficient of variation		13,74	12,82	20,45	6,78	63,48	10,95	11,94	3,16	4,14	16,63	45,64
Confidence interval		9,36	8,91	1,67	4,10	5,92	1,14	5,83	0,08	0,79	1,33	0,26
21.03.12.	*1.*	58	54	8	44	18,00	9	35	1,98	18	6,1	0,54
	2.	52	76	9	47	4,00	10	40	2,36	20	4,21	0,90
	3.	58	60	6	51	2,00	8	22	2,21	19	8,03	0,78
	4.	65	62	13	57	9,00	8	49	2,08	18	7,39	0,68
	5.	68	66	7	59	14,00	7	39	2,22	18	8,25	0,54
11,0	*6.*	78	72	4	56	5,50	8	44	2,37	18	7,35	1,06
Mean		63,17	65,00	7,83	52,33	8,75	8,33	38,17	2,20	18,50	6,89	0,75
Standard deviation		9,22	8,07	3,06	5,99	6,19	1,03	9,24	0,15	0,84	1,51	0,21
Standard error of mean		3,76	3,30	1,25	2,44	2,53	0,42	3,77	0,06	0,34	0,62	0,08
Coefficient of variation		14,59	12,42	39,07	11,44	70,80	12,39	24,21	6,96	4,52	21,94	27,49
Confidence interval		9,63	8,44	3,20	6,26	6,47	1,08	9,66	0,16	0,87	1,58	0,22
22.03.12.	*1.*	61	56	5	35	13,00	10,00	18,13	1,98	21,09	5,08	0,60
	2.	53	83	5	43	2,00	10,22	25,93	2,32	18,62	2,34	2,40
	3.	67	64	8	43	1,00	9,44	8,47	2,14	19,94	5,52	0,70
	4.	66	61	14	51	10,00	12,87	34,35	1,88	19,34	5,41	0,80
	5.	76	69	7	50	11,00	9,00	21,00	2,15	18,85	6,16	0,60
20,2	*6.*	84	78	5	50	7,00	10,63	25,93	2,29	18,62	5,05	1,10
Mean		67,83	68,50	7,33	45,33	7,33	10,36	22,30	2,09	19,41	4,93	1,03
Standard deviation		10,94	10,33	3,50	6,22	4,93	1,36	8,74	0,18	0,97	1,33	0,69
Standard error of mean		4,47	4,22	1,43	2,54	2,01	0,55	3,57	0,07	0,39	0,54	0,28
Coefficient of variation		16,13	15,08	47,76	13,72	67,17	13,11	39,19	8,37	4,98	26,98	67,23
Confidence interval		11,44	10,80	3,66	6,50	5,15	1,42	9,13	0,18	1,01	1,39	0,73
23.03.12.	*1.*	60	52	7	37	17,00	9,79	18,47	1,87	20,38	4,26	0,40
	2.	52	84	7	45	2,00	9,91	31,53	2,32	19,66	3,23	0,90
	3.	68	65	9	41	2,00	7,88	17,38	2,2	19,75	6,07	0,90
	4.	65	64	13	51	10,00	8,53	35,5	1,92	19,19	5,2	0,50
	5.	79	72	5	52	10,00	7,4	29,31	2,1	18,29	7,15	0,60
19,6	*6.*	76	78	8	53	7,00	8,03	31,91	2,14	18,6	6,25	1,10
Mean		66,67	69,17	8,17	46,50	8,00	8,59	27,35	2,09	19,31	5,36	0,73
Standard deviation		10,03	11,36	2,71	6,57	5,69	1,04	7,57	0,17	0,78	1,43	0,27
Standard error of mean		4,10	4,64	1,11	2,68	2,32	0,43	3,09	0,07	0,32	0,59	0,11
Coefficient of variation		15,05	16,42	33,23	14,12	71,15	12,12	27,69	8,14	4,02	26,74	37,26
Confidence interval		10,49	11,87	2,84	6,86	5,95	1,09	7,92	0,18	0,81	1,50	0,29
24.03.12.	*1.*	60	55	7	NA	22	9,13	25,22	1,95	19,91	5,44	0,30
	2.	51	78	10	NA	3	9,3	30,84	2,3	19,53	4,3	1,20
	3.	66	65	9	NA	4	8,47	16,97	2,24	19,69	6,53	1,00
	4.	63	61	9	NA	10	8,65	25,93	2,01	19,19	7,21	0,70
	5.	70	64	7	NA	12	7,55	32,62	2,22	18,34	8,22	0,70
11,8	*6.*	78	70	10	NA	1	8,75	43,03	2,37	18,34	7,34	0,80
Mean		64,67	65,50	8,67	NA	8,67	8,64	29,10	2,18	19,17	6,51	0,78
Standard deviation		26,40	26,74	3,54	NA	3,54	3,53	11,88	0,89	7,82	2,66	0,32
Standard error of mean		9,16	7,87	1,37	NA	7,79	0,62	8,74	0,17	0,68	1,42	0,31
Coefficient of variation		14,16	12,01	15,76	NA	89,87	7,14	30,02	7,60	3,56	21,88	39,07
Confidence interval		9,57	8,22	1,43	NA	8,14	0,65	9,13	0,17	0,71	1,49	0,32

Table 5.

Correlation of the testing groups and main results

	Flamingo balance test	Sit-Ups in 1 min	Flexibility (cm)	Plate tapping (sek.)	Bent arm hang (sek.)	Standing broad jump (m	Shuttle run (10x5m) sek	Endurance shuttle run (20 m) min.	Sweating (kg)	Right hand grip test (kg	Left hand grip test (kg)
1,7	7,83	57,83	8,92	10,00	46,67	2,37	18,17	7,67	3,30	65,17	66,50
11,0	7,83	52,33	8,75	8,33	38,17	2,20	18,50	6,89	4,50	63,17	65,00
20,2	7,33	45,33	7,33	10,36	22,30	2,09	19,41	4,93	6,20	67,83	68,50
19,6	8,17	46,50	8,00	8,59	27,35	2,09	19,31	5,36	4,40	66,67	69,17
11,8	8,67	NA	8,67	8,64	29,10	2,18	19,17	6,51	4,70	64,67	65,50
Corelation group	0,0241	0,9945	0,0069	0,8811	0,8811	0,9794	0,8403	0,9488	0,6343	0,3861	0,4346

Results

The Excel statistics package was used to calculate the statistical data of the results. Refer to Table 4 and Table 5 as well as source [10]. Five different sets were evaluated during the experiments with the following loads – 1,7 kg (light clothing mode – day 20.03.12), 11,0 kg (light armour mode – day 21.03.12), 20,2 kg (heavy armour mode – day 22.03.12), 19,6 kg (heavy armour mode without combat jacket – day 23.03.12), 11,8 kg (backpack mode – day 24.03.12). Six NAF soldiers were involved in the experiment. Results of the experiments were evaluated as an average score of the six soldier unit. The total score of the results was calculated in sweating test. Muscular endurance measured by Bent Arm Hang test showed a decrease of 43% when load was increased – (Figure 1). The location of the load had a significant influence on the decrease of muscular endurance – load 11,0 kg (light armour mode) - 38 sec., compared to 11,8 kg (backpack mode) - 29 sec. due to location of the load on the back. Explosive leg power measured by the Standing broad jump test showed a decrease by 26% when the load was increased - 2,36 m. (1,7 kg), 2,20 m. (11,0 kg), 1,75 m. (20,2 kg).

After removing the combat jacket, explosive leg power increased by 15% (Figure 1). Combat jacket restricts impulsive movement of the both hands before jump, what influents on the jump distance. Results of both tests statistically proved that strength is directly correlated with load modes (Table 4, Table 5).

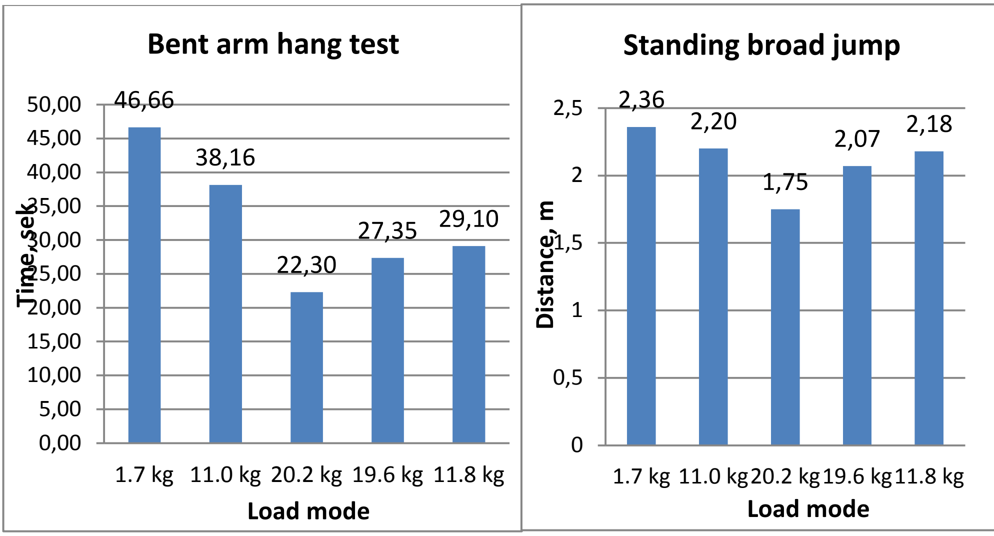

Figure 1. Results of the bent arm hang strength and leg power testing

A decrease of trunk strength by 22% was observed, measured by the 1 min sit-ups test. Sit-up testing was not carried out with the backpack load mode due to limitations of the space between soldier's back and floor (Fig. 2).

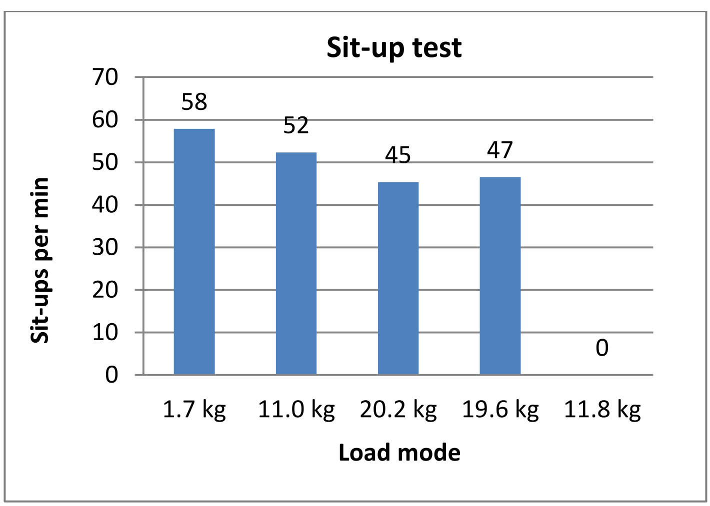

Figure 2. Results of the trunk strength testing

Results of the tests statistically proved that strength is directly correlated with load modes (Table 4, Table 5). There is no significant decrease in running speed and agility measured in a 10×5 m shuttle run test between load mode 1.7 kg and 11.0 kg. However there is significant decrease in running speed and agility between load 11.0 kg and 20.2 kg. (Fig. 3). Results of the shuttle run test show the high quality of the CIPS light load mode (11.0 kg) at high speeds, short time moving conditions. When performing long time, low speed movements, results show significant decrease in the cardiorespiratory endurance in maximum load mode of 20,2 kg by 35% (Figure 3). Heavy load mode is considered to be used for the load speed stationary type of the operations. Results of the tests statistically proved that strength is directly correlated with load modes (Table 4, Table 5).

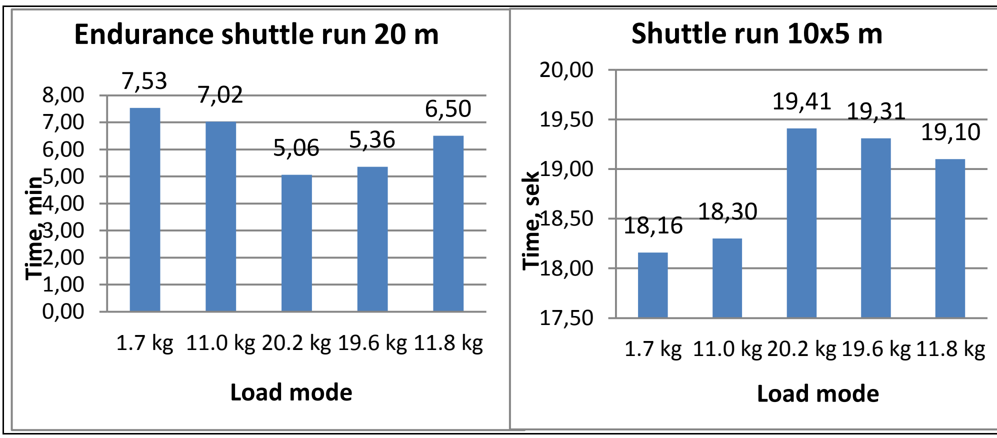

Figure 3. Results of the shuttle run and endurance shuttle run

The amount of water lost by sweating is a vital parameter in the quality evaluation of the CIPS. During the experiments the amount of water lost by sweating was measured by the difference in the soldier's weight before testing and after. They were not allowed to drink water during testing. The highest average water loss increase was 47% for the unit (Fig. 4). The amount of water lost decreased by 29% when the combat jacket was removed from the set with an equal amount of armour load 6,2 kg (20,2 kg), 4,4 kg (19,6 kg – without combat jacket). Such a decrease of sweating proves the necessity of a combat shirt as a design combination between combat underwear (1.level) T-shirt and a combat jacket (Figure 4). The influence of the combat jacket is one of the load modes from the aspect of the heat transfer and physiological evaluation of the clothing systems [11], proved also by EUROFIT testing. Due to the combat jacket removal during the load mode 19.6 kg, there is no strong correlation between sweating and the load mode, showing another type (thermal) loads' strong influence on the soldier's combat ability, which complies with the theory of the rectal temperature depending on the clothing system due to water vapour resistance. With the removal of the combat jacket the water vapour resistance decreased thereby decreasing the amount of water lost by sweating by 29% under the same armour load. The accuracy level of the results is higher than with separate measurements (Table 4), which, from the statistical aspect, made results not acceptable for interpretation. The reasons for such wide variations are the differences of the body strength to the reaction on increased load. Soldier Nr.6 showed following sweating results - 1.0 kg (1.7 kg load), 1.06 kg (11.0 kg load), 1.10 kg (22.2 kg load), 1.10 kg (19.6 kg load), 0.80 kg (11.8 kg load). Such results of one soldier in the group of six soldiers only create larger statistical variations. From the perspective of the heat transfer theory and physiological evaluation, with the growing armour load, sweating is increasing; with the increasing thermal load (clothing), sweating is increasing in all other equal conditions [11]. From the point of view of the heat transfer theory the results of the testing can be considered as acceptable.

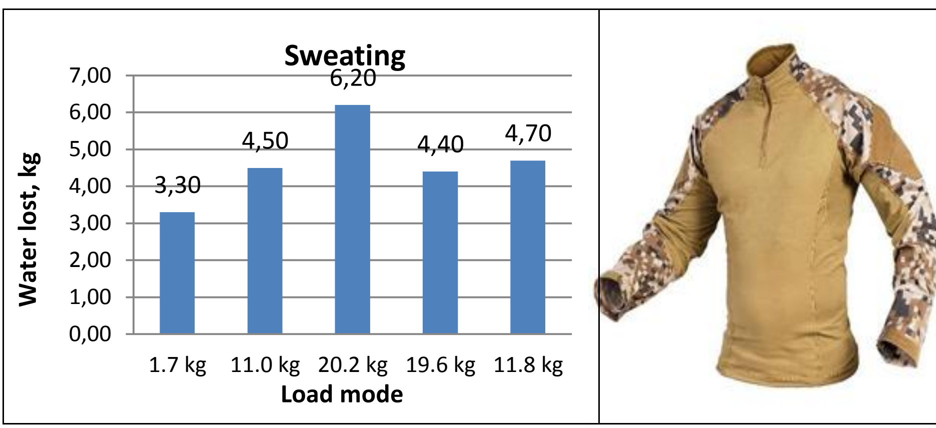

Figure 4. Results of the sweating evaluation and the combat shirt

During the flexibility evaluation by Sit-and-Reach testing, 18% of the flexibility lost was scored at maximal load – 20,2 kg accordantly 7,3 cm (Figure 5). Losing flexibility is not so significant. Even with full protection of the load bearing armour system, flexibility decreases by 18% only (Figure 5). Results of the flexibility testing were not statistically proved (Table 4). The reason for the wide variations of the results was the wide variation of the soldiers' body flexibility (Table 4). Example - day 21.03.2012, Soldier 1 (18.5 cm), Soldier 2 (6 cm), Soldier 3 (3 cm), Soldier 4 (9 cm), Soldier 5 (12 cm), Soldier 6 (5 cm). Further days of testing showed little influence of the CIPS, even when analysing every soldier's results (Table 4). Low CIPS influence on the flexibility was also proved by the low correlation with the load modes (Table 4). The low influence on the soldier flexibility demonstrates the high quality of the CIPS. From the perspective of the gained measurements, the CIPS can be considered to be of high quality, however, for future testing soldier groups should be set a flexibility range with a statistical deviation.

There is no significant change in CIPS balance evaluation by the Flamingo Balance test - 8 see (Fig. 5). However, the most frequent average number of falling actions (9) is scored during the 11,8 kg (backpack mode) load. The backpack is located behind the back with some distance between the body mass centre and the backpack mass centre, which causes a decrease in the level of stability and more frequent falling actions during the Flamingo Balance test. The results show the high quality level of the ergonomics of the load bearing armour system (Fig.5).

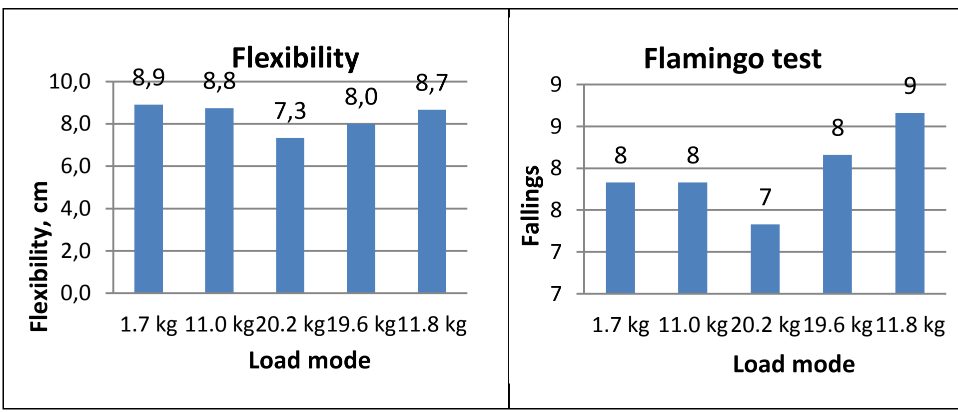

Figure 5. Results of the flexibility and balance evaluation

During the measurement tests of static arm strength by hand grip the following results were recorded showing insignificant influence of the CIPS on arm strength. Both tests show the high quality of CIPS. No significant decrease in arm strength and limb movement has been recorded. A supremacy of the left hand has been detected due to the significant strength of the left hand evaluator Nr.2 (Table 4). In the limb movement speed test, measured using the plate tapping method (Fig. 6). The results testify that limb movement is not influenced by load in this particular test, even with the heaviest load of 20,2 kg. The results of the plate tapping test showed no influence on soldiers by CIPS in the particular test method (Fig. 6). For future testing it is necessary to evaluate the necessity of arm strength and limb movement testing for the evaluation of CIPS due to the low correlation to load modes, not allowing interpreting the results as quality characteristics of the CIPS (see Flamingo test low correlation).

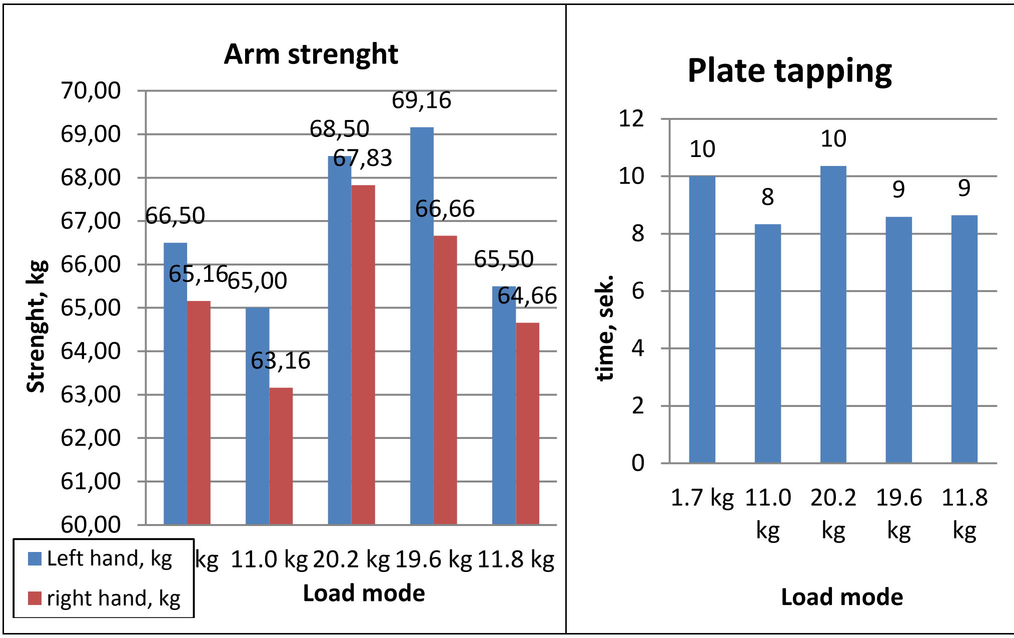

Figure 6. Results of the arm strength and limb movement evaluation

The Harvard Step test is an aerobic fitness test, developed by Brouha et al. (1943) in the Harvard Fatigue Laboratories during World War II [6]. The features of this test are that it is simple to conduct and requires a minimum of equipment. Harvard step testing results identify the adaptation of the muscle groups to the specific load type, not showing significant changes in strength.

During the tests some psychological influence of the results has been identified (Fig. 7). The recovery line of the heart rate on 1st test of the load mode 1,7 kg is higher compared to the 2nd test at load mode 11,0 kg. Such results can be explained by the psychological influence on the heart rate. Psychological influence can be avoided by a more thorough explanation about the testing aspects to the soldiers during the testing preparation period, as it is suggested by the EUROFIT testing methodology.

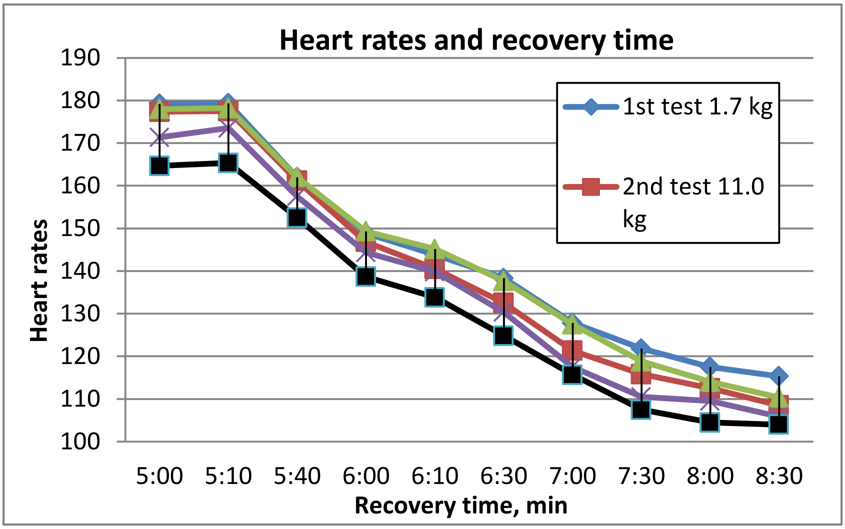

Figure 7. Results of the Harvard step test

Discussion

Since Republic of Latvia is the member of the North Atlantic Treaty Organization (NATO) the requirements of the Standardization agreement (STANAG) has been followed in the field of the quality evaluation combat clothing and personal protective equipment. Relevant STANAG 2138 PCS "Troop trial principles and procedures – Combat clothing and personal equipment" covering user trial of material (item of clothing or personal equipment) by military units in the field under operational conditions [12]. However negative feedback of the US Marine Corps (USMC) deployed modular tactical vests (MTV) [13, 14] after successful field trial [15] raises doubts about troop trial correct methodology and results analysis and interpretation. Unfortunately there is no such possibility to evaluate testing methodologies and result interpretation due to data not availability on open information sources. Such a doubt in the troop trials showing necessary in trial by imitation combat activity in laboratory condition by such EUROFIT and Harvard step test system before starting field trial by combat units in operational area. More over quality of the plate carrier mode type of the body armour (load mode 11.0 kg) comparing with full load bearing armour load (load mode 20.2 kg) can be evaluated during EUROFIT and Harvard step test. Both testing systems can be provided without involving military units like USMC did with evaluation of the body armour vest and scalable plate carriers [16]. Comparing with troop trial results laboratory troop trial by EUROFIT and Harvard step test showing statistically proved and trusted results with the same conclusions like troop trial.

Conclusion and future tasks

EUROFIT and Harvard step test are effective and statistically trusted testing tools can be applied on the quality evaluation of the CIPS influent on soldier by measurement several soldier body parameters, describing combat ability. Both testing systems can be successfully applied to newly developed body armour systems as well as benchmarking evaluation between several body armour system solution and other personal protection equipment in the event of the sole source decision making or decision of the implementation prototypes into Army logistics supply. From the perspective of the human sources EUROFIT and Harvard step test system are cost effective testing solutions without influent on the combat unit daily standard operation procedure, training and military tasks. EUROFIT and Harvard step test system are not required expansive laboratory equipment and facilities and can be provided by the responsible personnel for the Soldier Systems quality assurance as well as under supervision of Army fitness instructors. EUROFIT and Harvard step test results are statistically analysed, which avoid any doubts about trust to the results. After applying EUROFIT and Harvard step test the requirements in the troop trial also should be fulfilled as required STANAG 2138 PCS "Troop trial principles and procedures – Combat clothing and personal equipment". For the future task beside CIPS physiological influence on the soldiers body, additionally the psychological influence should be evaluated and testing system should be established to provide full spectrum evaluation system for the CIPS quality.

References

1. *State Defence Concept*. Government of the Republic of Latvia. May 20, 2008. Aproved by Saeima of the Republic of Latvia June 19, 2008.
2. Šitvjenkins, I. & Viļumsone, A. (2009). National Armed Forces Republic of Latvia Soldier Individual Protection System Concept. *Scientific Journal of RTU*, 9(4), 68-76.
3. Lāriņš, V. (2004). *Sporta medicīna (1.daļa)*. Latvijas Sporta pedagoģijas akadēmija, Rīga.
4. *EUROFIT metode*. Medicīniskās tehnoloģijas metodes izvērsts apraksts. Nacionālais veselības dienests. Retrieved March 22, 2012, from www.vmnvd.gov.lv http://www.vmnvd.gov.lv/lv/datu-bazes/arstnieciba-izmantojamo-medicinisko-tehnologiju-datu-baze/32-sporta-medicinas-mediciniskie-pakalpojumi/eirofit-metode

5. *Eurofit Fitness Testing Battery*. The sport science resource. Retrieved March 22, 2012, from http://www.topendsports.com/testing/eurofit.htm
6. *The Harvard Step test.* The sport science resource. Retrieved March 22, 2012, from http://www.topendsports.com/testing/tests/step-harvard.htm
7. 01.02.07 NBS komandiera pavēle Nr.128. Antropometrisko datu NBS karavīriem analīze. NBS. 2007.gads.
8. Šitvjenkins, I. (2008). *Karavīra individuālās aizsardzības sistēma*. Rīga, SIA MaxMor, 160.
9. Sauka, M., Priedite, I.S., Artjuhova, L., Larins, V., Selga, G., Dahlstrom, O. Et al. (2011). Physical fitness in northern European youth: Reference values from the Latvian Physical Health in Youth Study. *Scandinavian Journal of Public Health*, 39, 35-43.
10. *Heat transfer and evaluation of clothing. ACCP-1* (1992). Allied Combat Clothing publication. NATO International Staff – Defence Support Division. Military agency for standardization.
11. *Troop trial principles and procedures – Combat clothing and personal equipment. STANAG 2138 PCS*. (1996). MAS/161-PCS/2138. May 31st, 1996. NATO Military Agency for Standardization.
12. Soldier Systems Daily. Posted January 8th, 2009. Retrieved from http://soldiersystems.net/2009/01/08/usmc-prepares-for-improved-mtv-program/
13. Marine Corps Times. Corps: New body armor more comfortable. Posted: Monday January 10th, retrieved from http://www.marinecorpstimes.com/news/2011/01/marine-better-body-armor-on-the-way-011011/
14. Official U.S. Marine Corps Web Site. Systems Command improves Marines' combat effectiveness with new Modular Tactical Vest. Posted November 20th, 2006. http://www.marines.mil/searchcenter/Pages/Results.aspx?k=MTV&s=All%20Sites. By Corporate Communications, USMC HQ.
15. Official U.S. Marine Corps Web Site. Marines test body armor. March 3rd, 2009. http://www.marines.mil/unit/1stmardiv/Pages/Marinestestbodyarmor.aspx. By Lance Cpl. Eugenio Montanez, 1st Marine Division
16. Тихомиров, В.Б., (1974). Планирование и анализ эксперимента (при проведении исследований в легкой и текстильной промышленности). Москва, легкая индустрия.

AKNOWLIGEMENT

This work has been supported by the European Social Fund within the project “Establishment of interdisciplinary research groups for a new functional properties of smart textiles development and integrating in innovative products" No.2009/0198/1DP/1.1.1.2.0./09/APIA/VIAA/148.

EIROPAS SOCIĀLAIS FONDS

INVESTING IN YOUR FUTURE

EIROPAS SAVIENĪBA

Submitted: April 20, 2012
Accepted: May 29, 2012