EVALUATION OF FEELING OF COMFORT OF MILITARY SPORTSWEAR USERS DURING PHYSICAL ACTIVITY

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Abstract: *The article deals with the evaluation of the feeling of comfort of the user of the equipment during his physical activity. It is a subjective evaluation of the clothing comfort of a soldier dressed in selected military sportswear while simulating physical activity on an exercise bike, based on a questionnaire construction. The aim of this article was to test selected samples of sporting military equipment together with other suitable materials in order to get the closest possible experience with testing of military clothing in real conditions. Based on the evaluation of the results of the simulated load of tested soldiers to suggest a possible upgrade of equipment to improve the utility properties of sports equipment and ensure optimal conditions of clothing comfort of soldiers. The results are a source of important information for the stage of design and innovation in the introduction of new sports gear, leading to improved military equipment.*

Keywords: *clothing comfort, proband, sports military clothing, subjective evaluation.*

1 INTRODUCTION

Military clothing comfort is important for the soldiers of the Czech Armed Forces (CAF) because it helps them to achieve the best results not only within their physical preparation but also while executing tasks in military operations. Today high quality and more products, that are expensive, are replaced by cheaper and less smart. Comfort of the clothing material wearers is one of the most important aspects influencing mainly the performance of the occupant under physical strain and wearer's mental state. Quality and functional clothing material is important for professional soldiers performing highly strenuous activities and is vital for their ability to continue with this performance.

Comfort means absence of discomfort for the user while wearing the apparel. It is the status of organism when uncomfortable perceptions are felt by our senses and when we aren´t able to perform activities for longer time. Skin temperature 33.2±1°C, relative humidity of the ambient environment 50±10%, speed of air flux 25±10 cm/s, absence of water on the skin and content of CO_2 0.07% represent clothing comfort optimal conditions. If 25% of the skin surface moistened with sweat, an occupant feels heat or cold. It comes to physiological discomfort, which perceived by each human organism subjectively. It is a situation when the apparel user is not able to work for required period. It is obvious, that clothing assemblies should designed in a way to assure the above-mentioned conditions [1].

Clothing comfort separates into psychological and functional comfort. Psychological comfort involves climatic, economic, historical, cultural, social and group or individual aspects. It is a state of mind. Functional comfort includes thermophysiological, sensory and pathophysiological comfort. Sensory comfort implies direct perceptions and feelings of humans while their skin is in direct touch with the textile. Feelings can be pleasant or on the contrary unpleasant, irritating, scratchy, pricking or sticking. Thermophysiological comfort comes with the perception of the user`s thermal comfort. It closely relates to the transport of the air and liquid humidity, heat transfer in individual layers of the clothes and air fluxion in the apparel. Corresponding thermophysiological properties of military clothing are important especially if it is not possible to change it easily or take it off just like with the clothes intended for casual wear or fitness. Fitting clothing design is also important. It influences the way that the apparel adjusts while wearing and how it enables free movement [2]. Pathophysiological comfort is connected with the action of microorganisms occurring on human skin. Effect of these influences depends on the human skin resistance against chemical substances contained in particular fabrics.

Sportswear as the first contact layer should to fulfil following requirement. The first layer should firstly distribute the liquid sweat into large area (by capillary action in grooved polyester or polypropylene fibres), in order to reduce the local fabric humidity and

consequently keep the friction coefficient between the skin and the fabric as low as possible. Simultaneously, in this large area, sweat should evaporate easily, provided the adhesion between the fabric fibres and water is low. Unfortunately, cotton and viscose fibres exhibit high adhesion hence pure non-treated natural fibres will not offer good level of contact comfort (low friction). From the study [3] follows that thermophysiological comfort properties of underwear in dry state can be substantially lower than their comfort properties in real conditions in their use due to the absorbed sweat. This surprising observation emphasizes the importance of testing of thermal comfort properties of fabrics (thermal resistance and water vapour permeability) in dry and wet state by means of special instruments, as are non-destructive Czech fast testing instruments PERMETEST and ALAMBETA.

Subjective sensations of the individual are important within clothing comfort assessment and they can highly influence his or her performance. Clothing discomfort affects mental state of the sportsman and can result in a stressful situation, which leads to the augmentation of body temperature and worsens the individual performance. Using physiological properties assessment, we tried to describe more precisely the functional values of the particular textiles and clothing products. Evaluation can be conducted objectively using various gauges such as, e.g. thermal manikin or Sweating Guarded Hotplate (SGHP) or also subjectively by means of the group of probands simulating physical activity or combination of both of these approaches can be used. Reference [4] states, that subjective evaluation of comfort while wearing particular garments can be conducted in real conditions and also in laboratory by means of the study with probands, while group of probands simulates physical activity, e.g. on an exercise bike. Feelings of the apparel wearers can evaluated via subjective evaluation by means of the questionnaires. Tested proband perceives and distinguishes various feelings as hot (mild heat – heat – hot) and cold (cold – colder – congealing), moisture, sensory perceptions such as prickliness or irritation of the apparel and evaluates particular t-shirt design. After finishing physical activity, each proband notes the values related to the above-mentioned parameters according to the assigned scale into the questionnaire. The values are connect to three phases of the test (before the test, during the test, at the end of the test). The group of probands has to be acclimated to the climatic conditions in the laboratory and it is necessary to choose the appropriate level of load.

The paper is concentrated on the subjective evaluation of soldiers' comfort while wearing the clothing material. The assessment was conduct by means of probands measurement according to the precisely defined methodology in the laboratory of the Physical Training and Sports Centre of the University of Defence in Brno (CTVS). The research by focused only in the evaluation of the first layer of the sportswear, sport t-shirts. Basic clothing ensemble of the t-shirts was chose aiming at thermal feelings, humidity resistance and overall sensory feelings of probands such as prickliness or irritation. Subjective comfort evaluation and recommendations related to the clothing material innovations in order to improve feeling of comfort of soldiers wearing sports military clothing represent the results of the research.

2 EXPERIMENTIAL

2.1 Materials and probands

Basic clothing ensemble of the t-shirts for experimental testing was chose according to the material composition of commonly used either artificial or 100% natural fibres. T-shirts determined for military clothing support of the CAF form the basis of the clothing ensemble. Military t-shirts being use for the research are defined as the basic equipment for the professional soldiers by the standards of the CAF. Standards are defined for military clothing support of active soldiers and students according to their service rank [5].

Table 1 Overview of used military and other clothing

Marking	Material composition	Thickness [mm]	Square mass [g/m^2]	Structure of t-shirt	Producer and price
T-shirt 1	57% polyamide, 43% polypropylene	0.96	160	Weft double jersey (smooth)	MOIRA, a.s., Czech Republic 899,00- CZE
T-shirt 2	100% polypropylene	1.15	106	Weft double jersey with ribs	MOIRA, a.s., Czech Republic 699,00- CZE
T-shirt 3	100% merino wool	0.94	170	Weft single jersey	MOIRA, a.s., Czech Republic 1499,00- CZE
T-shirt 4	82% cotton, 18% polyamide	1.10	214	Weft double jersey (smooth)	Sintex a.s., Czech Republic 105- EP
T-shirt 5	85% functional polyester with silver ions content, 9 % antistatic fibre, 6% polyamide	0.91	125	Double-faced patterned binding made of profiled polyester fiber	Monitex Czech s.r.o., Czech Republic 125- EP
T-shirt 6	100% cotton	1.18	220	Weft single jersey	ALEA wear s.r.o., Czech Republic 150- EP

Examined t-shirts ensemble is complete with t-shirts commonly used for sport activities. Objects of the research are state in Table 1 together with material composition and their producers. Indicative price in CZK can be seen in the table as well and the value in equipment points (EP). The value of garments is determined in equipment points and derives from acquisition costs but it does not have to express the exact recalculation of the financial value [6].

Six students of the University of Defence in Brno participated physiological comfort testing. Students of all of the performance groups were chose in terms of statistically appropriate sample. All of the characteristics of probands are state in Table 2 and in the Figure 1; there is the presentation of testing of probands on exercise bikes in the laboratory of the CTVS. The tested group became acquainted with the details of the questionnaires before evaluation.

Table 2 Characteristics of probands

Marking	Age	Height [cm]	Mass [kg]	BMI*
1	19	178.5	98.5	30.9
2	20	174.5	66.2	21.7
3	20	180.5	64.6	19.8
4	20	182.5	79.7	23.9
5	20	179.8	101.7	31.5
6	20	182.7	66.9	20.0

*BMI - body mass index

Figure 1 Example of tested probands

2.2 Methods

The experiment of measurement of probands' subjective feelings of comfort was carried out within simulation of physical strain on exercise bike in the laboratory of the CTVS. Subjective evaluation of feeling of comfort was performed by probands via system of questionnaires.

The results of the experiment were analysed and evaluated by means of mathematical – statistical methods. The experiment was conduct in February 2020. Monitoring of the temperature and humidity of the first layer of the sports military clothing, sensory feelings and written record of the overall comfort of t-shirts made by probands formed the bases of the experiment. The climatic conditions of the experimental environment were fulfilled with according to ISO EN 139 Standard atmospheres for conditioning and testing. During the experiment, the air temperature range was 20±2°C and relative humidity 65±2%. Subjective evaluation of probands' comfort perception was carry out in three phases. Testing of the ensemble of the t-shirts before the start of the physical activity on exercise bike presented the first phase. The experiment continued with the subjective evaluation of comfort feeling by probands while reaching heart rate frequency (HRF) 150 of permanent load on stationary bike and after the end of the test, which took 15 minutes. Analysis of data being measure and its evaluation represented the next phase.

Changes in the temperature of the first clothing layer and in its humidity, sensory perceptions and written record of the overall comfort being prepared by probands were monitor. Assessment via questionnaires was perform in order to verify the above-mentioned assumptions. System of questionnaires was focus on the four main evaluation fields from the point of view of clothing comfort perception. Subjective evaluation can also include individual preference of the user and garment design. Tested persons subjectively evaluated their thermal, moisture and sensory feelings. The overall subjective assessment of the t-shirt made by proband formed the part of the questionnaire as well. Probands noted their opinions to the questionnaire according to the scale that had 10 degrees of sensitivity before the test, in the middle of testing and at the end after finishing their physical activity. The highest value 10 represents optimal evaluation (excellent) within particular field of interest and degree 1 is the worst evaluation (unsatisfactory). To conclude, the overall subjective point evaluation was complete for each t-shirt. Data was obtained based on point evaluation of particular fields of clothing comfort perception.

Ten degrees ordinary scale was using for statistical evaluation of thermal, humidity, sensor and overall subjective feelings of probands. The median of ordinary scale and its 95% confidence interval was using for evaluation of resulting data. Data was classification into categories 0-10 and relative frequencies (f_i) and cumulative relative frequencies (F_j) were calculated according to the equations:

$$f_i = n_i / n \quad (1)$$

$$F_j = \sum_{i=1}^{j} fi \quad (2)$$

where n_i is the number of subjective evaluation of textile comfort classification into „i" category and n is the total number of evaluators.

Median X_M was calculated based on the 2 steps approach. Median category M was determined in the first step $F_M\text{-}1<0.5$ *and* $F_M \geq 0.5$.

Median X_M was calculated in the second step:

$$X_M = M + 0.5 - (F_M - 0.5)/f_M \quad (3)$$

95% confidence interval of the median *Med* was constructed for the assessment of classification significance into median category in the following way.

Cumulative frequencies F_D^*, F_H^* were determined that are, used for the construction of 95% confidence interval. For $\alpha=0.05$, $u1\text{-}\alpha/2=1.96$ is chosen, where $u1\text{-}\alpha/2$ is the quantile N (0.1).

$$(F_D^*, F_H^*) = 0.5 \pm 0.5 u1\text{-}\alpha/2/\sqrt{n} \quad (4)$$

Categories D a H were defined, in which F_D^* and F_H^* lie and correction coefficients were established according to the equations:

$$d = (F_D^* - F_{D\text{-}1})/f_D; \quad h = (F_H^* - F_{H\text{-}1})/f_H \quad (5)$$

Finally, interval of median confidence was calculated:

$$D - 0.5 + d \leq Med \leq H - 0.5 + h \quad (6)$$

3 RESULTS AND DISCUSSION

Subjective evaluation method represents highly important assessment of clothing comfort perception. Subjective evaluation is suitable for assessment of apparel appropriateness in particular conditions in which proband can occur and can directly express his or her feelings of comfort or discomfort. However, each individual prefers different material or clothing design and that is why it is really demanding to suggest sports military clothing, which meets the requirements of the whole group of probands.

3.1 Subjective evaluation by questionnaire system

The overall subjective point evaluation was compiled for each t-shirt. The assessment was acquired based on point evaluation of particular fields of comfort perception.

Probands comfort or discomfort perception while wearing specific t-shirt was express via graphical analysis by means of radar charts in the Figures 2-7.

Diagrams come out on the average values of all of evaluations made by probands for each t-shirt. In the radar charts, it is obvious that feeling of comfort from the point of view of moisture sensation has strongly decreased for the t-shirts No. 2, 4 and 6 within all of the evaluation phases. The smallest differences in comfort feeling within all of the evaluation fields are visible for t-shirt No. 1.

Thanks to the total point evaluation that is illustrated in the Figure 8, it is possible to analyze the behavior of each testing sample in all of the phases of the test. It can be observed how the tested t-shirt behaved within particular period of time and how the comfort perception of proband got worse or improved. Maximum of points possible to reach was 120. The rule was establish, the more points particular t-shirt obtains, the more conditions and assumptions to reach optimal comfort are met with no matter what physical strain in a short or long time.

Subjective t-shirts' evaluation was divided into point assessment before the test, during the test and at the end of the test and the total evaluation for the whole period of testing. T-shirts reaching more than 90 points met determined conditions and assumptions to achieve optimal comfort during physical activity.

At the beginning of the test, the completely clothing ensemble of t-shirts achieved excellent or sufficient point evaluation. During the process of testing, t-shirts No. 6, 4 and 3-stated worse subjective feeling of comfort that was also evaluate by probands at the beginning of the test. Thermal feelings and moisture sensations also got worse for t-shirt No. 6. For the t-shirt No. 2, the values of subjective feeling of comfort were more than sufficient at the beginning but in the course of the test, the feeling of comfort strongly worsened. On the other hand, t-shirts No. 1 and 3 had the best results during the whole period of testing and they met all of the conditions to keep thermal, moisture, sensory feelings and total subjective feeling of clothing comfort during physical activity. T-shirts No. 6 and 4 proved critical values of moisture sensations and total subjective feelings at the end of the testing. They met given conditions and assumptions to reach optimal comfort during physical activity.

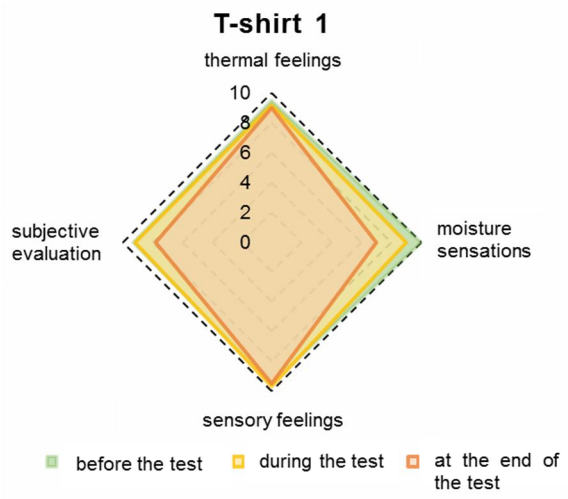

Figure 2 Diagram of testing T-shirt 1

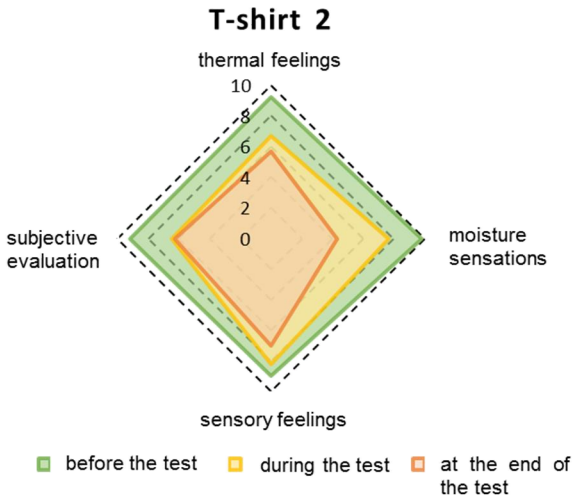

Figure 3 Diagram of testing T-shirt 2

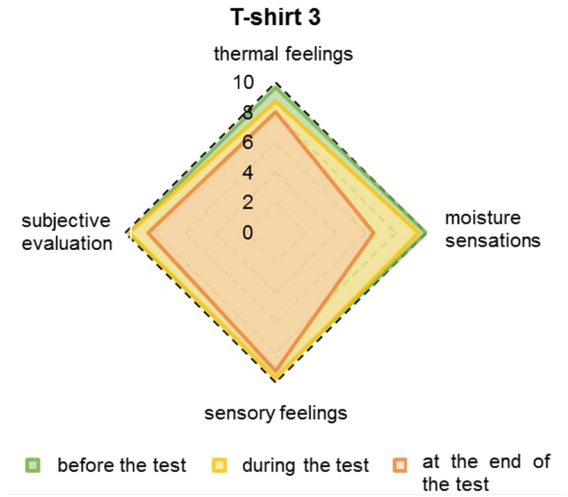

Figure 4 Diagram of testing T-shirt 3

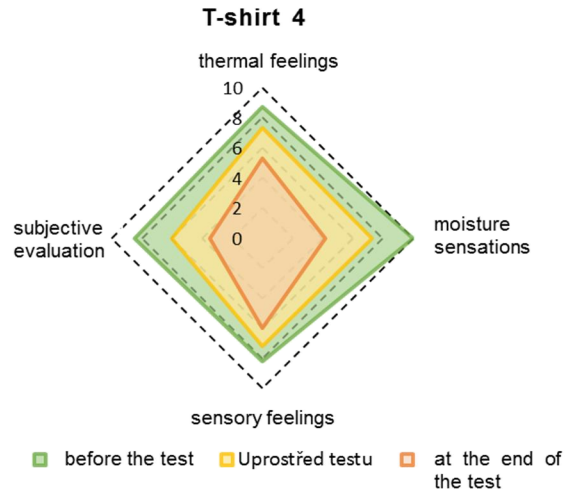

Figure 5 Diagram of testing T-shirt 4

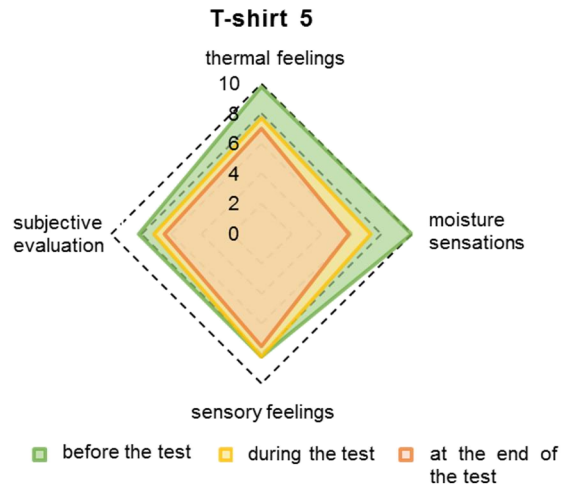

Figure 6 Diagram of testing T-shirt 5

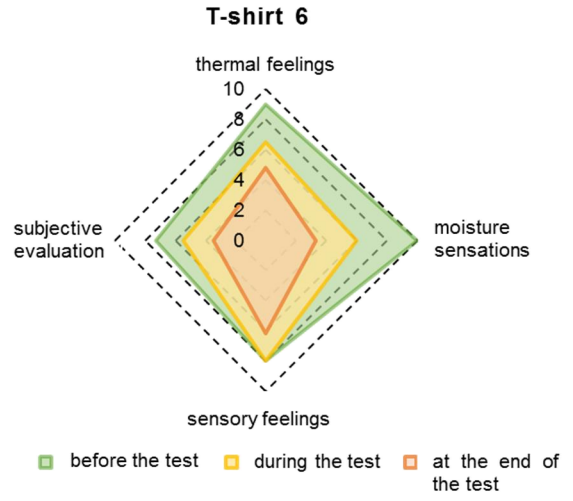

Figure 7 Diagram of testing T-shirt 6

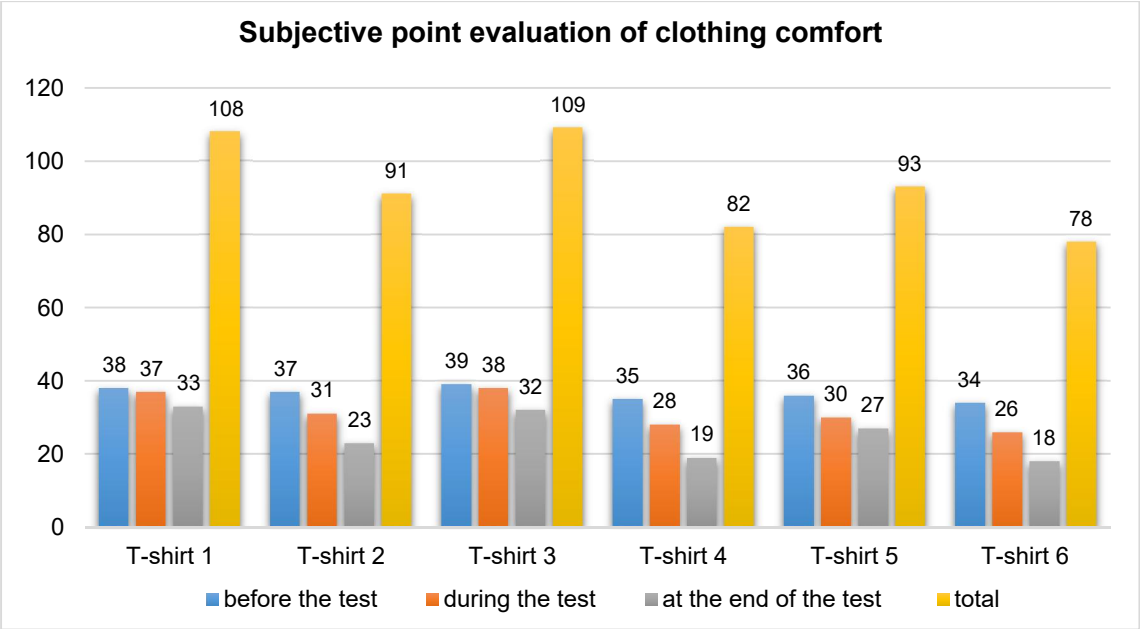

Figure 8 Total subjective point evaluation for all of the t-shirts

3.2 Statistical processing of results

The median of ordinary scale and its 95% confidence interval is using for statistical processing of results of subjective evaluation of comfort by probands in the course of physical strain on the exercise bike and for the verification of the analysis results' correctness. Values of medians being ascertain and classification into 10-degree scale are state in Table 3 and Figure 9 illustrates values of medians for all of the t-shirts within confidence intervals.

Table 3 Median value classification into 10 degree scale

Marking	T-shirt 1	T-shirt 2	T-shirt 3	T-shirt 4	T-shirt 5	T-shirt 6
Value of median	9.56	8.21	9.54	6.9	8.14	6.75
Evaluation scale description	excellent	above-average	excellent	average	above-average	average

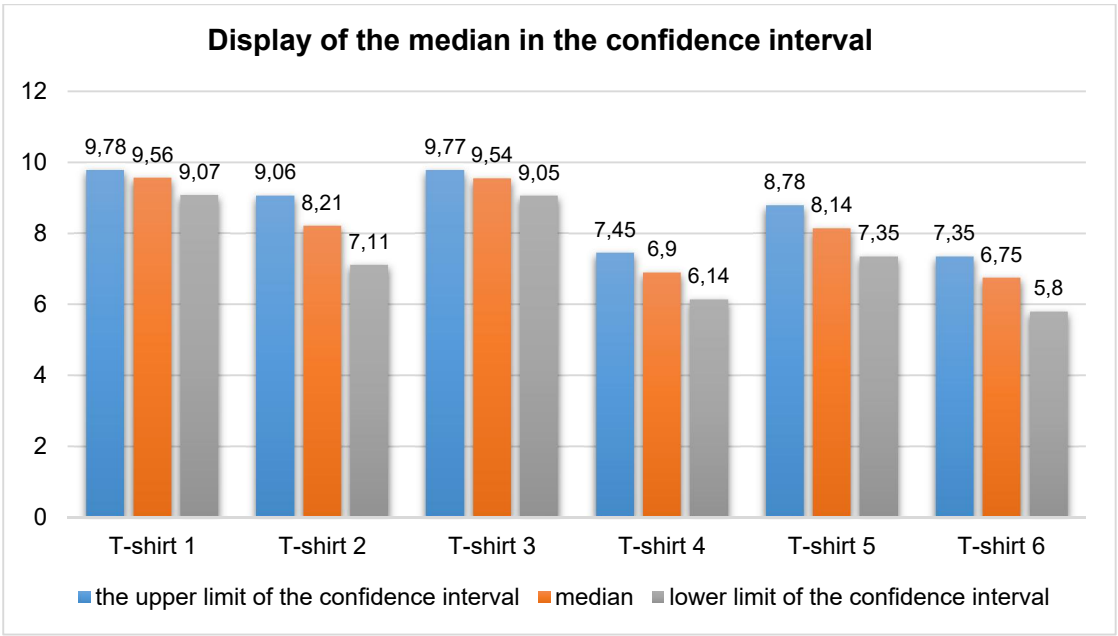

Figure 9 Median in the confidence interval for all of the measurements

If the confidence intervals overlap (which is the case of the t-shirts No. 1, 2, 3 and 5), they are not consider different from the point of view of clothing comfort level. It means that pursuant to the ascertained median values we can confirm the results of the analysis and evaluation of questionnaires.

3.3 Evaluation of the experiment

T-shirt samples No.1 and 3 are considered the best (excellent) based on the results of testing and its statistical processing. T-shirt No. 1 benefits from material properties of the front side and backside of knitted fabric so appropriate transfer of moisture and heat and free and comfortable sticking to the human body is suppose. T-shirt No. 1 is suitable not only for outside soft physical activities but also for the training in fitness center. T-shirt No. 3 is made of very soft and elastic knitted fabric and 100% merino wool, which while moistening, releases high quantity of sorption heat and assures breathability and comfort that is need for physical activities practising. Company Moira, a. s. is the producer of both of the evaluated t-shirts with the best results.

Next two t-shirts comparable from the point of view of comfort evaluation are the t-shirts No. 2 and 5, which were assess according to the same scale as above average. T-shirt No. 2 produced by the company Moira, a. s. is usable rather for winter season because it is warming. The same with the t-shirt No. 5, military garment with the specification Light thermo 2012, which is mainly use as the first layer on the body for layering of the other military garments for all of the seasons of the year.

T-shirts No. 4 and 6 were evaluated as average. Both of them are using as military clothing garments. T-shirt No. 6 is made of 100% cotton. It is necessary to count with the creation of significant amount of heat and moisture in the course of physical activity that intensifies feeling of discomfort caused by worsening of thermal, moisture and total subjective sensations. The research therefore proved that this military clothing garment does not meet appropriate conditions to reach comfort and it can be suppose that the performance of soldiers would be strongly influence by feeling of discomfort.

3.4 Further development of research

Capability of t-shirt material to keep the skin surface dry without sweat as long as possible is important to reach optimal clothing comfort. The longest period during which the t-shirt is able to take away and transport moisture without changing or significant increase of humidity in interlayer skin-clothes is required. During this process, the smallest increase of the body surface temperature is required at the same time. In case of significant temperature changes, it could come to the organism overheating and after the end of the physical activity and creation of heat in muscles to virulent body cooling and hypothermia. Therefore, it would be useful in future to conduct the evaluation via heat load determination (risk of the organism overheating) according to the WBGT index, as stated in the reference [7].

Future research in this particular field will be focus on the possibility to monitor temperature and moisture changes development inside the microlayer of the sportswear by means of the central wireless unit FlexiGuard. Based on the evaluation of temperature and moisture changes inside the microlayer of the sportswear, it is possible to determine heat load of the organism/ risk of the organism overheating according to WBGT. Risk of the organism overheating can be calculated and evaluated based on the index WBGT for the total evaluation of the clothing comfort of the first layer and it can be carry out separately for the front and backside of the t-shirt. Evaluation could be than divided in the average risk of the organism overheating and maximal risk of overheating. The other military sportswear garments, i.e. sport shoes, sweatpants and tracksuit jacket should be included in the further research activities.

4 CONCLUSIONS

If the soldier is required to reach appropriate performance and results during physical activity, military clothing of sufficient quality should be assure for him/her. The material of the clothes should be able to drain moisture away out of the body (sorption heat) in the form of vapour and at the same time, the material should become dry as fast as possible so as not to endanger the soldiers' health. Thermophysiological properties are influence not only by the clothing material composition but also by the standards of the clothing maintenance.

Based on the research being perform, materials made of merino wool or mixture of polyamide and polypropylene meet requirements placed on physiological comfort of soldier from the point of view of material composition and maintenance possibilities. That is why these textiles are recommended for the production of suitable quality sports clothing.

Generally, military clothing has to assure the best thermophysiological comfort of the user in highly different conditions and under physical strain. Especially sandwich structure of military clothing that means layering of particular clothing garments on each other should stay functional for the whole period of using. The first layer of clothes that takes sweat and vapour away out of the skin surface to the next clothing layers forms the basis of the clothes structure functionality. The first layer is in direct touch with skin, which is why the evaluation is focus not only on thermophysiological properties of the material from the point of view of its

construction and material composition but also on evaluation of sensory feelings of a particular textile.

Based on the experiment results we can conclude that sports military t-shirts being implement and use in practice are on the average level from the point of view of comfort feeling evaluation under physical strain. Especially t-shirt No. 6 made of 100%cotton does not meet criteria determined to keep optimal conditions of clothing comfort. The wearers evaluated T-shirt No. 5 as above average so we suppose that it meets clothing comfort conditions.

Our team suggests substituting currently used sports military t-shirt (tested t-shirt No. 6) for the new garment in order to meet criteria of clothing comfort optimal conditions during soldiers' physical activities. Data related to evaluated t-shirts with the best results can be used as the source of information for the technical specification of material of personal use of soldiers, material composition and technical parameters' values and it should be involved in the tender documentation for the new clothing equipment. T-shirts No. 1 and 3 produced by the company MOIRA, a. s. obtained the best results.

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