A RESEARCH OF SUBJECTIVE EVALUATIONS OF THE THERMAL COMFORT OF BUSINESS CLOTHING EVALUATED IN WARM AND SLIGHTLY COLD ENVIRONMENT

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Abstract: *This paper presents a study of subjective assessments of thermal comfort when wearing business clothing made from conventional textiles, such as wool and blends with wool and textiles combined with phase-change materials (PCMs), which are capable of providing adequate thermal physiological comfort to the wearer. The evaluation of thermal comfort was carried out on the basis of determining the subjective feeling of thermal comfort with the help of test subjects in a computer controlled climatic chamber, in artificially created warm and slightly cold environmental conditions, at ambient temperature of 25°C, 20°C, 15°C and 10°C. The impact of particular business clothing systems and varied environmental conditions on the wearer's subjective feeling of thermal comfort was determined with a questionnaire and an assessment scale of thermal comfort defined by standard ISO 10551:1995. For this purpose, an analysis of the subjective evaluation of thermal comfort, the desired thermal state, the acceptability of the current situation and their personal tolerance of the environment, was made before, during and after each experiment. The results of the research show that subjective evaluations of thermal comfort directly depend on environmental conditions, as well as clothing systems and activity levels. It was found that the test subjects felt most comfortable in the selected business clothing at an ambient temperature of 20°C and 15°C. It is also evident from the results that at an ambient temperature of 25°C, the persons in the selected clothing felt slightly uncomfortable, especially during and after walking when they felt hot. The test subjects felt uncomfortable also at an ambient temperature of 10°C, when they felt cold or slightly cold while wearing the analysed 3-layer clothing systems without an additional layer of clothing. This indicates that an additional layer of clothing, such as a coat is needed for performing adequate thermal comfort around and below 10°C.*

Keywords: thermal comfort, subjective evaluation, clothing, phase-change materials (PCMs), environment.

ISTRAŽIVANJE SUBJEKTIVNIH PROCENA TOPLOTNE UDOBNOSTI POSLOVNE ODEĆE U TOPLOJ I BLAGO HLADNOJ OKOLINI

Apstrakt: *Ovaj rad predstavlja studiju subjektivnih procena toplotne udobnosti pri nošenju poslovne odeće izrađene od konvencionalnih tekstila, poput vune i mešavina vune i tekstila u kombinaciji sa materijalima koji menjaju faze (PCMs), koji su sposobni da pruže odgovarajući termički fiziološki komfor. Procena toplotne udobnosti izvršena je na osnovu utvrđivanja subjektivnog osećaja toplotne udobnosti uz pomoć ispitanika u računarski kontrolisanoj klimatskoj komori, u veštački stvorenim toplim i blago hladnim uslovima okoline, na temperaturi*

od 25°C, 20°C, 15°C i 10°C. Uticaj određenih sistema poslovne odeće i raznovrsnih uslova okoline na subjektivni osećaj toplotnog komfora korisnika utrđen je upitnikom i skalom procene toplotne udobnosti definisanom standardom ISO 10551:1995. U tu svrhu izvedena je analiza subjektivne procene toplotne udobnosti, željenog toplotnog stanja, prihvatljivosti trenutne situacije i njihove lične tolerancije okoline pre, tokom i nakon svakog eksperimenta. Rezultati istraživanja pokazuju da subjektivne procene toplotne udobnosti direktno zavise od uslova okoline, kao i odevnih sistema i nivoa aktivnosti. Utvrđeno je da su se ispitanici najudobnije osećali u odabranoj poslovnoj odeći na temperaturi okoline od 20°C i 15°C. Iz rezultata je takođe vidljivo, da su se na temperaturi od 25°C osobe u odabranoj odeći osećale pomalo nelagodno, posebno tokom i nakon hodanja kada im je bilo vruće. Ispitanici su se osećali nelagodno i na temperaturi okoline od 10°C, kada im je bilo hladno ili malo hladno dok su nosili analizirane troslojne sisteme odeće bez dodatnog sloja odeće. To ukazuje na to, da je dodatni sloj odeće, poput kaputa, potreban za pružanje odgovarajuće toplotne udobnosti oko i ispod 10°C.

Ključne reči: toplotna udobnost, subjektivna procena, odeća, materiali koji menjaju fazu (PCMs), životna sredina.

1. INTRODUCTION

Clothing wear comfort is a complex subjective perception or a mental state of a person, and is expressed as the result of a balanced process of heat exchange between the human body, the clothing system and the environment. Because each individual has a different interpretation of clothing wear comfort, comfort cannot be defined as the authentic feature of a garment, but is the result of the decision of oneself. Although comfort is primarily a subjective perception, it can be studied from different perspectives. These are thermo-physiological, skin sensorial (tactile), mechanical and ergonomic, and psychological aspects of comfort [1-3].

This paper discusses the thermal comfort of clothing, which is often defined as a condition that expresses satisfaction with the thermal environment [4]. Thermal comfort of clothing can be evaluated using several physical and physiological testing methods. Umbach [5], Mecheels [3] and Parsons [6] have proposed a five-level system for developing and evaluating clothing comfort. Physical analysis of materials (Level 1) and biophysical analysis of clothing systems (Level 2) use some kind of device to simulate the skin's heat and/or water-vapor production, e.g. skin model [7], sweating cylinder [8], hot plate apparatus [9] and other methods [10-12]. Tests can be carried out either on textile materials [7-12] or on complete clothing systems using thermal and sweating manikins, e.g. Coppelius [13], Walter™ [14] and others [15]. An important method of measuring the thermo-physiological comfort is to perform wear trials with study participants. Levels 3, 4 and 5 involve human subjects and controlled climatic chamber tests, controlled field trials and field evaluations, respectively. In the physiological tests the study participants are dressed in

the experimental clothing systems and perform some kind of given metabolic workload in a controlled or real environment. Different physiological parameters (e.g. rectal and skin temperature, heart rate, weight loss, metabolic rate and other physical and physiological values of interest) and subjective perception of clothing comfort can all be determined according to research interest [6, 8].

The feeling of comfort is one of the key factors when selecting clothing and it is an important factor also in business garments, since they are intended to be worn throughout the whole day in different environmental conditions. This paper presents the findings of a study of subjective assessments of thermal comfort of male business garments made of common textile materials, as well as male business clothing that contains phase-change materials (PCMs). Phase-change materials, also called latent heat storage materials, were developed to regulate temperature fluctuations of the human body, assuring the thermal-physiological comfort of the wearer [16, 17]. Currently, PCMs are being used in a variety of outdoor apparel items (e.g. underwear, socks, sportswear, shoes, fire-fighting gear, ski wear, dry suits for divers, etc.), as well as in bedding, such as sheets and pillowcases, and in medical clothing [18, 19]. Therefore, we decided to incorporate PCMs into male business clothing in order to determine if these materials in combination with the common textile materials used for business clothing are able to interact with the human body and provide thermal comfort of the wearer under different environmental conditions.

The impact of particular business clothing systems, with and without PCMs, on the subjective assessment of the thermal comfort of clothing in warm and slightly cold environmental conditions at an ambient temperature of 25°C, 20°C, 15°C and 10°C was

determined experimentally with the help of test subjects according to standard ISO 10551:1995 [20]. For this purpose, a questionnaire and an assessment scale were used before, during and after each experiment in order to evaluate the wearer’s subjective feeling of thermal comfort.

2. MATERIALS AND METHODS

To evaluate the subjective assessment of thermal comfort of male business garments, an analysis was carried out based on an evaluation of clothing systems using study participants in simulated environmental conditions.

2.1. Experimental clothing systems and textile materials

Five male business clothing ensembles of 3-layer clothing system were developed for this investigation. 3-layer clothing systems (designated as cs1-cs5) consist of short underwear (pants and shirt), long sleeve

male shirt, and male suit with lining. The same underwear made of 100 % cotton, and male shirt made of 78 % cotton and 22 % polyester were used for testing. We varied textile materials of male suits and lining for the male suits. The determination of the basic material, thermal and water vapour transmission properties in steady-state conditions of conventional textiles and PCMs which make up the male clothing system were carried out according to standardized test methods and published in Celcar et al. [21]. Table 1 shows an overview of the selected materials and their basic properties, which were discussed in Celcar et al. [21]. Two of the selected textiles contain Outlast® PCMs. Fabric TK21 is a 100 % CV coated textile material with Outlast® PCM particles on the left side and is useful for lining outerwear, while fabric TK22 has built-in Outlast® PCMs in acrylic fibers and is useful for lighter outerwear. The thermal properties of men’s business garment systems were evaluated using a sweating thermal manikin “Coppelius” and discussed in Celcar et al. [13].

Table 1: Description of Test Materials and Their Basic Properties, Source: Celcar et al. [21]

Fabric sample	Clothing system layer	Fabric content	W	h	Q _{air}	R _{ct}	R _{et}
			gm ⁻²	mm	lm ⁻² s ⁻¹	m ² KW ⁻¹	m ² PaW ⁻¹
TK01	Male suit	100 % WO	179.0	0.51	323.5	0.016	0.994
TK02	Male suit	88 % WO, 12 % PA	206.0	0.49	75.2	0.011	1.118
TK03	Male suit	98 % WO, 2 % EA	189.0	0.49	223.0	0.011	0.795
TK07	Shirt	78 % CO, 22 % PES	85.0	0.21	322.0	0.005	0.451
TK12	Liner for suit	100 % CV	76.0	0.11	596.0	0.001	0.198
TK15	Underwear	100 % CO	221.0	1.59	618.0	0.036	2.340
TK21	Liner for suit	Layer 1: 100 % CV, Layer 2: Outlast®: Acryl with PCMs	93.0	0.21	151.0	0.002	0.474
TK22	Male suit	68 % Outlast®: Acryl with PCMs, 28 % WO, 4 % EA	168.0	0.49	277.0	0.014	0.842

Note. TK = textile material; CO = cotton; PES = polyester; WO = wool; PA = polyamide; EA = elastane (spandex); PCMs = Phase Change Materials; CV = viscose; WS = Cashmere; W=weight; h = thickness under a pressure by 0.069 gfc^{m-2} (1 gf = 0.9807 cN ≈ 1 cN); Q_{air} = air permeability; R_{ct} = thermal resistance; R_{et} = water vapor resistance.

Combinations of clothing systems, designated as cs1 - cs5:

cs1: underwear (TK15), shirt (TK07), male suit made of 100 % WO (TK01), and liner for suit made of 100 % CV (TK12)

cs2: underwear (TK15), shirt (TK07), male suit made of 88 % WO, 12 % PA (TK02), and liner for suit made of 100 % CV (TK12)

cs3: underwear (TK15), shirt (TK07), male suit made of 98 % WO, 2 % EL (TK03), and liner for suit made of 100 % CV (TK12)

cs4: underwear (TK15), shirt (TK07), male suit made of 68 % Outlast®: Acryl with PCMs, 28 % WO, 4 % EL (TK22), and liner for suit made of 100 % CV (TK12)

cs5: underwear (TK15), shirt (TK07), male suit made of 100 % WO (TK01), and liner for suit made of 100 % CV and Outlast®: Acryl with PCMs (TK21).

2.2. Subjects

Five males between 21 and 23 years of age (22.2 ± 0.8) participated in the wear trial tests. They were 180.2 cm tall (180.2 ± 4.6) on average and of an average weight of 80.0 kg (80.0 ± 2.4). The general purpose, procedure and risks were fully explained, and informed consent was given by all study participants, but they were not informed about the details of the clothing materials to avoid influencing their subjective ratings.

2.3. Experimental protocol and environmental conditions

All tests with study participants were performed under artificially created environmental conditions in a climate chamber at a constant air movement of 0.2 ms^{-1} and different environmental temperatures ranging from 25 °C to 10 °C, at increments of 5 °C, and 50 % relative humidity. The experimental protocol was approved by the National Ethics Committee (12.02.2008). Study participants (Figure 1) followed an exercise protocol for 113 minutes, consisting of five periods of activities:

1. Activity (A1) – Preconditioning (0-20 min): a 20 minutes rest on a chair at 20-23 °C and around 50 % RH.
2. Activity (A2) – Sitting (21-41 min): 20 minutes of sitting on a chair in a climate chamber at an ambient temperature from 25 °C till 10 °C (with step of 5 °C) and 50 % RH.
3. Activity (A3) – Walking (41-71 min): 30 minutes of walking (3.5 kmh^{-1}) on a treadmill

in a climate chamber at an ambient temperature from 25 °C till 10 °C (with step of 5 °C) and 50 % RH.

4. Activity (A4) – Sitting (72-92 min): 20 minutes of sitting on a chair in a climate chamber at an ambient temperature from 25 °C till 10 °C (with step of 5 °C) and 50 % RH.
5. Activity (A5) – Resting (93-113 min): a 20 minutes rest on a chair at 20-23 °C and around 50 % RH.

Notes: A1-A5: period of activity; RH: relative humidity

Figure 1: Participant with experimental clothing system in a climatic chamber while walking on a treadmill

2.4. Subjective assessment of the thermal comfort of clothing

The methods for evaluating subjective assessment of thermal comfort use different scales to measure thermal sensation and comfort. There are a number of subjective scales which have been used in the assessment of thermal environments; the most common of these are the seven-point scales of ASHRAE (1966) [6]. In this research subjective assessment of thermal comfort was obtained during the experiment according to a questionnaire and an assessment scale defined by ISO 10551:1995 [20]. Subjects answered at predetermined time of experiment using specially designed questionnaires; last minute of each period and second minute of next period. International standard ISO 10551:1995 [20] presents the principles and methodology for the construction and use of scales for assessing the thermal environment. Scales are divided

into two types: personal and environmental. Those related to the personal thermal state may be perceptual – How do you feel now? (e.g. hot) – affective – How do you find it? (e.g. comfortable) – and preference – How would you prefer to be? (e.g. warmer). Those related to the environment fall into two types: acceptance – Is the environment acceptable? and tolerance – Is the environment tolerable? [6, 20]. When determining the subject's thermal perception, the test subjects assessed the perceptual judgements of personal thermal state according to a scale from +4, which means that they felt very hot, up to a scale -4, which means that they felt very cold. The test subjects assessed the "affective" thermal comfort according to a scale from 0, which means that they felt thermally comfortable, up to a scale +4, which means that they felt extremely uncomfortable. In determining the desired thermal state, the test subjects have provided evaluation of the desired thermal state according to a preference scale, where scale +3 means that people desire much warmer thermal state, while scale -3 means that people desire much cooler thermal state. When assessing the acceptability of the current thermal conditions, the test subjects evaluated the current thermal environment as more acceptable (degree 0) and more unacceptable (degree 1). By judging the personal tolerance of the thermal environment, the test subjects determined whether they excellent tolerate the current thermal situation (degree 0), or they can't stand it any longer (degree 4) [20].

3. RESULTS AND DISCUSSION

The results of this research are presented as an analysis of the impact of warm and slightly cold environmental conditions on the subject's thermal perception and "affective" assessment of thermal comfort whilst wearing different business clothing systems made of both conventional textiles and textiles in combination with PCMs. Figure 2 shows the results of the mean subjective ratings of the perceptual judgements of personal thermal state (thermal perception), while Figure 3 shows the results of the mean subjective ratings of the evaluative judgements of personal thermal state (subjective assessment of thermal comfort) evaluated when wearing different clothing systems (designated as cs1-cs5) at ambient temperatures of 25°C, 20°C, 15°C and 10°C.

The results of the subjective evaluation of the perception of the personal thermal state analysed in a warm and slightly cold environment at ambient temperatures of 25°C, 20°C, 15°C and 10°C (Figure 2) show that subjective evaluations are directly dependent on climatic conditions and activity levels. It is evi-

dent that the highest evaluation ratings are obtained at an ambient temperature of 25 °C and the lowest at an ambient temperature of 10°C. However, there are also some fluctuations in the ratings between clothing systems. Therefore, subjective ratings also depend on the chosen clothing system. From the subjective assessments of the perception of the personal thermal state, we can see that the highest or slightly higher ratings were obtained during walking or in the last minute of walking, when the persons felt slightly warmer or hotter.

At an ambient temperature of 25°C, the test subjects on average felt warm (degree +2.0) or slightly warm (degree +1.0) and while walking they felt hot (degree +3.0). It is noted that test subjects felt slightly warm or warm after 20 minutes of sitting at an ambient temperature of 25°C, while during the last minute of walking the test persons in all analysed clothing systems felt hot. After two minutes of sitting (in 72nd minute), the subjects felt warm or still hot (in the clothing system cs2, Figure 2b). After 20 minutes of sitting (in 90th minute) the subjects felt still warm or slightly warm (in the clothing system cs1, Figure 2a). An analysis of the subjects' desired thermal state showed that test subjects at an ambient temperature of 25°C, while wearing all clothing systems, wanted a change of thermal state. This indicates that 3-layer clothing systems are still suitable but may not be (thermally) suitable for wearing at 25°C for longer time. At an ambient temperature of 20°C, the test subjects on average expressed neutral (degree 0) or only slightly warm and slightly warmer (while walking) perception of the personal thermal state, except while wearing the clothing system cs4 (Figure 2d), where they felt only slightly warm. After 20 minutes of sitting at 20 °C, the average thermal state of the subjects was still neutral or slightly warm. While walking or in the last minute of walking, the test subject on average felt warm, except while wearing the cs4 clothing system with PCMs, where some people felt only slightly warm or warm. After two minutes of sitting (in the 72nd minute), persons in the cs4 clothing system expressed their thermal feeling as neutral or only slightly warm, while in other clothing systems the persons felt slightly warm or warm. After 20 minutes of sitting before exiting the air conditioning unit (in the 90th minute), the subjects on average felt neutral or slightly warm. From the results of the subjects' desired thermal state it was noted that at an ambient temperature of 20°C, test subjects only wanted to change their thermal state while walking on the treadmill when they wished it would be a little cooler. At an ambient temperature of 15°C, people on average felt either neutral or only

Figure 2: The effect of ambient temperature on the perception of the personal thermal state when wearing different clothing systems at ambient temperatures of 25 °C, 20 °C, 15 °C and 10 °C

slightly cold (degree -1.0), whereas while walking or in the last minute of walking they on average felt warm. After 20 minutes of sitting at an ambient temperature of 15°C (in the 40th minute), subjects on average felt slightly cold or neutral, especially in the cs3 clothing system (Figure 2c). It was evident from the results that the test persons felt still slightly warm or neutral in the last minute of walking (in the 70th minute) and on average neutral after two minutes of sitting (in the 72nd minute). In the 90th minute of the test, the subjects on average still felt neutral at an ambient temperature of 15°C, while in the cs1 clothing system some persons already felt slightly cold. From the results of the subjects' desired thermal state evaluated at an ambient temperature of 15°C it was evident, that after 20 minutes of sitting, the persons wanted to be slightly warmer, and on average, during a walk or in the last minute of the walk, the test persons wished that they

would be a little cooler. The results of the personal thermal state evaluated at an ambient temperature of 10 °C show that test persons in the 22nd minute of test protocol on average already felt slightly cold (degree -1.0) or cold (degree -2.0) and after 20 minutes of sitting at 10 °C they felt chilly or cold, while in the cs4 clothing system (with PCMs) they felt only slightly cold. The results also show that in spite of lower mean skin temperatures (approximately 31.0°C) measured during a walk at 10 °C (published in Celcar, 2013 [22]), the test subjects on average felt only slightly cold during a walk or in the last minute of a walk; in the clothing system cs4 and cs5, on average, even neutral. It was also evident from the results that persons after walking felt slightly cold on average. In the last minute of sitting at an ambient temperature of 10°C, the subjects on average felt cold or slightly cold. This indicates that male business garments of 3-layer clothing

systems without an additional layer of clothing are not suitable for wearing below an ambient temperature of 10°C. For performing adequate thermal comfort at and below an ambient temperature of 10°C it is therefore recommended to wear an additional layer of clothing, such as a coat.

The results of the subjective assessments of thermal comfort (Figure 3) evaluated at ambient temperatures of 25°C, 20°C, 15°C and 10°C, show that the test subjects felt most comfortable at an ambient temperature of 15°C, as well as at an ambient temperature of 20°C, except during walking, when subjects felt slightly uncomfortable in the selected clothing systems.

At the ambient temperatures of 25°C the test subjects did not feel comfortable in clothing systems, especially when walking and after walking, when they

felt warm or slightly warm. It is also evident from the results that after 20 minutes of sitting at 25°C the persons on average felt still comfortable or slightly uncomfortable because they were slightly warm. After walking and 20 minutes of sitting at 25°C, it can be seen from the results that persons felt only slightly uncomfortable or even comfortable. From the analysis of the physiological parameters (published in Celcar [22]) of the subjects while wearing business clothing systems it was evident that at an ambient temperature of 25°C the mean skin temperatures of test subjects in an average range between 34.0°C and 34.5°C, but not up to 35.0 °C which represents upper limit value of the thermal comfort of no active persons. This means that the analysed clothing systems are still suitable for wearing at 25°C, although upon subjective

Figure 3: The effect of ambient temperature on the subjective assessment of thermal comfort when wearing different clothing systems at ambient temperatures of 25°C, 20°C, 15°C and 10°C

evaluations, test persons felt a little uncomfortable and warm. At the ambient temperature of 20°C, the test subjects felt still comfortable after 20 minutes of sitting and slightly uncomfortable during walking or at the last minute of walking because they were warm, except while wearing cs3 and cs4 clothing systems in which they felt more comfortable (while walking because they were only slightly warm). After walking or 20 minutes of sitting at 20 °C (in 90th minute), the persons again felt comfortable. From the results gained at an ambient temperature of 15 °C it is evident that after 20 minutes of sitting at 15°C, people on average felt comfortable or slightly uncomfortable (especially while wearing the cs1 clothing system) because they were slightly cold. It is also noted that test persons while walking or at the last minute of walking felt comfortable as they were slightly warmer, and that after walking and 20 minutes of sitting, test persons on average still felt comfortable, except while wearing the cs1 clothing system, where they felt slightly uncomfortable. In spite of little lower mean skin temperature values (31.5°C) [22] evident during walking at an ambient temperature of 15°C, test persons felt comfortable, which means that 3-layer clothing systems of male business garments are suitable for wearing at 15 °C. The results obtained at an ambient temperature of 10°C show that test persons when entering the air-conditioning chamber felt slightly uncomfortable because they were slightly cold, and after 20 minutes of sitting they felt chilly or even cold, because they felt slightly uncomfortable or unpleasant (especially when wearing the cs1 clothing system). While walking and at the last minute of walking, the test subjects felt a little more comfortable, in spite of low mean skin temperatures measured during the wear trials [22], especially in the clothing system cs3, cs4 and cs5. In other clothing systems they felt slightly uncomfortable because they were slightly cold. After walking and after 20 minutes of sitting, the test persons on average felt slightly uncomfortable. It was also evident that in the cs4 and cs5 clothing systems (with PCMs), three of five test persons even felt comfortable. At an ambient temperature of 10°C, when test persons wear 3-layer clothing systems (without an additional coat), mean skin temperatures in average range under the comfort limits (32.0°C) [22], which is evident also from subjective evaluations as test persons felt uncomfortable, and they were cold. This indicates that male business garments of 3-layer clothing systems without an additional layer, such as coat are not thermally protective enough and not suitable for wearing below an ambient temperature of 10°C. Therefore, an additional layer, such as a coat is recommended for wearing at and

below an ambient temperature of 10°C for an appropriate thermal comfort.

4. CONCLUSION

The analysis of the subjective evaluation of the thermal comfort of male business clothing systems, evaluated through wear trials in different warm and slightly cold climatic conditions simulating real conditions of wearing clothes, shows that environmental conditions, activity levels, as well as the clothing systems, have a considerable impact on the subjective assessment of thermal comfort in warm and slightly cold environment.

From the subjective assessments of thermal comfort, it can be concluded that test subjects while wearing clothing systems at an ambient temperature of 25°C expressed slight thermal discomfort, especially during and after walking. It is evident that they felt hot while walking at 25°C, and still warm or slightly warm after walking. This means that 3-layer male business clothing systems are still suitable but might be too warm for wearing at 25°C for longer time, especially while walking. It is also evident from the results that test subjects while wearing 3-layer business clothing systems at ambient temperatures of 15°C and 20°C felt most comfortable. At an ambient temperature of 15°C the test subjects felt on average neutral or only slightly cold (evident while sitting before walking), and warmer, but still thermally comfortable while walking. At an ambient temperature of 20°C, the test subjects on average felt neutral or only slightly warm, but thermally comfortable. While walking, they felt a bit warmer, except while wearing clothing system cs4 (male suit with built-in PCMs), in which they felt only slightly warm. It is also evident that after two minutes of sitting (after walking) the test subjects while wearing clothing system cs4, expressed their thermal state as neutral or only slightly warm, while in other clothing systems they felt slightly warm or warm. This indicates that the clothing system cs4 in combination with PCMs at an ambient temperature of 20°C provided a slightly better thermal condition and comfort. The test subjects felt uncomfortable at an ambient temperature of 10°C, because they were cold or slightly cold while wearing 3-layer clothing systems without an additional layer of clothing, such as coat. This indicates that the selected 3-layer clothing systems without an additional layer of clothing (coat) at an ambient temperature of 10°C do not provide adequate thermal protection and comfort. Therefore, an additional layer, such as a coat it is recommended for wearing around and below an ambient temperature of 10°C.

We can conclude from the analysis that the subjective evaluation of thermal comfort is one of the

parameters which, in combination with objectively measurable physiological parameters of thermo-physiological comfort, serve as very important information for understanding the thermal-physiological comfort of clothing in different environmental conditions.

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