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Case Study of the Impact of Motorcycle Clothing on the Human Body and Its Thermal Insulation

Abstract
The interest in motorcycles is growing year by year. It should be noted that motorcyclists belong to the group of most vulnerable road users who suffer the most severe consequences of road traffic accidents. During an accident, the only protection for the body is motorcycle clothing. Nevertheless motorcycle clothing hinders heat exchange between the motorcyclist's body and the environment. Unfortunately the problem of motorcyclists' assessment of thermal comfort is addressed marginally. Therefore it was decided to measure the thermal insulation of motorcycle clothing and relate values obtained to the possibility of feeling thermal comfort under various weather conditions. Apart from that, a case study under real conditions was carried out with the participation of 2 police officers. The research confirmed the problem related to high values of thermal insulation of motorcycle clothing and transport of moisture from the skin surface.

Key words: *thermal comfort, motorcycle clothing, thermal insulation.*

Introduction

Interest in motorcycles is growing year by year. The number of registered motorcycles may be proof of that process. In Poland, in 2007, there were 825 000 registered motorcycles; in 2009 that number increased to 975 000 and in 2010 it reached 1 013 000 [1].

Due to the growing number of riders on the road and increased motorcycle accident rates, the ACEM Group (the Motorcycle Industry in Europe) examined accidents which took place in the years 1999 - 2000 in 5 European countries (France, Germany, the Netherlands, Spain and Italy).

The MAIDS (The Motorcycle Accident In-Depth Study) report [2], in which 921 accidents were analysed, includes information on, among other things, the most frequent injuries of motorcyclists or places of the most frequent crashes of motorcycles with various objects (e.g. other vehicles). According to the MAIDS report, the largest number of injuries caused by an accident resulted in leg (approx. 32%), arm (approx. 24%) and head injuries (approx. 18%). Therefore it can be stated that using a helmet and motorcycle clothing is necessary for protecting motorcyclists' health [2].

Motorcycle clothing itself is quite diverse. According to data from the MAIDS report, most riders (36%) wore jackets (made of e.g. denim or nylon) ensuring medium protection. Almost 21% used heavier jackets, e.g. made of kevlar or artificial leather, whereas 17% of motorcyclists used leather jackets. On the other hand, most trousers provided medium protection (36%) (they were made of e.g. denim or nylon). Almost 21% of riders used trousers made of kevlar or artificial leather, whereas 17% used leather trousers [2].

Leather clothing is more resistant but, at the same time, it significantly hinders the flow of air to the environment, which effectively prevents heat exchange between the motorcyclist's body and the environment.

It should be noted that riding a motorcycle entails greater risk of accident than driving a car. During a ride, motorcyclists are not protected by a safety cage, crumple zones or even seatbelts. In the case of an accident, the only protection for the body is motorcycle clothing. The major role of the jacket and trousers is to protect the motorcyclist against weather conditions, but it also against–burns caused by hot parts of the motorcycle, hits of small stones coming from under the wheels of other vehicles or against hitting insects. Nevertheless that kind of clothing is the only protection during an unforeseen contact with asphalt.

For this reason, motorcycle clothing must in particular meet requirements relating to resistance to impacts, abrasion, bursting or cutting [3].

The authors of European Standard EN 13595-1:2002 [3] took into consideration clothing damage appearing during road accidents and identified 4 zones of danger resulting from crashes and abrasion: zone 1 - high risk of impacts, zones 1 - 2 - high risk of damage caused by abrasion, zone 3 - medium risk of abrasion, zone 4 - minor risk of abrasion (***Figure 1***).

It shows the size of a motorcyclist's body surface exposed to injuries as a result of contact with another object, as well as how important it is to use motorcycle clothing.

The main function of motorcycle clothing is to reduce the seriousness of bodily injuries occurring as a result of a road accident [4]. In Poland, there is no statutory

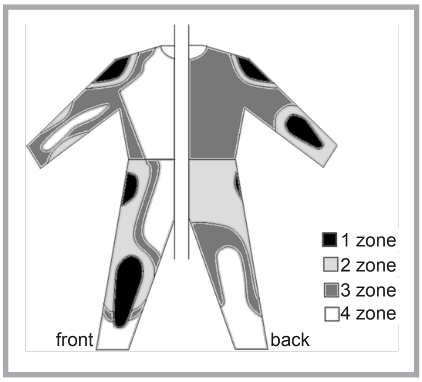

Figure 1. *Endangered zones according to EN 13595-1:2002.*

obligation of wearing specialist clothing while riding a motorcycle; only the Road Traffic Act obliges motorcyclists to use protective helmets which meet specific safety standards.

Thermal comfort depends on the type (intensity) of work done, parameters of the thermal environment of work and the thermal insulation of clothing worn by the employee. Motorcyclists do not have any influence on the parameters of the work environment (they depend on current weather conditions) and do everything in motorcycle clothing. The type of clothing used (its thermal insulation) can under certain conditions constitute a significant barrier which makes it difficult to maintain the thermal balance of the body. Unfortunately the problem of motorcyclists' assessment of thermal comfort is marginally addressed. Some recommendations regarding ergonomics (critical movements) may be found in Appendix A to EN 1621-2:2003 [5]. There is no information, however, about the feeling of thermal comfort or thermal insulation of motorcycle clothing.

Therefore it was decided to measure the thermal insulation of motorcycle clothing and to relate the value obtained to the possibility of feeling thermal comfort under various weather conditions.

Main goal of research

Until now, motorcycle clothing has been examined only against the requirements of adequate standards, mainly in the scope of protective parameters. Due to very limited availability of studies on the thermal insulation of motorcycle clothing, the authors decided to explore this problem and, additionally, to examine the influence of motorcycle clothing on selected physiological parameters during tests in real conditions.

Experiments were performed in a climatic chamber with the use of a 16-segment thermal manikin DIANA. Based on the results obtained, the value of the PMV index [6] (which describes the possibility of feeling thermal comfort) was estimated.

Apart from that, a case study with the participation of 2 policemen working for the motorcycle section of the Road Traffic Department of the Warsaw Metropolitan Police Headquarters was carried out.

Table 1. *Characteristics of the motorcycle clothing tested(commercially available).*

Clothing	Material	Membrane
A	jacket – HeavyPolyster trousers – ProPolyester	built-in, type 1, water vapour resistance value >100 m^2Pa/W
B	jacket and trousers – ProPolyster	fastenable, type 2, water vapour resistance value >100 m^2Pa/W

The tests were performed when the police officers were on duty.

Material and methods

Test ensembles

The clothing ensembles tested consisted of underwear (T-shirt – 65% polyester, 35% cotton; socks – 80% cotton, 16% polyamide, 4% lycra; boxer shorts – 100% cotton and a cotton balaclava) and a relevant type of motorcycle clothing - A and B, whose characteristics can be found in ***Table 1***.

Motorcycle clothes A and B also contained a quilted lining made of 37% polyamide, 13% polyurethane and 50% polyester.

Thermal insulation tests

Thermal insulation tests of selected ensembles of motorcycle clothing were done in accordance with guidelines of EN ISO 15831:2004 [7]. Thermal insulation is described with the use of two units: m^2K/W and clo (1 clo equals 0.155 m^2K/W). In the tests, the total (I_t) and effective (I_{cle}) thermal insulation of the clothing were established.

The total thermal insulation of the clothing (I_t) was defined as insulation from the body surface to the environment, including all elements of clothing, enclosed air layers and boundary air layer (***Figure 2***) [8].

On the other hand, the effective thermal insulation (I_{cle}) (according to EN ISO 9920:2007 [8]) was defined as an insulation garment compared to the nude manikin (***Figure 2***).

Due to the division of the manikin into segments, two methods of calculating thermal insulation were applied: the serial and parallel model [10]. In the case of the serial model, the total thermal insulation is defined as the sum of insulations calculated for particular segments:

$$I_t = \sum_1^n f_i \left[\frac{(t_{si} - t_a) \times a_i}{H_{ci}} \right]$$

where: t_{si} – temperature on the surface of i-segment manikin in °C; t_a – air temperature in °C; H_{ci} – sensible heat loss from i-segment of manikin in W; a_i – surface area of i-segment of manikin in m^2; f_i – the part of the total surface area which contains the i-segment of manikin.

In the case of the parallel model, thermal insulation is defined as the insulation relating to the whole manikin:

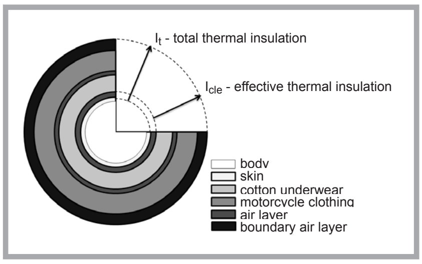

Figure 2. *Scheme of total thermal insulation (I_t) and effective thermal insulation (I_{cle}) [8].*

$$I_t = \frac{[(\sum f_i \times t_{si}) - t_a)] \times A}{\sum H_{ci}}$$

where: A – total surface area of manikin.

The condition in the climatic chamber was as follows: air temperature 18°C, relative humidity 45% and air velocity 0.4 m/s and 2.0 m/s (which simulated a slow ride on a motorcycle at a speed of 7.2 km/h). In accordance with EN ISO 15831:2004 [7], during tests of clothing thermal insulation, the ambient temperature in the climatic chamber should make it possible to maintain the manikin's sur-

Table 2. *Variant description of testing the thermal insulation of motorcycle clothing*

Variant	t_a, °C	V_a, m/s	RH, %	Description
v1	18	0.4	45	full ensemble (with lining and membrane)
v2	18	0.4	45	ensemble without lining (with membrane)
v3	18	2.0	45	full ensemble (with lining and membrane)
v4	18	2.0	45	ensemble without lining (with membrane)

Table 3. Physical characteristics of subjects.

Parameters	Subjects	
	vol_1	vol_2
Age, years	29	35
Weight, kg	96.047	95.496
Height, m	1.77	1.80

face temperature at a level of 34 °C, with heat stream on the segments not smaller than 20 W/m^2.

For the ensembles tested, several variants of testing thermal insulation were carried out. Their detailed description is included in ***Table 2***.

Case study with the participation of volunteers

Apart from tests with several variants of thermal insulation, the influence of the motorcycle clothing ensembles mentioned above was examined during a 2-hour test with the participation of 2 healthy men – police officers from the Warsaw motorcycle section. Both men were in a good physical and mental condition (***Table 3***). The tests were carried out when they were on duty. The policemen tested the same type of clothing on the same day.

During the test conducted in real conditions, the following parameters were taken: skin temperature (4 measuring points: 1 - neck, 2 - right scapula, 3 - left hand, 4 - right shin), humidity in the space between the body and clothing (3 measuring points: neck, right scapula, right shin), and humidity in the space between the underwear and clothing (2 measuring points: right part of the chest (5) and lumbar part of the spine (6)) (***Figure 3***).

All parameters mentioned were measured constantly by wireless sensors (i-button DS1923-F5, Maxim Integrated (TM), USA). The sensors were attached directly to the skin by an adhesives tape (to obtain skin temperature and humidity between the skin and underwear) or to a T-shirt (to obtain the humidity between the underwear and clothing).

Based on the skin temperature obtained at 4 measuring points, the weighted mean temperature of skin was calculated (according to EN ISO 9886:2004 [11]):

$$T = 0.28T_{1\_neck} + 0.28T_{2\_rightcapula} + 0.16T_{3\_lefthand} + 0.28T_{4\_rightshin}$$

During the test, the policemen used motorcycle clothing without a lining but with a membrane (v2). In the case of ensemble A, the weight of clothes the volunteers put on was 3.421 kg, and in the case of ensemble B the weight was 3.597 kg.

The following weather conditions were noted during the tests:

- ensemble A: air temperature 22 °C, relative humidity 55%, wind speed approx. 11 km/h; ensemble B: air temperature 17 °C, relative humidity 65%, wind speed approx. 14 km/h.

Tests with volunteers were carried out with a one-week interval, hence the difference in ambient conditions. The main rationale for conducting the tests was to determine changes in selected physiological parameters caused by motorcycle clothing in real conditions with considerable air velocity (impossible to carry out in laboratory conditions), in a forced body posture and with a high level of the rider's concentration. Thus it was decided that the tests would be performed despite different ambient conditions.

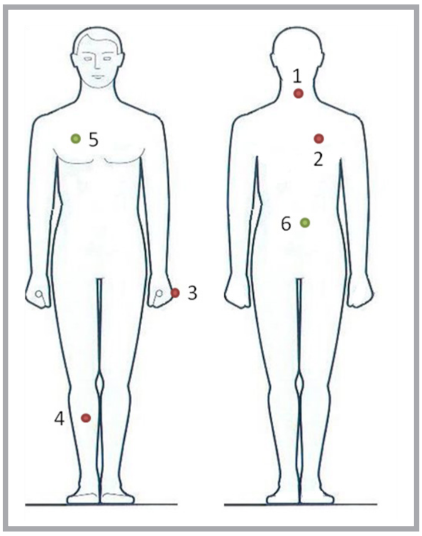

Figure 3. Distribution of sensors for measurement of skin temperature (1, 2, 3, 4) as well as relative humidity in the space between the clothing and body (1, 2, 4), and the relative humidity in the space between the clothing and underwear (5, 6).

Results

Tests with a thermal manikin provided the necessary input to determine thermal insulation values of motorcycle clothing. From the data obtained the PMV index was calculated, which made it possible to determine the temperature range of the thermal comfort sensation. Additionally a case study in real conditions was carried out with the participation of police officers.

Thermal insulation

The thermal insulation tests examined ensembles with a lining and membrane and ensembles without a lining but with a membrane.

In the case of the air velocity 0.4 m/s, ensemble B had the highest total thermal insulation (0.436 m^{2}K/W) (***Table 4***).

Furthermore the influence of the lining on the total thermal insulation was analysed. In the case of ensemble A (measured by the serial method), the lining was 11% of the total thermal insulation, whereas in the case of ensemble B - 13% (***Figure 4.a***).

In order to examine the total insulation of clothing during a slow motorcycle ride, identical experiments were conducted in

Table 4. Thermal insulation values for motorcycle clothing (air velocity of 0.4 m/s)

Textile ensemble	Total thermal insulation I_t, m^{2}K/W		Effective thermal insulation I_{cle}, m^{2}K/W	
	serial	parallel	serial	parallel
A_v1	0.405	0.308	0.311	0.214
B_v1	0.436	0.319	0.342	0.225
A_v2	0.359	0.283	0.265	0.189
B_v2	0.378	0.289	0.284	0.195

Table 5. Thermal insulation values for motorcycle clothing (air velocity of 2.0 m/s).

Textile ensemble	Total thermal insulation I_t, m^{2}K/W		Effective thermal insulation I_{cle}, m^{2}K/W	
	serial	parallel	serial	parallel
A_v3	0.338	0.250	0.245	0.156
B_v3	0.363	0.258	0.269	0.164
A_v4	0.286	0.220	0.191	0.126
B_v4	0.315	0.236	0.221	0.143

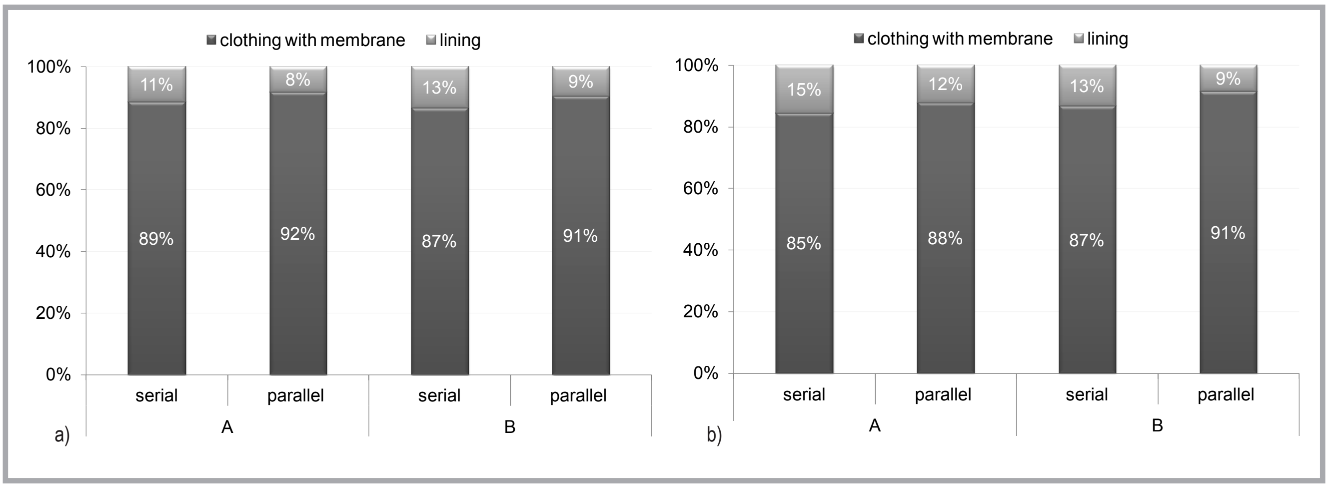

Figure 4. *Influence of lining on total thermal insulation (air velocity: a) 0.4 m/s, b) 2.0 m/s).*

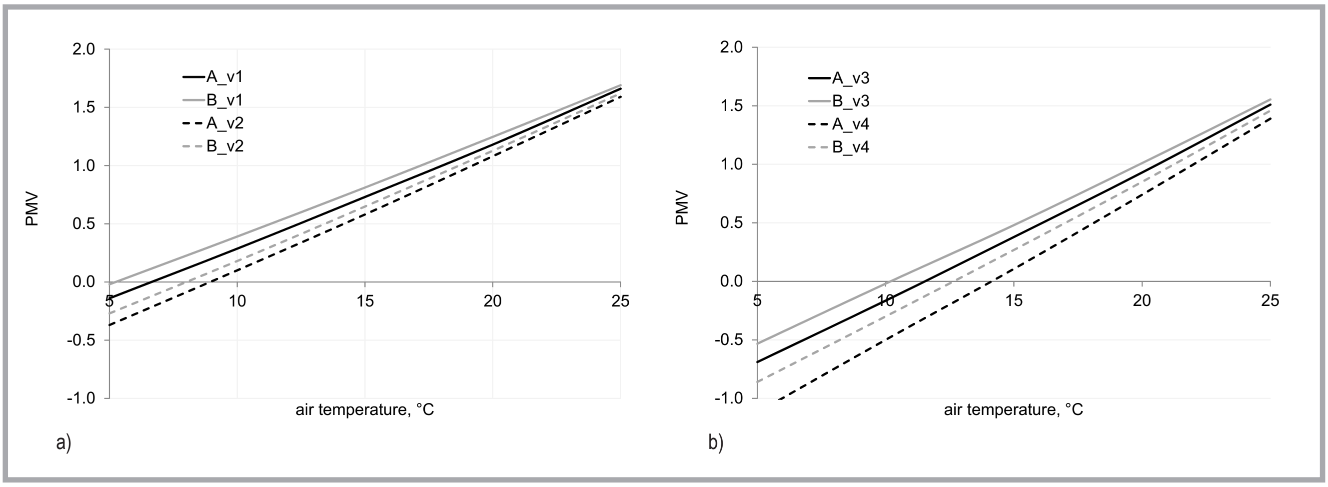

Figure 5. *Values of PMV index for motorcycle clothing (air velocity: a) 0.4 m/s, b) 2.0 m/s).*

a climatic chamber, with an air velocity of 2 m/s (7.2 km/h) (***Table 5***).

Also in this case, the highest total thermal insulation was observed in ensemble B. As compared to the tests carried out for an air velocity of 2.0 m/s, the value of the total thermal insulation (measured by the serial method) for ensembles A and B decreased by 17%.

For air velocity 2.0 m/s, the influence of the lining on the total thermal insulation increased: for ensemble A (calculated by the serial method) the lining was 15% of the total thermal insulation, whereas for ensemble B the percentage provided by the lining did not change and equalled 13% (***Figure 4.b***).

Based on the analysis obtained, it should be noted that for motorcycle clothing without a lining, the increase in air velocity to 2.0 m/s resulted in a decrease in the total thermal insulation by 20% for ensemble A and by 17% for ensemble B.

Assessment of users' thermal sensations by means of PMV index

An optimal environment in terms of thermal comfort of work and its safety is the moderate microclimate, assessed with the use of the PMV index (Predicted Mean Vote) [12]. It extends within a range of PMV index values from -2.0 to +2.0. It is assumed that the feeling of thermal comfort ranges from -0.5 to +0.5 [6]. Above +2.0 and below -2.0, the thermal environment is described as a hot or cold microclimate, respectively [12].

The PMV index was calculated for an air velocity of 0.4 m/s and 2.0 m/s, with the following assumptions: metabolic rate 100 W/m^2, work 0 W/m^2, radiation temperature equal to the ambient temperature, and relative humidity 45% (***Figure 5.a***).

For the motorcycle clothing tested (with a lining and membrane), the thermal comfort sensation ranges from below 5 °C (for both ensembles) to ~12.5 °C (ensemble A_v1). Removal of the lining from the motorcycle clothing resulted in shifting the upper limit of the comfort sensation to 14 °C (ensemble A_v2).

It is worth pointing out that motorcycle clothing is used mainly in summer, when the ambient temperature exceeds 20 °C. The PMV indices estimated show that motorcyclists feel thermal discomfort during a stop (e.g. police radar speed check, at traffic lights or works relating to traffic collisions).

Apart from that, the PMV index was analysed for air velocity 2.0 m/s, which simulated a slow motorcycle ride (7.2 km/h - e.g. slow motorcycle ride, police escort during public drives) (***Figure 5.b***).

In those cases, the range of the thermal comfort sensation begins from 5 °C (ensemble B_v3) and ends at 15 – 16 °C (en-

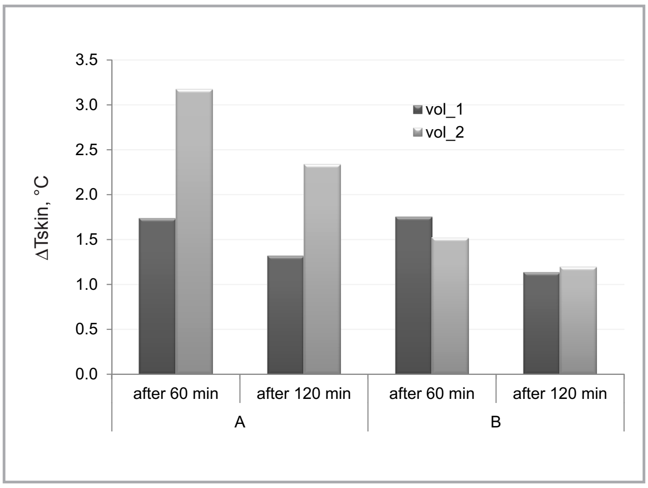

Figure 6. Increase in the mean skin temperature of on-duty police officers (t_{skin}) for each variant of the experiment.

sembles A_v3 and B_v3, respectively). When the lining is removed, the range changes and the lower limit starts from 8 °C (ensemble B_v4) to 18 °C (ensemble A_v4).

Increased air velocity resulted in a shift of the thermal comfort ranges towards higher temperature values.

Case study

Weighted mean skin temperature

The weighted mean skin temperature was calculated based on 4 measuring points located on the right scapula, neck, left hand and right shin (according to EN ISO 9886:2004 [11]).

In each case, at the beginning of the experiments, a rapid increase in the weighted mean skin temperature was observed (approx. 40 minutes of the test), followed by stabilisation. In the case of ensemble A, the highest value of weighted mean skin temperature observed during the test reached 36.2 °C, whereas for ensemble B it was 34.5 °C.

After 60 and 120 minutes of the test, a change in the weighted mean skin temperature was analysed in relation to the initial values.

Based on ***Figure 6***, it was noted that for ensemble A the increase in the skin temperature of volunteer_2 considerably exceeded the increase in t_{skin} of volunteer_1. After 60 minutes of the test, an increase in t_{skin} was noted for ensemble A, amounting to approx. 1.7 °C for volunteer 1 and 3.1 °C for volunteer 2; after 120 minutes an increase of approx. 1.3 °C and 2.4 °C was observed for volunteer 1 and 2, respectively.

For ensemble B, no significant differences were observed; after 60 minutes of the test, the skin temperature increased by approx. 1.5 °C, and after 120 minutes - by approx. 1.2 °C.

Relative humidity in the space between the body/underwear and clothing

During the tests, relative humidity (RH) measured in the space between the body and clothing (3 measuring points: right scapula, neck and right shin) and in the space between the underwear and motorcycle clothing (2 measuring points: lumbar part of the spine and right part of the chest) was registered. Furthermore, a change in the humidity in relation to the initial values was analysed after 60 and 120 minutes of the test.

Ensemble A

At the measuring point located on the right scapula the relative humidity measured at the end of the 2nd hour of the test was at the level of 70 – 80% (for vol_2) and even approached 90% (for vol_1). As compared to the initial value, RH increased by over 60% on the right scapula (vol_1, after 120 min), whereas the increase in mean humidity after 60 and 120 minutes of the test reached approx. 48% and 55%, respectively (***Figure 7.a***).

In the final stage of the test, the relative humidity on the volunteers' necks reached 70–75%. In this case, on the neck, an increase in relative humidity of 38 - 40% was recorded after both 60 and 120 minutes of the test (***Figure 6***).

Very high relative humidity was also observed on the right shin. In the final stage of the test, the highest recorded values were 93% (vol_1) and 80% (vol_2). After 60 and 120 minutes of the test, the mean humidity increase on the right shin amounted to 39% (vol_1) and 45% (vol_2) (***Figure 7.a***).

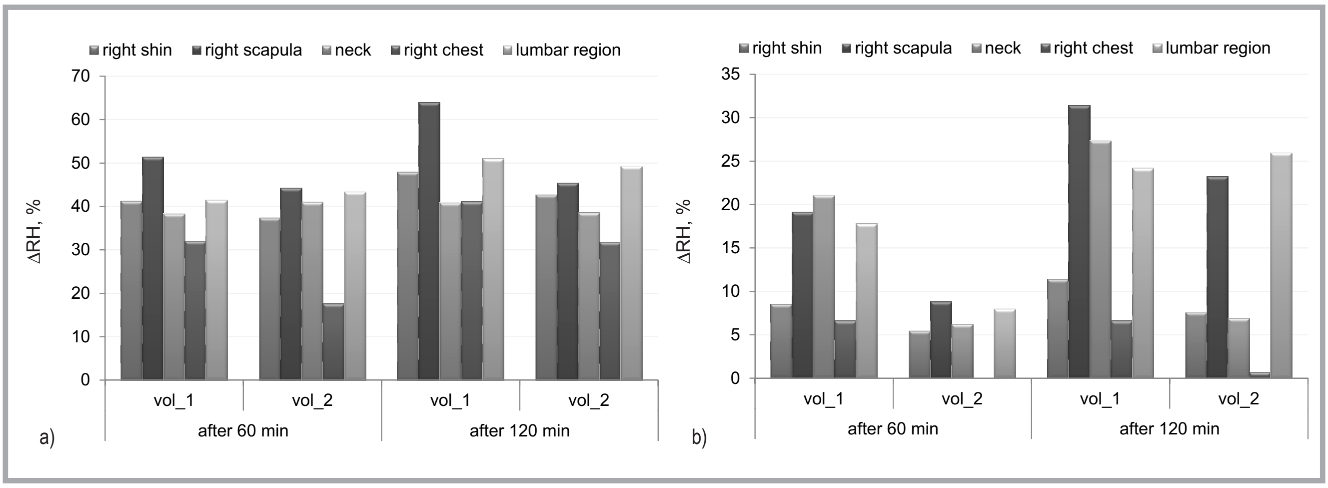

Figure 7. Increase in mean humidity in the space between the human body (or underwear for right chest and lumbar region) and clothing of on-duty police officers for each variant of the experiment for: a) ensemble A and b) ensemble B.

Relative humidity was also analysed in the space between the underwear and motorcycle clothing, specifically, on the chest and in the lumbar part of the spine. For the chest, the maximum value of humidity ranged between 75 - 80%. The increase in humidity after 60 and 120 minutes for vol_1 amounted to 32% and 41%, respectively, whereas for vol_2 it was 18 and 23% (***Figure 7.a***).

For the lumbar part of the spine, a rapid increase in humidity was observed at the beginning of the test. After 120 minutes, the humidity reached the maximum value of almost 90% for both volunteers. The mean increase in humidity after 60 and 120 minutes of the test for ensemble A was 42 and 50%, respectively (***Figure 7.a***).

Ensemble B

For ensemble B, the increase in humidity at the measuring points mentioned above was much lower than in the case of ensemble A.

At the measuring point located on the right scapula, the humidity was at the level of 63% (vol_1) and 55% (vol_2). For ensemble B, a lower increase in relative humidity was recorded - after 60 and 120 minutes of the test it amounted to 14% and 27%, respectively, (***Figure 7.b***).

In the final stage of the test, relative humidity of 50 – 60% was observed on the volunteers' necks. In this case, a lower increase was noted on the neck of vol_1, i.e. after 60 and 120 minutes of the test the relative humidity reached 22 and 27%, respectively. With regard to vol_2 a constant increase of approx. 7% was recorded (***Figure 7.b***).

At the beginning of the test a decrease in humidity was observed on the right shin, afterwards, it remained at the level of 25 – 30%. The mean increase in humidity after 60 and 120 minutes of the test amounted to approximately 7 and 9% (***Figure 7.b***).

As compared to ensemble A, in the case of ensemble B a lower increase was also observed for the relative humidity measured in the space between the underwear and motorcycle clothing on the chest and in the lumbar part of the spine.

The maximum relative humidity on the chest was 68% (the mean increase was approx. 5%).

For the lumbar part of the spine, the maximum value of humidity ranged between 65 – 70%. During the test, the mean increase in humidity after 60 and 120 minutes of the test amounted to 13 and 25%, respectively (***Figure 7.b***).

Discussion

Tests of motorcycle clothing with the use of a thermal manikin demonstrated how high the thermal insulation of that clothing is. Values of total thermal insulation ranged between 0.41 – 0.44 m^2K/W after taking out the lining (clothing with a membrane), with values amounting to 0.36 – 0.38 m^2K/W. Such a level of thermal insulation may be compared with clothing protecting against cold in a cold environment (below -5 ºC). According to EN 342:2004 [9], the required value of resulting effective insulation of clothes protecting against cold amounts to 0.310 m^2K/W. After converting the effective thermal insulation of the motorcycle clothing examined into resulting thermal insulation (for air velocity 0.4 m/s), values ranging between 0.24 m^2K/W (A_v2) – 0.28 m^2K/W (A_v1) were recorded for ensemble A and between 0.26 m^2K/W (B_v2) – 0.31 m^2K/W (B_v1) for ensemble B.. According to EN ISO 9920:2007 [8], the values of thermal insulation obtained may be compared, inter alia, with protective clothing consisting of underwear (a long-sleeved shirt and pants), a thermal jacket and trousers, a parka with heavy quilting, overalls with heavy quilting, socks, shoes, a cap and gloves – 0.395 m^2K/W. Similar insulation (0.308 m^2K/W) was measured for an ensemble of protective clothing against cold weather conditions consisting of briefs, a T-shirt, a shirt, trousers, a jacket, insulated trousers, insulated jacket, socks and shoes. For comparison, the thermal insulation of chemical protective clothing or nuclear power protective clothing amounts to 0.296 and 0.256 m^2K/W, respectively, [8].

Furthermore the influence of the air velocity on the total thermal insulation for the full ensemble of motorcycle clothing (v1) and that without a lining (v2) was examined. The estimated decrease in insulation, according to EN 342:2004 [9], when increasing the air velocity to 2.0 m/s amounts to approx. 17 – 18%. In the case of the clothes tested, the decrease was at the level of 21%.

From the values of thermal insulation obtained, the PMV index was calculated. Analysis of the PMV index showed that in the summer (when the air temperature exceeds 20 ºC), both in the case of the full ensemble (v1) and that without a lining (v2), users of motorcycle clothing do not feel thermal comfort. The same situation was observed when an air velocity of 7.2 km/h (for v3 and v4) was assumed. The conclusions presented above are reflected in tests results recorded during experiments carried out in real conditions (air temperature of 17 and 22 ºC).

According to Traczyk and Trzebski [13], the mean temperature of the skin of a naked man in a state of thermal comfort, i.e. in a thermally neutral environment, amounts to 33 - 34 ºC. In the case of the motorcycle clothing tested, the "comfort" values were exceeded. For ensemble A, the weighted mean skin temperature was approx. at the level of 36.2 ºC, whereas for ensemble B it it was 34.5 ºC. Therefore it can be stated that in the case of ensemble A the comfort conditions were exceeded and the volunteers were exposed to a temperature range characteristic of a hot environment. Heat could be accumulated in their bodies, which, in consequence, could translate into decreased mental and physical abilities [14]. Moreover it should be pointed out that during the tests of ensemble A, an increase in the temperature of skin was observed by as much as 3.1 ºC (in the case of ensemble B, the increase was only by 1.2 ºC).

Scientific theses emphasize the very significant influence of microclimate parameters on the feeling of comfort, with humidity between the clothing and skin of the user being of particular significance. In normal conditions, the relative humidity under the clothing is at the level of 40 - 60%, whereas values exceeding 70 - 80% (e.g. when wearing barrier clothes) cause a sensation of sultriness, mugginess or considerable discomfort. Accumulation of sweat inside the clothing leads to increased discomfort depending on the size of the surface of wet skin [15]. Impermeable protective clothing puts a strain on the thermoregulatory and circulatory systems during physical effort even under neutral environmental conditions, whereas thermal stress is especially significant in a hot environment [15].

Tests carried out at CIOP-PIB demonstrated that during work in certain barrier clothing the relative humidity (RH) in the space between the clothing and skin may range from 90% (e.g. acid- and lye-resistant clothing) to 100% (e.g. surgeon's gown). Although the tests were carried out in medium ambient temperature (17 - 22 ºC) and lasted only 2 hours, high values of relative humidity were observed in the space between the body and motorcycle clothing. During the tests of ensemble A, they reached 80 - 90% on the right scapula, 70 - 75% on the neck and 80 - 93% on the right shin, which means that they exceeded standard values of RH. Additionally the feeling of discomfort was intensified by the high relative humidity in the space between the underwear and motorcycle clothing, reaching a level of 90% in the lumbar part of the spine and 80% on the chest. In the case of ensemble B, slightly lower humidity was recorded (60 - 70% at all measuring points except for the right shin, where relative humidity amounted to 30%).

It should be noted that in the case of ensemble A, the relative humidity increased by approx. 40 - 55%, at practically every measuring point.

Conclusions

The results presented indicate a need to modify motorcycle clothing in order to improve the thermal comfort of its users. Discomfort may be reduced, in particular, by decreasing the thermal insulation of motorcycle clothing, as well as by increasing the effectiveness of channelling humidity off the skin surface.

Furthermore tests of the thermal insulation of motorcycle clothing show the necessity to modify the construction of that type of clothing. The findings confirm that in summer (despite removal of the lining) the users of motorcycle clothing will not feel thermal comfort, which, in turn, can adversely influence their psychomotor skills and, as a result, the safety of driving.

Motorcycle clothing is used mainly in summer, hence its thermal insulation should be reduced (but not at the cost of protection against a fall or weather conditions).

The test results of selected physiological parameters of police officers also prove that the problem exists. Data relating to the skin temperature or relative humidity in the space between the body and clothing demonstrate that motorcycle clothing can cause thermal stress.

High humidity values show the need to improve vaporisation and heat exchange at practically every measuring point.
From the relationships presented, it can be concluded that ensemble A turned out to be a better solution from the perspective of physiological parameters; however, differences between the ensembles examined can be a consequence not only of their construction, i.e. the membrane applied, but also of the actual (diversified/heterogeneous) weather conditions.

To improve air circulation in motorcycle clothing, producers apply, e.g. improved ventilation systems in the form of air vents placed in the most essential parts of the garment. Thermal comfort can be enhanced by taking out a membrane or, alternatively, by using a membrane which maintains optimal air permeability (to transfer sweat from the body) with improved protective properties against external conditions. The reduction of temperature in the underwear space is achieved by applying linings with PCM (phase change material). In the case of leather clothing, an innovative leather finish is used which makes it possible to e.g. reflect sun rays off the jacket, thus preventing the overheating of clothing.

Despite a number of techniques used to improve motorcyclists' comfort, they are often not sufficient therefore the search for new ways to reduce the thermal load should be pursued.

In order to better explore the matter, extensive tests of physiological differences, in particular clothing ensembles (including leather clothes), are planned in the near future. The tests, with a larger number of volunteers, will be repeated in summer, when ambient temperatures are higher.

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