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Subjective Evaluation of Novel Comfort Liners for Motorcycle Helmet

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Abstract

Motorcycle helmets manufactured in developing countries such as Tunisia are not specially designed, adapted or modified to provide extra comfort especially in hot and humid environment. In this study, three comfort liners manufactured from natural fibers are proposed and compared with standard liners. Subjective evaluation based on subject's opinions and objective evaluation using liners characteristics: are used in this comparison. It was found that non woven liner made from wool and alfa fibre is more advantageous in term of comfort and acceptance than the other liner. It was judged comfortable, acceptable, not sweating and not hot. This result was confirmed by liners characteristics witch can convince helmet designer that more work is needed in this aspect.

Keywords: Helmet comfort; Subjective evaluation; Natural fiber; Non woven

Introduction

Protective headgears are intended to protect the head against impacts or objects falling from a height in environments. However, in hot and humid climate such as of Tunisia, many workers and motorcycles are less willing to wear helmets simply because they are uncomfortable [1,2]. For this reason, the thermal discomfort of helmets has been a field of steady interest. To improve helmet acceptance, many of design suggestion has been proposed. The adding ventilation holes or slots can be considered with significant effect for intensifying forced convection and evaporative convection [3-6]. Characteristics of helmets such as effective materials, colour and general construction have been examined and selected to optimize heat transfer from the human head to the environment [7,8]. Abeyeskera et al. [9] affirmed that these studies and suggestions have led to some improvement in the design of protective headwear.

Objective and subjective methods are proposed equally for motorcycle and industrial helmets, in order to appreciate helmet wearability. In objective methods, thermal manikins and controlled human trials are used to measure heat transfer from the head to the helmet microclimate [4,10,11]. Bogerd et al. [12,13] studied the effect of full-face helmets on heat loss under a wide range of conditions. They found that heat loss through such helmets is low in the scalp section and has potential for improvement.

For subjective methods different human subjects were asked to wear a helmet, there perception was characterized after a curtain time period. Xiaoxiong et al. [14] conducted a subjective evaluation of helmet heat transfer in both hot and cold conditions using three commercially helmets. After this, the subjective results were compared with objectives results. Hsu et al. [4] presented a redesign of an industrial safety helmet shell. In order to improve thermal properties, they first suggested to use white paint or a reflective covering of the outer shell to provide better insulation against radiant heat. To intensify convection, ventilation holes were integrated into the helmet shell. After studying the heat loss in the scalp section of the helmet, Bogerd et al. [13] characterized the relationship between head form measurement and perception of subjects for vent-induced effects of full-face motorcycle helmet. They concluded that vent-induced heat loss of the helmets is the most important response factor and that lower perception thresholds were found for opening the vents compared to closing for temperature and airflow perception.

In Tunisia, the majority of manufactured motorcycle helmets are closed without ventilation. These helmets are composed of three liners; an outer shell from moulded thermoplastic, energy absorbing foam which is made from expanded polystyrene and a comfort liner made of urethane foam covered with synthetic textile fabric. Unfavourable temperature perception and thermal discomfort are frequently given arguments for not wearing these motorcycle helmets [4].

A study was carried out to intervene in the comfort liner and propose other liner made from natural fibre. The acceptability of these novel liners will be evaluated with two different methods: Firstly subjective opinions about thermal transfer properties and thermal acceptability are collected and analysed. Human subjects were asked to give their evaluations of helmets with different comfort liners. Secondly, subjective assessments are discussed using liners physicals properties.

Materials and Methods

Objectives

In this study, we propose three comfort liners for Tunisian helmet. These liners will be compared to a standard liner using subjective evaluations. The study was set-up to approximate the workload of helmet wearer in the hot environment typical of the Tunisian. Subjects cycled on fixed bicycle in an environmental chamber at a temperature of 30 ± 2°C and a relative humidity of 66 ± 5%. Responses were measured for helmets with a standard liner and three prototype liners.

Liner material

Helmets used in our study are red and without ventilation holes. The standard liner is made from polyurethane foam covered with cotton fabric (Figure 1). The raw materials used to prepare liners

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are: cotton, wool, Tencel and Alfa fiber (Steppa tenacessima). The liners composition is given in (Table1). The helmet selected was manufactured in Tunisia.

Procedure

Twelve male subjects between the ages of 20 and 32 years and with an average weight of 69 +10 kg were subjected to a step test during which period subjective evaluation were made (Figure 2). The following procedure was followed: Each subject completed four trials in a random sequence: one with the standard helmet (with liner S), the other with A, B and C. Before each subject arrived, the environment chamber was heated to 30 ± 2°C. Each subject wore his daily wear. After entering the chamber, the subject pedal his assigned cycle, put on a helmet and adjusted it for a comfortable fit.

The bicycle was calibrated to 5 ± 0.08 km/h approximates a workload of 320 kcal/h [15] and which correspond of a metabolic rate of 297 W measured using the cycle ergometer [16]. After finishing the trial (35 minutes), the subject was verbally asked survey questions concerning the helmet he had worn. In addition, comparison questions were asked after the subject had completed at least two helmets.

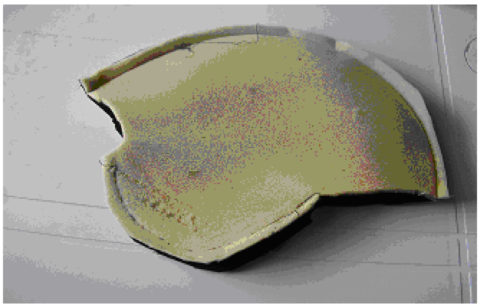

Figure 1: Standard liner (foam).

	Liner S (Standard liner)	Liner A	Liner B	Liner C
Composition	Polyurethane foam	40 % cotton-60% alfa fibre	40 % tencel / 60% alfa fibre	40 % wool-60% alfa fibre
Thickness (mm)	3.12 (±2.17)	3.32 (± 1.55)	3.27 (± 2.07)	3.19 (±2.43)
Weight (g/m²)	231.56 (±3.11)	206.14 (±4.63)	201.04 (±3.22)	220 (± 2.17)
Air permeability ((l/m²/s)	1270 (±1.94)	1464 (±1.85)	1962 (±1.29)	2782 (±2.85)
Adiathermic property (%)	52 (±2.57)	38.88 (±3.06)	39.98 (±3.78)	48.74 (±2.55)

*( ) = CV(%)

Table 1: Liners characterisation.

Figure 2: Subject during trial.

Properties / Range (Most to Least)	1	2	3	4
Comfort	C	B	A	S
Hotness	S	A	B	C
Acceptance	C	B	A	S
Sweating	S	A	B	C
Itch	S	A	B	C
lightweight	B	C	A	S

Table 2: Liners properties range.

Environmental chamber data

Table 2 summarises the ambient environmental conditions. Temperature varies between 29.2°C and 31.9°C. Relative humidity varies between 66.9 % and 69.3 %.

Non woven characterisation

Standard and non woven liners characterisation was done according to ISO standard recommended methods, including thickness (ISO 9863-1) and weight per unit area (ISO 9073). The air permeability is defined by the standard ISO 9237 as being the speed of a flow of air passing perpendicularly through a sample under conditions of surface test, and pressure losses. The adiathermic property can be defined as the ability of the fabric to be opposed to the heat cross and it was measured using NF G O7-107 (Table 2). For comparisons among the liners, all the data for each property were collected in a completely randomized design. The data were subjected to ANOVA analysis and the means were separated using the Tukey's Studentized test.

Results

Subject evaluation

The first part of the three-part survey contained opposite adjectives. All twelve subjects judged the helmet with liner C comfortable, acceptable, not hot, not itchy and heavy. However, helmet with standard liner S (polyurethane foam) was judged very hot, sweating, not comfortable, not acceptable and itchy.

In the second part of the survey, subjects ranked the helmets on a scale of 1-5 for comfort, hotness, acceptable, itch, sweating and heaviness. Results from (Figures 3-8) indicate that helmets B and C are considered more comfortable, acceptable, light, less hot and less sweating than A and standard helmet. About ten subjects rate that helmet A and S in the third or forth place for comfort and acceptance. About ten subjects rate the helmet S in the forth or fifth place for hotness and sweating. More than eight subjects consider that helmet S is itchy. At least eight subjects consider helmet B and C are not at all itchy.

The third part of the survey consisted of paired comparisons. No one preferred the standard helmet to the either of the other helmet. More subjects preferred the helmet C judging it to be more comfortable, less hot and less sweating than the other helmet. But it is judged more light than helmet A and B.

Discussion

All results were analysed using a Friedman test with Bonferroni corrected Wilcoxon test for post-hoc comparison. Statistical significance was defined was $p < 0.05$ and SPSS 14.0 for Windows was used for this analysis. Results indicate that wearing liners has a significant effect ($p < 0.05$) on: comfort, hotness, itch, acceptance, sweating and lightweight.

Subject's evaluation indicated that liner C is judged more comfortable, light and less hot and sweating than the other liners. During liners construction, we aimed to have the same thickness then

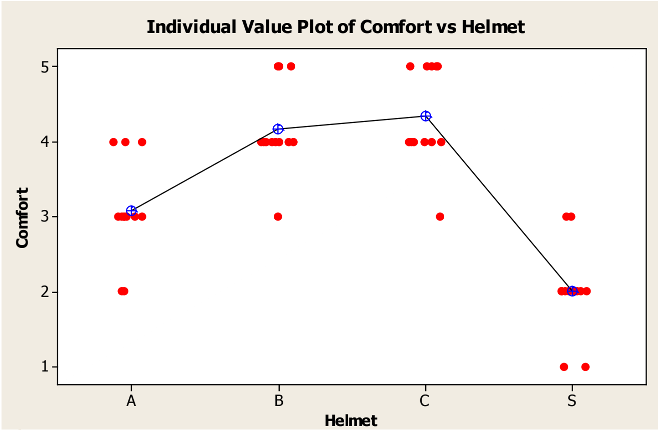

Figure 3: Individual value plot for comfort.

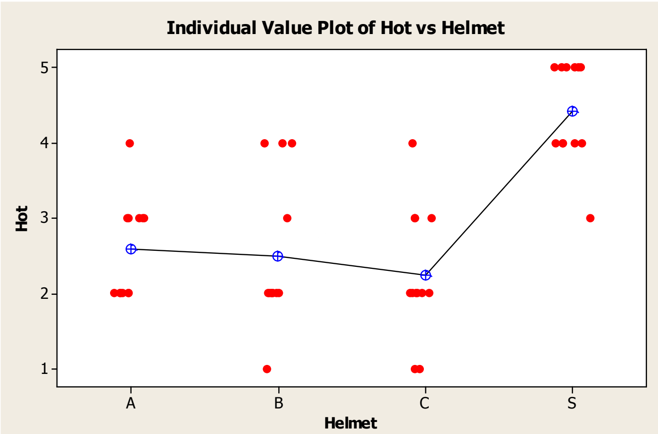

Figure 4: Individual value plot for hotness.

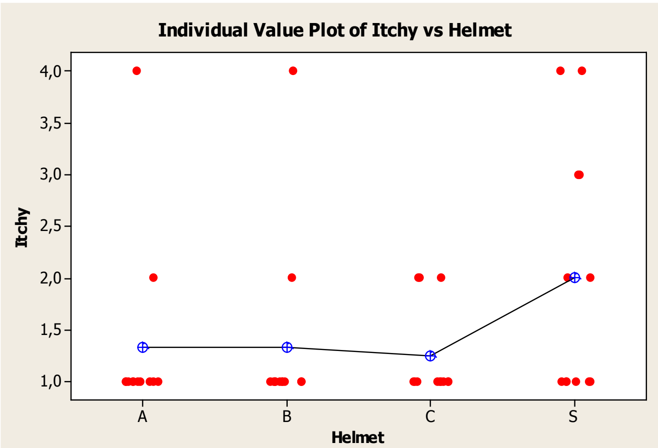

Figure 5: Individual value plot for itchy.

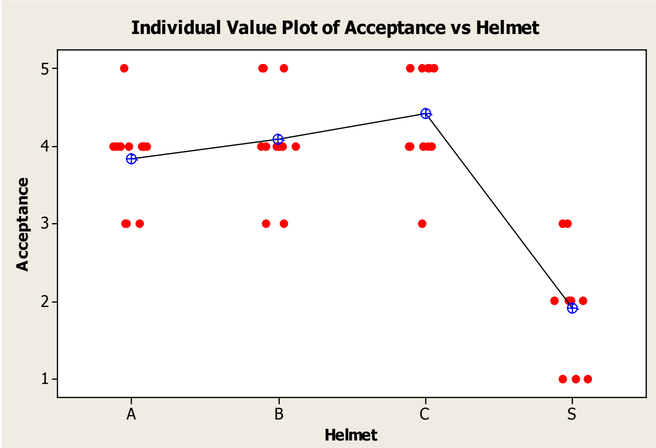

Figure 6: Individual value plot for acceptance.

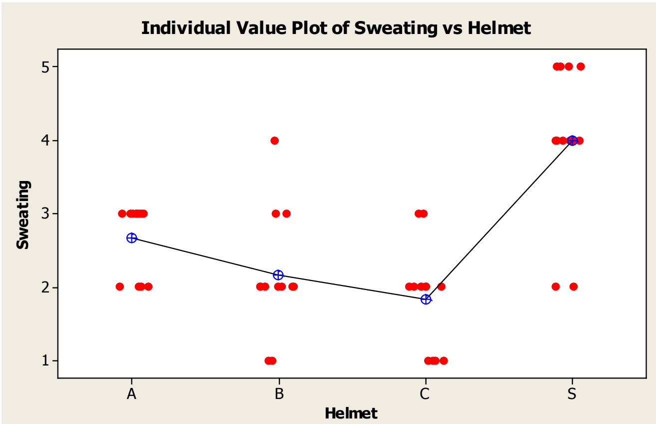

Figure 7: Individual value plot for sweating.

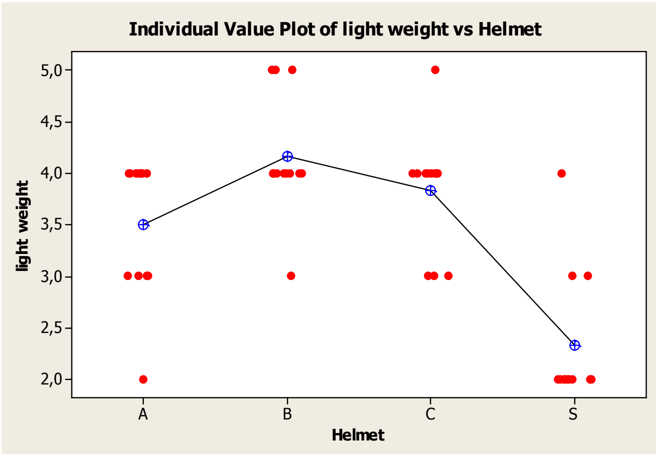

Figure 8: Individual value plot for lightweight.

standard helmet, in order to compare its characteristics. Liner C seems to have the higher air permeability comparing to the other liners: which can improve the helmet microclimate renewable and consequently the evaporation cooling for the wearer. That can explain the judgment of liner C to be more comfortable, more accepted and less sweating than respectively liner B, A and S.

In addition, during helmet wearing, the head is considered as a source of heat and vapour causing a heat stress. Results indicate that standard liner is the first among the other, which opposes to the heat crossing and stores heat between the head and the helmet. For this reason, it is judged by major subjects as very hot (Table 2).

In addition, result from subject evaluation depends on many factors such as: size, design style in addition to heat and mass transfer performance of the helmet. This can be explains the fact that subjective evaluation of comfort in helmet wear does not correspond exactly to the liner characteristics in some cases. For example with lightweight evaluation, liner C is considered the most light instead of liner B.

Conclusion

In Tunisia, thermal discomfort is one of the major reasons that motorcyclist do not like to wear safety helmets especially in summer. The standard liners used in commercially helmets in this country are judged not comfortable and not acceptable because they are very sweating. For this reason we are worked to propose new liners from natural fibres that improve hydro-thermal comfort.

Liner from wool and alfa fibre seems to be more advantageous that the other liner. It was judged comfortable, acceptable, not sweating and not hot. Results from this study can provide some insight into the use of other comfort liners but it remains an objective evaluation using manikin headform to confirm its performances. The commercially helmet especially in our country are very bad and it implies the design of new comfort liner.

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