EFFECT OF ADDITIVELY MANUFACTURED PADDING ON THE MECHANICAL AND THERMAL COMFORT OF MTB-BACKPACKS

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From the user's point of view, both optimal mechanical and thermal comfort are essential requirements for mountain bike (MTB) backpacks [1, 2]. Consequently, these aspects are also within the scope of product development in the field of bicycle backpacks. In general, a backpack system with thin, foam-based back padding material (so-called “full-contact backpack system”) is recommended for MTB activities. It should ensure optimal mechanical comfort in terms of load-bearing capacity and a reduced wobbling of the backback. However, due to the “full-contact” with the rider’s back, thermal comfort is lacking.

The aim of this research project was to improve the thermal and mechanical comfort of MTB-backpacks. This goal should be achieved by substituting foam-based pads with additively manufactured pads (Fig. 1). The stiffness properties of the 3D printed pads (120 x 60 x 20 mm) were modified based on initial pressure measurements and realized by adjusting the grid structure.

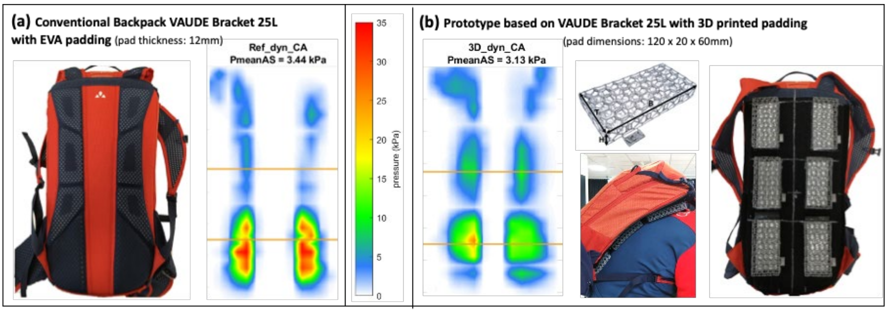

Fig. 1: View of the back panel padding and exemplary mean pressure distribution images for (a) conventional VAUDE Bracket 25L and (b) prototype with 3D printed padding.

Proof of concept was performed in a laboratory environment using a cyclocross bicycle (Centurion Crossfire 4000, Merida & Centurion Germany GmbH, Magstadt, Germany) fixed in an indoor bike trainer (Bushido, Tacx, Wassenaar, Netherlands) and a fan (FN091, ZIEHL-ABEGG, Künzelsau, Germany). Five male participants (age 40±13 years, height 180±4 cm, body mass 73±5 kg, and BMI 23±1 kg·m^{-2}) volunteered in a series of measurement sessions. In session 1, anthroprometric measurements were first taken. Then, both the bicycle and backpacks (4 kg payload) were adjusted to individual preferences. Pressure distribution was measured for 10 s during cycling (130 W, 80 rpm) using a pressure measurement system (Tactilus®, Sensor Products Inc., Madison, NJ, United States). In sessions 2 and 3, the backpacks were used in randomized order to evaluate the thermal comfort. Microclimate (temperature and humidity between skin and jersey) was measured with digital sensors and stored with a mobile data logger (MSR Electronics GmbH, Seuzach, Switzerland). Three sensors were placed along the spine on the cyclist's back. Participants were asked to ride for 25 minutes at a constant power output (130 W, 80 rpm) in a brakehood position. The fan simulated a headwind of approximately 25 to 30 km·h^{-1}, similar to the set cycling speed. During all three sessions the participants wore the same model of cycling jersey and shorts (VAUDE Sport GmbH & Co. KG, Tettnang, Germany). The study was in accordance with the Declaration of Helsinki.

Table 1 shows a representative selection of variables used to quantify mechanical and thermophysiological comfort aspects. To improve comfort, these variables should be minimized. The prototype with the novel additive padding (b) has significantly lower maximum (p_{max}) and mean contact pressures (p_{mean}) and significantly lower contact area at pressures >20 kPa ($A_{p>20kPa}$). Skin contact pressure greater than 20 kPa can cause discomfort in the form of pain, soreness, and local ischemia [2]. Thermal comfort was also improved in the prototype (b) compared to the conventional backpack (a) by noticeably reducing the temperature rise (ΔT) over time and reducing the relative humidity rise (ΔRH).

Table 1: Arithmetic mean (n=5) and standard deviation of mechanical (p_{max}, $A_{>20kPa}$, p_{mean}) and thermophysiological (ΔT, ΔRH) comfort variables for (a) conventional, (b) prototype.

Backpack	$\mathbf{p_{max}}$ (kPa)	$\mathbf{A_{p>20kPA}}$ (cm^2)	$\mathbf{p_{mean}}$ (kPa)	**ΔT** (K)	**ΔRH** (%)
(a)	5.7±0.8	22.7±13.0	3.5±0.5	4.7±1.2	38.8±15.3
(b)	5.1±0.7	4.6±6.9	3.1±0.2	1.8±0.9	33.3±20.1

The novel concept of backpack padding proved superior to an established design approach. The 3D printed pads result in a substantial benefit – not only for thermal comfort, but also for mechanical comfort. Future developments will focus on the specific layout and design of additively manufactured pads to meet market criteria for mass production.

Acknowledgments: The proof of concept was conducted within the framework of the Alliance for Sports Engineering Education (A4SEE) project, co-funded by the Erasmus+ Programme of the European Union.

1. Li QC, Luximon Y, Chu VH, Ip BM, Kwan SH, Lau KC (2018). An ergonomic solution for ventilating backpack design. In: Congress of the IEA, Springer, Cham, pp 559-568.
2. Wettenschwiler PD, Lorenzetti S, Stämpfli R, Rossi RM, Ferguson SJ, Annaheim S. Mechanical predictors of discomfort during load carriage. PloS one. 2015 Nov 3;10(11):e0142004.

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