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BOOK OF ABSTRACTS **Open Access**

Influence of an engineered backpack ventilation technology on thermal comfort during cycling – a pilot study.

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Purpose:

Thermoregulation in sports is an essential aspect for performance as well as thermal comfort (Ückert 2012) especially in endurance sports such as cycling. Alam et al. (2010) point out the potential of optimized bicycle helmet design on thermal comfort without compromising impact protection and aerodynamic efficiency. During a lot of cycling activities athletes often wearing a backpack. Weder et al. (2018) and Klauer et al. (2018) analysed different backpack systems during cycling in a climate chamber. They conclude that wearing a backpack during cycling affects the microclimate (temperature and humidity between skin and first clothing layer) as well as the interlayer climate (temperature and humidity between first clothing layer/base layer and backpack/mid layer) depending on the backpack system. Conventional ventilated backpack systems (Fig. 1) reduce the microclimate as well as the interlayer climate compared to full contact backpacks (Klauer et al. 2018; Weder et al. 2018). Due to the limited air flow channels of full backpack systems and the air impermeability of the upper mesh net and shoulder strap attachment of the ventilated backpack systems there is potential to optimize the thermal comfort of cycling backpack (Fig. 1).

The overall goal of the research project was to engineer a new backpack ventilation technology utilizing the relative headwind generated during cycling for convective heat transfer between backpack and first clothing layer. In a first iteration a computational fluid dynamic analysis (CFD) was performed to obtain insights on the flow pattern around the cyclist without a backpack generated by the headwind. Based on these insights different rear panel designs for the backpack were developed which were evaluated again by means of CFD analysis. This subject study represents a "proof of concept" comparing two new rear panel designs with a conventional full contact back (FC) and a ventilated backpack system (VS) regarding temperature and humidity related to microclimate and interlayer climate (Fig. 1).

Methods:

Four male sport students (∅25 years; ∅184cm; ∅76kg) participated on the pilot study. They performed a load profile of 30 min. cycling on a Tacx cycling trainer at a moderate intensity level of 130W (Heart frequency: ∅116 BFM) with 5 min. rest prior and 10 min. rest after the cycling part. The subjects were tested in a climate chamber at 20±1°C and 38±2% relative humidity. Four floor fans were positioned in front of the cyclist generating an airflow aimed at the ventral torso of the cyclist (Fig. 2). The air velocity around the shoulder region was $9kmh^{-1}$. During cycling the subjects had to ensure a sagittal torso angle of approx. 50°. Temperature and humidity were measured with combi sensors (SHT25, Sensirion, Switzerland) and stored with a mobile data logger (MSR147WD, MSR Electronics GmbH, Switzerland) for both microclimate and interlayer climate. As in the study of Klauer et al. (2018) and Weder et al. (2018) the sensors were attached along the spine region on the skin of the subject (microclimate) and the rear panel of the backpack (interlayer climate) (Fig. 2). Each subject had to cycle with all 4 backpack conditions in a randomized order (Fig. 3). Moreover, as a reference condition (Ref) each subject had to perform one trial without a backpack.

Results:

The results of the pilot study clearly demonstrate the improved thermo-physiological response of the AirTurbulencer (AT) and AirStreamer (AS) concept compared to the VS and FC systems regarding both the microclimate as well as interlayer climate (Fig. 3 and 4; Tab. 1). By wearing a regular backpack, the convective heat transfer on the back is limited. The conventional VS system enhances the convective heat transfer compared to a regular backpack system. However, the AS and AT prototypes feature a further decrease in temperature and relative humidity compared to VS. This is valid for both the microclimate and the interlayer climate respectively. The data points to a slightly better convective heat transfer for the AT compared to the AS concept. Besides, the results show a correlation between micro and interlayer climate. The temperature as well as the relative humidity decreases from the micro climate to the interlayer climate.

Conclusion:

Unfortunately, there is only little research about the influence of backpack wearing during cycling on the thermal comfort done. Klauer et al. (2018) applied a similar study setup and investigated similar test conditions (Ref, FC, VS). However, the exercise intensity was slightly higher, and they did not use fans to generate headwind. The temperatures of the microclimate for the FC and VS condition are slightly higher in the study done by Klauer et al. (2018) compared to the present data. This can lead to the assumption that the headwind - depending on the backpack design - really affects the convective heat transfer during cycling. That would confirm the finding by Defraeye et al. (2011) who demonstrated based on CFD analysis that headwind affects the convective heat transfer during cycling. Independently, the studies done by Klauer et al. (2018) and Weder et al. (2018) as well as the present results could demonstrate that backpack design can influence the microclimate as well as the interlayer climate during cycling with a backpack.

The results of the pilot study clearly illustrate the potential of the two newly developed rear panel designs (AS and AT) to improve the convective heat transfer during cycling. Depending on the backpack design the headwind during cycling can be used to enhance the thermal comfort of athletes. The next step within this research project involves a wind tunnel study applying a similar test setup but with more subjects to confirm the findings of the pilot study.

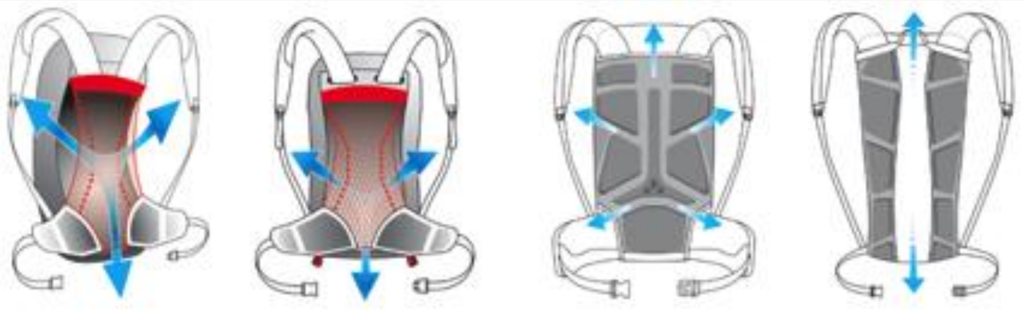

Figure 1. Left side: Ventilated backpack system with mesh net; Right side: Full contact backpack systems with limited air vent channels (blue arrows display possible air flows)

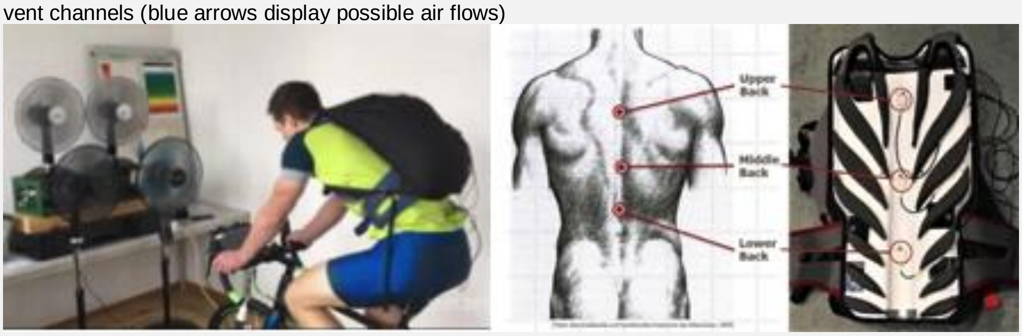

Figure 2. Left side: Test setup with 4 floor fans aligned with frontal upper torso; Right side: Sensor position on the back and the backpack

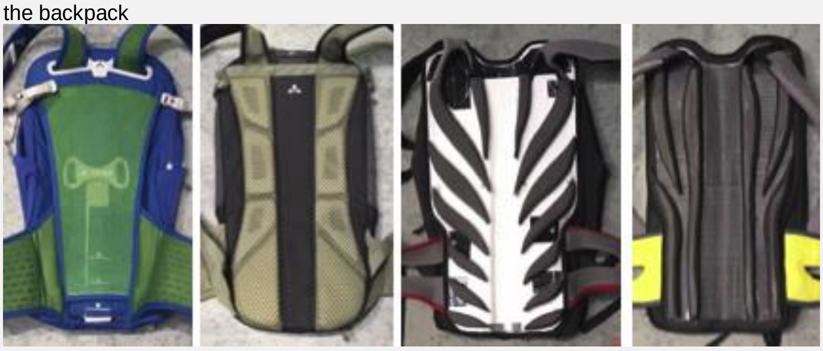

Figure 3. Rear panels of the tested backpack conditions; Left to right: Ventilated system (VS), full contact system (FC), AirTurbulencer concept (AT), AirStreamer concept (AS)

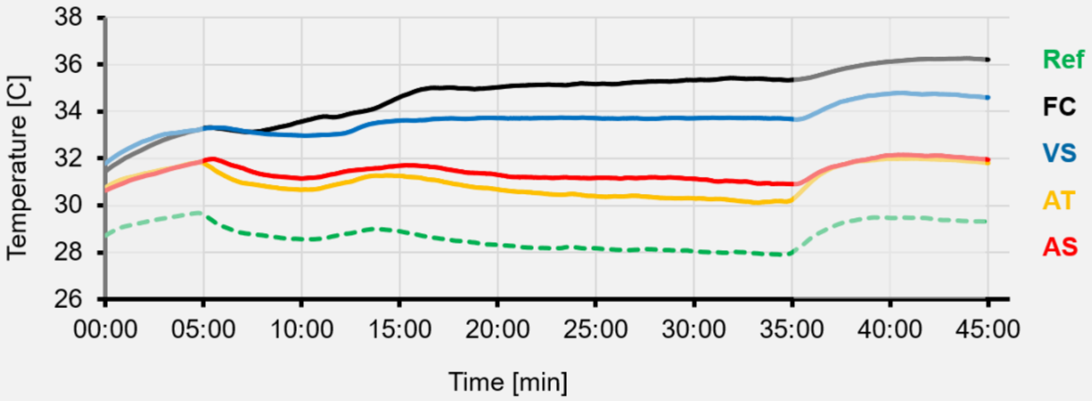

Figure 4. Microclimate - temperature; average of 3 back sensors and all 4 subjects (grey coloured area illustrates rest prior and after cycling.

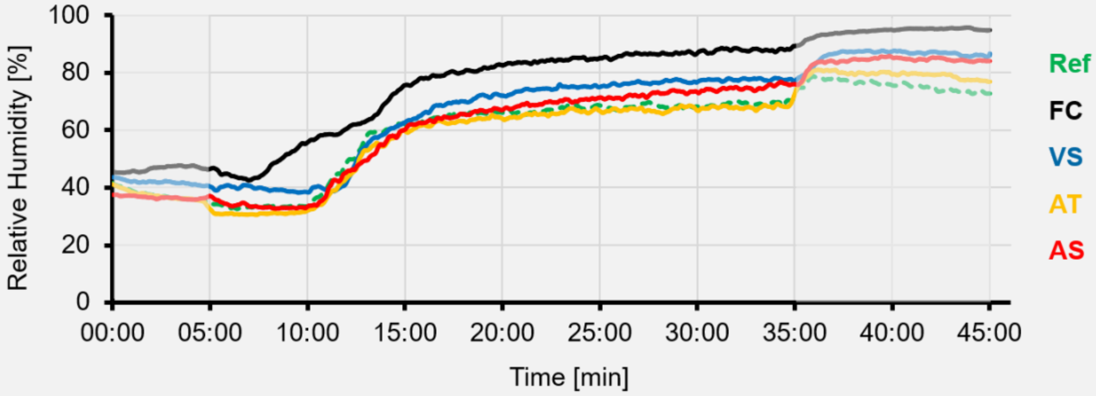

Figure 2. Microclimate - relative humidity; average of 3 back sensors and all 4 subjects (grey coloured area illustrates rest prior and after cycling)

Table 1. Selected averaged values (n=4 of all three sensors) derived from the graphs for microclimate and interlayer climate

Micro-climate	relative Humidity [%]			Temperature [°C]		
	5min	∅29-34min	Difference	5min	∅29-34min	Difference
Ref	34,6	69,0	34,4	29,6	28,0	-1,6
FC	46,6	87,7	41,1	33,3	35,4	2,1
VS	40,4	77,5	37,1	33,2	33,7	0,5
AT	32,5	67,9	35,4	31,8	30,2	-1,6
AS	37,1	74,2	37,1	31,9	31,0	-0,9
Interlayer Climate	relative Humidity [%]			Temperature [°C]		
	5min	∅29-34min	Difference	5min	∅29-34min	Difference
FC	46,7	69,2	22,5	27,1	29,7	2,6
VS	36,2	57,9	21,7	26,0	27,0	1,0
AT	37,3	42,9	5,6	23,8	22,8	-1,0
AS	38,1	46,4	8,3	23,4	23,3	-0,1

Figure 3. Rear panels of the tested backpack conditions; Left to right: Ventilated system (VS), full contact system

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