Effect of shoulder strap design and mechanical properties on the surface pressure of bike backpacks

Lars Timm[1], Frank I. Michel[1]

[1] VAUDE Sport GmbH &Co. KG, ***i***-team, Germany (www.vaude.com)

Introduction

Beside the growing health consciousness, cycling is enjoying growing popularity based on a new ecological and sustainable awareness. Therefore, the load transport on bicycles is gaining in importance. A crucial prerequisite for wearing a backpack is the absence of discomfort. With increasing loads and wearing time, mechanical discomfort can cause pain and serious medical issues like the damage of the brachial plexus (Knapik, Harman & Reynolds, 1996). Due to the specific anatomy, the shoulder region is particularly sensitive for the development of injuries. Recent studies showed that 43%-67% of pain caused by backpacks occur in the shoulder and neck region (Dockrell, Kane & O`Keeffe, 2006). According to Wettenschwiler (2016), the surface pressure between subject and backpack is a valid and quantifiable predictor to investigate mechanical discomfort during load carriage. Furthermore, Hadid et al. (2018) investigated the effect of shoulder strap design and material properties on surface pressure on the shoulder region and proved a positive effect of a double layer padding material with soft foam as outer layer and a stiff inner "backbone" on the surface pressure. However, all studies which determined the contact pressure to predict discomfort used military or trekking backpacks with payload between 15kg - 45kg while walking in a nearly upright posture (Fergenbaum, 2007).
The aim of this study was to compare the findings of Hadid et al. 2018 with bike backpacks as these differ in payload and trunk ankle of the cyclist.

Materials & Methods

Backpack modifications: Two designs of bike backpack shoulder straps were compared with a payload of 4kg. The first one corresponded to a commercially available backpack Bracket 22l (VAUDE GmbH; REF)(**Fig. 1 a**). For the second design, original shoulder straps were replaced by modified medialized straps (MS) similar to Hadid et al. (2018) to decrease and redistribute the pressure (**Fig. 1b**). Furthermore, with the modified strap, it was possible to change the padding material via Velcro. Moreover, polyethylene sheets (PE; 1mm thickness) could be inserted into the shoulder strap to investigate the influence of a double layer padding comparable to Hadid et al. (2018) (**Tab. 1**).

Tab. 1 Overview of the shoulder strap conditions included in the study

Configuration	Thickness	Material	Strap width
Ref (EVA)	10 mm + 2 mm	EVA + Mesh	60mm
MS (EVA)	10 mm + 2 mm	EVA + Mesh	60mm
MS-PORON®	12 mm + 2 mm	Poron + Mesh	60mm
MS-PORON® 1	12 mm + 2 mm + 1mm	Poron + Mesh + PE	60mm
MS-Mesh	2mm	Mesh	60mm
MS-Mesh 1	2mm + 1mm	Mesh+PE	60mm

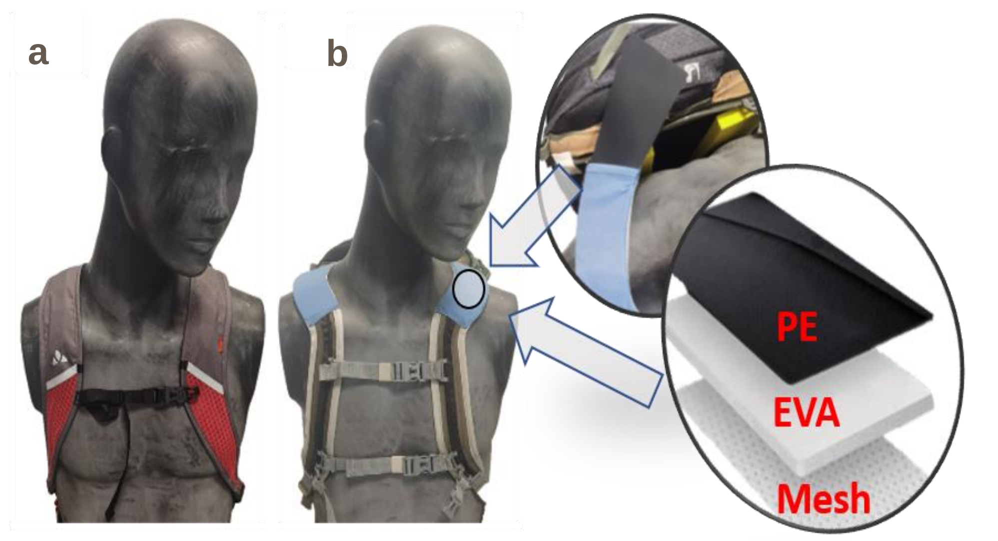

Fig. 1: Original shaped shoulder strap **(a)**, medialized shoulder strap **(b)** with the possibility to change the padding material and to insert a 1mm PE-sheet as a stiff backbone to optimize the pressure distribution ("load distributor")

Set-Up: 14 healthy male recreational cyclists used a gravel bike (Centurion) on a stationary roller trainer (Tacx Bushido) in the brake-hood position for 30 seconds with a trunk angle of ~50°. Surface pressure was measured via pressure mapping system (Tactilus, Sensor Products Inc.) with a senor size of 2cm² which was adjusted at the shoulder (**Fig. 2 a**).
Data Analysis: The mean pressure (P_{mean}) over the whole shoulder region and the peak pressure (P_{max}; point of maximum pressure) were calculated with MATLAB (R2020a, The MathWorks) and used to determine significant effects. These were statistically proven with a paired t-test ($p=0.05$) using SPSS® (SPSS® 27, IBM).

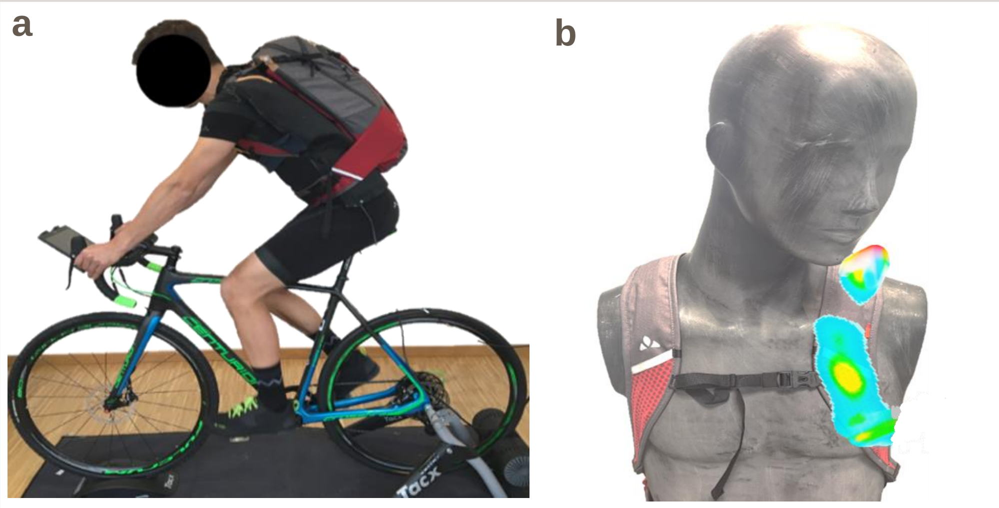

Fig. 2: a) Experimental set-up b) typical pressure distribution pattern (blue = low pressure, red = high pressure) for the use of bike backpacks in the brake-hood position

Results

The medialized shoulder strap course showed a significant lower mean pressure at the shoulder region (p=0,005). Furthermore, the peak pressure was significant reduced (p=0,041) (**Fig. 3 a**).
No significant differences were found in mean pressure between the single layer shoulder paddings (MS-PORON® vs. MS-EVA). Interestingly, there was also no significant difference between the 2mm Mesh shoulder straps and the straps with 10mm EVA and 12mm PORON® padding. However, the double-layer padding made up of PORON® and PE showed a significant smaller mean pressure than the single PORON® layer. No significant effect was found between the single- and double-layer paddings made of mesh (**Fig. 3 b**).

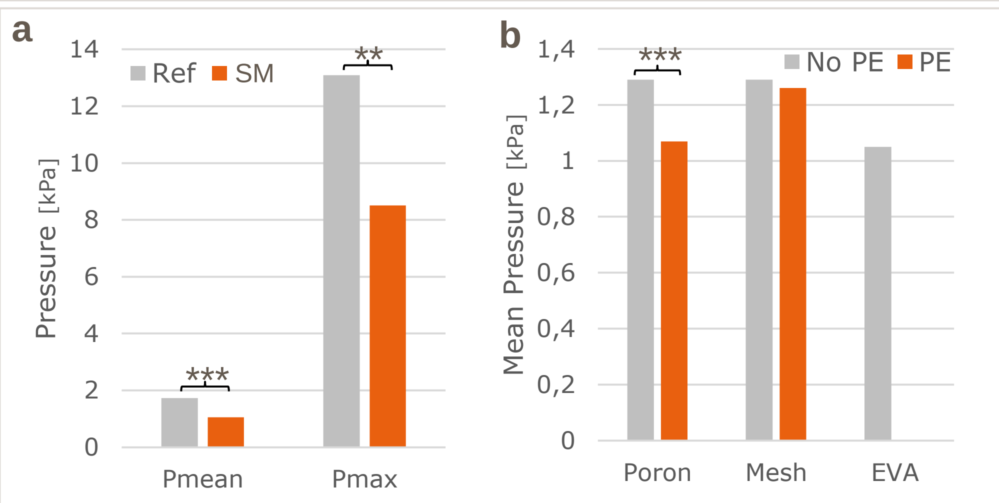

Fig. 3: Results of the paired t-test for the comparison of should strap designs **(a)** and the influence of padding material in single- and double-layer shoulder straps [SM-design only] **(b)** with p<0,05** and p<0,01*** (n=14).

Discussion & Practical Applications

To our best knowledge, this study was the first which investigates the pressure distribution and surface pressure of bike backpacks. The decreased mean and peak pressures at the shoulder region caused by the medialized shoulder strap course coincide with the findings of Hadid et al. (2018), although they used heavier payloads and subjects walked in an upright trunk posture. This finding indicate that the medialized shoulder strap design can lead to a stress reduction in the sensitive shoulder region and consequently improves comfort.
In general, the different material and construction modifications could not reveal substantial differences for the given payload of 4kg. Only the combination of PORON® and PE as a "load distributor" reveals significant less mean contact pressure. This finding is also in accordance with the results of Hadid et al. (2018). It is assumed, that with increasing payload such double-layer constructions become more important.
Basically, to improve the mechanical comfort of shoulder straps it seems that strap course and the strap width are more important than material characteristics and material thickness for a bike backpack with a given payload of ≥4kg and a trunk angle of ~50°.
It should also be point out that, the presented findings only serve as a starting groundwork in "bike backpack research" to improve the mechanical comfort. There are many more variables which should be investigated systematically like the upper shoulder strap attachment location in terms of distance (shoulder length/width) and shoulder angle as well.

References

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