Backpack impact protection in cycling – Comparison of a conventional foam-based vs. an air-based protection system

Nils Schneider[1/2], Kay Vogt[1], Frank Emmrich[2], Frank I. Michel[1]

[1] VAUDE Sport GmbH &Co. KG, ***i***-team, Germany
[2]German Sports University Cologne, Institute of Biomechanics and Orthopaedics, Germany

Introduction

Mountain biking as leisure activity and as a competitive sport enjoys an increasing popularity in the Western world and is often related to high speeds and difficult maneuvers. This can lead to serious injuries such as burst fractures, compression fractures, subluxation and cervical sprains (Tarazi et al., 1999). Injury rates of 0.37 riders per 100 h in cross country cycling and 4.34 riders per 100 h in downhill riding are observed (Carmont, 2008). In such cases a protective backpack may help prevent serious injuries (Michel et al., 2010).

Most protective backpacks have a foam-based protector at the inside, which usually consist of non-sustainable material such as polyurethane (PU). This leads to the conclusion that a different type of protector may be more sustainable than the conventional foam-based protectors.

The aim of this study was to compare the remaining impact force (RIF) as one important parameter accordingly to the norm EN 1621-2 (DIN, 2014) of an air-based backpack protection system (APS) to a conventional foam-based backpack protection system (FPS). In this context, the effect of different air pressure settings in combination with different padding thicknesses on the remaining impact force was investigated.

Material & Method

Accordingly, to the EN 1621-2 (standard for motorcycles), the experiments were carried out with a prescribed impactor with a drop mass of 5kg, predefined rectangular dimensions and a free-falling impact (ad Engineering, Typ 1011MAU 1002/2W/ALU/SF), which resulted in an impact of 50J kinetic energy (Figure 1). The distance between the drop mass and the sample was 100cm (drop height). Impacts with a horizontal as well as a vertical alignment of the test body were applied. This deviation from the EN 1621-2 was conducted to get an overview of the protective performance in several different backpack conditions. The standard includes two different safety levels (safety level 1: average RIF of <18kN; safety level 2: average RIF <9kN).

Fig. 1: a) Drop test device accordingly to EN 1621-2; b) test block (steel anvil) including load cell sensor; c) positioning of the backpack in between the test apparatus; d) Drop body alignment during impact - horizontal and vertical.

The backpacks were tested at 20±2°C and a humidity of 65±5%. The measured "remaining impact force" represents the resultant force measured with the load cell sensor positioned below the sample and the anvil.
A conventional FPS (Moab Pro 22L, VAUDE Sport GmbH) and an APS (consisting of an inflatable air mattress within the Bracket 22L, VAUDE Sport GmbH) (Figure 2) was used for the investigation. Ethylene-vinyl-acetat (EVA) paddings with a hardness of 20 Asker C in two different thicknesses (10 and 20 mm) were also used (Figure 2, right a).

Fig. 2: Left: a) Moab Pro 22L; b) 1,5 mm thick polyethylene plate; c) Ortema foam protector (2 cm thick, weight 395 g and 50 Asker C). Right: a) Bracket 22 L with 10, 20 mm thick EVA foam paddings (20 Asker C); b) 1,5 mm thick polyethylene plate (PE); c) inflatable air mattress (3 cm thick, weight 200 g)

Results

The air-based protection system shows considerably less remaining impact forces (3.1 kN) than the conventional foam-based protection system during impacts (7.4 kN) applying a horizontal aligned impact body (Figure 3, a). In regards to the air pressure of the air-based protection system, the remaining impact forces highly decreased to 16 % (from 18,3 to 3,1 kN), when the air pressure was increased for 100 % from 0,5 bar to 1,0 bar (Figure 3, b). For air pressures of 1,0 bar up to 2,0 bar, there were no marked differences between the remaining impact forces (Figure 3, b). The different padding thicknesses of 10 mm and 20 mm showed different RIF during a constant air pressure of 1,0 bar within the Bracket air protection system. The 20 mm padding showed lower RIF (3,1 kN) than the 10 mm padding (10,4 kN) (Figure 3, c).

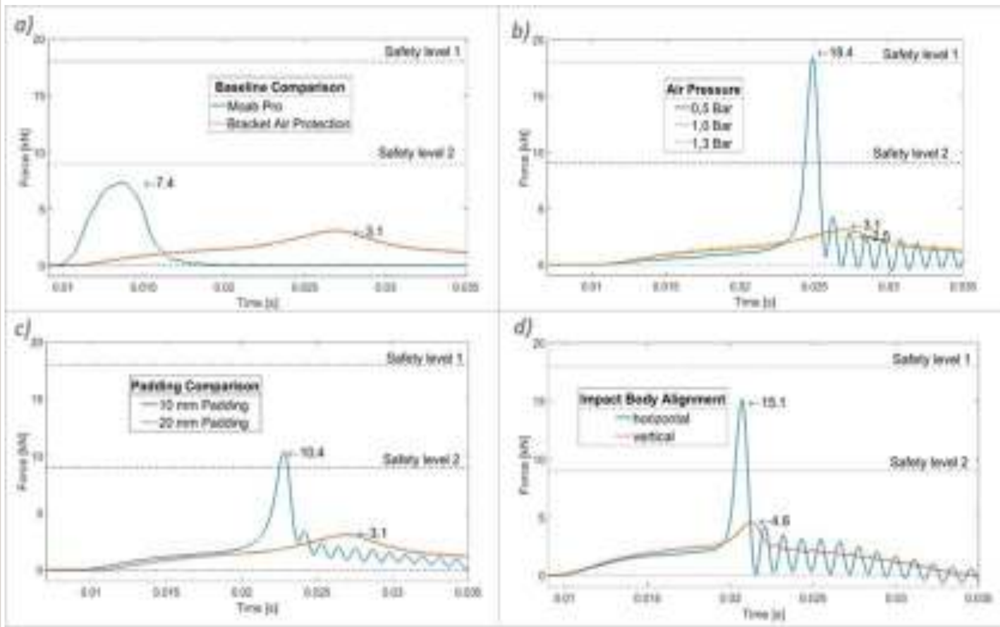

Fig. 3: a) RIF between the FPS and the APS (20 mm thick EVA padding and 1 bar air pressure); b) RIF between different air pressure setting within the APS (with 20 mm thick padding); c) RIF between different padding thicknesses at the APS system with a constant air pressure of 1,0 bar; d) RIF between two different alignment settings (horizontal and vertical) of the drop body during the impact on the APS with 0 mm thick EVA paddings and 2 bar air pressure.

Different drop body alignment settings influenced the RIF on the APS, vertical drop body alignment impact had a lower RIF (4.6 kN), compared to the horizontal one (15.1 kN) (Figure 3 d). The APS with 20 mm thick padding, a 1.5 mm thick PE plate and 0.5 bar air pressure within the air mattress reached a maximum remaining impact of 18.3 kN (safety level 1: RIF <18 kN). Pressure settings of 1.0 bar and above fulfilled the requirements of the safety level 2 and small variations for the RIF could be observed (Figure 4). It indicated a "steady state" for the remaining impact force for a certain air pressure threshold of 1 bar and above. This only accounted for the APS with a padding of 20 mm thickness and 20 Asker hardness (Figure 4).

Discussion & Conclusion

Discussion: The results demonstrate a difference of the air-based protection system (APS) compared to the foam-based (FPS) regarding the remaining impact forces (RIF). According to a product review (Mountain Bike Testguide, 2016), analyzing 9 exclusively foam-based back protectors for MTB the RIF of the whole backpack protection systems vary between 6,0 and 10,9 kN (Ø 7,6 kN). Eleven tested back protector systems for snow sports show an averaged RIF of 12,0 kN (Michel et al., 2010). These numbers clearly point out the impact protection potential of APS compared to FPS. The impact protection of the APS is strongly affected by the air pressure within the air mattress. Higher air pressures lead to lower RIF and a better impact protection up to a "steady state" where the RIF stays constant with air pressures above 1,3 bar.

The results also indicate that the thicker the EVA padding of the APS the lower is RIF, which is also confirmed in the literature (Derler, 2009).
Conclusions: This study gives an overview of the impact protection of a conventional FPS compared to an APS. Accordingly, to the drop body impact (only in the center region of the APS), the air mattress has a positive effect to minimize the RIF and therefore increases the impact protection. The results clearly point out the potential of an APS. In comparison to the conventional fossil-based FPS the APS is not only an air pressure adjustable system, it is also a more sustainable protection system when considering the materialization. Summarizing the findings with an air pressure of 1,5 bar the APS clearly reveals the enhanced impact protection potential to reduce the risk of severe back injuries during cycling.

References

Carmont, M. R. (2008). Mountain biking injuries: A review. British Medical Bulletin, 85, 101–112.
Derler, S. (2009). Untersuchung von kommerziellen Hüftprotektoren, Bericht zum Forschungsprojekt Nr. 205742, Empa: St. Gallen.
DIN (2014-05). Motorradfahrer-Schutzkleidung gegen mechanische Belastung - Teil 2: Rückenprotektoren - Anforderungen und Prüfverfahren; Deutsche Fassung EN 1621-2:2014. (EN 1621-2).
Michel, F. I., Schmitt, K.-U., Liechti, B., Stämpfli, R., & Brühwiler, P. (2010). Functionality of back protectors in snow sports concerning safety requirements. Procedia Engineering, 2(2), 2869–2874.
Mountain Bike Testguide (2016). Rückendeckung: 9 Protektoren im Test, 92-98.
Tarazi, F., Dvorak, M. F., & Wing, P. C. (1999). Spinal injuries in skiers and snowboarders. The American Journal of Sports Medicine, 27(2), 177-180.

SCIENCE & Cycling Conference, 3rd – 4th July 2019, Brussels - Belgium