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

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Purpose:
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).
Purpose: 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 materialization of the protector may be more sustainable than the conventional foam-based protectors The aim of this study is to compare the remaining impact force (RIF) as one important parameter accordingly to the norm EN 1621-2 (EN 1621-2) 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.

Methods:
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 measuring equipment consisted of a load cell sensor (Kistler®, Typ 9091, measuring range 0-1200kN), a charge amplifier (Kistler®, Typ 5015A) and a transient recorder (Bakker, Typ BE490, 12Bit). The data were recorded with a sampling frequency of 100kHz within a period of 25ms. The distance between the drop mass and the sample was 100cm (drop height). Dissenting from the EN 1621-2, one to three impacts per test sample condition at different locations were conducted, instead of five impacts. 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). In this study the safety levels are considered as orientation to evaluate the impact protection. 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). 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). The backpacks are 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.

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 decreases, when the air pressure increases from 0,5 bar to 1,0 bar (Figure 3, b). For air pressures of 1,0 bar up to 2,0 bar, there are no marked differences between the remaining impact forces (Figure 3, b). The different padding thicknesses of 10 mm and 20 mm show different RIF during a constant air pressure of 1,0 bar within the Bracket air protection system. The

20 mm padding shows lower RIF (10.4 kN) than the 10 mm padding (3.1 kN) (Figure 3, c). Different drop body alignment settings influence the RIF on the APS, vertical drop body alignment impact has a lower RIF (3.3 kN), compared to the horizontal one (10.4 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 reaches a maximum remaining impact of 18.3 kN (safety level 1 maximum of 18 kN). Pressure settings of 1.0 bar and above fulfill the requirements of the safety level 2 and small variations for the RIF can be observed (Figure 4). It indicates a steady state for the remaining impact force for a certain air pressure threshold of 1 bar and above. This only accounts for an APS with 20 mm thick and 20 Asker paddings (Figure 4).

Figure 1. 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 10 mm thick EVA paddings and 1 bar air pressure

Figure 2. Figure 4: Remaining impact force after horizontal impact alignment for different pressure settings on the APS with 20 mm thick EVA foam padding.

Conclusion:
The results show 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 (∅7,6 kN). Eleven tested back protector systems for snowsports 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 as thicker the EVA padding of the APS as lower is RIF, which is also confirmed in the literature (Derler 2009). Vertical drop body alignment impacts lead to lower remaining impact forces than horizontal drop body alignment impacts on the currently designed APS. It seems that the shape and channel system of the air mattress surface influences the RIF. The overall APS has an air pressure depending impact protection. Increased air pressure as well as thicker EVA padding lead to a reduction of the RIF. It is required to find the optimal combination of padding thickness and air pressure to get the best results in case of the lowest remaining impact forces and ensuring the wearing comfort.

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 can have 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. Moreover, the APS can provide a betterwearing comfort due to the reduced weight difference of the foam protector (200 vs. 395 g) and the adjustable air pressure. To further enrich better results the shape and the chamber system of the air protector needs to be adjusted, that the remaining impact force is not influenced by the drop body alignment. 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 back injuries during cycling. Besides, the higher sustainability of the air-based protection system and the lower weight conclude a reasonable potential in developing such a new protection technology which can soon substitute conventional foam-based protector.

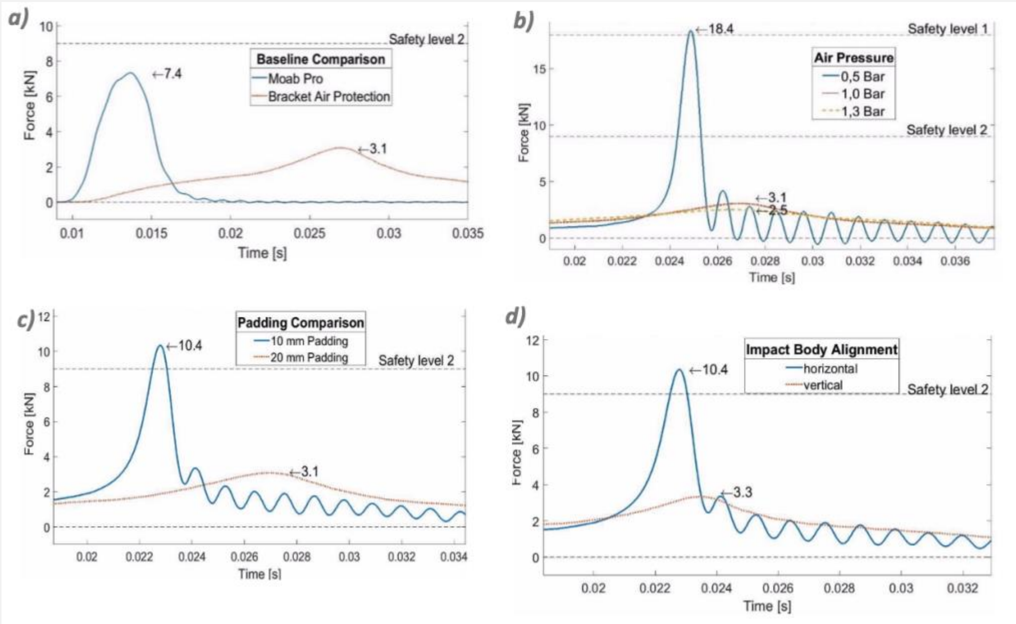

Figure 3. a) Drop test device accordingly to EN 1621-2; b) test block (steel anvil) including load cell sensor; c) positioning of the backpack in between the test device; d) Drop body alignment during impact - horizontal and vertical.

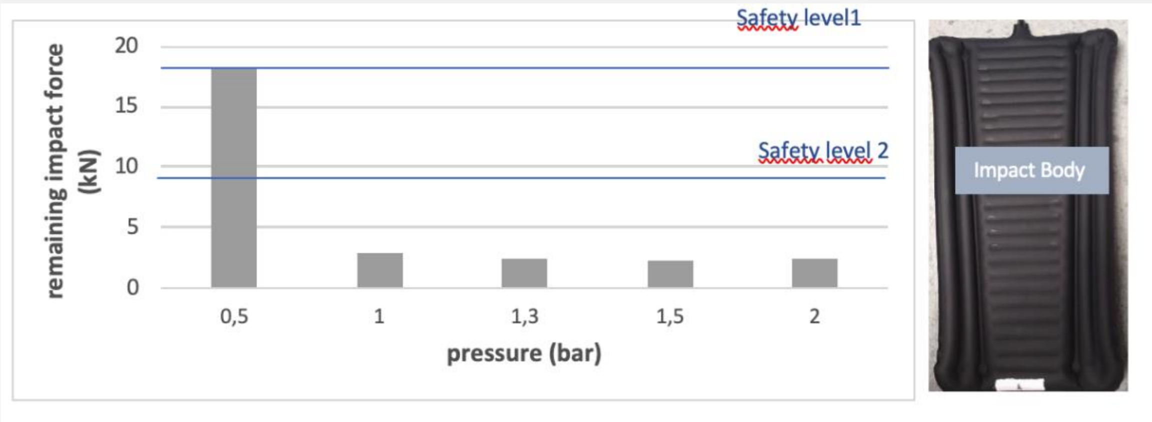

Figure 4. Left: a) Moab Pro 22L; b) 1,5 mm thick polyethylene plate; c) Ortema foam protector (2 cm thick, weight 395 g and 50 Asker C). Right: a) Bracket 22 L with 10, 20 mm thick EVA foam paddings (20 Asker C); b) 1,5 mm thick polyethylene plate (PE); c) inflatable air mattress (3 cm thick, weight 200 g)

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