HIP- AND BACK-PROTECTORS IN SPORTS AND EVERYDAY LIFE - EFFECTIVE PROTECTION?

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Hip and back protectors are recommended to reduce impact forces when falling in sports or everyday life. This study analyzed the shock-reducing effect of 29 different hip and back protectors using a drop test and a Kistler force plate. Our results showed large differences between the single protectors. Measured peak forces often and quickly exceeded the supposed limit of bone fracture strength. Therefore sufficient safety does not seem to exist yet and protectors must not be overestimated in their protection potential. In our opinion protectors should have a certain thickness preferably a combination of hardshell and viscoelastic material. Hip protectors for sports still show large deficits. Back protectors only protect against direct contusion but not against axial compressions or cervical spine.

KEY WORDS: back protector, hip protector, impact forces, risk sports, injury prevention.

INTRODUCTION: In alpine winter sports injury rates are decreasing, but collisions, concussions, spinal cord injuries and polytraumata are increasing (Knöringer, 2013). Trunk and hip are affected with about 19% of injuries. Although the incidence of spine injuries with 0.001/1,000 skiing days is very low, spinal lesions can be serious: in about 20% of the injuries the spinal cord is involved with similar rates for all parts of the spine, and 50 % need surgical treatment (Auswertungsstelle für Skiunfälle [ASU], 2014). The injury mechanism mainly is axial compression whereas direct contusions are rare (Ackery, Hagel, Provvidenza, & Tator, 2007). Fractures of hip region often arise when lateral forces are applied on the greater trochanter. In elderly persons with reduced bone density already a fall from standing can cause a fracture, in younger people higher forces are necessary like a fall from bicycle (Weinz & Schönle, 2006), collisions in alpine winter sports, traffic accidents or crashes when falling from larger heights. Fractures of hip, pelvis or femur neck are the consequence (Stöckle, Lucke, & Haas, 2005). At present in Germany the overall incidence of femur neck fracture is 90/100,000 inhabitants, in elderly (>65 years) up to 900/100,000 inhabitants/year. Life risk for coxal femur fracture is up to 23% in women and 11% in men (Stöckle et al., 2005). Impact forces are of great relevance for the occurrence of fractures. Force impact on human body when falling depends on the location of impact (direct or nearby spine or hip), the direction of fall, the fall height and the condition of ground (Kaack, 2000).

In elderly a simple fall as a bagatelle trauma is the most frequent cause for femur neck fracture. Men with body height of at least 183 cm showed a twofold higher hip fracture risk than men with body height of 175 cm or less (Hemenway, Azrael, Rimm, Feskanich, & Willett, 1994). Studies show that forces leading to pelvis or hip fractures vary between 3.61 kN and 8 kN (Etheridge et al., 2005; Song, Trosseille, & Guillemot, 2006). In addition a reduction of bone density lowers the fracture threshold (Beason et al., 2003). Also the characteristic and thickness of soft tissue changes fracture risk (Bouxsein et al., 2007). Older people with higher risk of falling as well as elderly in care homes use hip protectors even though the literature show different results concerning the efficacy of those protectors.

Once the use of ski helmets in winter sports has become normal, also back protectors particularly in younger skiers and snowboarders have found rising distributing (29%). About 76% of active sport participants are convinced of the protection potential (Schmitt, Liechti, Michel, Stämpfli, & Brühwiler, 2010). Lateral hip protectors are used mainly in biking, skiing, snowboarding, ice hockey and mountain biking. In the rising group of elderly athletes this protectors seem to be useful to reduce injury risk in falls.

The original test norm for back protectors (drop test, 5 kg, height 1 m) was applied to motorbike racing protectors (EN 1621) allowing a remaining energy of 8 kN in mean and 12 kN in maximum in latest level-2 (EN 1621-2, 2003), which is equal or higher than fracture limit of middle aged or elderly persons. A former study showed that each of 12 tested back protectors reached level-2, but also a simple backpack with pullover came to the same result (Schmitt et al., 2010). For hip protectors different biomechanical tests were published, but most of them do not use a high frequency of the force transducer. Therefore in those investigations high and very short impact forces perhaps were not registered. In our present study we tried to analyze the protection effect of available hip and back protectors measuring peak force reduction and time to peak delay.

METHODS: 21 hip protectors, thereof 14 for orthopedic protection (everyday life) and seven for sports, as well as eight back protectors for sports were analyzed in a drop test. A bowling ball (Ø 17 cm, 31 N) was dropped from different heights (25, 45, 65, 80 and 100 cm [H25… H100]) centrally on the protector (3-times each height), which was positioned on a force plate (Kistler, range 20 kN, frequency 20 kHz). To ensure constant falling conditions, the bowling ball was positioned on a rail with about 0.5% slope, than released by hand, consequently rolling slowly to the edge and falling down (figure 1). On the back protectors 5 different locations were tested: center, left, right, top, bottom (figure 2). Additionally an Airex balance-pad (thickness 6 cm) was tested as a comparison. Statistics were performed by t-test with significance level of 5%.

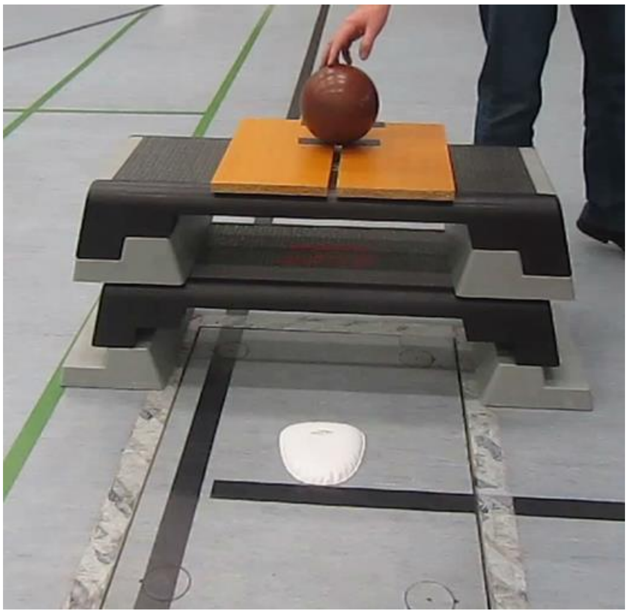

Figure 1: Test station constructed with reebok steppers over the force plate (here H45), bowling ball in starting position on the rail, protector positioned at center of impact.

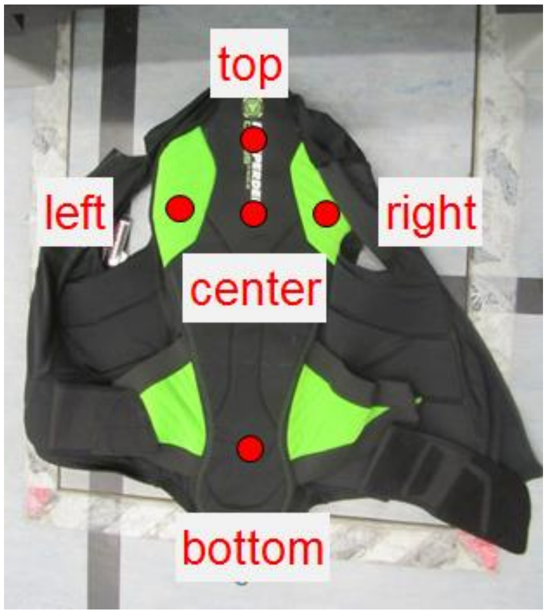

Figure 2: Different testing positions of the back protectors.

RESULTS: The direct fall of the bowling ball on the force plate (without protector) produced peak forces of 9.2 kN (H25) resp. 17.4 kN (H45) with times to peak of 1.32 ms (H25) resp. 1.18 ms (H45). Drop heights higher than H45 were out of measuring range for the direct fall of the bowl.
When testing different protectors following results were obtained: Airex balance-pad showed peak forces at impact of 0.5 kN (H25) resp. 1.8 kN (H100) with times to peak of 18.3 ms (H25) resp. 9.9 ms (H100). Orthopedic hip protectors reduced the peak forces in mean to 1.6 kN (H25) resp. 9.9 kN (H100) with times to peak of 5.6 ms (H25) resp. 3.9 ms (H100).

The data of all peak forces as well as times to peak of all protector groups in different drop heights are listed in table 1 & 2.
There were very wide spreads between different protectors: The results of peak forces ranged from 0.9 kN to 6.0 kN (H25) resp. 3.2 kN to 22.0 kN (H100) and times to peak from 1.4 ms to 14.0 ms (H25) resp. 1.0 ms to 8.9 ms (H100) (table 1, 2).
At highest drop heights (H100) back protectors showed significant better peak force reductions (p<.032) than hip protectors. Orthopedic hip protectors showed significant better peak force reductions at all drop heights (p<.024) except H100 than hip protectors for sports. Orthopedic hip protectors showed at least tendentially better peak force reductions at lower drop heights (H25, H45) and worse at higher drop heights (H80, H100) in comparison to back protectors. The times to peak force were the longest using the orthopedic hip protectors in comparison to the back protectors, but the results were only significant at H45 and H65 (p<.040). Hip protectors for sports show significant shorter times to peak force (p<.005) against other groups.

Table 1
Mean, min and max peak forces [N] of protector groups in different drop heights

height [cm]	peak force [N]		no pro-tection	balance-pad	hip protectors orthopedics		hip protectors sports		back protectors sports	
H25	mean	min max	9227	500	1578	918 3818	3727	2324 5960	2109	1272 3759
H45	mean	min max	16839	883	2941	1044 7451	6278	3985 11766	3510	1787 5166
H65	mean	min max	out of range	1266	4987	1841 10618	8840	5210 14813	4780	3005 7940
H80	mean	min max	out of range	1542	6837	2253 12612	10590	5843 17155	5369	3772 8213
H100	mean	min max	out of range	1848	9882	3236 16575	12382	6771 22042	6622	4096 11201

Table 2
Mean, min and max times to peak [ms] of protector groups in different drop heights

height [cm]	time to peak force [ms]		no pro-tection	balance-pad	hip protectors orthopedics		hip protectors sports		back protectors sports	
H25	mean	min max	1.32	18.28	5.57	2.98 8.32	2.08	1.35 3.55	5.27	1.85 13.95
H45	mean	min max	1.18	15.75	5.46	2.58 9.15	1.74	1.15 3.75	3.98	1.25 8.85
H65	mean	min max		14.12	5.11	2.02 10.62	1.62	1.20 2.60	3.23	1.35 6.70
H80	mean	min max		13.42	5.06	2.00 9.73	1.64	1.25 2.10	3.10	1.15 5.25
H100	mean	min max		9.87	3.89	1.47 8.87	1.45	1.00 1.95	2.77	1.30 6.55

DISCUSSION: Only 11 of 29 protectors remained below test norm EN 1621-2 resp. below the limit for bone fracture of 8 kN, thereof six of the eight back protectors. Our used bowling ball (31 N) is distinctly lighter than the weights used in standard test (50 N). Orthopedic hip protectors tend to have better results at lower and back protectors at higher drop heights. Times to peak force as second important criterion shows best results at orthopedic hip protectors, indicating good damping properties of used viscoelastic material. In summary the protecting effect essentially depends on the construction and thickness of the protector. Best protection at highest drop heights showed protectors with a combination of hardshell and viscoelastic material. Protectors like the orthopedic hip protectors without a hardshell should have a certain thickness (≥19 mm) in order to develop a sufficient efficacy. Four of the seven hip protectors for sports application exceed the limits considerably, indicating that the damping material was too thin (viscoelastic) or unsuitable (foam).

CONCLUSION: Suitable protectors can distinctly reduce higher impact forces caused by crashes or falls and are recommended for elderly or people with hip endoprosthesis as well as for (leisure) athletes in risk sports as for example mountain biking or snowboarding. Nevertheless the remaining peak forces often and quickly exceed the supposed limit of 3.6 - 8 kN of bone fracture strength. Therefore a sufficient safety seems not to exist until now. For risk sports a combination of hardshell and viscoelastic material seems to be advisable. With respect to the back protectors it has to be considered, that sufficient protection exists only against direct contusion. In contrast no protection exists against the risk factor of axial compression for the lumbar, thoracic and especially cervical spine. In all protectors the protection potential seems to be overestimated. Therefore the results also suggest that the best protection outside the use of protectors consists in reduction of risks, avoidance of falls and reducing the speed.

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