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Effects of Including a Penetration Test in Motorcyclist Helmet Standards: Influence on Helmet Stiffness and Impact Performance

Óscar Juste-Lorente [1,*], Mario Maza [1], Ana Piqueras [1], Ana I. Lorente [1] and Francisco J. López-Valdés [2]

[1] Impact Laboratory, Aragon Institute for Engineering Research (I3A), University of Zaragoza, 44600 Alcañiz, Spain; mmaza@unizar.es (M.M.); apiquera@unizar.es (A.P.); analorente@unizar.es (A.I.L.)

[2] Instituto de Investigación Tecnológica (IIT), ICAI Engineering School, Comillas Pontifical University, 28015 Madrid, Spain; fjlvaldes@comillas.edu

* Correspondence: ojuste@unizar.es

Abstract: Regulation ECE-22.05/06 does not require a helmet penetration test. Penetration testing is controversial since it has been shown that it may cause the helmet to behave in a non-desirable stiff way in real-world crashes. This study aimed to assess the effect of the penetration test in the impact performance of helmets. Twenty full-face motorcycle helmets were penetration tested at multiple locations of the helmet shell. Then, 10 helmets were selected and split into two groups (hard shell and soft shell) depending on the results of the penetration tests. These 10 helmets were then drop tested at front, lateral, and top areas at two different impact speeds (5 m/s and 8.2 m/s) to assess their impact performance against head injuries. The statistical analyses did not show any significant difference between the two groups (hard/soft shell) at 5 m/s. Similar results were observed at 8.2 m/s, except for the top area of the helmet in which the peak linear acceleration was significantly higher for the soft shell group than for the hard shell group (230 ± 12 g vs. 211 ± 11 g; p-value = 0.038). The results of this study suggest that a stiffer shell does not necessarily cause helmets to behave in a stiffer way when striking rigid flat surfaces. These experiments also showed that hard shell helmets can provide better protection at higher impact speeds without damaging helmet performance at lower impact speeds.

Keywords: motorcyclist helmet; penetration test; impact test; shell stiffness

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1. Introduction

About 4000 people died in 2019 in the European Union as a direct result of moped and motorcycle crashes, accounting for 18% of the total motor vehicle fatalities [1]. Motorcyclists have an increased risk of injury in case of collision, which is particularly relevant in the case of head injuries [2]. The use of helmets is the most effective way of preventing motorcyclists' head injuries [3], and improving the impact performance of helmets leads to reduce the risk of head injury and fatalities. Most helmets are developed and designed according to the requirements prescribed in the relevant helmet standards. There are numerous motorcycle helmet safety standards around the world: ECE-22.05/06 in Europe [4,5], DOT and Snell in USA [6,7], and JIS-T in Japan [8] are among some of them. The objective of a motorcycle helmet standard is to ensure a minimum level of head protection under some specific test conditions. However, methods and requirements vary from one standard to another and, therefore, the performance against impact of motorcyclist helmets is influenced by the requirements included in each standard [9,10].

One of these requirements, which has been controversial over the last decades, is the need of a penetration test. The penetration test measures the resistance of the helmet shell to impacts against sharp objects. In these tests, the helmet is positioned on a headform or a spherical device support. Then, a conical striker is dropped to hit the outer surface of the static helmet shell. The required performance criterion consists of ensuring that there is no contact between the striker tip and the headform or spherical support.

Over the years, some research has pointed out that the penetration test was either not necessary or that it could negatively influence helmet performance in more common real-life crash scenarios. In a statistical study, Otte et al. found that the frequency of motorcycle accidents involving penetrating objects was extremely small [11]. Shuaeib et al. stated that the penetration test is the main parameter that would determine the thickness of the helmet shell, leading to a thicker shell that would account for about 50% of the weight of the helmet [12]. Furthermore, some researchers stated that the penetration test causes helmets to be designed with a stiffer shell that could result in an increased risk of head injury in impacts against rigid flat surfaces [13,14]. These concerns resulted in the elimination of the penetration tests from some standards, while others continue demanding this requirement. In Europe, a penetration test is not required in the current regulation ECE-22.05/06 [4,5], while several other standards and regulations do require this procedure as part of the helmet assessment program [6–8,15].

However, the link between increased helmet shell stiffness and a higher acceleration headform response in case of impact has been addressed on the basis of simplified models of the helmet behavior that, for instance, do not take into account the effects on the helmet behavior of different impact velocities [16] and other contributing factors to impact energy management such as the role of the shell in producing a proper load distribution over a greater liner area [17] and the variation of protective padding density at different helmet locations [18,19]. The aim of this study was to empirically demonstrate if the inclusion of a penetration test in motorcyclist helmet testing standards results in an increased risk of head injury for the motorcyclists in a set of commercially available helmets. More specifically, the goal of this paper was to assess the influence of the shell resistance to the penetration test on the impact performance of helmets at two different impact velocities.

2. Materials and Methods

The experimental method was designed to study if the shell stiffness assessed by the penetration test influences the impact performance of motorcycle helmets. First, 20 full-face motorcycle helmet models were exposed to a penetration test. Then, on the basis of the observed results from the penetration tests, we classified four helmet models as hard shell helmets and six as soft shell helmets. The 10 remaining helmet models were unclassified and then not further considered in the study. Only the 10 classified helmet models were selected to be drop tested at two different velocities. A new helmet sample was used for each velocity, and therefore 20 helmets were drop tested. Thus, a total of 40 helmet samples were used in this study.

All the helmets were composed of composite shell and the protective padding was made of expanded polystyrene (EPS). The retention system of the helmets was based on the double D-ring buckle. All the helmets complied with the European regulation [4]. The tests were performed at the Impact Laboratory of the University of Zaragoza.

2.1. Penetration Test

A conventional penetration test was conducted on one sample of each helmet model (see Figure 1). The striker mass was 3 kg with a 60° conical head, and it was dropped from a height of 2 m above the surface of the helmet shell [15]. Between 2 and 4 points were randomly tested on each sample. Typical impacted areas were the front, top, lateral, and rear of the helmet shell on or above the test line, as defined by Snell [7]. Impacts on vent openings were not performed. The locations for the impact points as well as the order in which they were tested were randomly selected for each helmet as prescribed in the test procedure [6–8,15]. The intrusion of the conical tip of the striker into the helmet was measured after each impact. Then, the average and the standard deviation values of the intrusion measurements were calculated for each helmet and used as an indicator of the shell stiffness to classify the helmets. Only helmets with an average intrusion higher than

15 mm (soft shell helmets) and lower than 10 mm (hard shell helmets) were selected for the impact performance comparison and were exposed to the drop test. The rest of the helmets that resulted in intermediate values of intrusion were not further considered in the study.

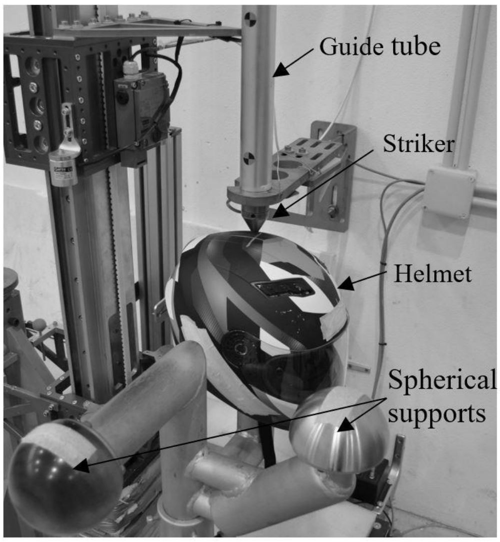

Figure 1. Penetration test set-up.

2.2. Impact Absorption Tests (Drop Tests)

The test matrix consisted of 60 impacts onto a flat anvil. After the selection process based on the penetration test results, a new sample of each selected helmet model was drop tested at 5 m/s and another sample at 8.2 m/s. Each helmet was tested on the front, lateral, and top areas (three impacts per helmet sample at each impact speed). The selected impact areas corresponded with the points B, X (right), and P, as described in the European regulation [5] and shown in Figure 2.

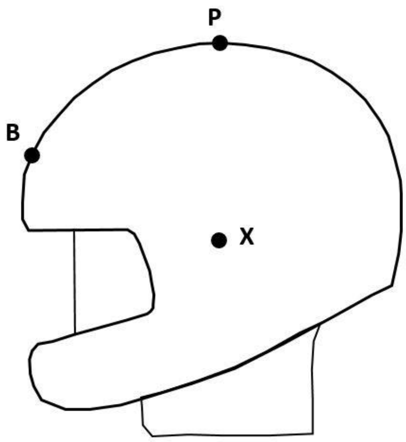

Figure 2. Impact points for the impact absorption tests.

A free fall guided impact machine (Model: Quebrantahuesos 6.0, +D, Pozuelo de Alarcón, Spain) was used for the impact absorption tests (see Figure 3). As the helmets tested were not of the same size, three metallic headform sizes were used (Model: 100_04_FMH, Cadex Inc., Saint-Jean-sur-Richelieu, QC, Canada) to ensure an appropriate fitting of the headform for each helmet size, as prescribed in the regulation [4,5]. Four helmet types were tested with the 535 mm headform circumference, three with the 575 mm headform, and three with the 605 mm headform [20]. The corresponding headform masses were 4.1 kg, 4.7 kg, and 5.6 kg respectively. The headforms were positioned inside the helmets according to the requirements of Annex 5 of ECE-22.06 [5], and the retention system was adjusted under the chin of the headforms and tightened to a tension of 75 N [15]. Before each impact, the headform was re-positioned, and the retention system re-tensioned.

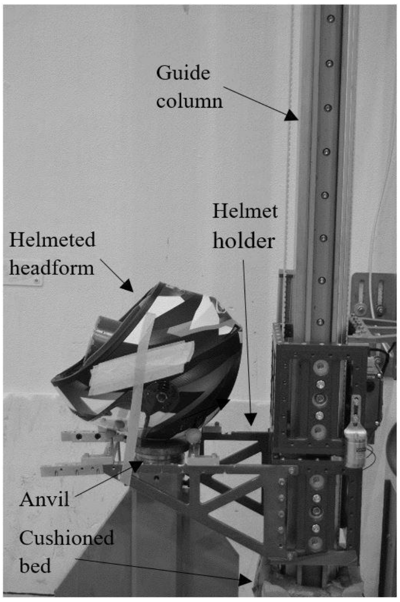

Figure 3. Impact absorption test set-up.

A wireless system (Model: iCONO, +D, Pozuelo de Alarcón, Spain) was used to measure the linear acceleration at the center of gravity of the headforms. The wireless system incorporates three orthogonal uniaxial accelerometers (Model: 64C-2000, MEAS, Nanshan District Shenzhen, China) and an acquisition system (Model: SLICE NANO, DTS, Seal Beach, CA, USA). Data were recorded at 10 kHz, filtered using a low-pass filter CFC-1000, and post-processed using a validated and developed in-house script of Matlab (Matlab R2013b, MathWorks, Natick, MA, USA).

2.3. Statistical Hypothesis Testing

The objective of the main statistical hypothesis testing was to assess the influence of the shell stiffness on the impact performance of the helmets against head injuries. For that reason, the helmet models were classified into two groups (soft and hard shell groups) depending on the result of the penetration test. As aforementioned, 10 out of the 20 penetration tested helmets were selected for the impact performance comparison. Within the selected group, four helmet models were grouped into the hard shell group, while the remaining six helmet models were included in the soft shell group. Both groups had helmets of three different sizes. The hard shell group was composed of two helmets that were tested with the 535 headform, one with the 575 and one with the 605. The soft shell group was composed of two helmets tested with the 535 headform, two with the 575, and two with the 605.

The peak resultant linear acceleration (PLA) and the head injury criterion (HIC) measured at the center of gravity of the headform were the selected metrics to determine the impact performance of the helmets because they are the usual parameters included in helmet standards to assess head protection [5].

Since three different headform sizes were used in this study, a preliminary statistical hypothesis testing was carried out to rule out any possible influence of the headform size on the PLA or HIC variables. A non-parametric Kruskal–Wallis H test with a significance level of 0.05 was performed to analyze whether the size of the headform (three different sizes) was significantly related to the values of either PLA or HIC. The Kruskal–Wallis test is an extension of the two sample hypotheses testing to more than two independent samples and it replaces the ANOVA test when sample sizes are small. The results of this analysis are included in the Appendix A.

After ensuring the independence of the PLA and HIC variables from the helmet size, we carried out the main statistical analysis for the comparison of the impact performance between the two shell groups. A non-parametric test, the Mann–Whitney *U* test for independent samples with a significance level of 0.05, was used for this analysis due to the limited sample size. Statistical analyses were performed using the Real Statistics Resource Pack add-in in Excel (Excel 2016, Microsoft, Redmond, WA, USA).

3. Results

The study results are presented into three subsections. First, the penetration test results of all tested helmets are reported. Second, the results of the impact absorption tests at two impact speeds are presented. Finally, the statistical analysis results of the influence of the shell stiffness on the impact performance of the helmets are shown.

3.1. Penetration Test Results

Out of a total of 20 penetration tested helmets, we selected 10 helmets and classified them into either the hard or soft shell group. The average of the intrusion values of each helmet model was used as an indicator of the shell stiffness to classify the helmets. The hard shell helmet group consisted of the four helmets in which the measured average intrusion in the penetration tests was under 10 mm. The six helmets that were included in the soft shell helmet group resulted in average intrusion higher than 15 mm. The helmets that exhibited results in between these two magnitudes were no longer considered in the study. Figure 4 includes the average and the standard deviation (SD) of the intrusion measured in the penetration test for each helmet. Details of the penetration test results for each helmet model are included in the Appendix A (Table A3). The mean average value of intrusion and SD for the hard shell group was 7 ± 3 mm, while the mean average of intrusion and SD for the soft shell group was 21 ± 6 mm.

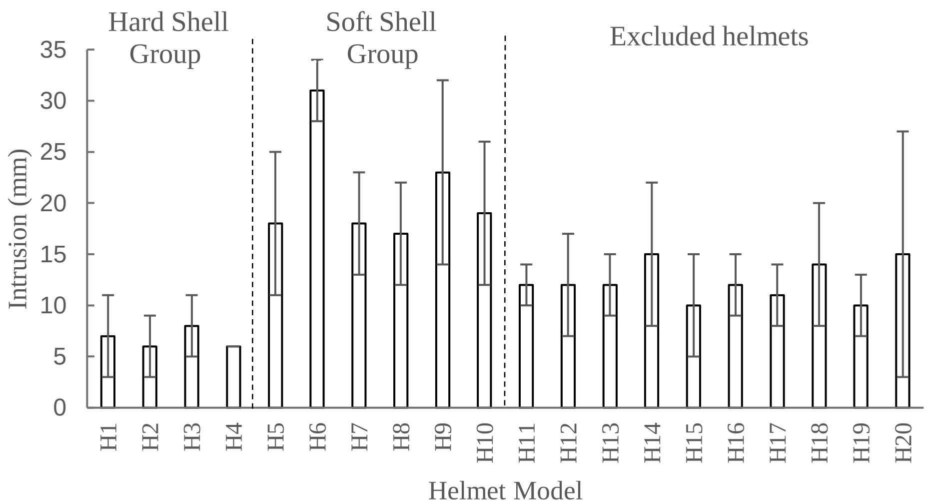

Figure 4. Mean and standard deviation (SD) of the intrusion measured in the penetration tests for each helmet model. The standard deviation of H4 was zero (3 sites were tested in this case).

3.2. Impact Absorption Test Results

At 5.0 m/s, PLA and HIC values were similar, regardless of impact point and shell type (Figure 5). The similarity between PLA and HIC values was even more noticeable when considering the standard deviations due to their similar range of values. While PLA values were between 120 and 140 g, regardless of the impact point and the shell stiffness, the HIC value was slightly higher for both shell groups when the helmet was dropped on the P point. Regardless of the slight magnitude differences observed between both shell groups, different impact locations showed different trends between the two groups. While PLA and HIC values were higher for the hard shell group in the B and P impact points, they were lower in the X point.

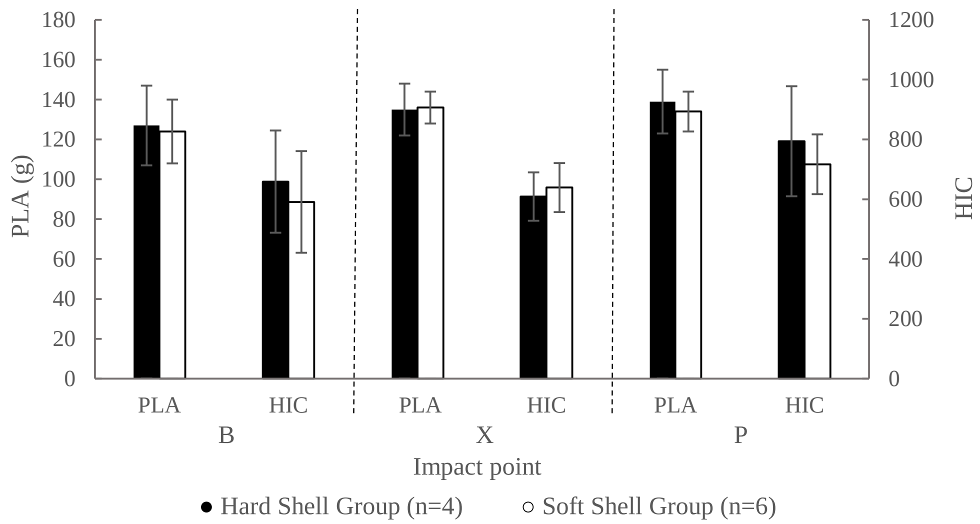

Figure 5. Mean and standard deviation (SD) of the peak resultant linear acceleration (PLA) and head injury criterion (HIC) for each shell group and each impact point in the impact absorption tests at 5 m/s.

Figure 6 includes the mean and the SD of the PLA and HIC for each impact point at 8.2 m/s. One of the helmets (H7) of the soft shell group had a higher acceleration peak when testing B point (see Table A5 in Appendix A), causing the SD to be larger than in the other impact locations. Regardless of this helmet, the values measured for the hard shell helmets at 8.2 m/s resulted in more repeatable results and therefore reduced SD values. This effect was particularly true for HIC at the P location of the helmet. Again, different impact locations showed different trends. However, at this impact velocity, the results showed the opposite of what was observed at 5 m/s. In this case, while PLA and HIC values were lower for the hard shell group in the B and P impact points, they were higher in the X point.

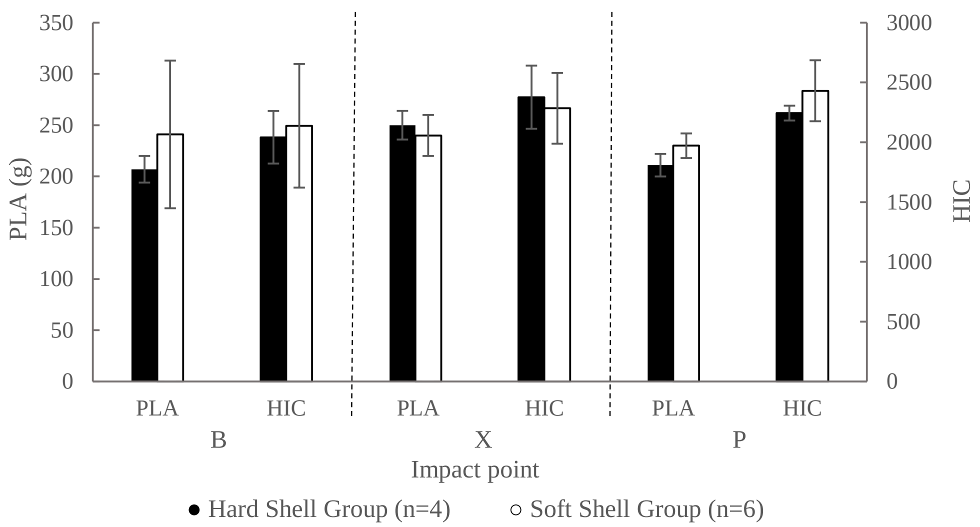

Figure 6. Mean and standard deviation (SD) of the peak resultant linear acceleration (PLA) and head injury criterion (HIC) for each shell group and each impact point in the impact absorption tests at 8.2 m/s.

In view of the observed results at the two impact velocities and for the different impact locations, we cannot conclude that helmets with stiffer shells result in higher acceleration or HIC (and therefore higher risk of injury) than those with less stiff shells.

3.3. Statistical Hypothesis Testing Results

Table 1 includes the results of the main statistical hypothesis testing (p-values) for each impact point tested at 5 m/s together with the mean and SD of the PLA and HIC for each shell stiffness group. Since all p-values are much higher than the significance level (0.05), the statistical analysis could not find any significant difference in PLA or HIC variables between the two shell groups at 5 m/s. Therefore, shell stiffness was not found to have an effect on the impact performance of the helmets tested at 5 m/s.

Table 1. Mean and SD of the PLA and HIC for each shell group with the Mann–Whitney U test results (p-value) for each impact point tested at 5 m/s. Significant values are shown in bold font.

Impact Point	Variable	Hard Shell Group (n = 4)	Soft Shell Group (n = 6)	p-Value
B	PLA (g) HIC	127 ± 20 659 ± 171	124 ± 16 591 ± 170	0.9143 0.6095
X	PLA (g) HIC	135 ± 13 609 ± 81	136 ± 8 639 ± 82	0.6095 0.4762
P	PLA (g) HIC	139 ± 16 794 ± 184	134 ± 10 717 ± 100	0.9143 0.6095

The same analysis was repeated for the data obtained in the drop tests at 8.2 m/s. As above, Table 2 includes the mean and SD of the PLA and HIC for each shell group together with the p-value for each impact point tested. In this case, PLA was significantly higher for the soft shell group (p-value = 0.0381) but only when the testing point was the P location. These results suggest that the effective PLA and HIC values provided by the helmet in drop tests are influenced by other parameters different from the shell stiffness alone.

Table 2. Mean and SD of the PLA and HIC for each shell group with the Mann–Whitney U test results (p-value) for each impact point tested at 8.2 m/s. Significant values are shown in bold font.

Impact Point	Variable	Hard Shell Group (n = 4)	Soft Shell Group (n = 6)	p-Value
B	PLA (g) HIC	207 ± 13 2042 ± 220	241 ± 72 2138 ± 517	0.1714 0.9143
X	PLA (g) HIC	250 ± 14 2377 ± 264	240 ± 20 2284 ± 296	0.6095 0.9143
P	PLA (g) HIC	211 ± 11 2244 ± 62	230 ± 12 2431 ± 255	**0.0381** 0.3524

4. Discussion

The objective of this study was to provide insight into the effects of including a penetration test, which is the main driver that determines helmet shell thickness and therefore of its stiffness, in order to improve the protective performance of helmets. To that end, the impact performance of 10 helmet models, which were sorted into either hard or soft shell groups, were compared at two impact speeds. PLA and HIC variables were selected to determine the protection capability of the helmets.

Since three headform sizes were used in the impact absorption tests, the influence of the headform size on the PLA or HIC variables was analyzed prior to carry out the main statistical analysis of this study. In Appendix A, Tables A1 and A2 include the PLA and HIC mean and the SD for each headform group, together with the p-value for each impact point tested at 5 m/s and 8.2 m/s, respectively. The preliminary statistical hypothesis testing could not find any significant influence of the headform size on the PLA or HIC values at neither of the tested speeds. This result was expected because normally, the requirements of the helmet standards are the same for all headform sizes and therefore helmet manufacturers individually adjust the performance of each helmet size.

Regarding the impact performance comparison, the main statistical hypothesis testing showed no significant differences between the hard shell group and the soft shell group on the results of the impact absorption tests at 5 m/s. Similar results were observed in the tests at 8.2 m/s, except for the impacts on the helmet P point, which, showing contrary results to what had been suggested in previous research [13,14], resulted in significantly higher PLA for the soft shell group (p-value = 0.038), even if the HIC value was not significantly different (p-value = 0.352). These findings seem to be contradictory with the statement that including a penetration test in regulations causes helmets to be designed with a stiffer shell that behave very rigidly when striking flat surfaces [13,14]. While the above statement is correct for helmets in which only the shell thickness or helmet stiffness is increased [21], it does not hold for actual helmets in which both the shell and the protective padding can be varied jointly. Indeed, the impact performance of a motorcycle helmet depends both on the material and dimensions of the shell and on the characteristics of the protective padding or liner, and then there is a combination of the characteristics of the shell and liner that makes it possible to improve the helmet impact performance [22]. During an impact, a stiffer shell distributes the impact load over a greater area of the helmet, reducing the crushed volume of the liner and, therefore, decreasing the energy absorption, which may result in an increase of the linear acceleration. However, this effect can be compensated using a lower density of protective padding as long as its thickness is enough to prevent a bottom out effect. This practice is very common in current helmet design to compensate shell stiffness caused by shell geometry. For example, the higher shell stiffness due to the concavity form of the top part of full-face helmets is compensated with lower density or grooved shape liner at the top part [23]. This attempts to make the helmet impact response site-independent; however, other limitations such as liner thickness, especially at the side of the helmet, makes this point site-dependent because higher liner densities must be used at this location in order to prevent a bottom out effect of a liner. The site-dependent impact response could explain the contradictory results observed in the X point impacts (side impact) of this study. Therefore, a stiffer shell does not necessarily mean that the helmet will exhibit a global stiff mechanical behavior, but that the characteristics of the liner will be chosen to balance the effects of the stiffness of the shell, which depends on the material, thickness, and external geometry. Therefore, if a helmet stiffness increase caused by a stiffer shell can be compensated with the characteristics of the liner, the next question is: which type of stiff shell or soft shell improves the protection capabilities of the helmets?

Although no general trend was observed in the results of this study to provide a convincing answer to the above question, some particular results such as the significantly higher PLA for the soft shell group for the point P at 8.2 m/s and the extremely high acceleration peak in the impact on the B point of one helmet within the soft shell group also at 8.2 m/s suggest that hard shell helmets would provide better protection at higher impact speeds. These results are in line with a simulation study that stated that the impact speed is an important parameter in helmet design and concluded that for high impact speeds, the helmet should be designed with a stiffer shell and denser protective padding than for low speeds [16]. Furthermore, the importance of the impact speed in helmet impact performance can also be appreciated by comparing the impact absorption test results between both impact speeds for each impact location. If the PLA and HIC values within the hard shell group were lower at 5 m/s for the X point than the values of the soft shell group, then the results of the hard shell group were higher at 8.2 m/s for the X point and vice versa for the B and P points. These results also highlight that shell stiffness has an important influence in the overall dynamic performance of the helmets. While helmets with stiffer shells tend to absorb energy by liner deformation from the inside, where the load distribution is determined by the compatibility of the liner dimensions and headform shape, helmets with softer shells tend to absorb energy predominantly from the outside, where the load distribution is determined by the geometry of the object hit. As a result of the higher load distribution capacity of helmets with stiffer shells, helmets with softer shells tend to bottom out sooner compared to helmets with stiffer shells [17]. In addition, hard shell helmets would provide better protection when striking objects with a greater variety of shapes, especially during concentrated impacts on small or sharp objects [24].

The results of our study suggest that hard shell helmets, even if they can be strongly influenced by the penetration test, would provide better protection at higher impact speeds without harming the helmet performance at lower impact speeds. In addition, another effect of the penetration test is the control of the size of the vent openings of the helmet, which could result in a decrease load distribution capacity on those areas if the size of the openings was large enough. However, the energy of the penetration test must be chosen carefully because high energy penetration tests could lead composite shells to do not delaminate for impacts into real-life crash scenarios [25], and delamination is an additional energy absorbing mechanism of composite shells that improves helmet impact performance [26]. On the negative side, hard shell helmets result in heavier helmets that may negatively impact rider's comfort. In this study, the hard shell helmets were around 200 g heaviest when compared with soft shell helmets of the same size.

A potential limitation of this study is the focus only on linear injury metrics (PLA and HIC) to assess the protection performance of the helmets. It is well known that these metrics do not consider the rotational kinematics of the head, which are proposed as the main mechanism of brain diffuse injuries [27]. In this regard, the project COST 327 carried out oblique tests at different impact speeds with two almost identical helmets that differed only in mass and shell stiffness, concluding that neither the helmet mass nor the shell stiffness seems to significantly affect the rotational accelerations and tangential forces in oblique impacts with composite shell helmets [28]. In addition, although rotational kinematics are being included in several recently proposed testing programs and only in oblique impacts [5,15], most existing mandatory helmet regulations only consider linear injury metrics to date [4,6–8].

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Preliminary statistical hypothesis testing results about the influence of the headform size on the PLA or HIC variables.

Table A1. PLA and HIC mean and SD for each headform group with the Kruskal–Wallis H test results (p-value) for each impact point tested at 5 m/s.

Impact Point	Variable	Headform (E)	Headform (J)	Headform (M)	p-Value
B point	PLA (g)	125 ± 20	131 ± 8	120 ± 23	0.7967
	HIC	615 ± 174	691 ± 79	551 ± 235	0.7047
X point	PLA (g)	136 ± 14	135 ± 6	137 ± 9	0.9775
	HIC	610 ± 94	598 ± 68	679 ± 61	0.4372
P point	PLA (g)	136 ± 17	135 ± 11	135 ± 11	0.9426
	HIC	776 ± 168	707 ± 128	751 ± 141	0.7275

Table A2. PLA and HIC mean and SD for each headform group with the Kruskal–Wallis H test results (p-value) for each impact point tested at 8.2 m/s.

Impact Point	Variable	Headform (E)	Headform (J)	Headform (M)	p-Value
B point	PLA (g)	203 ± 16	213 ± 10	275 ± 96	0.2367
	HIC	1934 ± 287	2091 ± 251	2330 ± 657	0.6889
X point	PLA (g)	243 ± 16	238 ± 25	251 ± 16	0.5538
	HIC	2361 ± 274	2132 ± 330	2458 ± 165	0.3039
P point	PLA (g)	222 ± 12	221 ± 5	225 ± 26	0.7859
	HIC	2439 ± 212	2259 ± 127	2343 ± 314	0.3166

Table A3. Penetration test results: intrusion values by impacted area, mean, and standard deviation (SD) in millimeters for each helmet model. Intrusion values that failed the penetration test are shown in bold font.

Helmet	Front	Top	Lateral Right	Lateral Left	Rear	Mean	SD
H1	-	-	-	4	10	7	4
H2	-	4	5	-	10	6	3
H3	11	4	-	10	7	8	3
H4	-	6	6	-	6	6	0
H5	-	18	-	**25**	11	18	7
H6	-	33	29	-	-	31	3
H7	-	14	**23**	-	16	18	5
H8	13	14	**22**	-	-	17	5
H9	-	13	27	-	**30**	23	9
H10	12	18	-	26	-	19	7
H11	-	14	13	-	10	12	2
H12	-	15	15	-	7	12	5
H13	-	-	10	10	15	12	3
H14	-	22	-	10	13	15	7
H15	6	10	9	-	17	10	5

Table A3. *Cont.*

Helmet	Front	Top	Lateral Right	Lateral Left	Rear	Mean	SD
H16	14	14	11	7	-	12	3
H17	12	8	14	-	-	11	3
H18	-	7	18	-	17	14	6
H19	-	13	-	11	6	10	3
H20	-	29	8	-	7	15	12

Table A4. Impact absorption test results at 5 m/s: PLA and HIC results for each helmet model.

Helmet	B Point		X Point		P Point	
	PLA (g)	HIC	PLA (g)	HIC	PLA (g)	HIC
H1	146	818	129	626	142	905
H2	134	697	129	580	157	993
H3	99	416	154	711	117	609
H4	130	706	129	520	139	670
H5	139	761	138	638	144	849
H6	146	811	122	494	143	817
H7	105	376	146	746	122	628
H8	108	459	137	666	142	719
H9	123	605	139	636	123	602
H10	120	535	137	655	127	684

Table A5. Impact absorption test results at 8.2 m/s: PLA and HIC results for each helmet model.

Helmet	B Point		X Point		P Point	
	PLA (g)	HIC	PLA (g)	HIC	PLA (g)	HIC
H1	216	2257	241	2311	200	2211
H2	191	1917	235	2199	205	2317
H3	201	1799	265	2767	224	2272
H4	219	2196	257	2232	218	2178
H5	219	2272	210	1764	218	2405
H6	226	2339	230	2189	230	2742
H7	386	3020	269	2637	223	2117
H8	222	1713	243	2426	252	2702
H9	201	1805	247	2399	227	2195
H10	194	1681	241	2288	232	2427

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