Kinetic Energy Non-Lethal Weapons Testing Methodology

Ballistic Load Sensing Headform Evaluation

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Abstract

The Ballistic Load Sensing Headform (BLSH) designed originally to evaluate the severity of behind armour blunt trauma for ballistic helmets is now being considered for assessing the dynamic loading pattern of Kinetic Energy Non-Lethal Weapons (KENLW). 20 different projectiles simulating KENLW impact conditions were launched at different velocities on the BLSH mounted on flexible and rigid necks to assess injury potential.

In general, a good correlation was observed between the peak total force measured with the BLSH and the projectile velocity. The results indicated that most of the KENLW conditions tested were severe, and most likely would have caused injury. No difference was noticed between the flexible and rigid neck configurations for similar impact conditions. Pre and post-test verification showed that the BLSH force response remained constant throughout this evaluation.

The BLSH appears suitable for assessing the insult to the head caused by KENLW projectiles but future evaluations must be limited to a maximum peak total force of 15 kN to preserve the integrity of the measured responses and to reduce the risk of equipment damage.

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Executive summary

Kinetic Energy Non-Lethal Weapons Testing Methodology: Ballistic Load Sensing Headform Evaluation

Benoit Anctil; DRDC Valcartier CR [enter number only: 9999-999]; Defence R&D Canada – Valcartier; March 2013.

Introduction: The Ballistic Load Sensing Headform (BLSH) was initially designed to evaluate the load severity to the head caused by the deformation of ballistic helmets from non-penetrating impact. It is now being considered for assessing the insult to the head caused by Kinetic Energy Non-Lethal Weapons (KENLW).

A series of experimental trials were conducted to assess the BLSH force response for different types of KE projectiles. Repeatability of the test device and the type of support (flexible vs. rigid) were also evaluated in this investigation. 20 different projectiles simulating KENLW impacts were launched at different velocities on the BLSH for more than 280 tests.

Results: In general, a good correlation was observed between the peak total force measured with the BLSH and the projectile velocity. The results indicated that most of the KENLW conditions tested were severe, and most likely would have caused injury (>25% risk of skull fracture). No difference was noticed between the flexible and rigid neck configurations for similar impact conditions. Pre and post-test verification showed that the BLSH force response remained constant throughout this evaluation.

Significance: Terminal effects assessment of KE projectiles is essential to the Canadian Forces for selecting the most appropriate NLW for their needs. A repeatable and robust test method is required to reliably assess the injury consequenses.

Future plans: The BLSH appears suitable for assessing the insult to the head caused by KENLW projectiles but future evaluations must be limited to a maximum peak total force of 15 kN to preserve the integrity of the measured responses and to reduce the risk of equipment damage. While the level is anticipated to be well above acceptable injury limits, future updates from the NATO LCG-9 Blunt impact KENLW WGE will be invaluable to confirm a suitable force threshold and, hence, measurement range.

Table of contents

List of figures

List of tables

1 Introduction

The objective of this task is to evaluate the force response of the Ballistic Load Sensing Headform (BLSH) under various blunt impact conditions related to Kinetic Energy Non-Lethal Weapons (KENLW).

The BLSH (Figure 1) has been designed originally to measure the dynamic force caused by the deflection of helmet shell for non-penetrating ballistic impact [1-4]. It is now intended to extend its capabilities for assessing the dynamic loads and injury potential from KENLW.

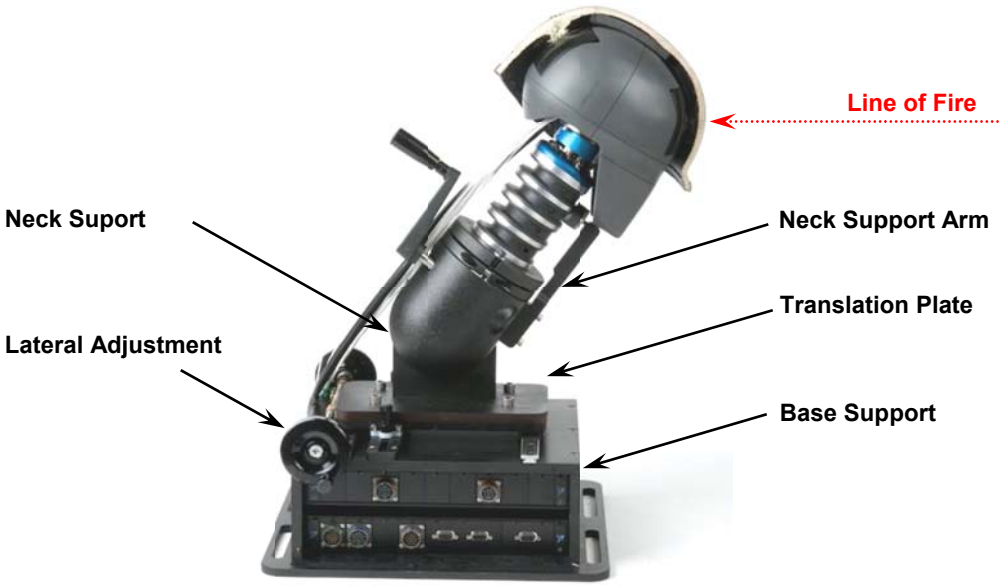


Figure 1. Ballistic Load Sensing Headform with helmet cross-section.

Various projectiles were proposed for use in this evaluation. A series of hard plastic and aluminium batons were manufactured and commercially available KENL ammunitions were acquired. A total of 20 different projectiles were used and each projectile was tested at 7 different velocities. Testing was repeated for flexible and rigid neck conditions as indicated the test matrix (Table 1).

Table 1. Test matrix.

Serial	Model No.	Projectile Description	Diameter (mm)	Mass (g)	Reference Velocity (m/s)	# Tests	
						Flexible Neck	Rigid Neck
1	C01	Cylinder (hard plastic)	37	96	20-80	7	7
2	C02	Cylinder (hard plastic)	37	29	50-70	7	7
3	C03	Cylinder (hard plastic)	37	49	40-80	7	7
4	C04	Cylinder (hard plastic)	37	64	40-80	7	7
5	C05	Cylinder (Al)	37	92	20-80	7	7
6	C06	Cylinder (Al)	40	92	20-55	7	7
7	C07	Cylinder (hard plastic)	37	111	40-70	7	7
8	C08	Cylinder (hard plastic)	37	130	20-80	7	7
9	C09	Cylinder (hard plastic)	37	140	10-40	7	7
10	C10	Cylinder (hard plastic+ steel core)	37	378	10-40	7	7
11	C11	XM1006 sponge grenade	40	27	50-100	7	7
12	C12	12-gauge drag-stabilized (DS) bean bag	24	40	40-90	7	7
13	C13	12-gauge fin-stabilized (FS) round	18	5	100-150	7	7
14	C14	FN 303 projectile	18	8.5	30-90	7	7
15	C15	MK Ballistics FB-1-FS	18	6.5	90-150	7	7
16	C16	MK Ballistics 40 mm elastomeric baton	40	41	20-55	7	7
17	C19	Defense Technology Direct Impact Inert	40	35	30-110	7	7
18	B01	Golf ball	43	46	20-60	7	7
19	B02	Baseball	70	144	20-60	7	7
20	B03	Softball	97	189	10-50	7	7
21	C01	Cylinder (hard plastic)	37	96	20-80	7	7

2 Materials and Methods

2.1 Test Projectiles

The projectiles used for this study are shown in Figure 2 below and are detailed in Table 1.

Figure 2. Test projectiles.

2.2 Setup

The majority of projectiles were fired using a portable gas gun designed and manufactured by CADEX Inc. (Figure 3) as per the requirements established by DRDC Valcartier under a previous contract. Light gates integrated into the gas gun were used to measure the velocity of the projectiles. The target was positioned at approximately 0.8 m from the muzzle in a containment chamber (Figure 4). Projectiles C14, B01, B02, and B03 were fired using Biokinetics' air cannon (Figure 5) with the target positioned at approximately 0.3 m from the muzzle (Figure 6).

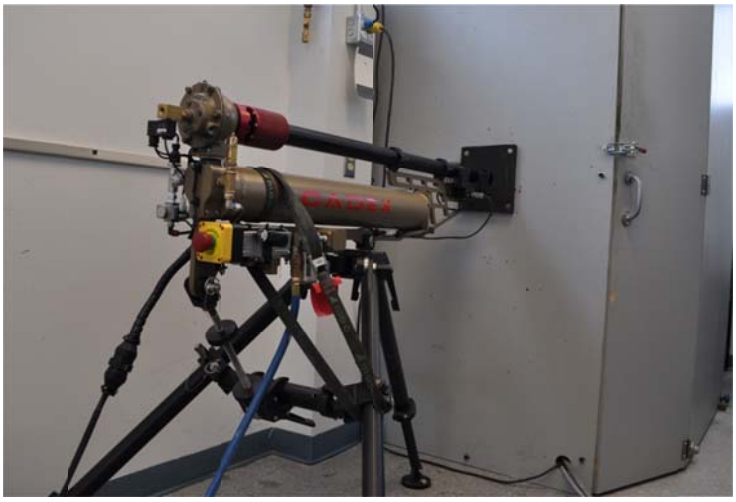


Figure 3. Portable gas gun.

Figure 4. BLSH mounted on a rigid neck.

Figure 5. Biokinetics' air cannon.

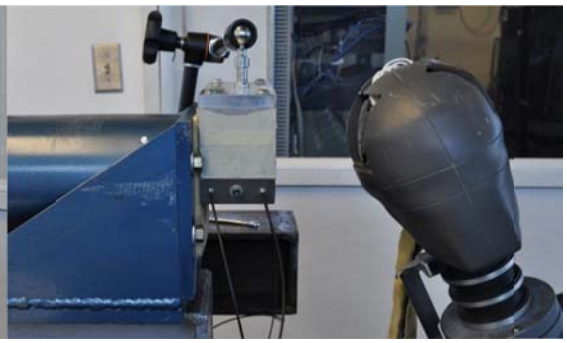


Figure 6. BLSH mounted on a flexible neck.

Load cell signals were conditioned with Kistler PiezoSmart Power Supply Coupler (Type 5134B) set to the appropriate gains to maximize signal to noise ratio. A 10 kHz (-3 dB) lowpass anti-alias filtering (4-pole Butterworth) was performed on the signal prior to analog-to-digital conversion and data recording was conducted with a National Instruments' data acquisition unit connected to

a personal computer. The sampling frequency corresponded to 100 kHz. The load cell signals were filtered using a 4-pole Butterworth zero-phase forward and reverse digital lowpass filter (4.5 kHz at -3 dB).

Polyurethane skin pads were replaced after deterioration, when visible damage was observed.

3 Results

Projectiles were launched initially at the lowest velocity indicated in the statement of work. The velocity was increased gradually up to the maximum target velocity or until a total peak force of approximately 10 kN was reached. This force limitation was defined to avoid permanent damage of BLSH components. Figure 7 shows a typical force response recorded with the individual load sensors of the BLSH and their total.

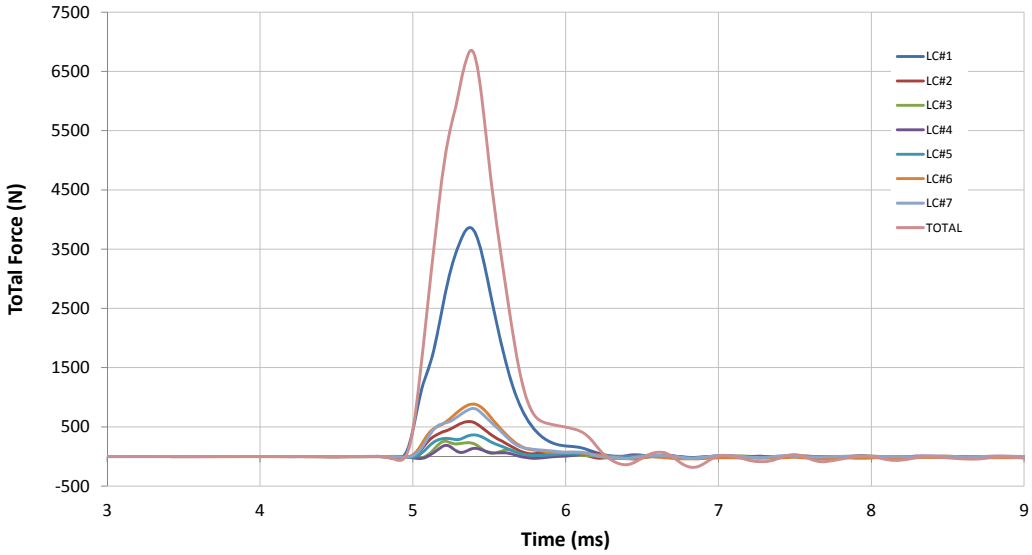


Figure 7. Typical BLSH force response (C01 at 25 m/s).

A summary of the test data is provided in Annex A and Annex B. Raw and filtered signals are provided separately in electronic format.

3.1 Flexible Neck Configuration

For each projectile tested with the standard (flexible neck) configuration, a correlation was observed between the impact velocity and the peak total force consistent with the impulse, momentum laws of conservation for elastic collisions (Figure 8). When comparing the responses obtained for the different projectiles, the slope increases with the mass of the projectile.

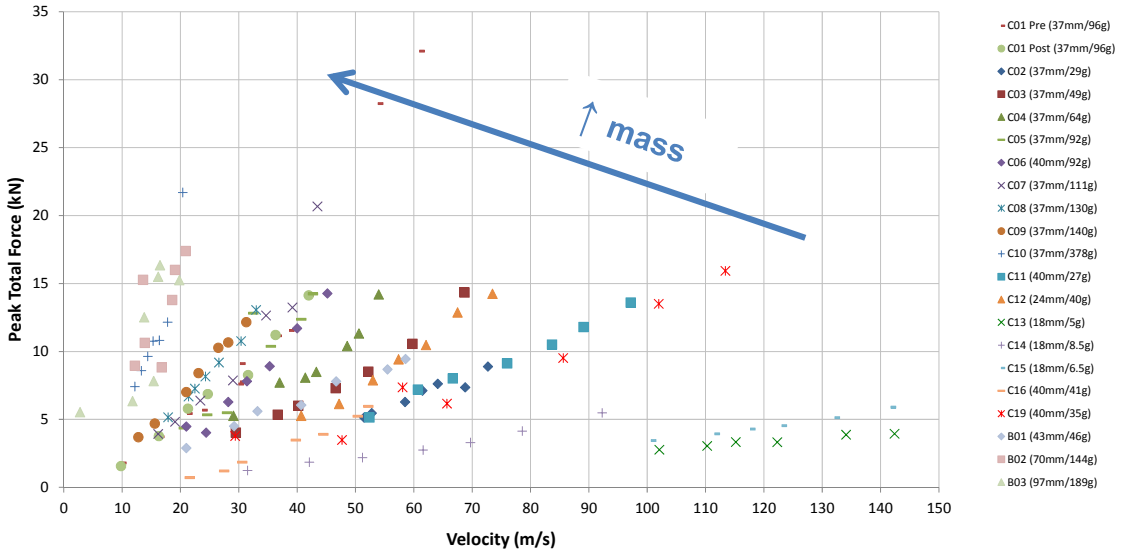


Figure 8. Peak total force vs. impact velocity.

Poorer distinction between projectiles was noted when comparing the peak total force with impact energy (Figure 9). An interesting trend was observed when looking at the momentum vs. the peak total force (Figure 10) where the projectile's mass defined the overall responses. The responses of projectiles with comparable mass are grouped together while the extremes (C10: 378 g vs. C13, C14, and C15: 5-8.5g) are separated from the rest.

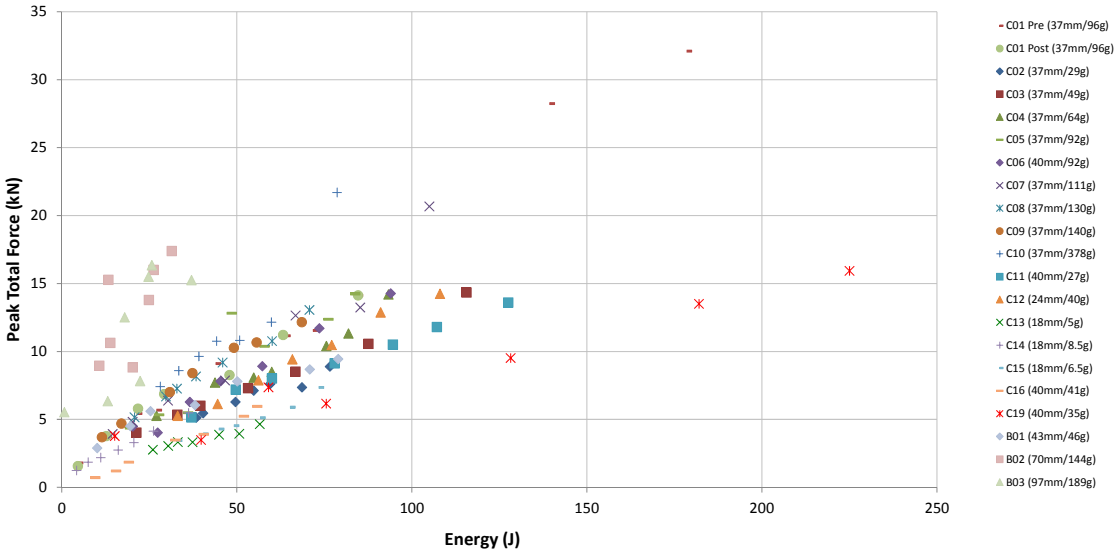


Figure 9. Peak total force vs. impact energy.

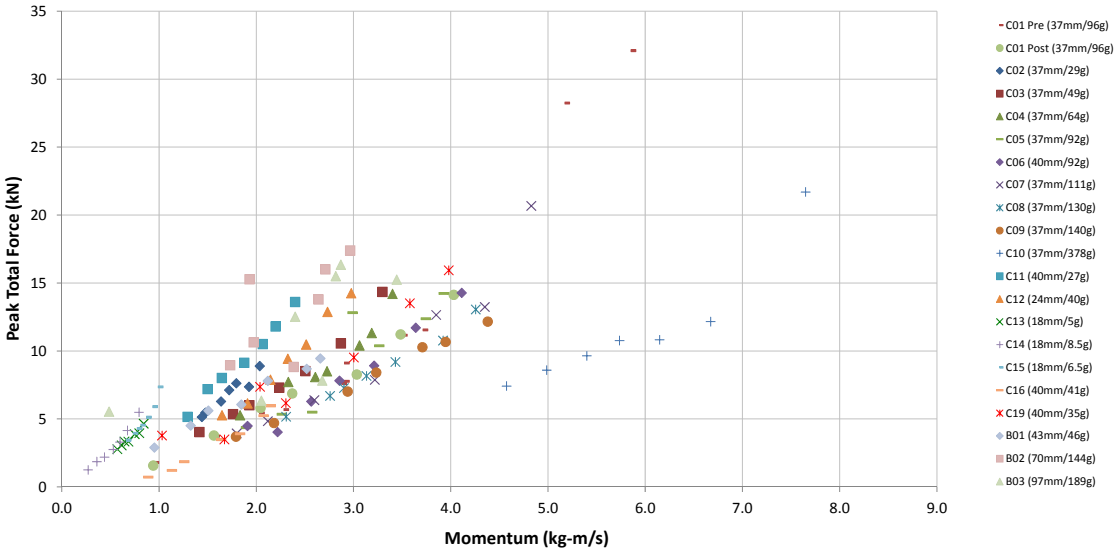
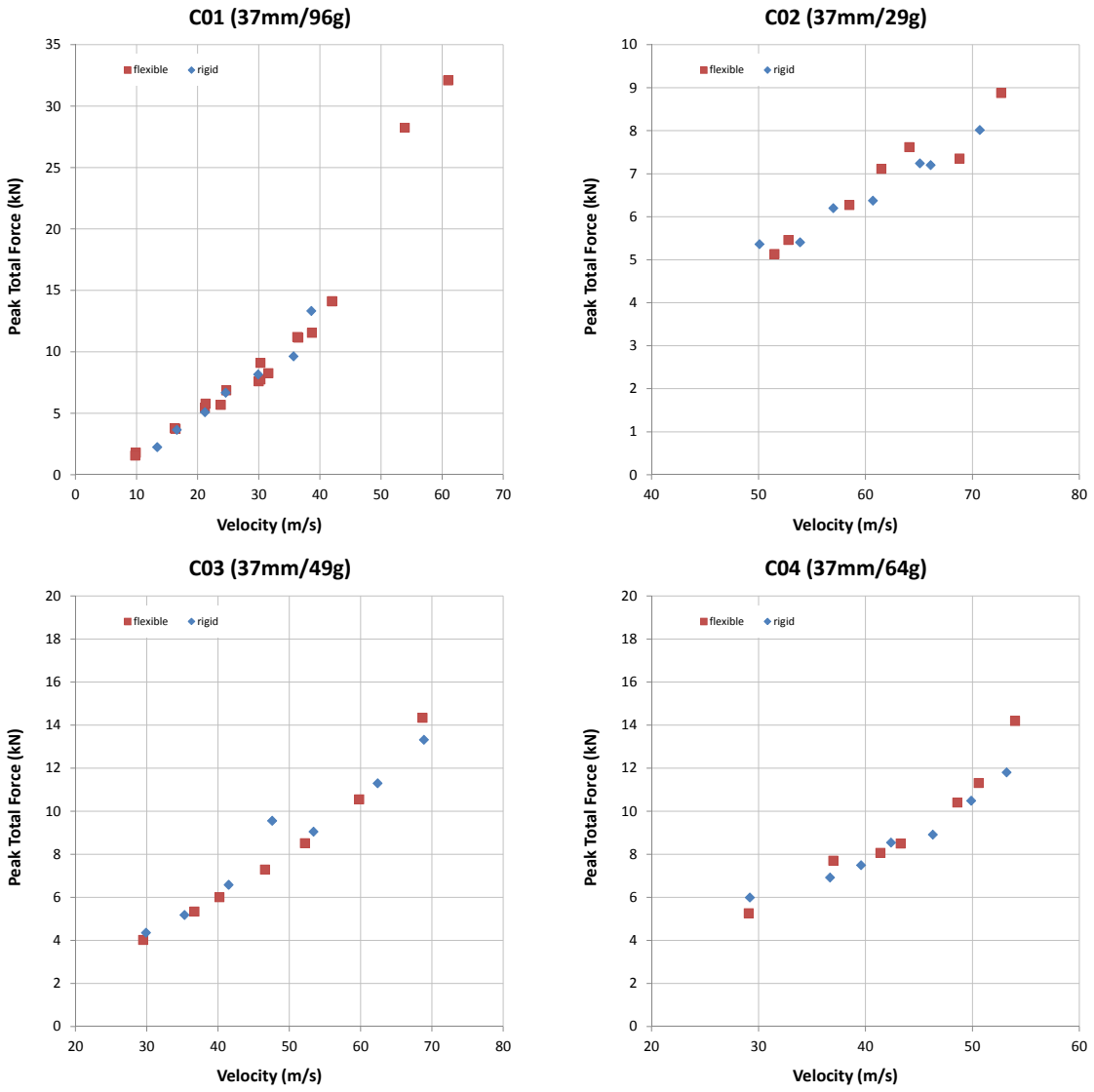
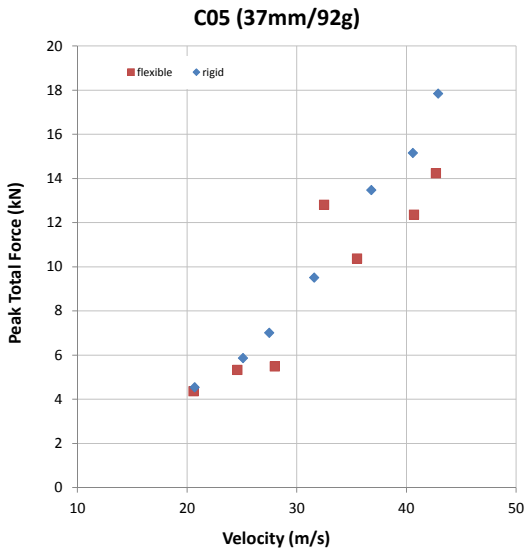


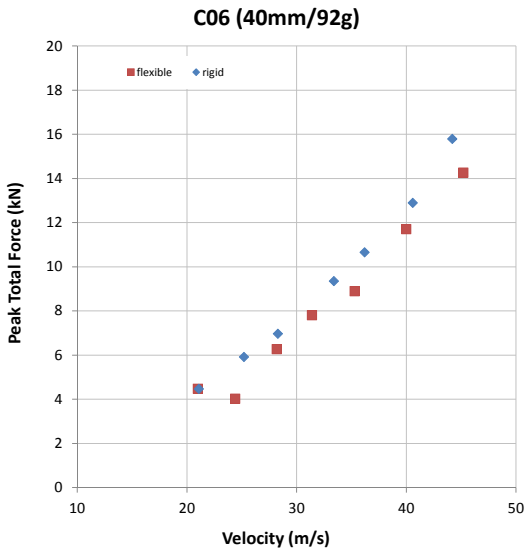
Figure 10. Peak total force vs. momentum.

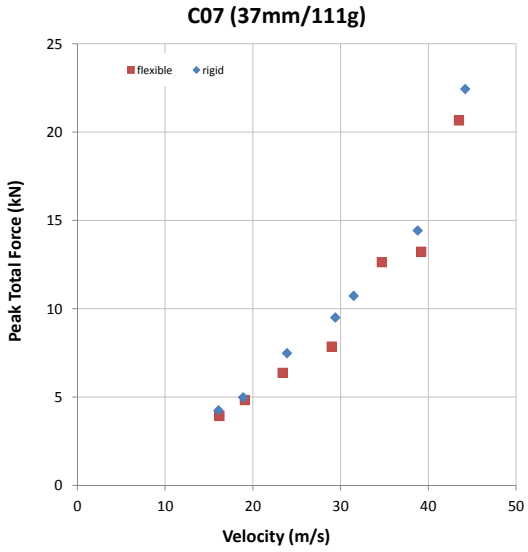
3.2 Flexible vs. Rigid Neck

Peak total forces were comparable between the flexible and rigid neck configurations (Figure 11). It is assumed that the differences observed are most likely due to non-perpendicular or off-centre impacts even though precautions were taken to minimise these issues. For some projectiles, there were a greater number of outliers. This was more obvious for the 378 g baton (C10), the baseball (B02) and the softball (B03). The contributing factors to these observations are not known but is potentially linked to the mass due to the strong association with heavier projectiles.




C05 (37mm/92g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
0
2
4
6
8
10
12
14
16
18
20
10
20
30
40
50


C06 (40mm/92g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
0
2
4
6
8
10
12
14
16
18
20
10
20
30
40
50


C07 (37mm/111g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
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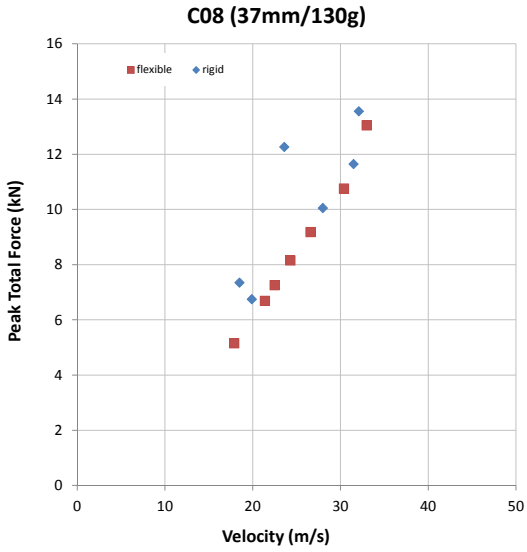
5
10
15
20
25
0
10
20
30
40
50


C08 (37mm/130g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
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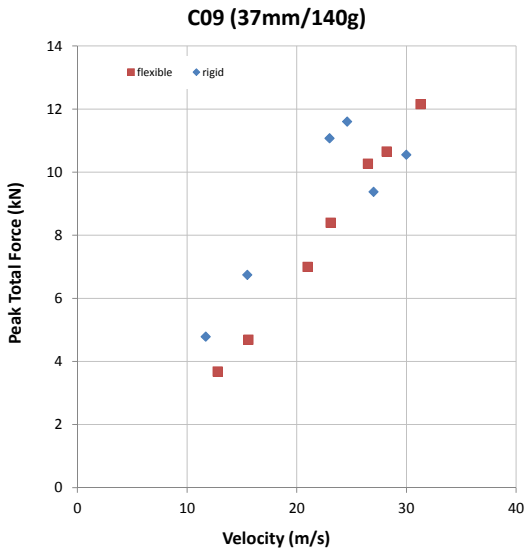
4
6
8
10
12
14
16
0
10
20
30
40
50


C09 (37mm/140g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
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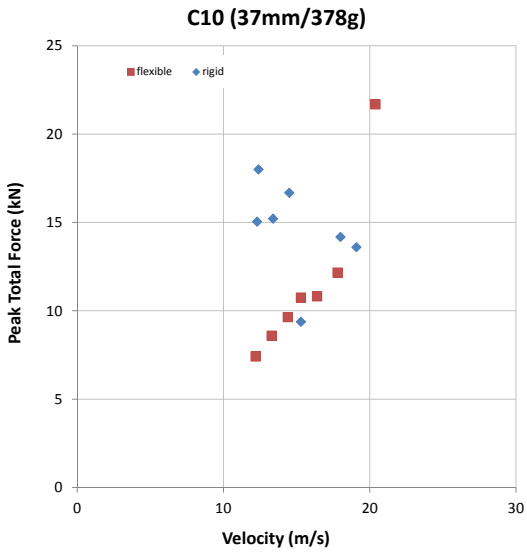
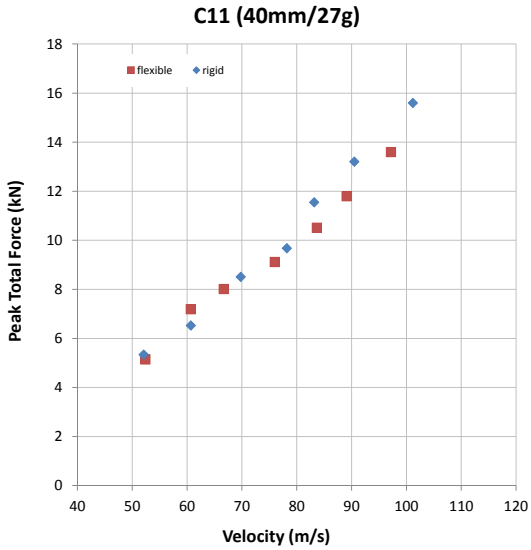
2
4
6
8
10
12
14
0
10
20
30
40


C10 (37mm/378g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
0
5
10
15
20
25
0
10
20
30


C11 (40mm/27g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
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2
4
6
8
10
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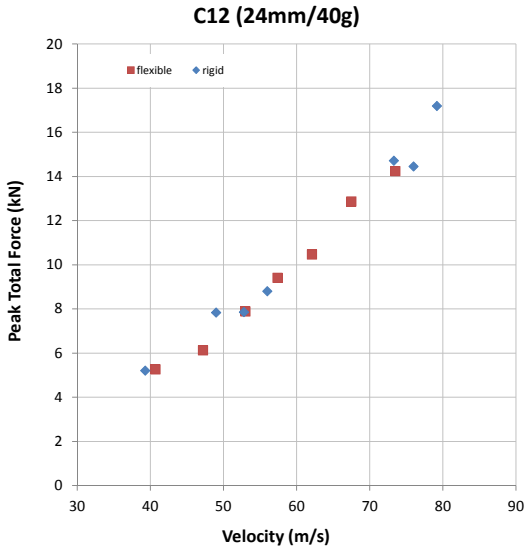
18
40
50
60
70
80
90
100
110
120


C12 (24mm/40g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
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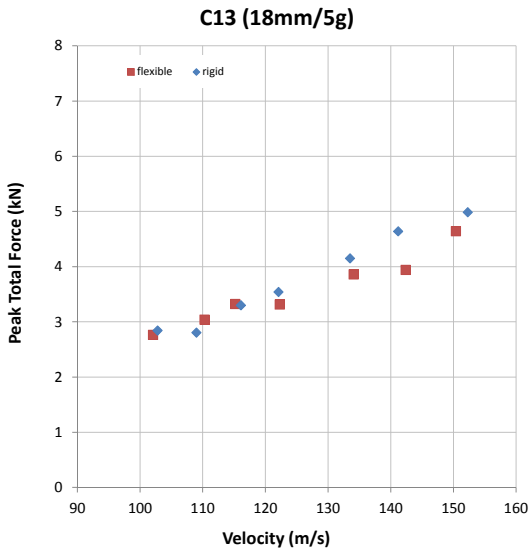
2
4
6
8
10
12
14
16
18
20
30
40
50
60
70
80
90


C13 (18mm/5g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
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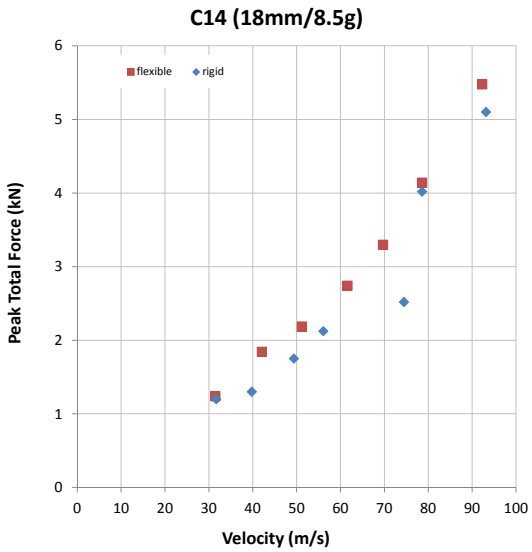
1
2
3
4
5
6
7
8
90
100
110
120
130
140
150
160


C14 (18mm/8.5g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
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30
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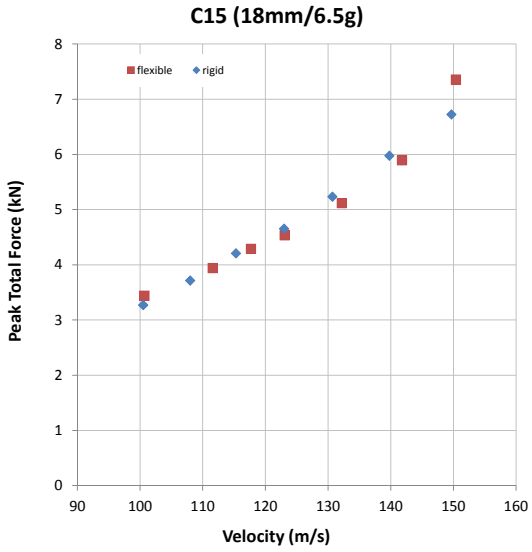
50
60
70
80
90
100


C15 (18mm/6.5g)
flexible
rigid
Peak Total Force (kN)
Velocity (m/s)
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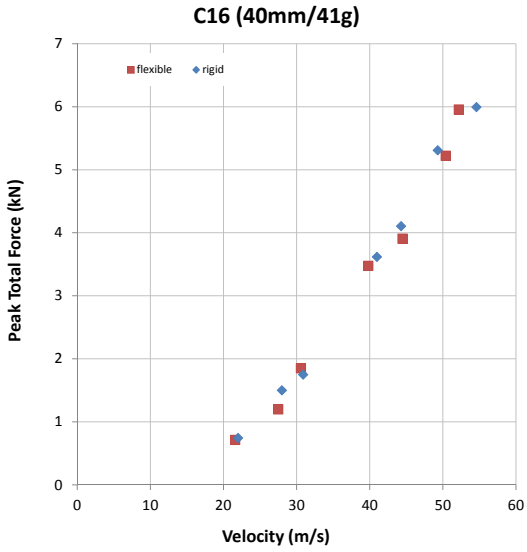
6
7
8
90
100
110
120
130
140
150
160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rigid
Peak Total Force (kN)
Velocity (m/s)
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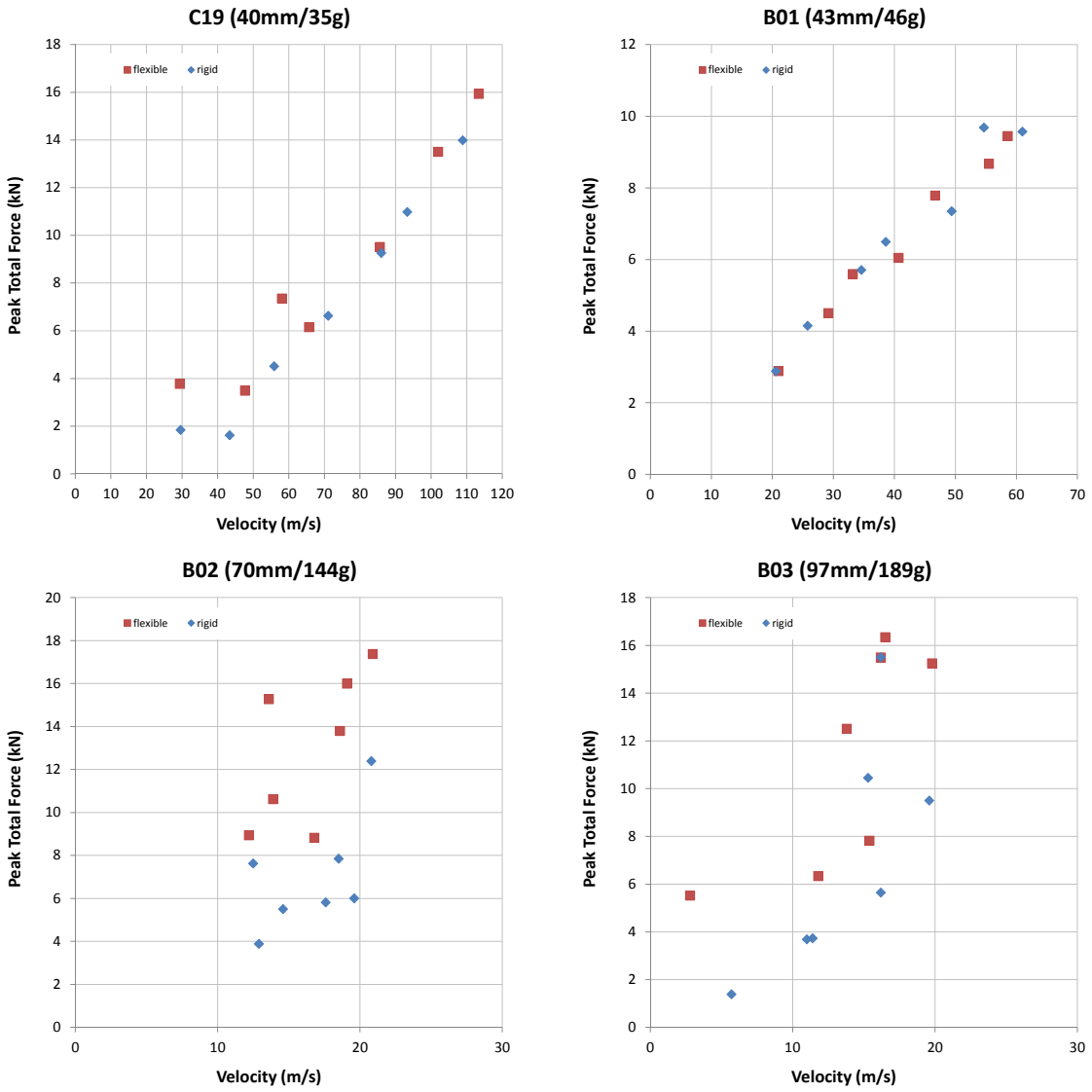

Figure 11. Flexible vs. rigid neck force responses.

3.3 Repeatability

The pre and post-test repeatability of the BLSH was evaluated using the 37 mm / 96 g hard plastic baton (C01). One series of tests was conducted initially and the same conditions were repeated after all the trials were completed, i.e. after approximately 270 impacts on the headform. It should be noted that the pre and post tests were conducted with different skin pads over the load cell array. No major difference was observed between these two test series in the peak total force recorded as shown in Figure 12.

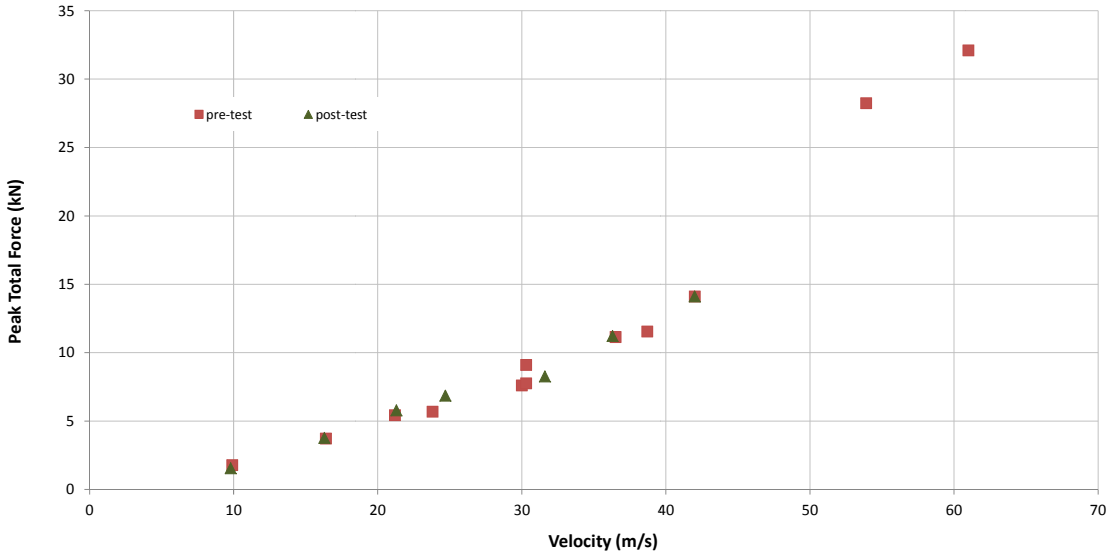

Figure 12. Pre vs. post-test results.

3.4 2006 Test Series

In 2006, a similar test series was conducted using an earlier generation of the Ballistic Load Sensing Headform (Figure 13) with the projectiles C11, C12, C13, and C14 [5]. The load sensing module of this headform used only five load cells in comparison with seven for the current configuration (Figure 14). As a result, more of the impact force is distributed outside the sensing area for the 2006 BLSH version. In comparison with the peak total force data recorded for the current study, the 2006 results are consistently lower (Figure 15). This is most likely due to the loads bridging the smaller sensing area of the previous BLSH generation.

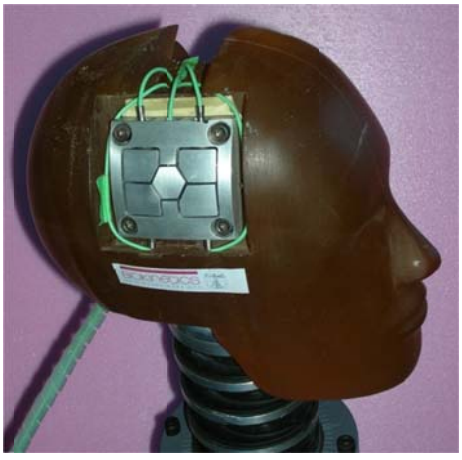

Figure 13. BLSH (2006 version).

Figure 14. BLSH (current version).

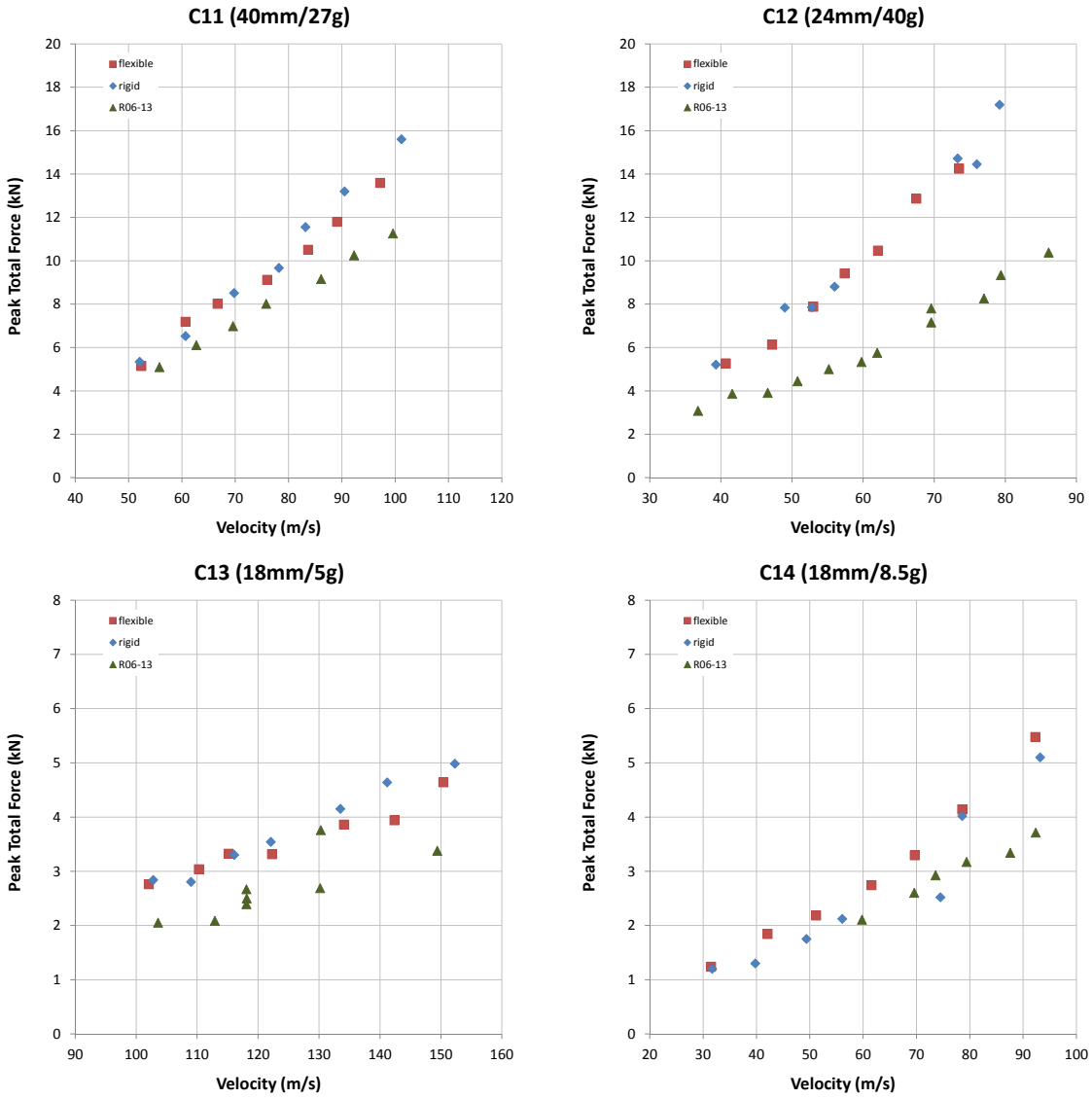

Figure 15. Comparison with the 2006 test series.

4 Conclusions and Recommendations

The Ballistic Load Sensing Headform was able to differentiate the dynamic loading characteristics of various projectiles simulating KENLW impacts. In general, a good correlation was observed between the peak total force and the impact velocity data but more inconsistencies were noticed for heavier projectiles (> 130 g). This may indicate a limitation of the measurement system or non-elastic impact condition but further experimentation will be required to confirm this observation.

When comparing the recorded data to the proposed head injury risk curve proposed by Bolduc et al. [6], it is noticed that most of the impact conditions tested were above the 25% risk of skull fracture (Figure 16). For severe impacts (peak total force > 15 kN), the polyurethane skin pad, which cover the load cell module, degraded rapidly and had to be replaced more frequently than the manufacturer suggested limit of 50 impacts.

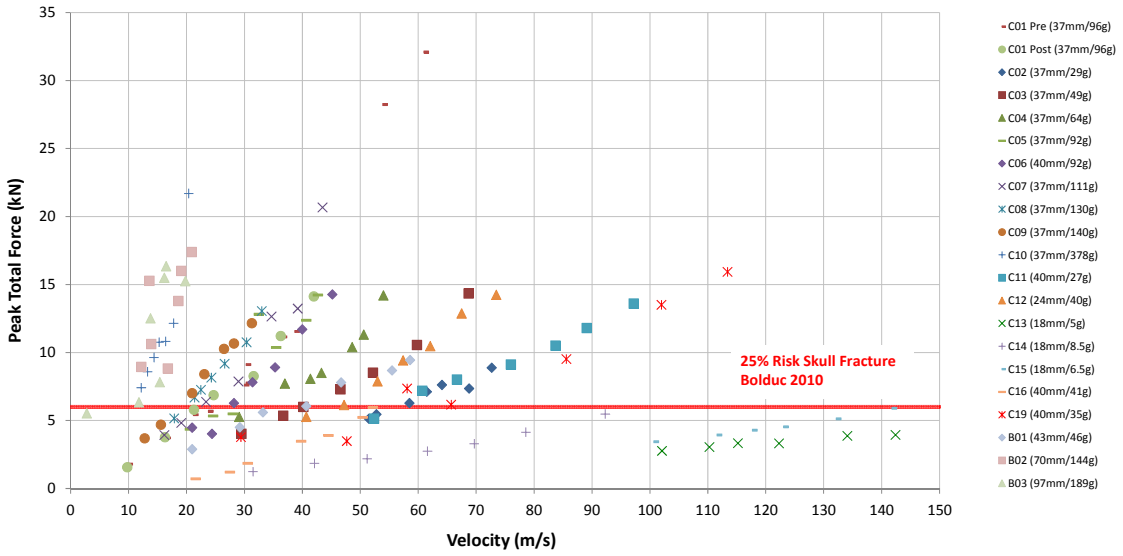

Figure 16. Risk injury assessment.

Interestingly, a rigid support (neck) provided similar results when comparing to the standard configuration which uses the flexible Hybrid III (crash test dummy) neck. Future experimentation may benefit from this finding as it can simplify the test setup.

The initial BLSH response was comparable to the results recorded at the end of the test program as demonstrated by comparing the peak total forces measured for the same loading conditions.

Higher force values were obtained in the current study when compared to the previous tests conducted in 2006 with an earlier version of the Ballistic Load Sensing Headform. These differences were expected due to the loads bridging the smaller sensing area of the previous BLSH generation.

Based on the strong relationship between the input loads and the measured responses, the Ballistic Load Sensing Headform appears suitable for assessing the insult to the head caused by KENLW projectiles. However, future experimental evaluations must limit the peak total force recorded to a maximum of 15 kN to preserve the integrity of the measured responses and to reduce the risk of equipment damage. Furthermore, a peak total force value greater than 15 kN exceeds, by far the human head tolerance and thus does not provide meaningful information in terms of injury prediction. Testing with projectiles heavier than 130 g should be conducted carefully (i.e. low velocity) as the BLSH appears to be more sensitive to these impact conditions.

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Annex A Test Data (Flexible Neck)

C01	Cylinder (hard plastic)

TEST ID 1 **CONFIGURATION** HyIII Neck

SHOT	VELOCITY (m/s)	MOMENTUM (kg-m/s)	ENERGY (J)	LC #1	LC #2	LC #3	LC #4	LC #5	LC #6	LC #7	TOTAL FORCE (N)	LOCATION
1	30	2.9	43	4185	947	770	703	387	361	377	7604	front
2	30	2.9	44	4160	1085	940	676	388	389	417	7755	right
3	30	2.9	44	5070	808	1049	762	478	509	479	9103	right
4	21	2.0	22	2930	180	343	605	712	513	159	5429	right
5	39	3.7	72	7465	1333	756	606	508	720	814	11542	right
6	42	4.0	85	9710	1626	1219	693	440	582	968	14115	right
7	61	5.9	179	22739	3208	1081	833	913	2220	3756	32093	right
8	10	1.0	5	500	19	253	814	252	15	8	1781	right
9	54	5.2	139	21579	2221	986	796	828	1491	1616	28235	left
10	16	1.6	13	1915	306	750	533	185	66	66	3726	left
11	24	2.3	27	3058	536	929	631	301	215	256	5683	left
12	37	3.5	64	7233	1349	641	467	452	708	885	11147	left

C02	Cylinder (hard plastic)

TEST ID 2 **CONFIGURATION** HyIII Neck

SHOT	VELOCITY (m/s)	MOMENTUM (kg-m/s)	ENERGY (J)	LC #1	LC #2	LC #3	LC #4	LC #5	LC #6	LC #7	TOTAL FORCE (kN)	LOCATION
1	53	1.5	40	2600	582	502	414	399	538	602	5457	right
2	52	1.5	38	2500	620	483	397	350	440	594	5130	right
3	64	1.9	60	3357	1114	506	369	359	824	1314	7618	right
4	59	1.7	50	3188	748	389	332	379	769	951	6272	right
5	62	1.8	55	3214	1531	475	227	132	517	1475	7113	right
6	69	2.0	69	3090	1210	215	242	200	983	1788	7351	right
7	73	2.1	77	4365	1012	366	309	445	1335	1658	8874	right

C03	Cylinder (hard plastic)											
TEST ID	3										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	30	1.4	21	2152	769	720	260	152	162	226	4020	right
2	47	2.3	53	4759	943	763	497	352	404	644	7287	right
3	40	2.0	40	3817	356	414	570	565	527	439	6003	right
4	52	2.6	67	5824	959	530	386	455	808	1061	8511	right
5	60	2.9	88	8437	1273	1066	749	608	699	1067	10553	right
6	69	3.4	116	11892	1864	1343	766	642	933	1423	14332	right
7	37	1.8	33	3005	540	581	491	333	345	421	5339	right

C04	Cylinder (hard plastic)											
TEST ID	4										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	41	2.6	55	5061	928	700	559	429	511	692	8064	right
2	49	3.1	76	6860	1033	623	520	538	988	1261	10397	right
3	54	3.5	93	10850	1006	706	670	749	1088	1214	14194	right
4	37	2.4	44	4972	533	536	580	537	569	553	7703	right
5	29	1.9	27	3331	296	361	401	407	383	314	5259	right
6	43	2.8	60	4962	1220	895	605	449	560	873	8495	right
7	51	3.2	82	7507	1105	699	560	554	971	1343	11309	right

C05				Cylinder (Al)								
TEST ID	5										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	33	3.0	49	6717	826	1221	2045	964	679	706	12806	left
2	36	3.3	58	5320	1180	1206	2441	1300	1222	1237	10373	left
3	41	3.7	76	8930	925	952	895	916	956	968	12363	left
4	28	2.6	36								5486	left
5	25	2.3	28								5331	left
6	21	1.9	20								4357	left
7	43	3.9	84	9572	1318	1358	1342	1548	1432	1378	14231	left

C06				Cylinder (Al)								
TEST ID	6										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	21	1.9	20								4475	left
2	24	2.2	27								4019	left
3	28	2.6	37								6270	left
4	31	2.9	45								7806	left
5	35	3.2	57								8898	left
6	40	3.7	74	6397	1282	1324	1299	1581	2627	1351	11701	left
7	45	4.2	94	8982	1510	1571	1504	1508	2250	1510	14265	left

C07	Cylinder (hard plastic)

TEST ID 7 **CONFIGURATION** HyIII Neck

SHOT	VELOCITY (m/s)	MOMENTUM (kg-m/s)	ENERGY (J)	LC #1	LC #2	LC #3	LC #4	LC #5	LC #6	LC #7	TOTAL FORCE (kN)	LOCATION
1	44	4.8	105	15293	1661	1458	874	604	686	968	20661	front
2	39	4.4	85	8773	875	1293	980	785	584	675	13223	front
3	35	3.9	67	8813	1023	1330	739	456	380	480	12640	front
4	29	3.2	47	4469	541	739	703	680	468	416	7858	front
5	23	2.6	30	3415	440	1019	934	409	145	150	6371	front
6	19	2.1	20	2628	441	845	610	216	97	105	4822	front
7	16	1.8	15	2088	172	609	687	317	91	56	3929	front

C08	Cylinder (hard plastic)

TEST ID 8 **CONFIGURATION** HyIII Neck

SHOT	VELOCITY (m/s)	MOMENTUM (kg-m/s)	ENERGY (J)	LC #1	LC #2	LC #3	LC #4	LC #5	LC #6	LC #7	TOTAL FORCE (kN)	LOCATION
1	21	2.8	30	3706	173	405	813	1001	510	151	6685	right
2	24	3.2	38	4766	340	650	866	815	481	271	8153	right
3	30	4.0	60	7015	360	266	388	1139	1666	663	10756	right
4	23	2.9	33	3994	182	423	902	1127	557	171	7257	right
5	27	3.5	46	5319	459	782	954	853	518	336	9176	right
6	18	2.3	21	2944	125	283	634	725	391	100	5149	right
7	33	4.3	71	9518	614	653	716	785	752	620	13045	right

C09	Cylinder (hard plastic)											
TEST ID	**9**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	13	1.8	11	1761	25	331	951	585	68	20	3681	right
2	16	2.2	17	2501	56	217	700	885	355	42	4687	right
3	27	3.7	49	5994	537	645	817	964	875	504	10269	right
4	21	2.9	31	3854	159	296	724	1182	688	181	6998	right
5	31	4.4	69	8676	655	837	901	906	724	580	12156	right
6	28	3.9	56	6371	900	965	751	579	561	581	10652	right
7	23	3.2	37	4952	440	842	942	684	347	233	8397	right

C10	Cylinder (hard plastic+ steel core)											
TEST ID	**10**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	20	7.7	79	16147	309	895	1685	1921	769	224	21687	right
2	16	6.2	51	3522	44	1012	4522	2193	66	123	10816	right
3	15	5.8	44	3353	41	1077	4402	1995	57	77	10749	right
4	14	5.4	39	5102	144	744	1651	1498	452	68	9634	right
5	13	5.0	33	4350	97	726	1739	1343	323	37	8586	right
6	12	4.6	28	3248	40	758	2038	1236	140	30	7407	right
7	18	6.7	60	6910	116	971	2562	1734	356	86	12154	right

C11	XM1006 sponge grenade

TEST ID 11 **CONFIGURATION** HyIII Neck

SHOT	VELOCITY (m/s)	MOMENTUM (kg-m/s)	ENERGY (J)	LC #1	LC #2	LC #3	LC #4	LC #5	LC #6	LC #7	TOTAL FORCE (kN)	LOCATION
1	89	2.4	107	4475	1798	686	429	570	1700	2288	11792	left
2	61	1.6	50	2611	1029	725	592	704	828	938	7185	left
3	67	1.8	60	3131	1313	1243	726	502	511	766	8011	left
4	76	2.1	78	3846	1619	1215	594	584	604	1140	9115	left
5	84	2.3	95	3595	2491	1063	548	588	953	1786	10504	left
6	52	1.4	37	2036	483	502	573	647	571	451	5144	left
7	97	2.6	128	4910	2455	1568	1193	884	1058	1944	13592	left

C12	12-gauge drag-stabilized (DS) bean bag

TEST ID 12 **CONFIGURATION** HyIII Neck

SHOT	VELOCITY (m/s)	MOMENTUM (kg-m/s)	ENERGY (J)	LC #1	LC #2	LC #3	LC #4	LC #5	LC #6	LC #7	TOTAL FORCE (kN)	LOCATION
1	41	1.6	33	3566	339	146	165	201	595	661	5261	left
2	47	1.9	45	4485	342	266	325	323	610	567	6127	left
3	53	2.1	56	6070	243	268	523	766	530	315	7880	left
4	57	2.3	66	6926	301	358	1009	1081	432	286	9412	left
5	62	2.5	77	6524	257	522	2232	1612	362	286	10467	left
6	68	2.7	91	4844	310	320	1520	5307	1433	322	12870	left
7	74	2.9	108	4930	233	251	2309	6195	1040	234	14238	left

C13	12-gauge fin-stabilized (FS) round											
TEST ID	**13**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	102	0.5	26	1657	218	230	188	270	440	227	2761	left
2	110	0.6	30	2017	294	270	231	246	298	346	3036	left
3	115	0.6	33	2158	352	284	268	244	270	363	3321	left
4	122	0.6	37	2149	345	498	282	186	208	214	3313	left
5	134	0.7	45	2409	254	270	468	354	232	275	3860	left
6	142	0.7	51	2347	352	500	748	380	395	379	3941	left
7	150	0.8	57	2441	434	1009	670	279	313	300	4639	left

C14	FN 303 projectile											
TEST ID	**14**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	42	0.4	8	1643	91	74	33	67	79	77	1841	right
2	51	0.4	11	1795	92	180	74	61	105	54	2184	right
3	32	0.3	4	849	177	35	29	61	38	126	1237	right
4	70	0.6	21	2535	357	69	85	78	72	236	3295	right
5	62	0.5	16	2178	262	77	57	70	69	141	2740	right
6	79	0.7	26	3355	332	90	126	105	100	204	4140	right
7	92	0.8	36	4570	359	167	177	160	150	185	5476	right

C15				MK Ballistics FB-1-FS								
TEST ID	**15**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	101	0.7	33	2049	82	148	324	645	314	135	3439	right
2	112	0.7	40	2143	86	184	487	790	310	163	3940	right
3	118	0.8	45	2066	86	199	802	1025	224	174	4286	right
4	123	0.8	49	2033	93	227	1049	1074	184	179	4534	right
5	132	0.9	57	2515	99	215	978	1133	260	198	5118	right
6	142	0.9	65	2068	112	274	1923	1497	172	197	5894	right
7	150	1.0	74	4251	166	452	1295	869	278	252	7355	right
C16				MK Ballistics 40 mm elastomeric baton								
TEST ID	**16**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	45	1.8	41	1092	649	292	235	328	619	770	3905	right
2	28	1.1	16	468	123	95	101	153	211	142	1197	right
3	31	1.3	19	655	156	164	193	318	286	162	1849	right
4	40	1.6	32	1135	408	291	324	405	531	498	3474	right
5	22	0.9	10	353	85	79	60	83	121	97	713	right
6	50	2.1	52	1522	692	415	397	557	847	887	5223	right
7	52	2.1	56	1672	889	643	605	599	713	913	5956	right

C19	Defense Technology Direct Impact Inert											
TEST ID	**19**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	48	1.7	40	1006	513	540	343	392	477	393	3479	left
2	29	1.0	15	1163	606	625	528	538	509	526	3768	left
3	58	2.0	59	1361	1021	1059	1042	1052	1069	1081	7348	left
4	66	2.3	76	1997	899	774	747	756	768	830	6152	left
5	86	3.0	128	3297	1389	882	854	846	1261	1931	9509	left
6	102	3.6	182	5192	1962	1243	1041	1054	1507	2076	13502	left
7	113	4.0	225	5781	3089	1449	972	979	1446	2593	15928	left
B01	Golf ball											
TEST ID	**20**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	21	1.0	10	928	1446	326	19	35	51	184	2880	right
2	29	1.3	20	2313	254	48	39	69	809	1119	4501	right
3	47	2.1	50	5103	191	157	294	1033	1300	379	7786	right
4	33	1.5	25	2254	626	2310	501	48	86	78	5592	right
5	56	2.6	71	3924	2234	219	110	76	368	2348	8672	right
6	59	2.7	79	6790	463	873	1093	772	439	382	9445	right
7	41	1.9	38	3042	794	91	104	79	577	1773	6046	right

B02				Baseball								
TEST ID	**21**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	17	2.4	20	2482	1071	887	856	1048	1291	1200	8823	left
2	21	3.0	31	3829	1757	2011	2761	3048	2246	1821	17375	left
3	14	2.0	13	3106	1797	1953	2205	2340	2064	1873	15267	left
4	19	2.8	26	3390	1782	1776	1832	2370	2717	2127	15990	left
5	19	2.7	25	3115	1537	1498	1561	2011	2180	1890	13791	left
6	12	1.8	11	2137	1060	1070	1094	1238	1232	1114	8939	left
7	14	2.0	14	2477	1162	1197	1288	1607	1604	1285	10620	left

B03				Softball								
TEST ID	**22**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	14	2.6	18	3295	1353	1235	1255	1566	2090	1710	12503	left
2	16	3.1	25	3747	1647	1653	1787	2326	2439	1897	15496	left
3	15	2.9	22	1843	1104	1282	1270	1276	1080	1094	7819	left
4	20	3.7	37	4308	1620	1334	1339	1885	2653	2106	15245	left
5	17	3.1	26	2273	2274	2388	2324	2346	2360	2408	16340	left
6	3	0.5	1	764	734	764	746	753	909	850	5520	left
7	12	2.2	13	963	1014	796	774	781	862	1876	6331	left

C01				Cylinder (hard plastic)								
TEST ID	**44**										**CONFIGURATION**	HyIII Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (N)**	**LOCATION**
1	32	3.0	48	4321	331	265	401	1161	1649	678	8259	right
2	21	2.0	22	3361	269	217	238	572	765	422	5783	right
3	42	4.0	85	9710	1626	1219	693	440	582	968	14115	right
4	10	0.9	5	682	20	226	492	174	51	29	1556	right
5	16	1.6	13	2265	216	153	98	227	507	344	3772	right
6	25	2.4	29	3864	591	259	190	366	885	811	6855	right
7	36	3.5	63	6758	504	186	225	738	2250	1133	11211	right

Annex B Test Data (Rigid Neck)

C01				Cylinder (hard plastic)								
TEST ID	**44**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	30	2.9	43	4116	774	1477	953	421	216	283	8165	left
2	21	2.0	22	2550	148	1060	970	396	120	110	5086	left
3	39	3.7	72	8942	333	1031	1395	912	536	414	13320	left
4	13	1.3	9	782	90	97	83	774	522	100	2230	left
5	17	1.6	13	1146	94	1350	921	156	96	118	3659	left
6	25	2.4	29	3345	726	1126	746	309	197	235	6663	left
7	36	3.4	61	5021	635	1438	1208	722	324	323	9628	left
C02				Cylinder (hard plastic)								
TEST ID	**23**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	50	1.5	36	3592	434	383	251	181	243	528	5359	left
2	54	1.6	42	2770	587	435	451	411	494	633	5401	left
3	65	1.9	61	3239	1159	567	440	340	679	1169	7240	left
4	57	1.7	47	3070	928	734	494	377	366	621	6199	left
5	61	1.8	53	2735	1336	429	282	198	483	1223	6373	left
6	66	1.9	63	3492	1357	504	356	234	476	1103	7200	left
7	71	2.1	72	3162	1840	1189	477	285	387	991	8012	left

C03				Cylinder (hard plastic)								
TEST ID	**24**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	42	2.0	42	3906	417	655	708	544	361	388	6577	left
2	69	3.4	116	9058	1380	662	583	767	1643	2456	13318	left
3	30	1.5	22	2723	271	314	330	340	305	247	4352	left
4	53	2.6	70	5280	583	529	751	1018	1148	907	9044	left
5	62	3.1	95	7363	960	639	749	1049	1636	1514	11300	left
6	48	2.3	56	5084	714	458	508	713	1126	1010	9553	left
7	35	1.7	31	3033	453	456	484	402	303	382	5179	left

C04				Cylinder (hard plastic)								
TEST ID	**25**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	37	2.3	43	3871	500	476	612	621	597	554	6918	left
2	46	3.0	69	5689	776	629	696	658	860	947	8910	left
3	50	3.2	80	6777	588	517	743	1014	1351	1018	10485	left
4	40	2.5	50	3977	476	332	487	650	1177	860	7489	left
5	29	1.9	27	3119	419	835	788	450	237	217	5984	left
6	42	2.7	58	5086	876	1061	749	515	494	595	8543	left
7	53	3.4	91	6881	537	371	537	1042	2872	1492	11806	left

C05				Cylinder (Al)								
TEST ID	**26**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	32	2.9	46	4653	1278	142	138	91	1203	2388	9501	right
2	37	3.4	62	5838	606	90	161	215	3657	3399	13467	right
3	41	3.7	76	6034	416	134	218	391	5624	2938	15146	right
4	28	2.5	35	3939	406	110	133	416	1303	867	6997	right
5	25	2.3	29	3448	714	244	135	179	547	681	5857	right
6	21	1.9	20	2727	484	98	46	90	380	734	4534	right
7	43	3.9	85	7770	410	123	198	379	7312	2348	17833	right

C06				Cylinder (Al)								
TEST ID	**27**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	44	4.1	90	10055	647	1069	1413	1538	868	695	15779	right
2	25	2.3	29	3169	159	318	731	995	459	234	5910	right
3	28	2.6	37	3446	198	221	441	1408	1145	348	6955	right
4	33	3.1	51	5278	554	484	547	918	1216	767	9345	right
5	36	3.3	60	5782	445	680	1151	1643	842	598	10644	right
6	41	3.7	76	8136	722	760	812	1168	1140	850	12886	right
7	21	1.9	20	2455	93	220	499	763	405	123	4461	right

C07				Cylinder (hard plastic)								
TEST ID	**28**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	44	4.9	108	16745	276	776	2419	1792	804	419	22439	left
2	39	4.3	84	8464	417	1866	2705	1175	315	308	14426	left
3	32	3.5	55	3067	119	2331	4473	973	117	117	10727	left
4	29	3.3	48	2719	366	3836	2598	237	74	74	9503	left
5	24	2.7	32	2162	135	1680	2877	602	102	118	7486	left
6	19	2.1	20	2474	191	754	1035	516	119	67	4978	left
7	16	1.8	14	1403	235	1358	1089	192	85	95	4249	left

C08				Cylinder (hard plastic)								
TEST ID	**29**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	28	3.6	51	3616	204	1903	3359	1010	189	186	10051	left
2				381	163	308	154	142	115	95	1335	left
3	32	4.1	64	3584	319	4228	3337	398	105	114	11644	left
4	24	3.1	36	4497	1046	1286	1430	1582	1434	1161	12262	left
5	20	2.6	26	3412	473	574	642	714	616	432	6743	left
6	19	2.4	22	3188	538	1001	1133	943	606	508	7347	left
7	32	4.2	67	4614	135	2080	5842	1345	117	114	13557	

C09				Cylinder (hard plastic)								
TEST ID	**30**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	12	1.6	10	1432	500	577	986	744	539	523	4784	left
2	16	2.2	17	2663	700	1105	876	539	422	441	6742	left
3	25	3.4	42	4957	1160	1127	1026	1124	1167	1069	11604	left
4	30	4.2	63	7258	1400	537	327	339	622	895	10549	left
5	27	3.8	51	5700	457	385	412	733	1031	694	9374	left
6	23	3.2	37	5160	761	901	1188	1150	1001	928	11072	left
7												

C10				Cylinder (hard plastic+ steel core)								
TEST ID	**31**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	18	6.8	61	5184	748	2452	3412	1559	782	818	14171	left
2	19	7.2	69	10117	768	968	915	928	815	668	13601	left
3	15	5.5	40	4628	1171	2403	4130	2085	1168	1099	16679	left
4	12	4.6	29	3217	1344	2619	3918	1769	1389	1400	15044	left
5	13	5.1	34	3299	1138	2532	4172	1872	1130	1147	15215	left
6	12	4.7	29	3660	1615	3138	4213	2155	1608	1631	18000	left
7	15	5.8	44	3563	463	1381	2916	1222	490	508	9375	left

C11	XM1006 sponge grenade

TEST ID 32 **CONFIGURATION** Rigid Neck

SHOT	VELOCITY (m/s)	MOMENTUM (kg-m/s)	ENERGY (J)	LC #1	LC #2	LC #3	LC #4	LC #5	LC #6	LC #7	TOTAL FORCE (kN)	LOCATION
1	91	2.4	111	5173	1684	860	751	1159	1796	1912	13199	right
2	61	1.6	50	2336	426	367	477	1094	1249	666	6521	right
3	70	1.9	66	3042	595	462	516	1125	1885	1157	8508	right
4	78	2.1	83	3705	796	488	463	1102	1923	1272	9670	right
5	83	2.2	93	4405	1127	1037	920	1207	1651	1385	11546	right
6	52	1.4	37	2132	535	440	444	558	672	646	5335	right
7	101	2.7	138	5730	1399	1341	1284	1674	2456	1876	15598	right

C12	12-gauge drag-stabilized (DS) bean bag

TEST ID 33 **CONFIGURATION** Rigid Neck

SHOT	VELOCITY (m/s)	MOMENTUM (kg-m/s)	ENERGY (J)	LC #1	LC #2	LC #3	LC #4	LC #5	LC #6	LC #7	TOTAL FORCE (kN)	LOCATION
1	39	1.6	31	3646	139	81	194	569	602	270	5207	right
2	49	2.0	48	5319	186	210	592	1247	585	291	7834	right
3	53	2.1	56	4405	170	199	879	1804	1029	194	7853	right
4	56	2.2	63	5731	214	413	1517	1764	394	284	8803	right
5	73	2.9	107	5414	208	295	2058	5638	1666	337	14715	right
6	76	3.0	116	5727	192	256	2531	6291	968	299	14449	right
7	79	3.2	125	9198	382	648	2576	3668	1465	586	17190	right

C13	12-gauge fin-stabilized (FS) round											
TEST ID	**34**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	103	0.5	26	2045	148	87	133	165	286	226	2840	right
2	109	0.5	30	1898	170	103	166	412	396	163	2804	right
3	116	0.6	34	2393	157	137	192	214	280	261	3299	right
4	122	0.6	37	2605	156	185	240	283	262	226	3540	right
5	134	0.7	45	2739	155	313	447	417	213	246	4150	right
6	141	0.7	50	2702	372	816	476	202	250	284	4637	right
7	152	0.8	58	2571	175	750	1089	401	249	323	4984	right
C14	FN 303 projectile											
TEST ID	**35**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	49	0.4	10	1218	145	39	30	55	66	291	1750	right
2	40	0.3	7	959	83	27	21	49	56	168	1299	right
3	32	0.3	4	902	80	27	22	51	42	133	1197	right
4	75	0.6	24	1732	225	62	54	68	110	391	2519	right
5	56	0.5	13	959	201	47	82	95	98	856	2121	right
6	79	0.7	26	3531	177	83	100	87	122	177	4018	right
7	93	0.8	37	3244	316	110	158	131	185	1188	5101	right

C15	MK Ballistics FB-1-FS											
TEST ID	**36**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	101	0.7	33	2297	150	93	188	120	362	401	3268.8	right
2	108	0.7	38	2552	155	107	216	136	419	451	3713.4	right
3	115	0.7	43	3146	151	125	214	223	344	320	4205.8	right
4	123	0.8	49	3381	127	136	243	455	477	287	4650.4	right
5	131	0.8	56	3739	149	158	279	605	543	288	5233.5	right
6	140	0.9	64	4008	151	155	432	883	498	288	5974.8	right
7	150	1.0	73	4024	300	933	1017	294	286	347	6725.1	right

C16	MK Ballistics 40 mm elastomeric baton											
TEST ID	**37**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	44	1.8	40	1116	857	493	252	239	457	733	4105	right
2	28	1.1	16	418	107	100	146	556	279	92	1501	right
3	31	1.3	20	628	215	198	152	228	257	161	1748	right
4	41	1.7	34	940	372	259	312	572	674	509	3618	right
5	22	0.9	10	354	114	115	77	99	108	73	744	right
6	49	2.0	50	1483	801	523	386	417	794	925	5309	right
7	55	2.2	61	1593	991	627	527	569	773	993	5993	right

C19	Defense Technology Direct Impact Inert											
TEST ID	**40**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	43	1.5	33	733	385	175	264	274	358	206	1622	right
2	30	1.0	15	1235	167	177	140	102	71	55	1840	right
3	56	2.0	55	1607	995	597	214	147	277	708	4506	right
4	71	2.5	88	2088	1336	655	360	280	644	1302	6626	right
5	86	3.0	129	3312	1794	908	429	402	885	1603	9257	right
6	93	3.3	152	4210	2060	968	375	394	1106	1969	10984	right
7	109	3.8	208	4643	2933	1063	509	633	1379	2910	13985	right
B01	Golf ball											
TEST ID	**41**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	21	0.9	10	1385	38	33	39	489	899	96	2881	right
2	26	1.2	15	2403	79	55	49	559	962	190	4149	right
3	39	1.8	34	3356	458	463	73	948	1925	324	6492	right
4	35	1.6	28	3477	132	98	55	287	1247	650	5704	right
5	55	2.5	69	6374	393	323	438	789	918	689	9683	right
6	61	2.8	86	6714	665	530	432	587	857	881	9568	right
7	49	2.3	56	4383	1614	1083	234	153	248	548	7346	right

B02				Baseball								
TEST ID	**42**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	15	2.1	15	1607	809	440	375	396	721	1158	5504	left
2	20	2.8	28	2291	634	743	870	803	653	662	5999	left
3	18	2.5	22	1913	814	846	824	834	862	927	5813	left
4	13	1.9	12	1530	434	451	504	736	456	453	3882	left
5	19	2.7	25	2363	1097	1142	1118	1123	1134	1145	7847	left
6	13	1.8	11	2101	947	981	946	915	866	872	7623	left
7	21	3.0	31	3127	2329	1998	1247	1031	1167	1497	12387	left
B03				Softball								
TEST ID	**43**										**CONFIGURATION**	Rigid Neck
SHOT	**VELOCITY (m/s)**	**MOMENTUM (kg-m/s)**	**ENERGY (J)**	**LC #1**	**LC #2**	**LC #3**	**LC #4**	**LC #5**	**LC #6**	**LC #7**	**TOTAL FORCE (kN)**	**LOCATION**
1	15	2.9	22	3015	1449	1524	1482	1529	1502	1512	10442.202	left
2	16	3.1	25	3747	1647	1653	1787	2326	2439	1897	15495.672	left
3	11	2.2	12	776	123	138	717	1611	332	126	3720.7875	left
4	16	3.1	25	1245	1634	2097	339	200	197	208	5638.4969	left
5	11	2.1	11	966	516	530	520	526	936	911	3674.5412	left
6	6	1.1	3	676	192	203	195	197	201	200	1380.3058	left
7	20	3.7	36	3663	1327	1382	1351	1362	1371	1384	9492.4896	left