6

Lateral Impact Studies

Lap Belt Shoulder Harness Investigations

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ABSTRACT

A series of controlled deceleration experiments was performed with 52 young human male volunteers to determine, if possible, human tolerance to lateral impacts while restrained with a combination seat belt and torso (two straps attached to the seat at the shoulder line, passed over the shoulders parallel to the vertebral column and attached to the lap belt) harness. The subjects were exposed in 87 different experiments at average impact G's of 4.47 to 11.59 and durations of 0.22 to 0.09 seconds, respectively. No permanent physiological changes were noted.

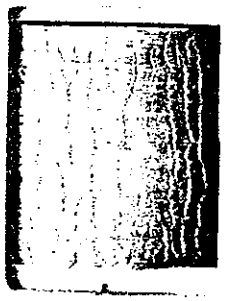
Minor subjective physical complaints were reported by more than 60% of the subjects when exposed to 8.8 average G's or more. The possibility of cardiovascular involvement halted the experiments after two subjects were exposed to the 11.59 average G pattern (12 G series).

INTRODUCTION

Everyday usage in aircraft and ground vehicles has shown that the lap belt provides maximum restraint with simplicity of design. The simple lap belt is an effective restraining device when used within a limited deceleration range, in the forward facing position [5, 4].

The lap belt has serious limitations when used under conditions of lateral impact [7].

The next basic restraining system uses a simple lap belt and adds some form of upper torso restraint. The two most common upper torso restraint configura-



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tions are: over the shoulder harnesses (often attached at one end to the lap belt itself) and a single strap used in a bandolier fashion. The characteristics of both configurations have been described by [6] for the shoulder harness and [2] for the bandolier under conditions of full forward facing impact.

The military makes extensive use of the basic over-the-shoulder design and often the conditions of use are such that pure lateral loads are imposed on the restrained subject. These loads may be experienced in spacecraft and aircraft lateral oscillations. Lateral impact is possible with encapsulated ejection systems on landing. The conditions here may be likened to intersection collisions of automobiles.

PURPOSE

Limited investigations have been reported on studies in lateral impacts with human volunteers and, in all cases, the upper torso restraints have varied and comparison is difficult [1].

The purpose of this study is to investigate and, if possible, to define human tolerance to lateral impact with the subject being restrained with a simple lap belt and over-the-shoulder harness configuration. Human tolerance as defined for this study is based on kinematic motion and physiological endpoints. These endpoints are defined as follows:

a. Abnormal changes from a pre-run medical examination that includes evaluation of the musculoskeletal, cardiovascular, respiratory, and nervous systems.

b. Abnormal physiologic changes as indicated on the electrocardiogram and blood pressure records taken during the experiment.

c. Excessive vertebral column flexion, especially in the neck as recorded by motion pictures.

d. Reports of discomfort by subjects or persistent localized pain.

MATERIALS

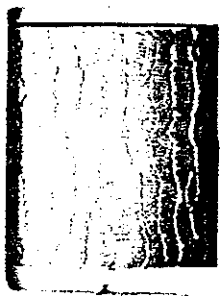
This series of experiments required the use of:

a. A controllable reproducible deceleration device.

b. A system for recording physiological, physical, and kinematic data for later analysis.

c. A group of volunteer human subjects.

The deceleration device used was a 6571st Aeromedical Research Laboratory Biodynamics Branch, crash restraint demonstrator commonly known as the Bopper. (Figure 1) The Bopper is a bungee propelled seat-sled system with a programmable mechanical friction brake. The seat was positioned with the back parallel to the direction of travel and the subject so faced that his left



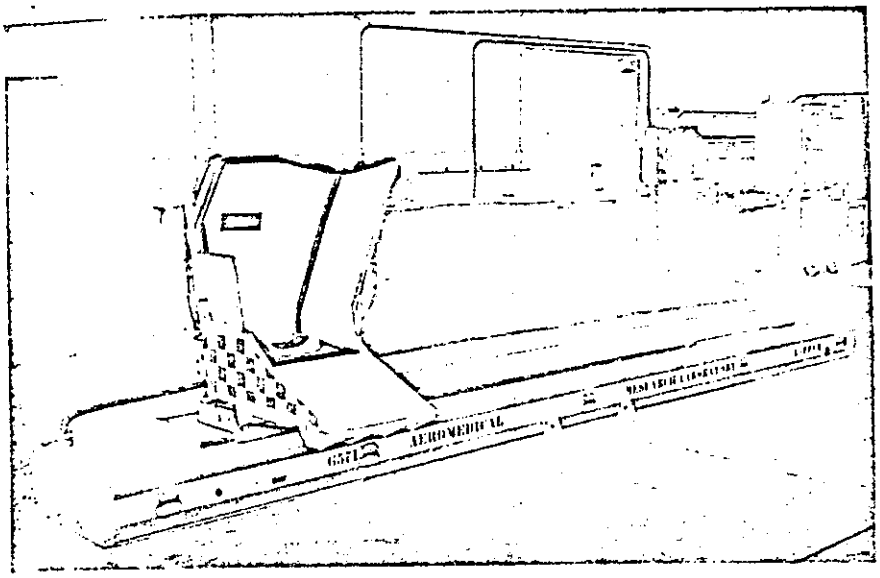


FIGURE 1. The Bopper Facility

shoulder pointed in the direction of travel. The seat belt dimensions specified in military specifications: Seat, Upward, Ejection, Aircraft, MIL-S-9479 (USAF) 19 Mar 1954 with a 12° seat back angle. The seat shown has a 30° left side plate modification and a right butt plate. The function of the left side plate was to provide safety for the subject in a previous series of tests and, because of weight considerations, was not removed for this particular series. The right butt plate assisted the subject in maintaining an upright position during the acceleration of the run.

The subject was restrained by a lap belt and over-the-shoulder harness that was fabricated with two layers of three-inch wide polyester with nylon filling a single twill weave Type IV Webbing of 8700 lbs breaking strength. The webbing conforms to military specifications MIL-W-25361. The webbing was sewn with the quarter-inch spaced stitching, quarter-inch parallel to each edge and in a diagonal diamond shape on three-inch centers. Two over-the-shoulder harness straps were used with loops at one end through which a lap belt was continuously passed. The lap belt and free end of the shoulder harness were then securely attached to the seat.

Physical data were recorded from strain gage type accelerometers fixed to the sled and attached to the subject. All accelerometers were oriented into three primary axes. For the sled system X direction is a vector in the direction of travel, Y is 90° perpendicular to X in the horizontal plane and pointing right, while Z is in the vertical plane pointing upwards 90° from X. To the subject, the X direction is perpendicular to the anterior-posterior plane, and the same relationship of Y to X and Z to X exists as described for the sled.

The sled was instrumented with a single accelerometer for the X vector. Statham Type A-6 accelerometers were used in all cases on the sled. Subjects (Figure 2) were instrumented both for chest and head accelerations. Strapped tightly over the subject's sternum was a triaxial accelerometer pack of the Statham Type A-6. An adjustable harness was designed and fabricated to hold a triaxial pack of A-52 accelerometers over the right temporal region of the head.

All accelerometer transducer data were recorded on a Consolidated Electrodynamics Oscillograph Type 5-119 and equipped with 135 cps galvanometers for the acceleration traces with a paper speed of 63 inches per second (2.06 meters per second).

Kinematic data were recorded with 16 mm Ippolito high speed cameras operating at 2,000 frames per second. The cameras were positioned to photograph a top and front view of the subject in the deceleration brake area.

Subject's physiological responses were measured with instrumentation for blood pressure and electrocardiogram.

The automatic blood pressure system is an in-house contractor developed device by Dynalectron, Inc., using an automatically inflatable cuff and sensor microphone. The assembly was attached to the subject's right upper arm.

The electrocardiograph is a single channel system with electrodes located over the sternum and on the lower back at L-5. The ground lead is placed over the thoracic vertebra at T-8. Sanborn Redux electrode paste was used, and the electrodes were attached with tape. All physiological data were recorded on a Sanborn 305 unit with a paper speed of 25 mm per second.

SUBJECTS

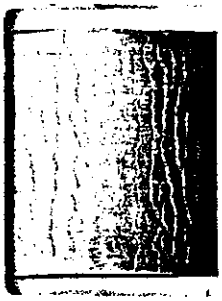
This series of 87 different tests required 52 male Air Force volunteers with an average age of 23.6 years, a range of 20 to 43 years. All subjects had undergone a rigorous physical examination (AF Class II Flight Physical) and additional tests. These tests were radiographic examinations of the spine, tonemetric examination of the eye, and baseline electroencephalogram.

A series of tests were scheduled beginning with a 4G plateau deceleration pattern and continuing on at 2 G increments until the tolerance level based on the established criteria had been reached.

The Bopper brake was set and calibration runs were made with an Alderson Anthropomorphic Dummy Model F50 instrumented with external accelerometers to establish the specific brake pattern. Deceleration profile data was obtained from the sled mounted accelerometer.

The subjects were instructed to be well rested and not have taken any solids or fluids since midnight preceding the test day. In general, experiments were scheduled beginning at 8 AM and 20 to 25 tests in any particular series were scheduled for any one day.

On arrival at the test site, the pre-run physical examination was accomplished. The subject was instrumented for physiological data, led to the sled and strapped in. The lap belt was fitted snugly over the iliac crests of the pelvis and secured in place. The over-the-shoulder harness was then positioned with



the straps parallel. The straps were pulled taut by technicians and clamped in position. The subject was given instructions on riding position; that is, fold his hands clasped in his lap and to try to maintain, if possible, a semi-relaxed position seated upright. Calibrations were performed and a completed series of electronic physiological data was made. A brief countdown procedure was then initiated of 20 seconds duration during which time all instrumentation was operating and continued operating for approximately 40 seconds post-

FIGURE 2. The Instrumented Subject in Position in the Seat just Prior to the Test

impact. The sled system was then fired (Figure 3) and immediately after impact the lap belt and shoulder harness was loosened. Post-run calibrations were made and physiological data collected. Total time of the experiment, in general, was approximately three minutes. The subject was then released from the seat and the post-run physical examination was completed. The subject then reported his experiences and after effects in the subjective report 72 hours post-run.

Five series of runs were scheduled with 20 tests accomplished at the 4 G series, 20 at the 6 G, 25 at the 8 G, 20 at the 10 G, and 2 at the 12 G series. (Figures 4, 5, 6, 7).

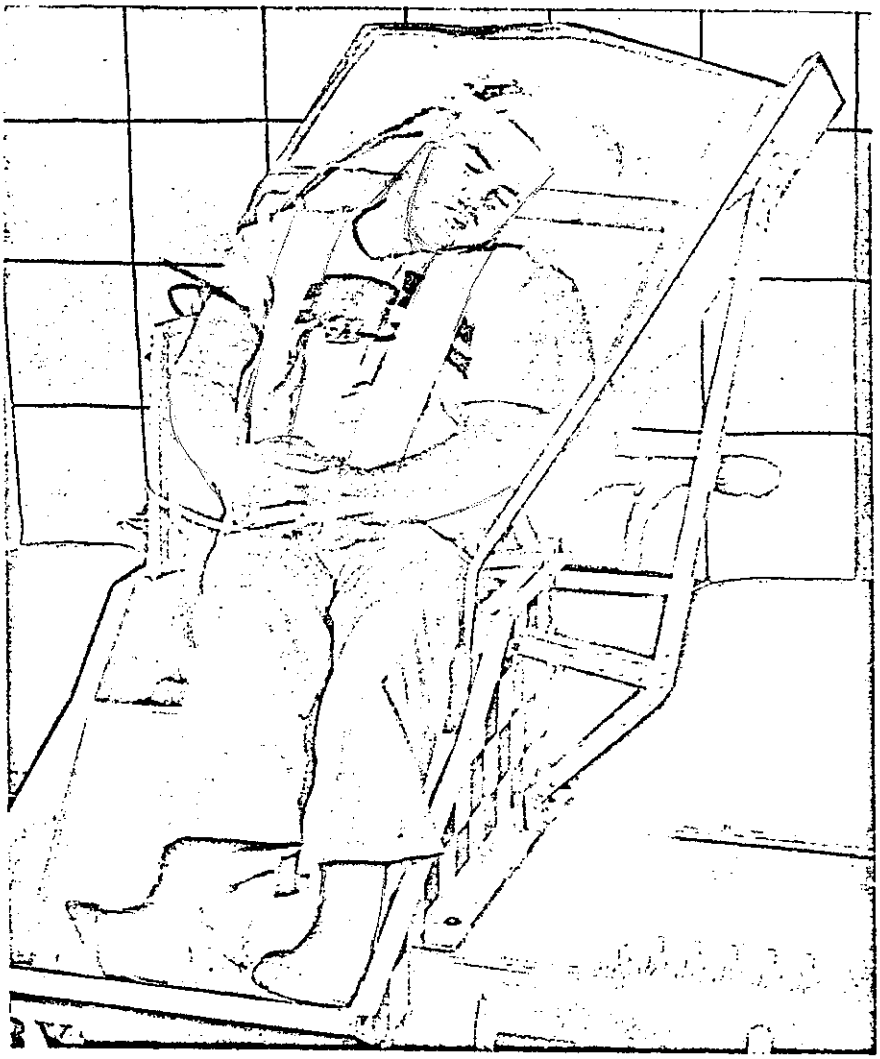


FIGURE 3. The Subject During Impact

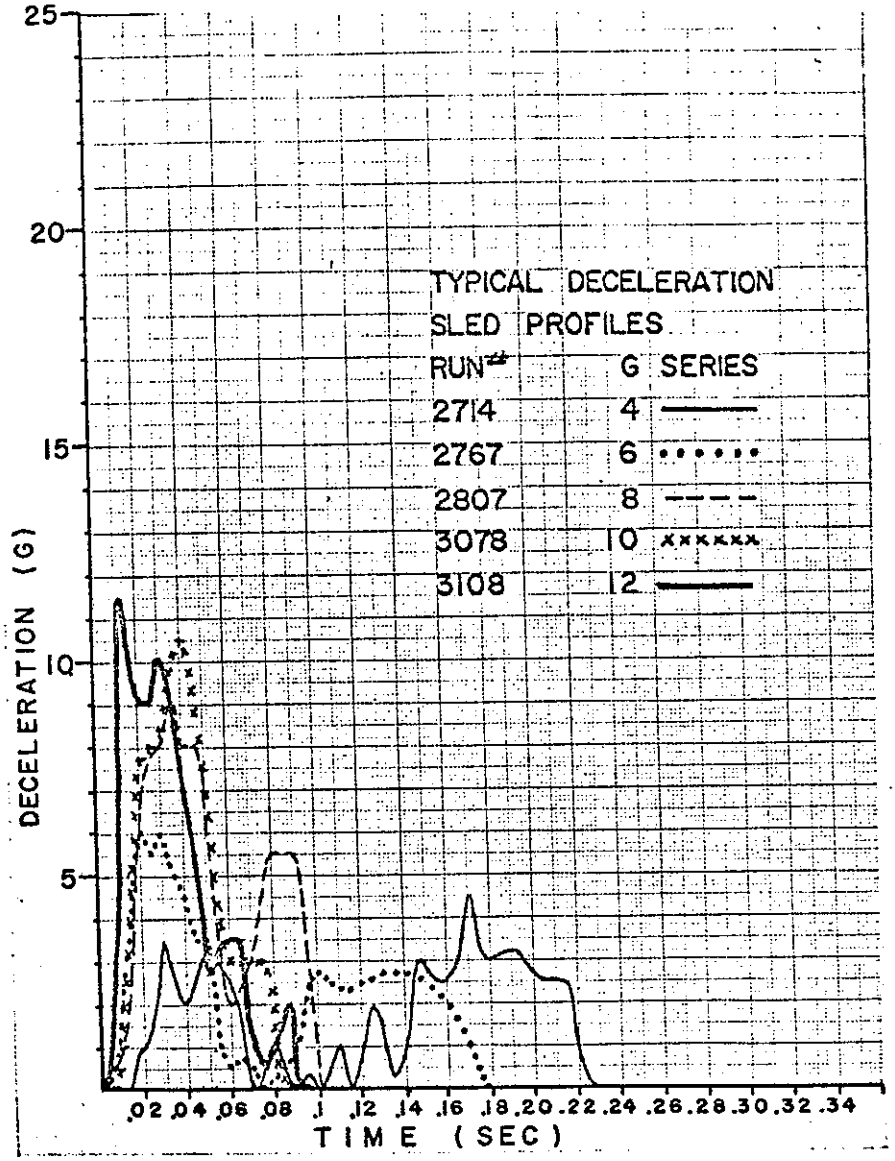
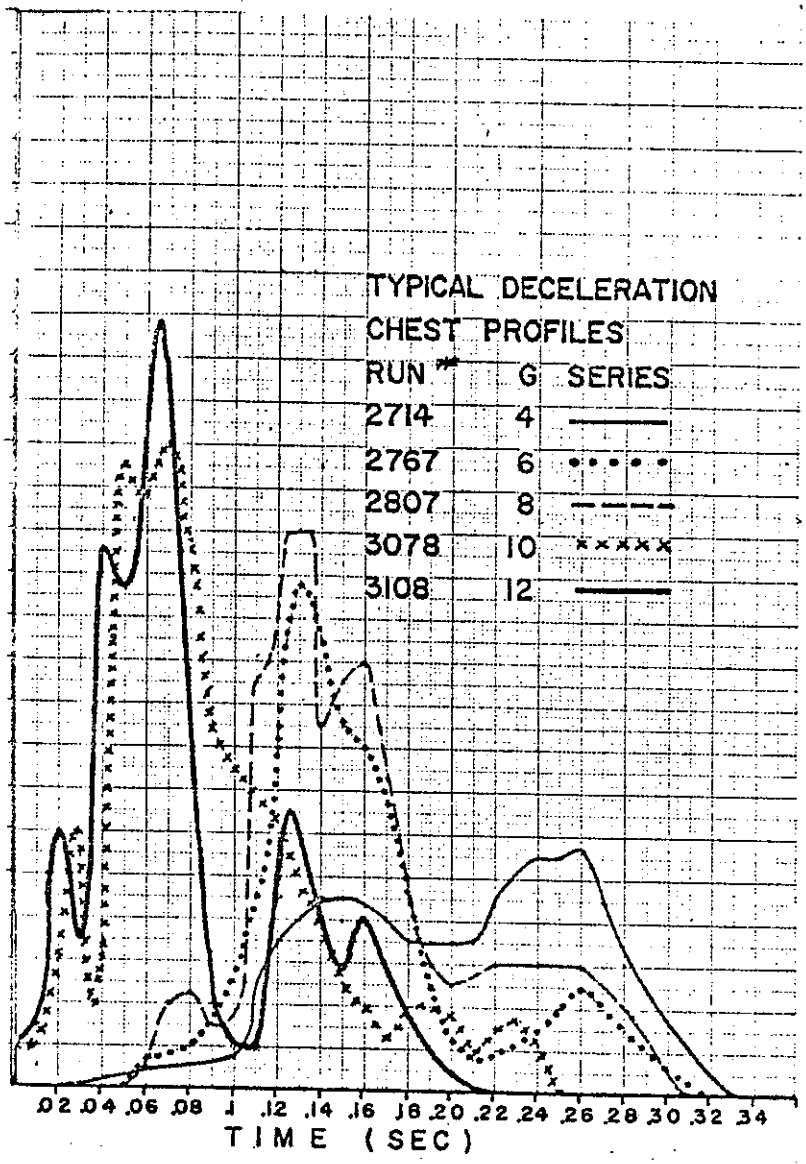
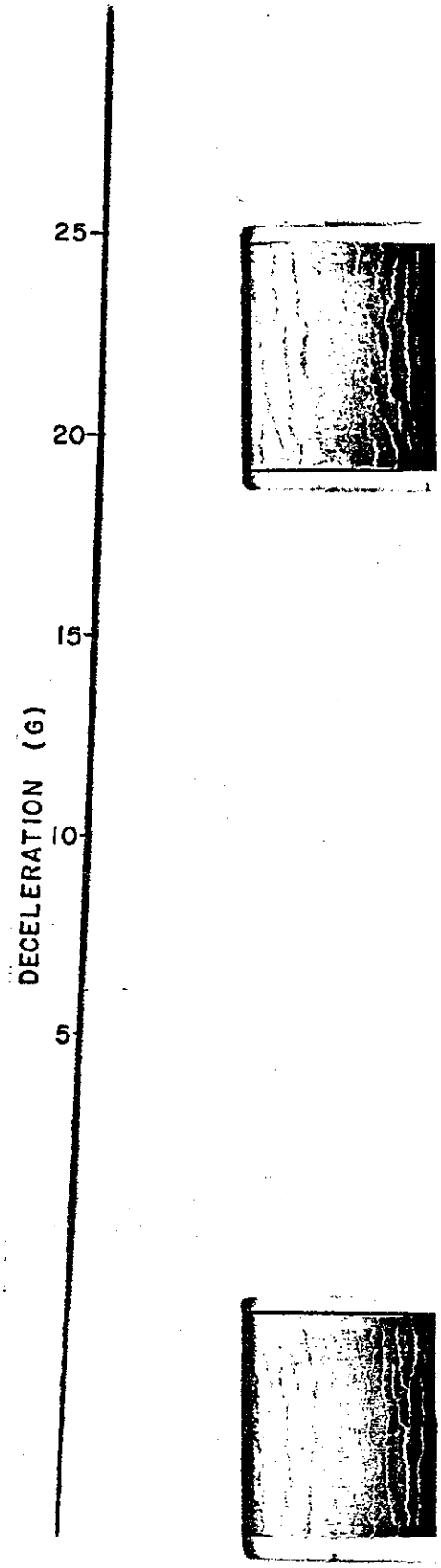


FIGURE 4. Typical Deceleration Profile-Sled—4, 6, 8, 10 and 12 G Series



IGURE 5. Typical Deceleration Profile—Chest—4, 6, 8, 10 and 12 G Series



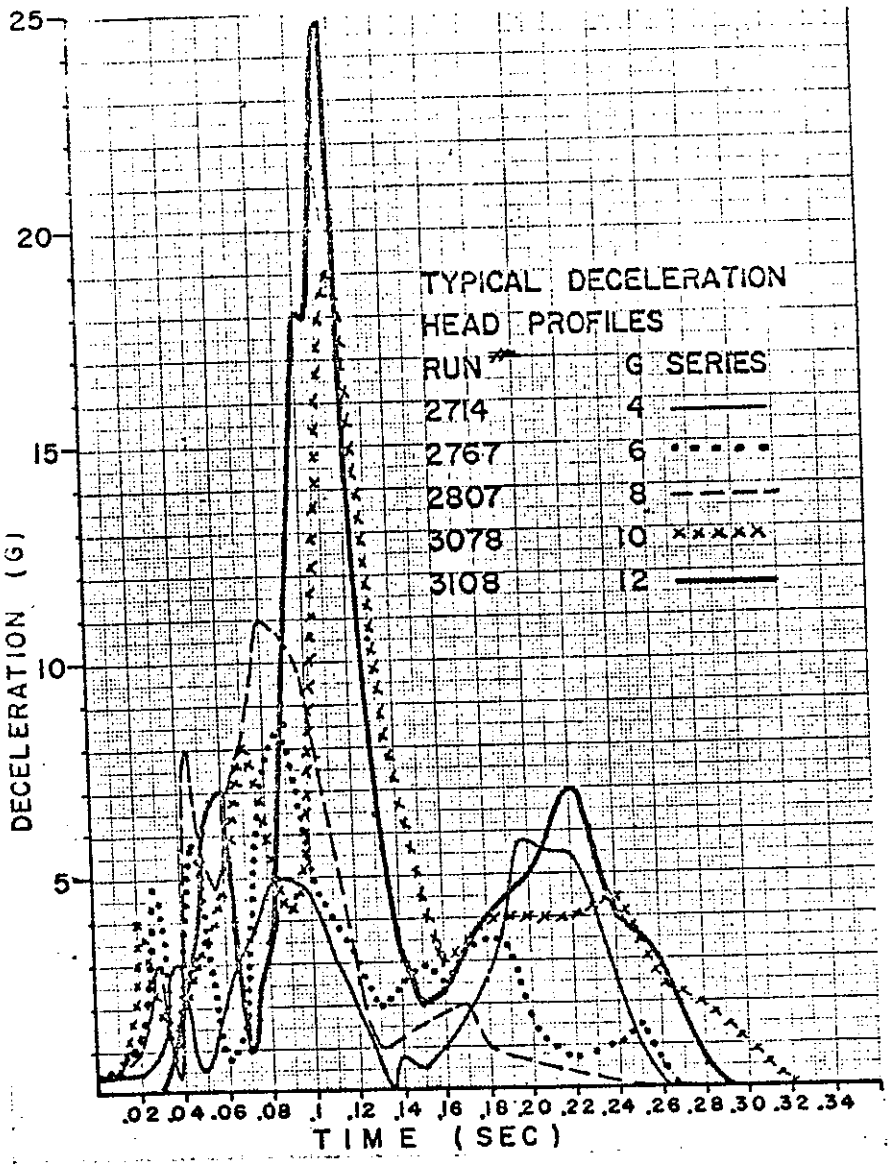
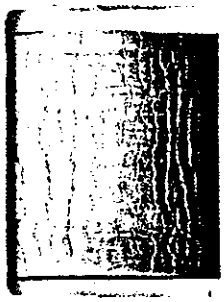
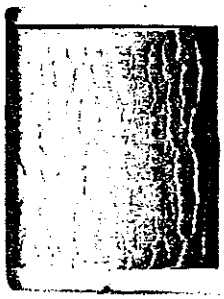


FIGURE 6. Typical Deceleration Profile—Head—4, 6, 8, 10 and 12 G Series





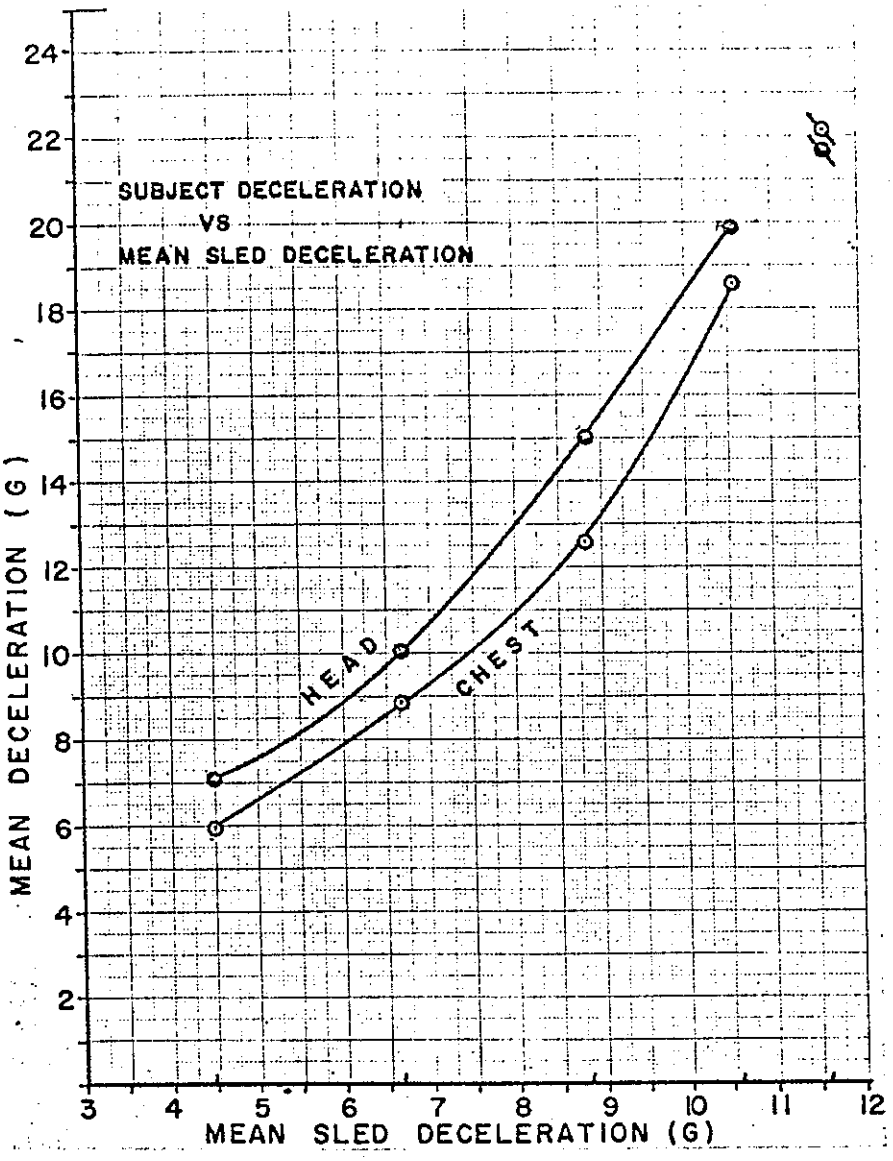


FIGURE 7. Mean Head and Chest Decelerations

Some subjects rode in more than one experiment but never at the same level or with an interval less than one month between tests.

DISCUSSION

The physiological data, in general, indicates that there were no important differences in Pre- and Post-Physiological Responses, Heart Rates, and Blood Pressures (Figures 8 and 9) with the exception of subject RR (Run No. 3109) whose recovery was considerably longer than the usual for experiments of this type. The subject's heart rate and blood pressure usually return to average published normals within a two minute period after exposure to deceleration even though during the experiment itself they may exceed average normal values momentarily. Subject RR showed a marked decrease in blood pressure and heart rate. The automatic physiological data acquisition system did not record a useable blood pressure immediately post-run (+20 sec) but at +40 seconds the subject's blood pressure was 70/30 mm Hg and his pulse at 43 beats/minute. Approximately one minute post-run he had fainted in the seat, and at this time his blood pressure could not be detected with the sphygmomanometer. His pulse rate was down to 20-30 beats/minute. Recovery was rapid and within 5 minutes after being laid in a supine position the subject revived. Blood pressures of 104/72 mmHg and a pulse of 72 beats/minute was recorded then. The subject's immediate complaints were of nausea, dizziness, and impingement of the left shoulder strap on the left side of the neck.

Unpublished data recently gathered (Zaborowski, Brown) in other lateral impact studies indicate that sustained relative bradycardia may result from lateral impacts. Generally, the subject returns to his pre-experiment heart rate within 20 seconds. Since the mechanism of bradycardia in relation to impact has not yet been adequately defined, the medical decision was made to halt the test series.

Chest to sled acceleration ratios [3] that are determined from chest pack accelerometer vector sums and sled accelerations increase in value (Figure 10) from a mean of 1.34 to 1.75 for the 4 to 10 G series, and the two isolated cases in the 12 G series recorded an average of 1.92. The head to chest ratios as determined from the head mounted accelerometer pack and the chest pack remain relatively stable at 1.15.

When the body is represented as a mathematical model consisting of lumped masses, viscous dampers and linear springs amplification factors greater than two are not possible.

The data recorded here, considering the difficulties of mounting accelerometers to the living human, falls within the limitations set by theory.

CONCLUSIONS

Human tolerance to lateral impact while restrained with a lap belt and over-the-shoulder harness has been demonstrated in a limited sense.

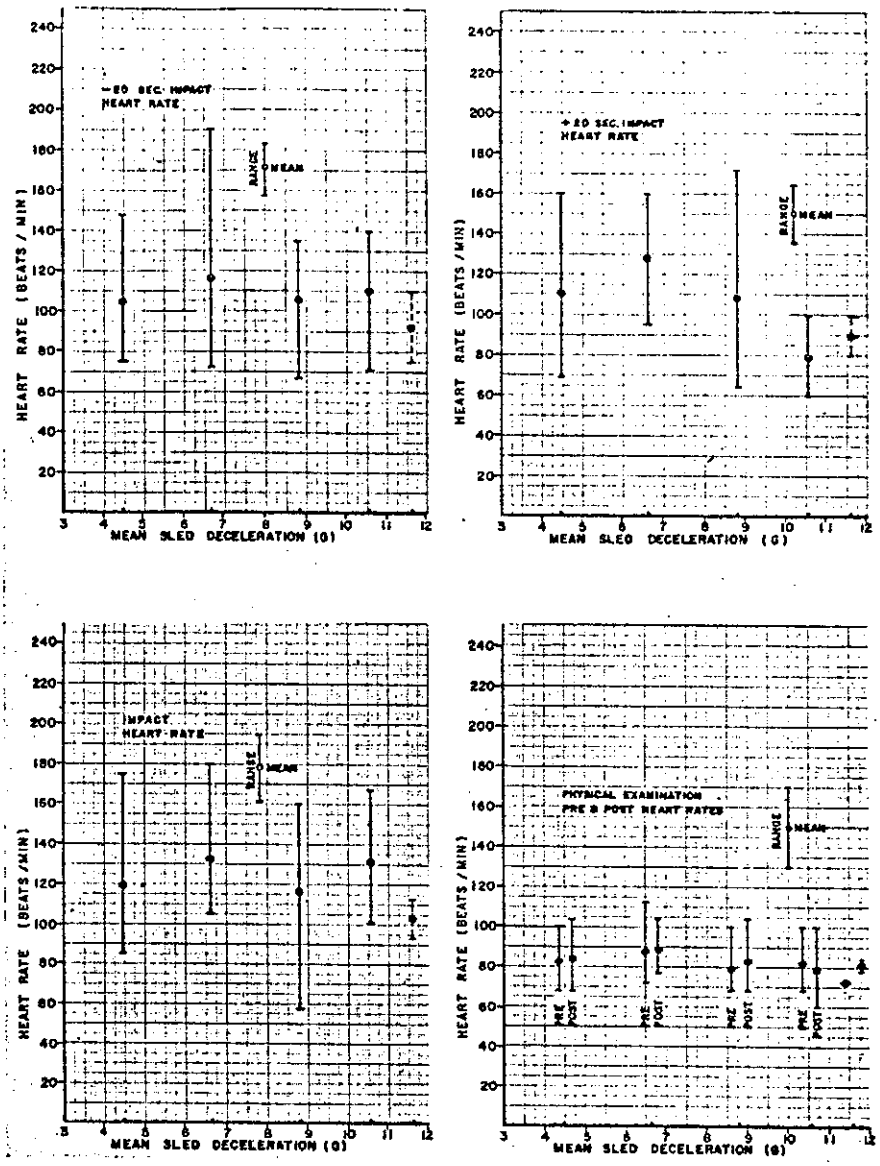


FIGURE 8. Physiological Data—Subject Heart Rates (beats/min)

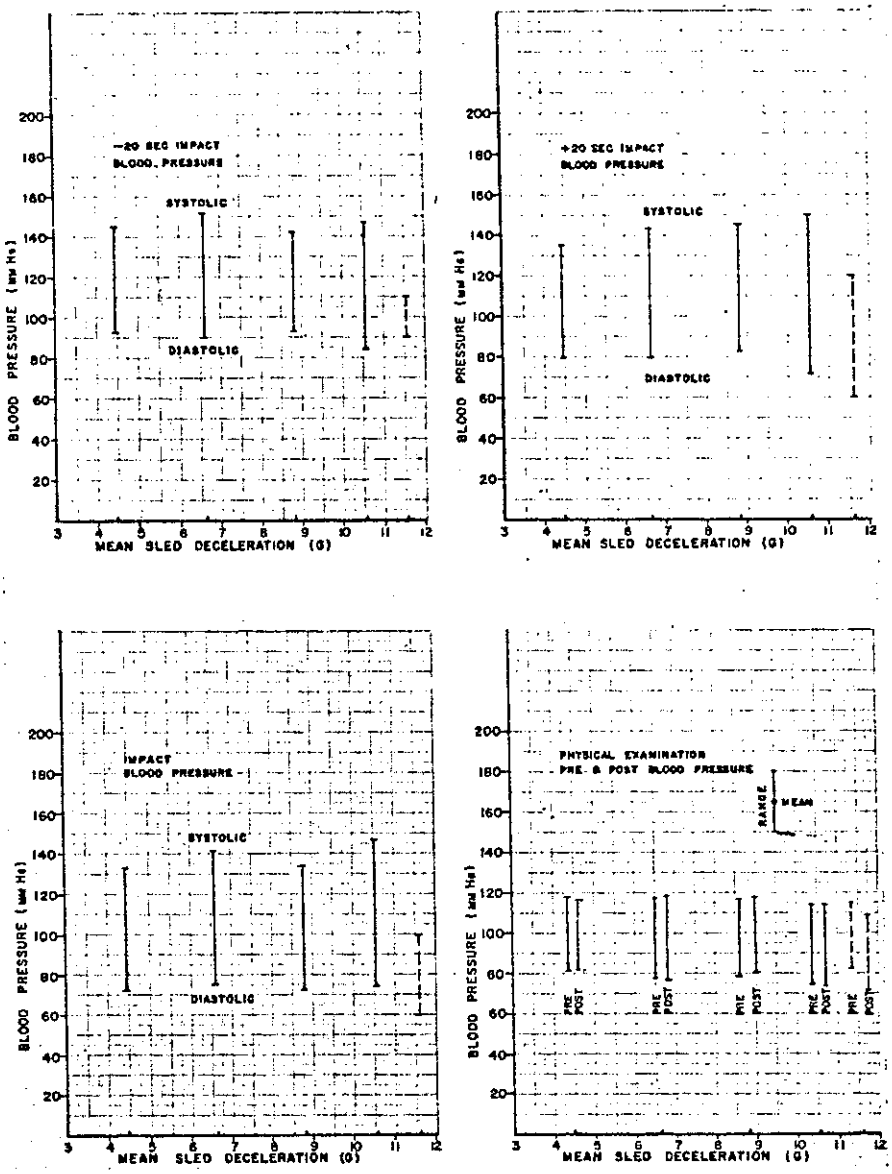


Figure 9. Physiological Data—Subject Blood Pressures (mmHg)

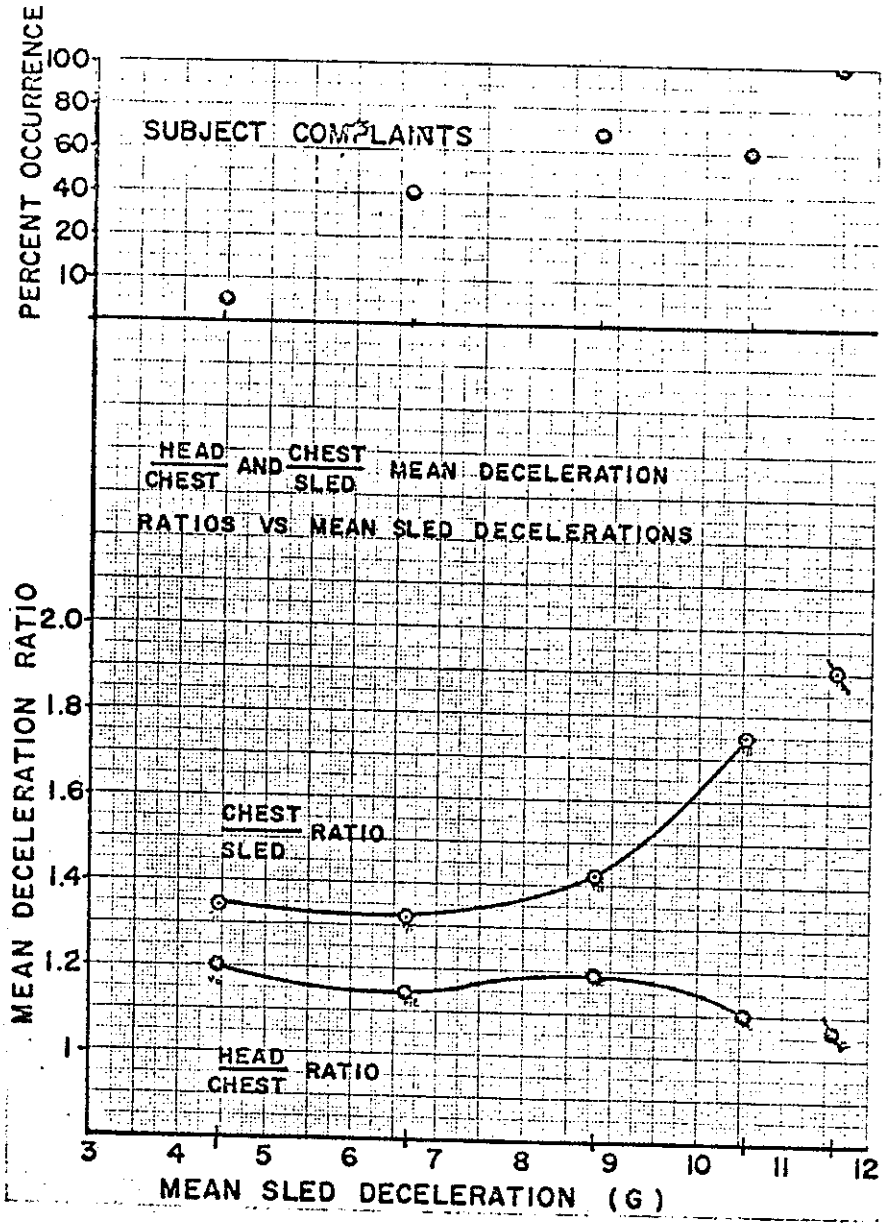


FIGURE 10. Mean $\frac{\text{Head}}{\text{Chest}}$ and $\frac{\text{Chest}}{\text{Sled}}$ Peak Deceleration Ratios and Percent Occurrence Subject Complaints

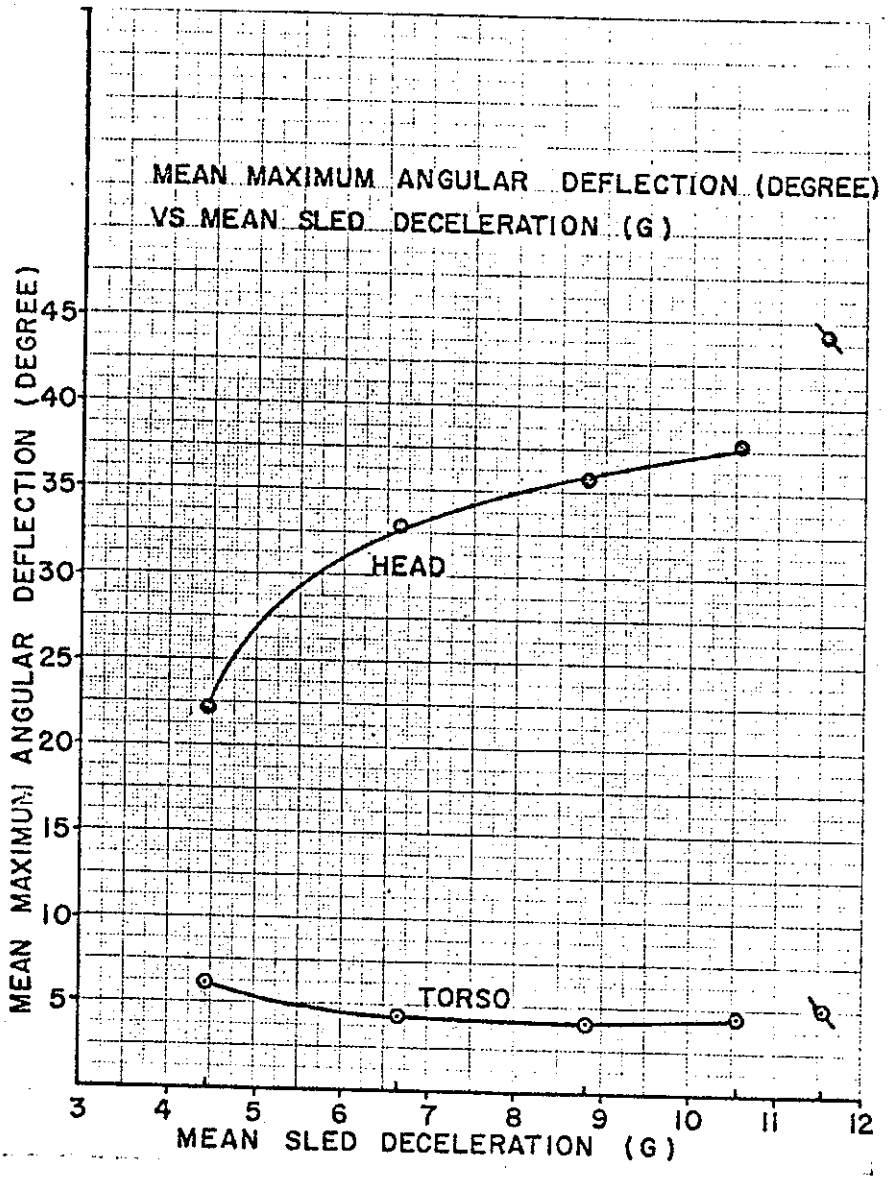


FIGURE 11. Mean Maximum Head and Torso Angular Deflections

a. No permanent physiological changes have been reported for healthy young male volunteers while exposed to impacts of 11.59 G's average and durations of approximately 0.1 seconds.

b. Minor physical complaints, such as muscle stiffness (neck musculation), occurred in greater than 60% of the exposures after the 8 G series (average exposure 8.8 G's).

c. The combination lap belt and over-the-shoulder harness is effective in restraining the torso at all levels tested (maximum average 11.47 G) as shown by a stabilized average torso deflection of approximately 5 degrees from the vertical in the direction of travel. (Figure 11)

d. Head angular deflection should be considered as a possible problem area while the torso is restrained. Subjective complaints indicate a predominance of neck musculature discomfort.

e. Chest/sled average amplification factor increased with increasing vehicle decelerations reaching an average of 1.75 for the 10 G series (average 10.56 G).

f. Head/chest average amplification factor fluctuated throughout the series between 1.15 and 1.20.

g. Exposure of volunteers to decelerations greater than approximately 12 G's laterally and time durations of approximately 0.1 seconds should be investigated with biological specimens other than man to investigate possible cardiovascular responses to impact.

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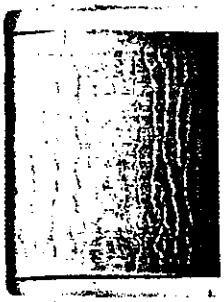


APPENDIX

TABLE 1. Selected Anthropometric Data

Subject	Age (yrs)	Weight (lbs.)	Weight (kg.)	Standing Height (in.)	Standing Height (cm.)	Sitting Height (in.)	Sitting Height (cm.)
CRA	25	135	61.37	68.5	174	35.6	89.8
DNA	29	128.5	58.41	65.1	165.3	32.7	83.2
GVA	26	119	54.09	64.8	164.7	34.9	88.6
JLA	30	150	68.18	65.7	169.9	35.4	89.5
JSA	23	195	88.64	71.6	181.8	35.6	90.3
MPA	20	135	61.37	67.6	171.9	35.8	91.0
WNA	35	197	89.55	69.8	177.3	35.6	90.5
GTB	26	174.8	79.46	74.3	188.8	37.2	94.5
JRB	24	130	59.09	71.0	180.6	35.1	89.2
LMB	22	184	83.64	72.3	183.7	37.2	94.8
RJB	32	171	77.73	67.7	174.6	35.8	90.9
TJB	23	156	70.91	71.0	180.4	36.41	92.5
WDB	25	195	88.64	70.9	180.2	37.0	94.0
WKB	31	140.5	63.87	67.9	172.5	34.8	88.4
CAC	34	152	69.09	67.1	170.5	34.4	87.3
GAC	22	179.5	81.60	65.8	167.2	35.6	90.3
GWC	21	174.5	79.32	67.4	171.2	35.6	90.3
LFC	25	129	58.64	68.0	172.7	34.9	88.7
PLC	22	140	63.64	70.7	179.6	35.1	89.2
WCC	27	181.5	82.50	66.3	168.3	34.6	87.8
RWD	29	165.5	75.23	65.4	166.2	35.7	90.7
JFE	22	168.5	76.60	70.6	179.2	37.2	94.6
JOE	25	179.5	81.59	69.1	175.5	35.9	91.3
JHF	26	160	72.73	68.7	174.7	34.4	87.3
DF	23	135.3	61.50	71.7	182.0	35.9	91.3
YSF	26	208.5	94.77	67.7	172.0	35.6	90.5
GAG	27	178	80.91	67.9	172.1	36.2	92.0
CWH	25	156.5	71.14	70.8	179.8	36.8	93.6
JFH	29	173	78.64	69.1	175.6	34.8	88.3
KDH	33	182.3	82.36	71.7	182.1	36.3	92.3
RAH	20	154	70.00	67.4	171.2	35.2	89.3

TABLE 1. Selected Anthropometric Data (Cont.)

Subject	Age (yrs)	Weight (lbs.)	Weight (kg.)	Standing Height (in.)	Standing Height (cm.)	Sitting Height (in.)	Sitting Height (cm.)
AAK	31	197.5	89.75	71.6	181.8	36.4	92.5
BDL	23	154	70.00	66.6	169.3	35.6	90.4
GEM	22	163	74.09	67.5	171.5	35.5	90.1
TWM	26	160	72.7	69.5	176.6	35.7	90.8
CGO	27	157	71.36	71.4	181.3	37.4	95.0
JLP	22	164	74.55	69.9	177.8	35.4	89.8
JWP	27	191	86.82	69.1	175.4	36.1	91.7
CAR	23	159	72.18	68.1	173.0	36.1	91.7
GAR	27	203	92.18	71.5	181.6	36.5	92.6
JWR	23	150.8	68.6	70.1	178.1	36.8	93.5
MDR	23	179	81.37	69.9	177.7	36.0	91.5
RR	23	125	56.82	66.4	168.7	35.1	89.2
JHS	43	141	64.09	68.3	173.5	33.2	84.3
JLS	22	179	81.37	71.77	182.3	36.2	92.0
LMS	22	146.5	66.59	69.17	175.5	35.5	90.3
TES	27	169.0	76.82	70.7	179.6	36.8	93.5
FRT	23	140	63.64	68.6	174.2	35.6	90.5
JDT	32	162.8	69.8	69.8	177.4	37.7	95.8
TRT	23	163	74.09	70.8	179.9	37.2	94.4
WCT	42	140	63.64	66.1	169.9	35.2	89.3
JPW	32	185	84.09	70.6	179.4	36.2	92.0

TABLE 2. Physical Data Sled Decelerations

4 G Series

Run Number	Velocity ft/sec	Velocity m/sec	Stopping Distance ft.	Stopping Distance meters	Sled G	Sled Onset G (G/sec)
2708	15.3	4.66	2.08	.64	5.05	238
2709	15.1	4.60	2.10	.64	4.95	256
2710	14.7	4.48	2.08	.64	5.15	284
2711	15.0	4.57	2.10	.64	4.59	256
2712	13.8	4.21	2.10	.64	3.69	200
2713	14.8	4.51	2.06	.63	4.65	230
2714	14.4	4.39	2.10	.64	4.51	234
2715	14.2	4.33	2.09	.64	4.33	217
2716	13.8	4.21	2.13	.65	3.71	215
2717	14.8	4.51	2.10	.64	4.89	237
2719	15.2	4.63	2.10	.64	4.88	140
2720	14.6	4.45	2.09	.64	4.36	259
2721	15.8	4.82	2.10	.64	4.84	283
2722	13.9	4.24	2.08	.64	3.95	231
2723	14.5	4.42	2.10	.64	3.69	199
2726	14.7	4.48	2.08	.64	4.46	189
2727	14.8	4.51	2.06	.63	3.90	221
2728	14.8	4.51	2.10	.64	4.77	250
2729	15.3	4.66	2.10	.64	4.59	199
2730	N/R*		2.10	.64	4.50	234
Max	15.8	4.82	2.13	.65	5.15	284
Min	13.8	4.21	2.06	.63	3.69	140
Average	14.71	4.4848	2.0957	.6388	4.47	228.6

* Not Recorded.

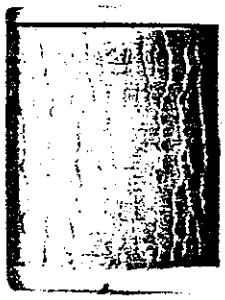


TABLE 3. Physical Data Sled Decelerations

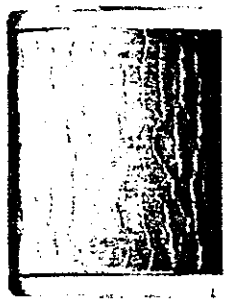
6 G Series

Run Number	Velocity ft/sec	Velocity m/sec	Stopping Distance ft.	Stopping Distance meters	Sled G	Sled Onset G (G/sec)
2741	15.0	4.57	1.08	.33	8.41	227
2742	14.7	4.48	1.06	.32	8.05	241
2743	14.5	4.42	1.08	.33	7.46	203
2750	15.5	4.73	1.31	.40	6.90	183
2751	14.4	4.39	1.29	.39	6.87	298
2752	15.6	4.76	1.23	.37	7.16	426
2753	15.2	4.63	1.29	.39	6.80	381
2754	15.7	4.79	1.29	.39	6.88	425
2755	15.0	4.57	1.31	.40	7.30	575
2756	15.5	4.73	1.31	.40	7.06	422
2760	14.3	4.36	1.46	.44	5.72	356
2761	15.1	4.60	1.44	.44	5.86	377
2762	14.6	4.45	1.46	.44	6.01	411
2763	13.7	4.18	1.44	.44	6.07	386
2764	14.2	4.33	1.48	.45	5.81	400
2765	14.0	4.27	1.44	.44	6.18	367
2766	14.6	4.45	1.48	.45	6.02	408
2767	13.9	4.24	1.44	.44	6.19	430
2768	14.6	4.45	1.52	.46	5.97	417
2771	14.4	4.39	1.48	.45	6.12	331
Max	15.7	4.7865	1.52	.4634	8.41	575
Min	13.7	4.1768	1.063	.3239	5.72	183
Average	14.73	4.4892	1.3447	.4099	6.64	363.2

TABLE 4. Physical Data Sled Decelerations

8 G Series

Run Number	Velocity ft/sec	Velocity m/sec	Stopping Distance ft.	Stopping Distance meters	Sled G	Sled Onset G (G/sec)
2783	15.1	4.60	.92	.28	8.50	483
2784	14.4	4.39	.92	.28	8.68	316
2785	15.1	4.60	.91	.28	9.42	356
2786	14.8	4.51	.94	.29	8.29	596
2787	14.9	4.54	.94	.29	8.74	615
2788	13.9	4.24	.98	.30	8.57	491
2789	14.6	4.45	.92	.28	8.32	557
2790	14.6	4.45	.88	.27	9.58	521
2791	15.5	4.73	.96	.29	9.31	584
2792	14.4	4.39	.94	.29	8.71	519
2793	14.6	4.45	.92	.28	8.96	611
2794	14.6	4.45	.92	.28	8.62	570
2795	14.7	4.48	.94	.29	8.66	521
2800	14.9	4.54	.94	.29	8.43	554
2801	14.2	4.33	.96	.29	8.57	332
2802	14.8	4.51	.94	.29	7.70	267
2803	15.3	4.66	.94	.29	9.26	374
2804	15.4	4.70	.93	.28	9.62	383
2805	14.6	4.45	.92	.28	9.34	268
2806	14.8	4.51	.94	.29	9.00	268
2807	14.7	4.48	.94	.29	8.81	263
2808	13.8	4.21	.92	.28	8.36	302
2809	14.5	4.42	.92	.28	9.18	340
2810	15.3	4.66	.94	.29	8.63	349
2811	14.6	4.45	.94	.29	8.84	314
Max	15.5	4.73	.98	.30	9.62	615
Min	13.8	4.21	.875	.27	7.70	263
Average	14.724	4.489	.93	.28	8.80	429.92



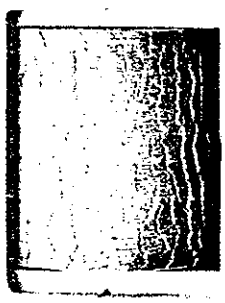


TABLE 5. Physical Data Sled Decelerations

10 G Series

Run Number	Velocity ft/sec	Velocity m/sec	Stopping Distance ft.	Stopping Distance meters	Sled G	Sled Onset G (G/sec)
3069	14.2	4.33	.79	.24	9.40	532
3072	14.2	4.33	.75	.23	10.37	548
3073	13.4	4.09	.71	.22	10.28	537
3074	13.8	4.21	.75	.23	9.92	534
3075	13.6	4.14	.73	.22	9.46	499
3076	13.6	4.15	.73	.23	9.92	554
3077	13.5	4.12	.73	.22	10.10	444
3078	13.4	4.09	.73	.22	10.54	501
3079	14.4	4.39	.73	.22	11.51	364
3080	14.4	4.39	.75	.23	11.60	391
3081	13.5	4.12	.71	.22	10.26	310
3082	13.4	4.09	.73	.22	11.33	317
3083	N/R		.73	.22	12.18	360
3084	14.4	4.39	.75	.23	10.85	353
3085	13.7	4.18	.73	.22	10.34	310
3086	14.5	4.42	.75	.23	11.37	354
3087	13.4	4.09	.75	.23	9.79	306
3088	12.6	3.84	.75	.23	9.49	275
3089	13.6	4.15	.73	.22	11.21	342
3090	14.3	4.36	.73	.22	11.18	333
Max	14.5	4.42	.79	.24	12.18	554
Min	12.6	3.84	.73	.22	9.40	275
Average	13.78	4.20	.74	.23	10.56	408.2

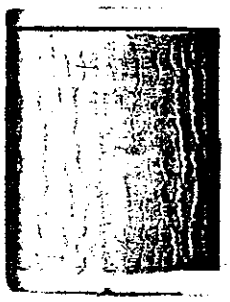


TABLE 6. Physical Data Sled Decelerations

12 G Series

Run Number	Velocity ft/sec	Velocity m/sec	Stopping Distance ft.	Stopping Distance meters	Sled G	Sled Onset G (G/sec)
3108	13.3	4.05	.63	.19	11.44	1015
3109	14.6	4.45	.60	.18	11.74	1162
Max	14.6	4.45	.63	.19	11.74	1162
Min	13.3	4.05	.60	.18	11.44	1015
Average	13.95	4.25	.61	.19	11.59	1088.5

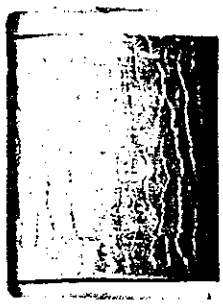


TABLE 7. Physical Data Subject Decelerations

4 G Series.

Run Number	Chest G	Chest Onset G (G/sec)	Head G	Head Onset G (G/sec)	Head G / Chest G Ratio	Chest G / Sled G Ratio
2708	6.71	179	7.89	77	1.17	1.33
2709	4.87	114	6.31	71	1.29	0.98
2710	6.80	100	6.05	80	.88	1.32
2711	6.50	148	7.81	82	1.20	1.70
2712	5.88	116	7.21	61	1.22	1.59
2713	5.79	114	10.21	139	1.76	1.24
2714	5.73	134	6.33	76	1.10	1.26
2715	5.86	84	6.45	107	1.10	1.35
2716	4.65	54	5.51	79	1.18	1.25
2717	5.90	126	7.44	112	1.26	1.21
2719	6.72	144	7.61	76	1.13	1.38
2720	5.94	75	6.01	81	1.01	1.36
2721	6.34	86	9.14	113	1.44	1.31
2722	4.98	69	5.84	88	1.17	1.26
2723	5.11	78	7.05	121	1.38	1.38
2726	5.75	208	5.70	84	.99	1.29
2727	5.65	121	8.05	26	1.42	1.45
2728	6.23	159	7.20	85	1.15	1.31
2729	6.09	161	7.82	79	1.28	1.33
2730	6.63	216	6.27	80	.95	1.47
Max	6.80	216	10.21	139	1.76	1.70
Min	4.65	54	5.51	26	0.88	0.98
Average	5.91	124.3	7.1	85.85	1.20	1.34

TABLE 8. Physical Data Subject Decelerations

6 G Series

Run Number	Chest G	Chest Onset G (G/sec)	Head G	Head Onset G (G/sec)	Head G / Chest G Ratio	Chest G / Sled G Ratio
2741	13.72	513	13.47	499	.98	1.63
2742	13.32	282	21.16	932	1.58	1.65
2743	11.41	188	13.60	255	1.19	1.53
2750	8.67	652	8.19	105	.94	1.26
2751	8.46	155	8.51	156	1.00	1.23
2752	10.94	251	10.21	395	.93	1.53
2753	9.85	375	9.10	411	.92	1.45
2754	10.58	172	9.66	110	.91	1.34
2755	10.07	261	13.48	324	1.34	1.58
2756	9.35	339	9.37	241	1.00	1.32
2760	6.07	670	6.92	40	1.14	1.06
2761	7.87	291	9.44	165	1.19	1.34
2762	7.97	546	10.45	356	1.31	1.33
2763	5.35	114	7.89	46	1.47	.88
2764	6.13	94	4.44	95	.72	1.06
2765	7.84	188	7.80	285	.99	1.27
2766	7.17	99	9.66	937	1.35	1.19
2767	8.31	377	11.73	354	1.41	1.34
2768	6.89	287	9.17	256	1.33	1.15
2771	7.13	219	7.56	113	1.06	1.16
Max	13.72	670	21.16	937	1.58	1.65
Min	5.35	94	4.44	40	0.72	0.88
Average	8.86	303.65	10.09	303.75	1.14	1.32

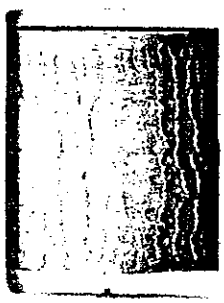


TABLE 9. Physical Data Subject Decelerations

8 G Series

Run Number	Chest G	Chest Onset G (G/sec)	Head G	Head Onset G (G/sec)	Head G / Chest G Ratio	Chest G / Sled G Ratio
2783	10.79	414	13.16	346	1.26	1.27
2784	12.17	269	11.39	321	.93	1.40
2785	14.31	499	14.46	239	1.01	1.52
2786	13.06	499	15.63	352	1.19	1.58
2787	13.58	363	23.10	1444	1.70	1.55
2788	11.06	1180	12.03	220	1.08	1.29
2789	9.92	553	14.90	373	1.50	1.19
2790	14.83	372	16.37	427	1.10	1.55
2791	12.26	868	18.91	391	1.54	1.32
2792	10.84	344	13.01	275	1.20	1.24
2793	14.13	453	24.78	651	1.75	1.58
2794	13.91	574	13.84	289	.99	1.61
2795	12.78	411	12.00	175	.94	1.38
2800	11.57	176	12.45	203	1.07	1.37
2801	13.32	403	9.55	84	.71	1.55
2802	9.40	140	12.55	120	1.33	1.22
2803	14.67	348	14.48	189	.99	1.58
2804	14.65	266	12.15	128	.82	1.52
2805	13.34	196	19.05	281	1.27	1.43
2806	13.50	236	16.71	194	1.24	1.50
2807	11.01	172	12.23	170	1.11	1.25
2808	10.61	150	14.33	193	1.35	1.27
2809	12.88	325	14.68	163	1.14	1.40
2810	13.51	230	14.91	149	1.10	1.56
2811	12.38	212	19.01	200	1.53	1.40
Max	14.83	1180	24.78	1444	1.75	1.61
Min	9.40	150	9.55	84	.71	1.19
Average	12.58	386.12	15.02	303.08	1.19	1.42

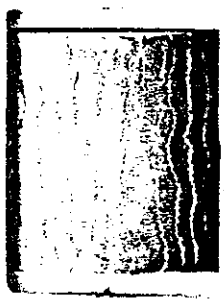


TABLE 11. Physical Data Subject Decelerations

12 G Series

Run Number	Chest G	Chest Onset G (G/sec)	Head G	Head Onset G (G/sec)	Head G / Chest G Ratio	Chest G / Sled G Ratio
3108	17.55	441	24.72	625	1.41	1.53
3109	26.71	800	18.63	1050	.71	2.28
Max	26.71	800	24.72	1050	1.41	2.28
Min	17.55	441	18.63	625	.71	1.53
Average	22.13	620.5	21.68	837.5	1.06	1.90

TABLE 12. Physical Position Data

4 G Series

Run Number	Torso Deflection (degrees)	Head Deflection (degrees)	Head-Torso Deflection (degrees)
2708	8	5	−3
2709	5	12	7
2710	7	18	11
2711	4	29	25
2712	5	34	29
2713	8	31	23
2714	3	22	19
2715	8	19	11
2716	11	10	−1
2717	2	12	10
2719	8	43	35
2720	6	17	11
2721	6	26	20
2722	0	32	32
2723	8	33	25
2726	9	13	4
2727	6	14	8
2728	6	19	13
2729	10	22	12
2730	8	32	24
Max	11	43	32
Min	0	5	−3
Average	6.4	22.15	15.75

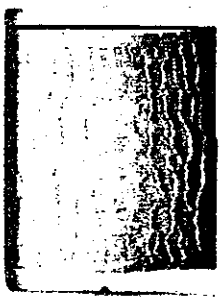
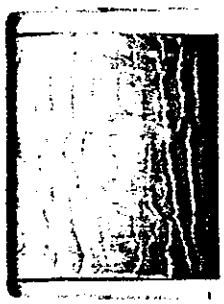


TABLE 10. Physical Data Subject Decelerations

10 G Series

Run Number	Chest G	Chest Onset G (G/sec)	Head G	Head Onset G (G/sec)	Head G / Chest G Ratio	Chest G / Sled G Ratio
3069	15.83	330	17.16	1597	1.08	1.65
3072	17.83	1042	14.84	1041	.83	1.72
3073	18.34	393	23.35	857	1.27	1.78
3074	19.83	554	17.68	615	.89	1.99
3075	14.92	855	26.23	1642	1.75	1.55
3076	15.80	412	18.80	516	1.18	1.59
3077	16.21	486	16.06	503	.99	1.60
3078	15.44	979	19.17	449	1.24	1.46
3079	23.15	517	17.08	210	1.35	2.01
3080	23.84	603	24.37	375	1.02	2.06
3081	16.71	470	15.72	295	.94	1.63
3082	19.97	294	21.42	602	1.07	1.76
3083	23.26	772	45.41	1239	1.95	1.91
3084	19.12	548	15.18	171	.79	1.76
3085	17.65	295	17.28	245	.97	1.71
3086	21.80	1200	18.08	476	.83	1.92
3087	17.10	279	17.12	485	1.00	1.75
3088	13.63	190	12.45	125	.91	1.44
3089	18.26	406	21.22	243	1.16	1.63
3090	22.59	378	18.82	237	.83	2.02
Max	23.84	1200	45.41	1642	1.95	2.06
Min	13.63	190	12.45	125	0.79	1.44
Average	18.56	550.15	19.87	596.15	1.10	1.75



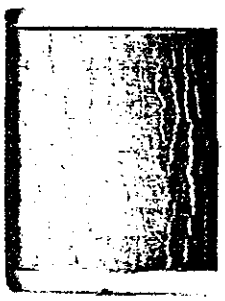


TABLE 13. Physical Position Data

6 G Series

Run Number	Torso Deflection (degrees)	Head Deflection (degrees)	Head-Torso Deflection (degrees)
2783	4	61	57
2784	11	56	45
2785	6	57	51
2786	2	14	12
2787	8	34	26
2788	−3	35	38
2789	0	22	22
2790	5	32	27
2791	5	24	19
2792	5	29	24
2793	4	29	25
2794	10	29	19
2795	3	29	26
2800			
2801	0	8	8
2802	1	33	32
2803	5	45	40
2804	2	29	27
2805	4	28	24
2806			
2807	11	61	57
2808	−3	8	8
2809	4	33	29
2810			
2811			
Max			
Min			
Average			

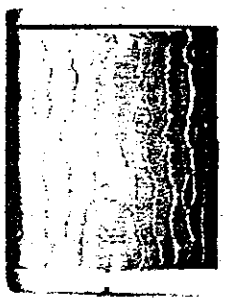


TABLE 14. Physical Position Data

8 G Series

Run Number	Torso Deflection (degrees)	Head Deflection (degrees)	Head-Torso Deflection (degrees)
2783	−5	32	37
2784	−1	43	44
2785	5	27	22
2786	3	41	38
2787	2	29	27
2788	4	34	30
2789	2	31	29
2790	3	45	42
2791	6	62	56
2792	1	36	35
2793	6	63	57
2794	1	22	21
2795	−1	14	15
2800	4	31	27
2801	1	20	19
2802	−2	31	33
2803	7	47	40
2804	7	26	19
2805	10	50	40
2806	2	31	29
2807	13	42	29
2808	5	29	24
2809	6	29	23
2810	1	45	44
2811	9	30	21
Max	13	62	57
Min	−5	22	19
Average	3.56	35.6	32.04

TABLE 15. Physical Position Data

10 G Series

Run Number	Torso Deflection (degrees)	Head Deflection (degrees)	Head-Torso Deflection (degrees)
3069	5	15	11
3072	1	19	18
3073	9	48	39
3074	3	43	40
3075	10	44	34
3076	4	44	40
3077	6	34	28
3078	3	34	31
3079	2	34	32
3080	4	46	42
3081	7	42	35
3082	4	34	30
3083	3	66	63
3084	5	30	25
3085	3	17	14
3086	8	59	51
3087	3	33	30
3088	10	28	18
3089	1	45	44
3090	0	41	41
Max	10	59	63
Min	0	15	11
Average	4.5	37.8	33.3

TABLE 16. Physical Position Data

12 G Series

Run Number	Torso Deflection (degrees)	Head Deflection (degrees)	Head-Torso Deflection (degrees)
3108	5	43	38

Only one data point available.

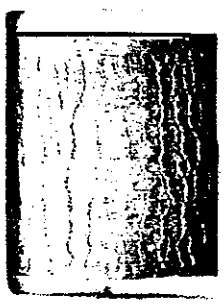
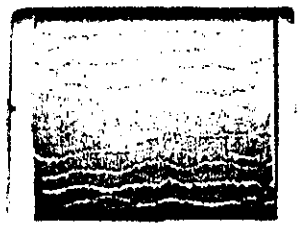


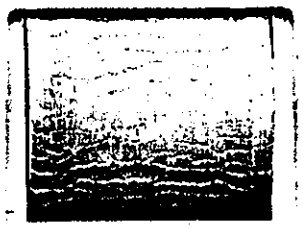
TABLE 17. Physiological Data

4 G Series

Run Number	Subject	Heart Rate (Beats/min.)					Blood Pressure (mm Hg)				
		Physical Examination		Experimental			Physical Examination		Experimental		
		Pre	Post	−20 sec	Impact	+20 sec	Pre	Post	−20 sec	Impact	+20 sec
2708	PF	76	72	90	120	108	122/82	114/74	175/75	150/70	165/70
2709	WCT	76	N/R*	98	103	100	114/70	N/R*	120/110	110/70	110/80
2710	CWH	96	88	95	110	109	118/74	112/70	160/80	120/60	130/70
2711	JHS	84	80	101	120	111	120/86	118/90	140/90	130/70	130/70
2712	KDH	76	96	106	120	120	128/88	126/88	150/90	140/90	140/90
2713	CHR	76	72	112	118	107	118/92	110/86	150/70	150/70	140/80
2714	JLP	72	80	75	103	103	116/90	126/94	150/110	135/60	140/90
2715	GWC	80	76	105	107	80	122/74	120/80	120/80	110/70	130/80
2716	YSF	92	88	97	95	85	132/90	118/84	140/85	115/70	120/100
2717	RWD	88	84	140	145	120	108/82	112/82	140/90	170/70	140/90
2719	LMS	88	84	125	175	155	118/76	112/76	135/80	140/70	150/95
2720	JDT	84	92	85	107	108	128/92	124/88	170/120	160/110	165/75
2721	GVA	68	80	106	118	92	106/64	104/58	165/100	150/60	120/80
2722	GAR	80	88	90	85	69	130/92	128/94	125/100	115/80	120/95
2723	GTB	84	92	118	130	117	132/84	130/84	150/105	120/80	150/60
2726	JLA	84	80	97	106	93	114/66	108/62	130/90	110/70	160/75
2727	CGO	92	104	115	130	147	106/76	108/82	130/100	120/70	110/70
2728	WKB	72	88	98	135	135	114/76	116/78	160/100	135/70	130/60
2729	JRB	100	88	148	165	160	112/74	118/78	130/80	120/70	110/70
2730	JHF	72	68	85	105	95	118/84	110/78	160/95	160/70	150/80
Max		100	104	148	175	160	132/92	130/94	175/120	170/110	165/95
Min		68	68	75	85	69	106/64	104/58	120/70	110/60	110/60
Average		82	84.2	104.3	119.4	110.7	118.8/81	116.4/80.3	145/92.5	133/72.5	135.5/79.0

* Not recorded.





Run Number	Subject	Heart Rate (Beats/min.)					Blood Pressure (mm Hg)				
		Physical Examination		Experimental			Physical Examination		Experimental		
		Pre	Post	−20 sec	Impact	+20 sec	Pre	Post	−20 sec	Impact	+20 sec
2741	BDL	72	84	104	110	106	122/80	118/76	140/90	140/70	150/90
2742	RGB	92	92	120	123	123	116/74	112/84	130/70	130/60	130/90
2743	JFH	92	92	118	140	121	118/68	106/72	N/R*	120/70	140/70
2750	CRA	80	84	117	160	145	114/84	118/84	130/80	130/80	130/80
2751	WDB	88	92	118	160	150	122/86	126/82	190/90	150/90	150/40
2752	LFC	88	92	108	145	130	112/78	118/70	120/90	110/70	160/40
2753	TJB	88	92	120	135	155	112/72	112/68	180/80	150/70	150/90
2754	FRT	92	104	145	175	160	114/76	116/64	160/40	160/50	150/60
2755	GEM	88	80	111	145	140	118/84	118/80	140/100	150/90	150/90
2756	MPA	112	88	150	180	160	116/88	124/82	N/R*	110/80	140/90
2760	GAG	88	N/R*	105	107	109	122/78	118/72	140/100	130/80	150/80
2761	CGO	92	100	113	115	125	116/78	122/80	150/110	130/70	130/90
2762	TES	96	100	116	115	145	114/72	108/70	160/100	150/90	140/90
2763	AAK	72	76	85	107	102	116/80	122/86	150/100	170/90	170/110
2764	MDR	76	72	106	120	120	118/84	118/76	190/110	180/80	170/90
2765	JSA	80	76	71	112	107	122/76	122/72	150/90	130/70	120/70
2766	JFE	88	96	116	150	145	110/76	109/72	160/90	190/70	140/90
2767	LMB	80	76	190	118	112	114/66	128/82	190/90	140/70	140/70
2768	RAH	84	92	94	105	95	128/78	136/78	130/80	110/70	130/70
2771	GHC	96	100	120	130	114	120/78	118/86	130/100	130/80	130/90
Max		112	104	190	180	160	128/88	136/86	190/110	190/90	170/90
Min		72	72	71	105	95	110/66	106/64	120/40	110/50	120/40
Average		87.2	88.8	116.4	132.6	128.2	117.2/77.8	118.5/76.8	152.2/89.4	140.5/75	143.5/79.5

* Not recorded.

TABLE 19. Physiological Data

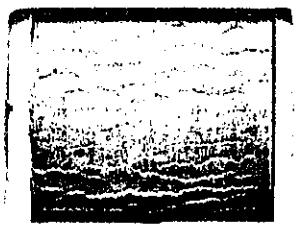


TABLE 19. Physiological Data

8 G Series

Run Number	Subject	Heart Rate (Beats/min.)					Blood Pressure (mm Hg)				
		Physical Examination		Experimental			Physical Examination		Experimental		
		Pre	Post	−20 sec	Impact	+20 sec	Pre	Post	−20 sec	Impact	+20 sec
2783	WNA	68	72	87	101	73	114/76	126/84	140/120	140/90	150/100
2784	JOE	72	92	130	94	112	126/88	122/86	130/110	110/80	170/80
2785	CAC	68	92	128	140	172	114/80	116/82	150/90	110/50	160/60
2786	WCT	76	72	101	105	106	116/82	112/84	N/R	130/70	140/80
2787	DNA	76	92	107	117	115	108/78	128/84	140/100	130/80	140/80
2788	JPW	68	76	94	95	105	130/88	122/84	160/90	N/R	130/70
2789	RWD	88	96	130	160	135	116/80	114/74	140/100	130/70	130/90
2790	JHS	80	92	135	155	130	116/84	124/86	190/90	150/70	160/90
2791	GVA	80	84	116	112	95	120/66	116/72	120/80	170/70	170/80
2792	GWC	76	76	110	105	97	116/78	118/82	150/90	110/70	N/R*
2793	JHF	68	68	82	115	107	118/82	122/82	160/90	140/70	170/90
2794	CWH	88	104	90	115	107	122/76	108/68	160/80	150/80	140/80
2795	JWR	88	84	86	108	112	108/72	108/80	160/80	130/80	140/70
2800	JLA	80	N/R*	101	105	100	114/80	N/R*	120/90	110/60	110/70
2801	JLP	92	80	100	150	120	122/84	128/88	140/100	190/70	200/80
2802	KDH	84	88	112	125	120	128/92	134/90	150/100	140/80	160/80
2803	LMS	92	76	130	140	116	118/76	114/76	140/90	120/60	130/80
2804	PF	80	76	103	118	106	112/72	110/80	150/90	150/70	150/70
2805	JDT	88	76	90	97	96	118/80	110/76	130/110	150/100	150/100
2806	TRT	72	84	67	57	64	106/64	104/62	130/90	110/60	130/80
2807	CAR	76	72	108	116	112	112/82	110/80	140/70	130/70	150/100
2808	YSF	100	88	112	109	90	128/80	128/96	150/110	190/80	170/110
2809	WCC	68	84	112	105	107	108/76	116/78	110/90	100/70	100/80
2810	RR	76	82	98	110	84	106/74	110/80	130/90	90/60	N/R*
2811	TWM	80	88	115	148	112	124/82	120/78	130/90	130/70	120/70
Max		100	104	135	160	172	130/92	134/96	190/120	190/100	200/110
Min		68	68	67	57	64	106/64	104/62	110/70	90/50	110/60
Average		79.4	83.1	105.8	116.1	107.7	116.8/78.9	117.5/80.5	142.5/93.3	133.8/72.1	145.7/82.6

* Not recorded.

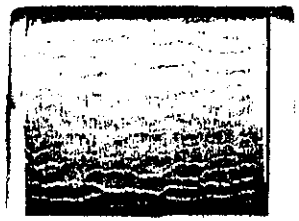
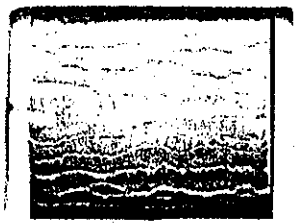


TABLE 20. Physiological Data

10 G Series

Run Number	Subject	Heart Rate (Beats/min.) Physical Examination Pre	Physical Examination Post	Experimental −20 sec	Experimental Impact	Experimental +20 sec	Blood Pressure (mm Hg) Physical Examination Pre	Physical Examination Post	Experimental −20 sec	Experimental Impact	Experimental +20 sec
3069	LFC	88	84	125	149	137	110/68	110/70	130/70	120/70	120/60
3072	JLA	72	72	114	120	122	112/68	100/70	110/70	120/70	100/70
3073	WCC	80	88	99	105	90	100/70	120/76	110/70	110/80	130/70
3074	JLP	68	72	94	118	108	120/80	110/80	120/80	N/R*	110/50
3075	AAK	84	76	100	116	120	120/82	120/80	140/80	N/R*	160/60
3076	JFH	68	80	89	114	99	120/76	110/64	140/80	N/R*	200/70
3077	MDR	68	70	100	100	64	120/74	130/80	170/100	170/90	160/80
3078	JLS	84	88	136	150	132	100/70	120/80	200/80	N/R*	N/R*
3079	LMS	76	80	140	167	146	100/64	100/62	N/R*	180/N/R*	190/70
3080	PF	76	60	71	114	95	106/70	100/74	170/100	170/80	120/60
3081	WDB	88	72	115	115	94	118/88	120/88	150/100	140/70	160/70
3082	RGB	88	80	125	140	136	118/70	110/60	180/90	N/R*	170/100
3083	JHS	84	68	115	136	107	110/70	100/76	150/70	140/70	140/70
3084	CRA	84	84	103	125	122	100/72	100/74	180/80	200/70	200/80
3085	JFE	88	100	136	161	148	112/70	120/70	140/80	180/70	180/60
3086	JRB	96	80	115	149	148	100/85	100/70	140/80	130/60	120/70
3087	GHC	80	72	125	152	137	120/84	120/80	120/90	110/70	110/80
3088	YSF	100	88	100	105	86	112/76	110/80	N/R*	N/R*	150/80
3089	LMB	88	82	110	152	133	100/64	100/60	160/90	N/R*	130/70
3090	PLC	76	80	94	132	110	120/80	118/78	150/100	140/80	190/90
Max		100	100	140	167	148	120/88	130/88	200/100	200/90	200/100
Min		68	60	71	100	64	100/64	100/60	110/70	110/60	110/50
Average		81.8	78.8	110.3	131.0	116.7	110.9/74.1	110.9/73.6	147.8/83.9	146.9/73.3	149.5/71.6

* Not recorded.



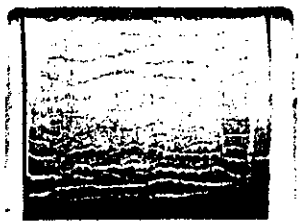


TABLE 21. Physiological Data

12 G Series

Run Number	Subject	Heart Rate (Beats/min.)					Blood Pressure (mm Hg)				
		Physical Examination		Experimental			Physical Examination		Experimental		
		Pre	Post	−20 sec	Impact	+20 sec	Pre	Post	20 sec	Impact	+20 sec
3108	JWP	72	84	110	113	99	120/86	114/70	120/90	100/60	120/60
3109	RR	72	78	75	93	80	110/78	104/72	100/90	N/R*	N/R*
Max		72	84	110	113	99	120/86	114/72	120/90	100/60	120/60
Min		72	78	75	93	80	110/78	104/70	100/90	100/60	120/60
Average		72	81	92.5	103	89.5	115/82	109/71	110/90	100/60	120/60

* Not recorded.