TECHNICAL REPORT

ISO TR 9790-6

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Road vehicles — Anthropomorphic side impact dummy —

Part 6 : Lateral pelvic impact response requirements to assess biofidelity of dummy

Véhicules routiers — Mannequin anthropomorphe pour essai de choc latéral — Partie 6 : Caractéristiques de réponse du bassin à un choc latéral permettant d'évaluer la biofidélité d'un mannequin

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Foreword

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The main task of ISO technical committees is to prepare International Standards. In exceptional circumstances a technical committee may propose the publication of a technical report of one of the following types:

- type 1, when the necessary support within the technical committee cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development requiring wider exposure;
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Technical reports are accepted for publication directly by ISO Council. Technical reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 9790-6, which is a technical report of type 3, was prepared by Technical Committee ISO/TC 22, *Road vehicles*.

ISO/TR 9790 consists of the following parts, under the general title *Road vehicles — Anthropomorphic side impact dummy*:

- *Part 1: Lateral head impact response requirements to assess biofidelity of dummy*
- *Part 2: Lateral neck impact response requirements to assess biofidelity of dummy*
- *Part 3: Lateral thoracic impact response requirements to assess biofidelity of dummy*
- *Part 4: Lateral shoulder impact response requirements to assess biofidelity of dummy*
- *Part 5: Lateral abdominal impact response requirements to assess biofidelity of dummy*
- *Part 6: Lateral pelvic impact response requirements to assess biofidelity of dummy*

Road vehicles — Anthropomorphic side impact dummy — Part 6 : Lateral pelvic impact response requirements to assess biofidelity of dummy

1.0 INTRODUCTION

The impact response requirements presented in this Technical Report are the result of a critical evaluation of data selected from experiments agreed to by experts as being the best and most up-to-date information available.

Three sets of lateral pelvic impact response requirements are defined. The first requirement is based on impactor tests of ONSER (1, 2, 3)*, the second is based on free fall cadaver tests of Association Peugeot-Renault (4) and the third set is based on cadaver sled tests of the University of Heidelberg (5). All cadaver data were normalized to be representative of the responses of the 50th percentile adult male using the method described by Mertz (6).

2.0 SCOPE AND FIELD OF APPLICATION

This Technical Report is one of six reports that describe laboratory test procedures and impact response requirements suitable for assessing the impact biofidelity of side impact dummies. This Technical Report provides information to assess the biofidelity of lateral pelvic impact response.

3.0 ISO REFERENCES

ISO DP 9790-1 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Head Impact Response Requirements to Assess the Biofidelity of the Dummy.

*Numbers in parentheses denote papers in References, Section 7.0.

ISO DP 9790-2 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Neck Impact Response Requirements to Assess the Biofidelity of the Dummy.

ISO DP 9790-3 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Thoracic Impact Response Requirements to Assess the Biofidelity of the Dummy.

ISO DP 9790-4 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Shoulder Impact Response Requirements to Assess the Biofidelity of the Dummy.

ISO DP 9790-5 Road Vehicles - Anthropomorphic Side Impact Dummy - Lateral Abdominal Impact Response Requirements to Assess the Biofidelity of the Dummy.

4.0 REQUIREMENT NO. 1

4.1 Original Data

Researchers of ONSER studied the response of 22 unembalmed cadavers to lateral impacts delivered to the greater trochanter (1, 2, 3)*. Pelvic acceleration was measured by an accelerometer attached to the posterior of the sacrum. The unbelted cadavers were seated without lateral support and impacts were delivered at various speeds by either a rigid or padded impactor. Forces and accelerations of the impactor were measured. Data from these tests are summarized in Appendix A.

4.2 Peak Impactor Force Requirements

The peak impactor forces were normalized (see Appendix A) using the technique suggested by Mertz (6). The normalized peak forces are plotted against their impact velocities in Figure 1. Also shown is the proposed response corridor for a 17.3 kg rigid impactor striking the greater trochanter region. For dummy impacts between 6 m/s and 10 m/s, the normalized peak impactor force should lie within the corridor.

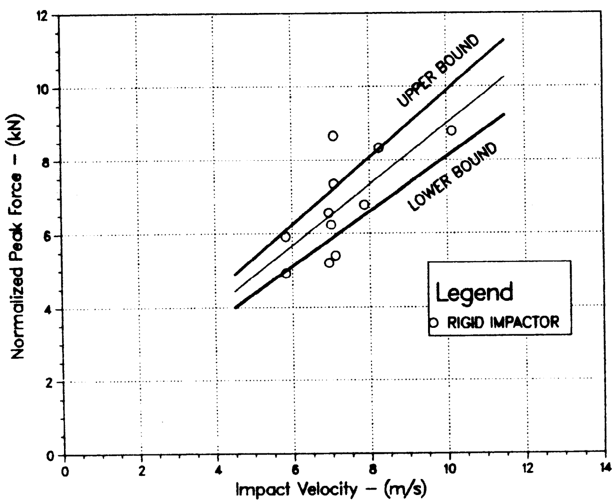

FIGURE 1. SCATTER PLOT OF IMPACT VELOCITY VERSUS NORMALIZED PEAK FORCE, LINEAR RELATIONSHIP BETWEEN IMPACT VELOCITY AND NORMALIZED PEAK FORCE, AND PROPOSED CORRIDOR FOR A 17.3 KG RIGID IMPACTOR STRIKING THE GREATER TROCHANTER REGION.

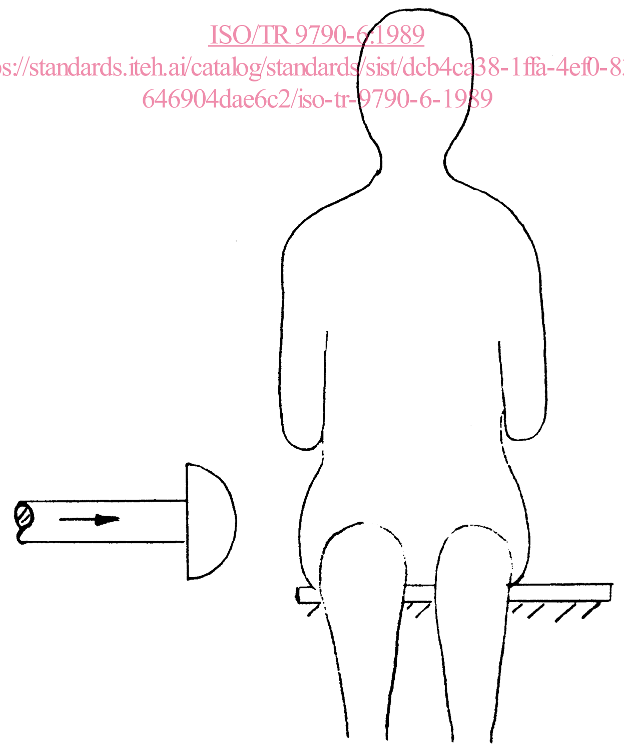

FIGURE 2. LATERAL PELVIC IMPACT TEST CONFIGURATION.

4.3 Test Setup

A 17.3 kg impactor with a rigid spherical segment impact face (R = 600 mm, r = 175 mm) is required. Seat the side impact dummy as shown in Figure 2 and adjust the impactor to strike the greater trochanter region at velocities between 6 m/s and 10 m/s.

4.4 Instrumentation

Instrument the side impact dummy to monitor acceleration of the pelvis. Provide force measurement capabilities for the impactor. Forces and accelerations are to be filtered using SAE Channel Class 1000.

4.5 Normalization Procedure

Determine the impulse by integrating the force-time curve.

The effective mass is defined by,

$$M_e = [\int_0^T F dt] / (V_o) \quad (1$$

where $\int_0^T F dt$ is the impulse and V_o is the initial impact velocity. The mass ratio is defined by,

$$R_m = 14.5\ kg/M_e \quad (2$$

Calculate the effective mass and mass ratio for each test.

It is assumed that the dummy has the same pelvic stiffness as the standard subject. Thus, the stiffness ratio, R_k, is equal to 1.

The normalizing factor for force is given by,

$$R_f = (R_m\ R_k)^{\frac{1}{2}} \quad (3$$

Normalize the peak force by multiplying it by its normalizing factor.

A dummy with reasonable response characteristics will have a normalized peak force that lies within the proposed response corridor.

5.0 REQUIREMENT NO. 2

5.1 Original Data

Researchers of the Association Peugeot-Renault studied the response of 26 unembalmed cadavers to lateral free falls onto either rigid or padded impact surfaces (4). Pelvic acceleration was measured by an accelerometer attached to the sacrum. The impact surfaces were positioned to impact with the pelvis and thorax. The cadavers were dropped from heights ranging from 0.5 to 3.0 meters. Data for these tests are summarized in Appendix B.

5.2 Peak Pelvic Acceleration Requirements

The peak pelvic acceleration values were normalized (see Appendix B) using the technique suggested by Mertz (6). Upper and lower bounds for peak normalized pelvic accelerations defined for each combination of drop height and impact surface stiffness are given in Table 1. Normalized peak pelvis acceleration of the dummy should lie within these bounds.

5.3 Test Setup

Suspend the dummy the required height above the impact targets with its sagittal plane horizontal. Use a "Quick Release" device to ensure that the dummy drops freely. Conduct the tests indicated in Table 1.

TABLE 1 - RESPONSE BOUNDS FOR PEAK NORMALIZED PELVIC ACCELERATION

Drop Height (m)	Impact Surface*	Average Normalized Peak Pelvic Acceleration (G)	Peak Normalized Acceleration Bounds	
			Lower (G)	Upper (G)
0.5	Rigid	41	37	45
1.0	Rigid	70	63	77
2	APR Pad	43	39	47
3	APR Pad	53	48	58

* Characteristics of the APR Pad are given in Appendix D.

5.4 Instrumentation

Instrument the dummy to monitor acceleration of the sacrum. Provide force measurement capabilities for the pelvic impact surface. Forces and accelerations are to be filtered using SAE Channel Class 180.

5.5 Normalization Procedure

The mass ratio, R_m, is calculated using the following equation:

$$R_m = 76 \text{ kg}/M_i \qquad (1$$

where M_i is the total body mass of the dummy. This is the same relationship that was used to analyze the cadaver data given in Appendix B.

It is assumed that the dummy has the same pelvic stiffness as the standard subject. Thus the stiffness ratio, R_k, is equal to 1.

The normalizing factor for acceleration is given by,

$$R_a = (R_k)^{\frac{1}{2}}(R_m)^{-\frac{1}{2}} \qquad (2$$

Normalize the peak acceleration value by multiplying it by its normalizing factor.

A dummy with reasonable response characteristics will have a normalized peak pelvic acceleration that lies within the proposed bounds given in Table 1.

6.0 REQUIREMENT NO. 3

6.1 Original Data

Researchers at the University of Heidelberg conducted two sled test series using unembalmed cadaver subjects (5). Rigid surface impacts were conducted at 23 km/h, 24 km/h and 32 km/h. Padded surface impacts were conducted at 32 km/h. Pelvic acceleration was measured in both test series. Impact force was measured only in the second test series. Data for both test series were provided by NHTSA who funded the studies. A summary of the data is given in Appendix C.

6.2 Peak Response Requirements

The peak acceleration and force data were normalized (see Appendix C). Data from tests with similar impact velocity and impact surface stiffness were grouped and average values of normalized peak pelvic acceleration and normalized peak impact force were calculated. These averages were used to define reasonable upper and lower bounds for these parameters. These response requirements are given in Table 2 along with their respective test conditions.

TABLE 2 - RESPONSE REQUIREMENTS FOR PEAK NORMALIZED PELVIC ACCELERATION AND PEAK NORMALIZED IMPACT FORCE

Impact Velocity (km/h)	Impact Surface	Normalized Peak Pelvic Acceleration Average (G)	Lower (G)	Upper (G)	Normalized Peak Impact Force Average (kN)	Lower (kN)	Upper (kN)
23.5	Rigid	70	63	77	7.1	6.4	7.8
32	Rigid	106	96	116	24.4	22.4	26.4
32	APR Pad	68	61	75	12.6	11.6	13.6

6.3 Test Setup

A seat with a force sensing side panel is to be secured to an impact sled, sideways to the direction of travel. The top edge of the side board is to be 540 mm above the seat plane. The surface of the seat is to have a low coefficient of friction to assure that the dummy will translate relative to the seat without rotating. The dummy is to be placed on the seat at a sufficient distance from the side board to assure that the sled is completely stopped prior to impact. For padding tests, 140 mm x 140 mm blocks of APR open cell urethane foam are to be fastened to the thorax and pelvis impact surfaces. Characteristics of APR padding are given in Appendix D.

6.4 Instrumentation

The dummy is to be instrumented to measure pelvis acceleration. An inertia compensated load transducer is to be attached to the side board to measure pelvic force. Force and acceleration measurements are to meet SAE Channel Class 1000 filter requirements. For comparison to the biomechanical response requirements of Table 2, the data must be filtered using a 100 Hz FIR filter (5).

6.5 Normalization Procedure

The mass ratio, R_m, is calculated using the following Equation:

$$R_m = 76\ \text{kg}/M_i \qquad (1$$

where M_i is the total body mass of the dummy. This is the same relationship that was used to analyze the cadaver data given in Appendix C.

It is assumed that the dummy has the same pelvic stiffness as the standard subject. Thus, the stiffness ratio, R_k, is equal to 1.

The normalizing factors for force and acceleration are given by,

$$R_f = (R_m\ R_k)^{\frac{1}{2}} \qquad (2$$

$$R_a = (R_k)^{\frac{1}{2}}(R_m)^{-\frac{1}{2}} \qquad (3$$

Normalize the peak force value by multiplying it by its normalizing factor. Normalize the peak acceleration value by multiplying it by its normalizing factor.

A dummy with reasonable response characteristics will have normalized peak force and normalized peak acceleration values that lie within the proposed response bounds defined in Table 2.

7.0 REFERENCES

1. Cesari, D., Ramet, M., and Clair, P., "Evaluation of Pelvic Fracture Tolerance in Side Impact", SAE 801306, Twenty-Fourth Stapp Car Crash Conference, Oct. 1980.

2. Cesari, D. and Ramet, M., "Pelvic Tolerance and Protection Criteria in Side Impact", SAE 821159, Twenty-Sixth Stapp Car Crash Conference, Oct. 1982.

3. Cesari, D., Ramet, M., and Bouquet, R., "Tolerance of Human Pelvis to Fracture and Proposed Pelvic Protection Criterion to be Measured on Side Impact Dummies", Ninth International Technical Conference on Experimental Safety Vehicles, Nov. 1982.

4. Tarriere, C., Walfisch, G., Fayon, A., Rosey, J., Got, C., Patel, A., Delmas, A., "Synthesis of Human Tolerances Obtained from Lateral Impact Simulations", Seventh International Technical Conference on Experimental Safety Vehicles, June 1979.

5. Kallieris, D., Mattern, R., Schmidt, G., and Eppinger, R., "Quantification of Side Impact Responses and Injuries", SAE 811008, Twenty-Fifth Stapp Car Crash Conference, Sept. 1981.

6. Mertz, H. J., "A Procedure for Normalizing Impact Response Data", SAE 840884, Warrendale, PA, May 1984.

APPENDIX A

ANALYSIS OF ONSER LATERAL PELVIC IMPACT DATA

This appendix describes the application of the normalization techniques of Mertz (6) to the lateral pelvic impact data provided by ONSER (1, 2, 3).

A.1 Original Data

Researchers of ONSER studied the response of 22 unembalmed cadavers to lateral impacts delivered to the greater trochanter. Pelvic strains were measured by 3 strain gages on the internal face of the ileal wing and 1 strain gage on the ileo-pubic ramus (3). Pelvic acceleration was measured by an accelerometer attached to the posterior of the sacrum. The unbelted cadavers were seated without lateral support, as shown in Figure 1. Lateral impacts were delivered at known speeds by a 17.3 kg rigid or padded impactor. The impact surface of the rigid impactor was a segment of a sphere (R = 600 mm, r = 175 mm). The padded surface was a polyurethane block. Forces and accelerations of the impactor were measured. Each cadaver was impacted at increasing speeds until pelvic fracture was diagnosed by X-ray or external examination (2).

The mass and height of cadavers struck by the rigid impactor are summarized in Table 1. The impact velocity, peak force, and impulse of the first impact to each cadaver are also given. Only results where data for the first impact were given and the cadavers had acceptable bone condition were analyzed.