TECHNICAL REPORT

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Road vehicles — Pedestrian protection — Targets for the assessment of the biofidelity of pedestrian-leg test devices

Véhicules routiers — Protection des piétons — Objectifs pour évaluer la biofidélité des dispositifs d'essai de la jambe du piéton

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Foreword

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ISO/TR 15766 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 12, *Restraint systems.*

Introduction

The impact-response targets 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.

Road vehicles — Pedestrian protection — Targets for the assessment of the biofidelity of pedestrian-leg test devices

1 Scope

This Technical Report describes laboratory-test procedures and impact-response targets for the assessment of the impact biofidelity of thigh, knee and leg test devices and mathematical models used in pedestrian-protection studies.

The targets apply to impacts to either the inside (medial) or outside (lateral) surfaces of the leg.

2 Biomechanical studies

Four types of tests are specified for assessing the biofidelity of pedestrian leg-test devices: two lateral knee-bending tests conducted at 15 km/h and 20 km/h (see clause 3), a lateral knee-shear test conducted at 15 km/h (clause 4), a lateral knee-impact test conducted at 2,6 m/s (clause 5), and a static lateral knee-stiffness test (clause 6). The targets for the lateral knee-bending and -shear tests are based on cadaver tests conducted at INRETS in Marseilles, in cooperation with Chalmers University of Technology, Sweden. Six legs were used to define the 15 km/h knee-bending guideline, eight for the 20 km/h knee-bending guideline, and five for the 15 km/h knee-shear guideline. The cadaver test results are reported in two IRCOBI papers by Kajzer *et al.* [1], [2][1)]. The target for the lateral knee-impact test is based on the results of tests on 12 cadaver legs reported by Levine *et al.* [3]. The lateral knee-stiffness target is based on static-load-versus-deflection tests using 13 legs reported by Van Hoeck [4].

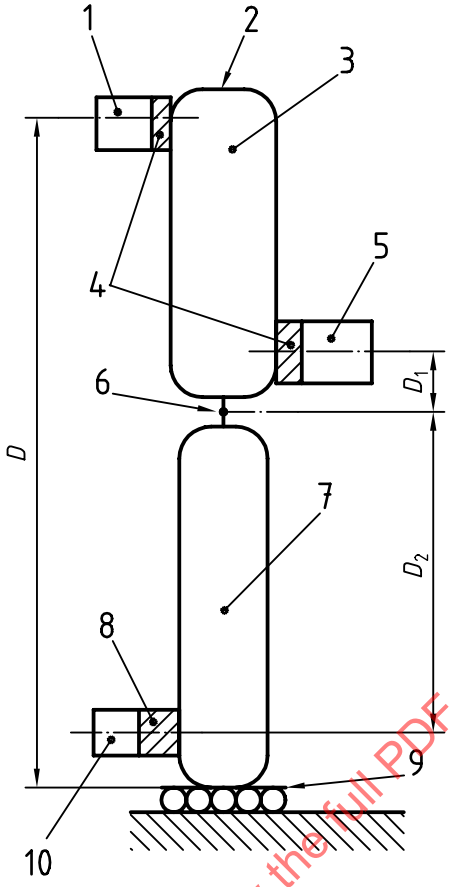
The following word of caution should be kept in mind when assessing the biofidelity of a test device based on the lateral knee-bending, -shear and -stiffness guidelines. In order for the biofidelity descriptions to be complete in respect of lateral knee-bending and -shear, data is required for the change in angle between the longitudinal axes of tibia and femur known as the valgus angle (see Figure 6), as well as for tibia-to-femur displacement. In addition, it should be noted that the lateral knee-stiffness guideline is based on static-load-versus-deflection data, and that dynamic-stiffness data are needed to complete it.

3 Lateral knee-bending tests

3.1 Test setup

The lateral-knee-bending test setup is shown in Figure 1.

1) The numbers between square brackets refer to the bibliography.



Key

1 Lateral support
2 40 kg preload
3 Thigh
4 Support blocks of 25 mm-thick, rigid polystyrene foam
5 Medial support
6 Knee joint
7 Leg
8 Impactor block of 50 mm-thick, rigid polystyrene foam
9 Low-friction mobile plate
10 Impactor

Figure 1 — Lateral-knee-bending test setup

3.2 Impactor characteristics

The impactor characteristics of the lateral-knee-bending test setup are:

— 40 kg mass

— rectilinear-motion constraint

— impactor face measuring 50 mm × 150 mm

— block of rigid polystyrene foam[2)] measuring 50 mm × 50 mm × 150 mm (see element 8 in Figure 1).

2) Styrodur is an example of a suitable product available commercially. This information is given for the convenience of users of this Technical Report and does not constitute an endorsement by ISO of this product.

3.3 Support blocks

The full dimensions of the rigid polystyrene foam support blocks (see element 4 in Figure 1) used in this test setup:

25 mm × 50 mm × 150 mm.

3.4 Test apparatus dimensions

The dimensions of the lateral-knee-bending test apparatus (Figure 1) are:

D = 904 mm, D_1 = 74 mm, D_2 = 400 mm

3.5 Measurements

The following measurements are made in this test:

— impactor acceleration, a_y (CFC 180); calculate impactor force, $F_y = a_y \times 40$ kg;

— impactor velocity at time of impact;

— medial support load $F_{\text{knee},\,y}$ (CFC 180).

NOTE CFC: chemical frequency class, as defined in ISO 6487 [5].

3.6 Biofidelity targets

3.6.1 Impact at 15 km/h

For a lateral knee-bending test with an impact of 15 km/h, the impactor force should be within the corridor shown in Figure 2.

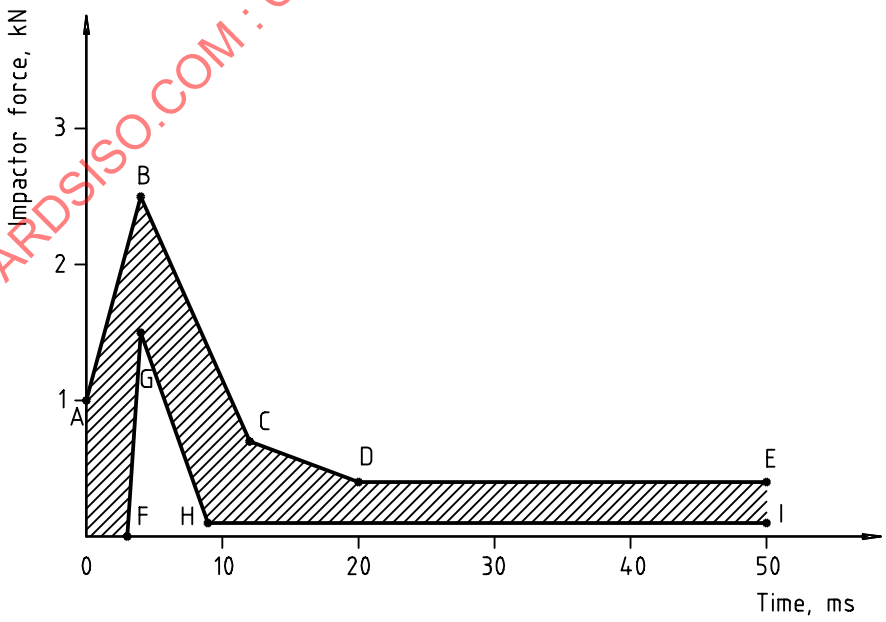


Figure 2 — Lateral knee-bending test: 15 km/h corridor

The coordinates for this corridor are presented in Table 1.

Table 1 — Lateral knee-bending test: 15 km/h corridor

Coordinates (ms; kN)			
A	(0; 1,0)	F	(3; 0,0)
B	(4; 2,5)	G	(4; 1,5)
C	(12; 0,7)	H	(9; 0,1)
D	(20; 0,4)	I	(50; 0,1)
E	(50; 0,4)		

3.6.2 Impact at 20 km/h

For a lateral knee-bending test with a 20 km/h impact, the impactor force should be within the corridor shown in Figure 3.

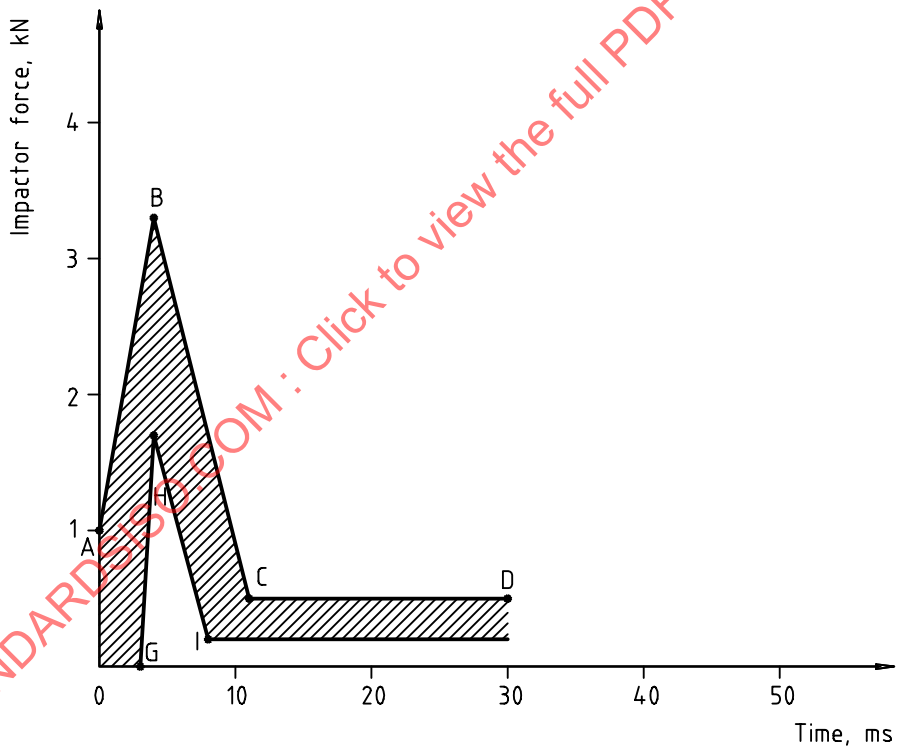


Figure 3 — Lateral knee-bending test: 20 km/h corridor

The coordinates for this corridor are presented in Table 2.

Table 2 — Lateral knee-bending test: 20 km/h corridor

Coordinates (ms; kN)			
A	(0; 1,0)	G	(3; 0,0)
B	(4; 3,3)	H	(4; 1,7)
C	(11; 0,5)	I	(8; 0,2)
D	(30; 0,5)		

3.7 Comments concerning lateral knee-bending test

The characteristics of the polystyrene-foam blocks used in the test are presented in annex A.

Use new blocks for each test.

4 Lateral knee-shear test

4.1 Test setup

The lateral-knee-shear test setup is shown in Figure 4.

4.2 Impactor characteristics

The impactor characteristics for the lateral knee-shear test are:

— 40 kg mass

— rectilinear-motion constraint

— impactor face measuring 50 mm × 150 mm

— Rigid, polystyrene-foam block measuring 50 mm × 50 mm × 150 mm.

4.3 Support blocks

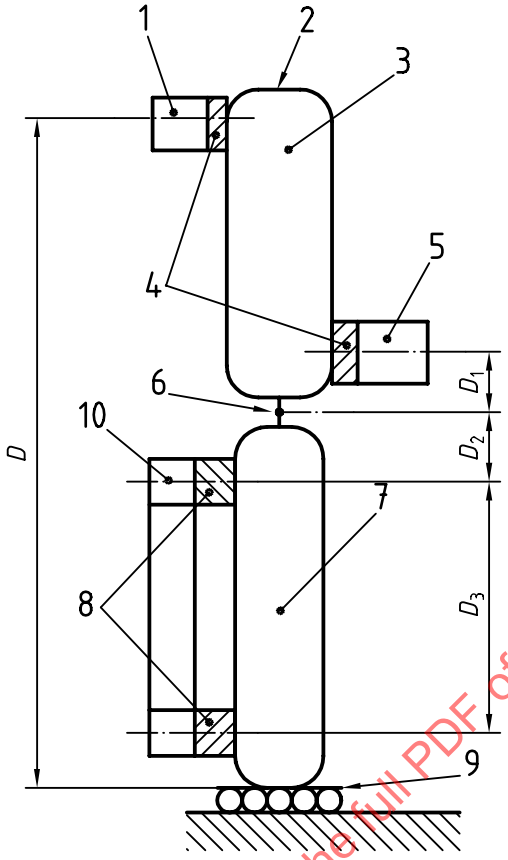
The full dimensions of the polystyrene-foam support blocks (see element 4 in Figure 4) used in this test setup:

25 mm × 50 mm × 150 mm

4.4 Dimensions of the test-setup apparatus

The dimensions of the lateral-knee-shear test apparatus (Figure 4) are:

D = 874 mm, D_1 = D_2 = 45 mm, D_3 = 400 mm



Key

1	Lateral support	6	Knee joint
2	40 kg preload	7	Leg
3	Thigh	8	Impactor block of 50 mm-thick, rigid polystyrene foam
4	Support blocks of 25 mm-thick, rigid polystyrene foam	9	Low-friction mobile plate
5	Medial support	10	Impactor

Figure 4 — Lateral-knee-shear test setup

4.5 Measurements

The following measurements are made in this test:

— impactor acceleration, a_y (CFC 180); calculate impactor force, $F_y = a_y \times 40$ kg;

— impactor velocity at moment of impact;

— medial support load $F_{\text{knee},\,y}$ (CFC 180).

4.6 Biofidelity targets

The lateral knee-shear test is performed with an impact of 15 km/h: the impactor force should be within the corridor shown in Figure 5.

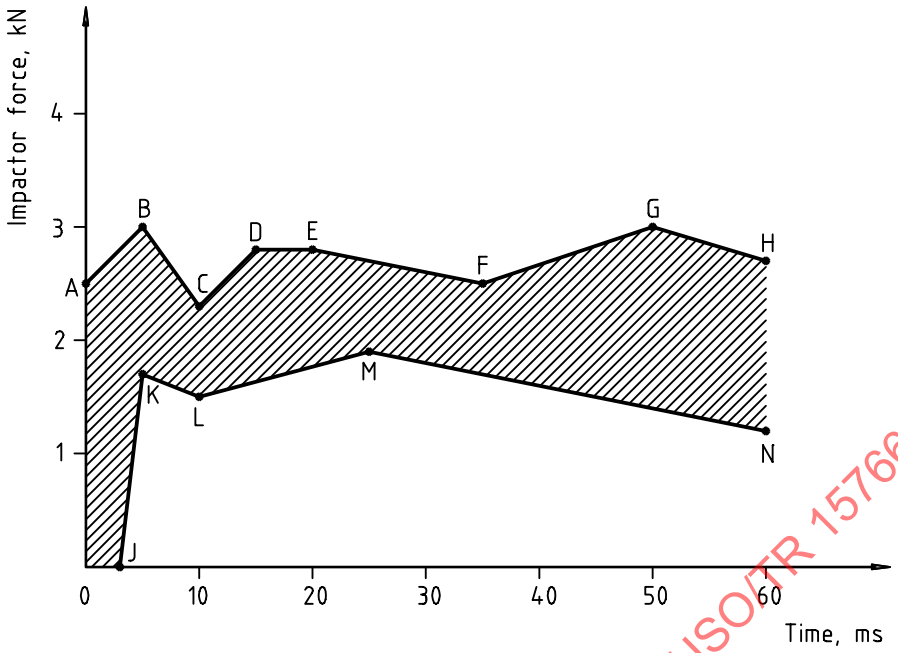


Figure 5 — Lateral knee-shear-test: 15 km/h corridor

The corridor coordinates for this test are presented in Table 3.

Table 3 — Lateral knee-shear-test: 15 km/h corridor

Coordinates (ms; kN)					
A	(0; 2,5)	F	(35; 2,5)	K	(5; 1,7)
B	(5; 3,0)	G	(50; 3,0)	L	(10; 1,5)
C	(10; 2,3)	H	(60; 2,7)	M	(25; 1,9)
D	(15; 2,8)	J	(3; 0,0)	N	(60; 1,2)
E	(20; 2,8)				

4.7 Comments concerning lateral knee-shear test

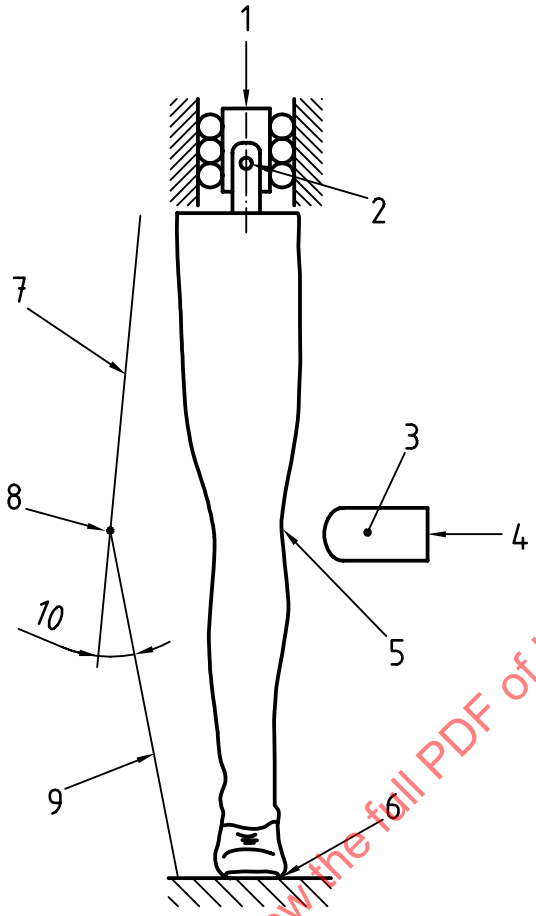
The characteristics of the polystyrene-foam blocks used in this test are presented in annex A.

Use new blocks for each test.

5 Lateral knee-impact test

5.1 Test setup

The lateral-knee-impact test setup is shown in Figure 6.



Key

1 Static preload: 860 N
2 Leg pinned at H-point level and free to translate vertically
3 Free mass impactor, 74 kg radius of impact surface: 150 mm
4 v = 2,6 m/s
5 Impact to lateral aspect of knee joint
6 Frictional coefficient μ = 0,35 to 0,45
7 Femur
8 Knee
9 Tibia
10 Valgus angle, θ

Figure 6 — Lateral-knee-impact test setup

5.2 Measurements

The following measurements are made in this test:

— impactor acceleration, a_y, calculate knee impact force, $F_y = a_y \times 74$ kg;

— valgus angle, θ (film analysis).

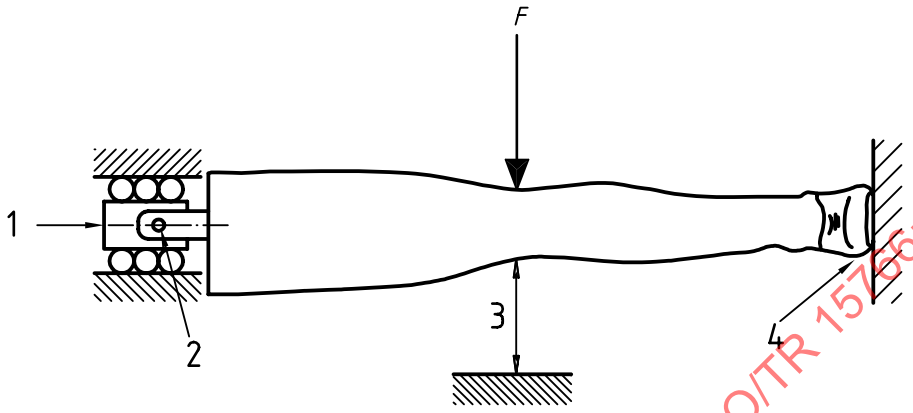
5.3 Biofidelity targets

For an impact of 2,6 m/s, the maximum knee-impact force should be between 1,2 kN and 1,5 kN, while the maximum valgus angle should be between 25° and 31°.

6 Lateral knee-stiffness test

6.1 Test setup

The lateral-knee-stiffness test setup is shown in Figure 7.



Key

1 Preload: 350 N
2 Leg free to rotate and translate
3 Fixed shoe
4 Medial knee deflection

NOTE Loading rate: 100 mm/s

Figure 7 — Lateral-knee-stiffness test setup

6.2 End constraints

The shoe is fixed to a rigid support plate.

The thigh is pinned at the H-point level and is free to translate along its axis.

6.3 Measurements

The following measurements are made in this test:

— lateral knee load, F (see Figure 7);

— medial knee deflection, δ.

6.4 Biofidelity target

At a medial knee deflection of 25 mm, the knee stiffness ($K = F/\delta$) should be between 4,0 N/mm and 4,5 N/mm.

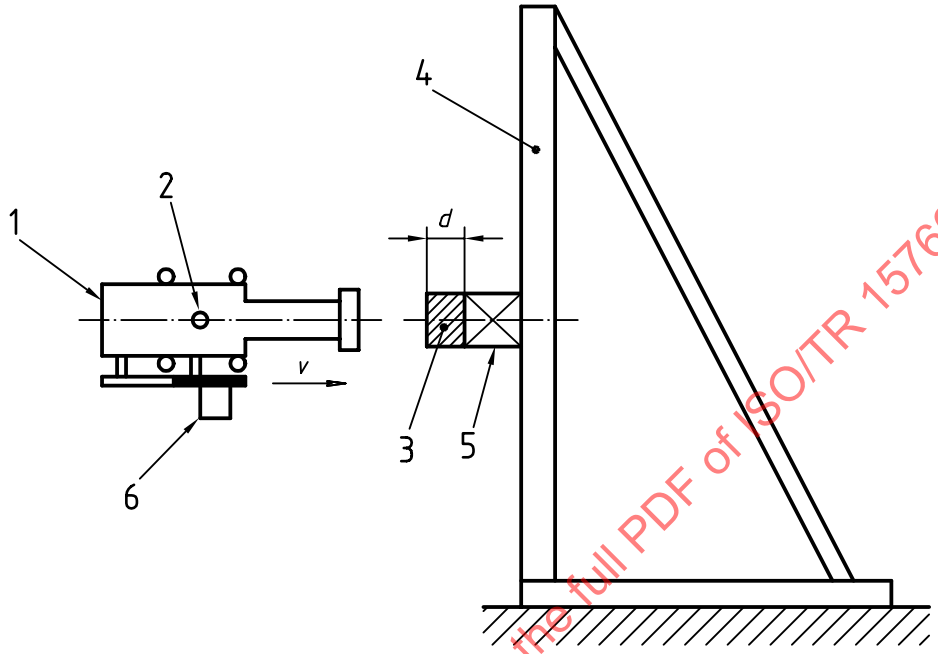
6.5 Comments concerning lateral knee-stiffness test

The leg may be mounted either vertically or horizontally for testing.

The knee loading surface should be concave with a width of 25 mm and a length sufficient to span the knee. The edges should be rounded to assure central loading.

Annex A

Characteristics of the polystyrene-foam blocks



Key

1 Impactor (6,29 kg)
2 Accelerometer
3 Test piece (d × 50 mm × 50 mm)
4 Rigid frame
5 Load cell
6 Magnetic sensor for velocity and displacement

Figure A.1 – Polystyrene-foam-block test setup