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(R) Performance Specifications for a Midsize Male Pedestrian Research Dummy

RATIONALE

Evaluating the biofidelity of pedestrian dummies is crucial to ensure the validity of research results obtained using such dummies. This Information Report provides performance specifications for a pedestrian dummy at both the component and full-scale assembly levels. While a previous version of the Information Report (SAE J2782_201010) provided performance requirements for a research pedestrian dummy, the requirements for both the thigh and leg components have been recently modified to more accurately represent vehicle-pedestrian interactions. Additionally, internal biofidelity requirements for the pelvis have also been specified in order to further ensure biofidelic response of the pelvis. Furthermore, requirements for whole-body trajectories and head velocity have also been defined to quantify interaction with the generic buck specified in the Information Report SAE J3093.

FOREWORD

Worldwide, vehicle impacts with pedestrians constitute the most frequent cause of traffic-related fatalities. As a result, knowledge about pedestrian crashes is essential to the reduction of fatalities and injuries for these "vulnerable road users" (see definitions). Currently available tools and methods for studying pedestrian casualties include statistical databases, component testing, and computer simulations. While currently in limited use, full-scale vehicle tests with a pedestrian crash-test dummy are an essential component for understanding the motions and sequence of body component impacts which lead to pedestrian trauma and for developing appropriate countermeasures. Possible uses for such a dummy could include the:

- Study of pedestrian kinematics
- Facilitation of crash reconstruction techniques including pedestrian kinematics
- Assessment of injury risk probabilities for given vehicle, crash, and countermeasure combinations
- Design of pedestrian protection systems
- Evaluation of active systems (pop-up hoods, airbags, etc.)
- Refinement of component test parameters and procedures
- Validation of computer simulations

NOTE: This SAE document is intended as a guide toward standard practice and is subject to change to keep pace with experience and technical advances.

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1. SCOPE

While it is recognized that collisions involve pedestrians of all sizes, this Information Report addresses performance specifications for a midsize adult male research dummy. This approach stems from the greater knowledge of biomechanics and existing dummy technologies for the midsize male relative to other adult sizes and children. While not the initial objective, it is envisioned that additional performance specifications for other sizes of pedestrian research dummies will be developed in the future based on accepted scaling procedures.

The specific requirements for the pedestrian dummy have been based on a collective assessment of pedestrian injury, response, and anthropometry priorities from the experimental, epidemiologic, and computational literature. In general, the objective was to specify performance specifications based on human characteristics and the impact response of post-mortem human subjects rather than to specify the design of a particular physical device.

Based on the perceived applications for a research pedestrian dummy, the primary focus of this document centered on biofidelic whole-body kinematics during a vehicle-pedestrian impact. Specific body regions were prioritized (see A.1.5) based on a combination of pedestrian injury, including both severity and frequency. Based on the priorities established by a review committee, the specifications provided in this document include both mandatory and recommended requirements as indicated by the terms “shall” and “should,” respectively. As pedestrian injury trends and dummy hardware continue to evolve in the future, it is anticipated that this document will expand to include more mandatory requirements in more body regions.

Finally, it should be noted that the test procedures described in this document only apply to the specific tests required to assess pedestrian dummy biofidelity. It is anticipated that pedestrian dummies meeting the performance criteria of this document will be used in a wide variety of tests, requiring specialized test and data procedures.

1.1 Purpose

This document specifies the performance requirements for a midsize adult male pedestrian dummy that can be used to study pedestrian-vehicle interactions.

2. REFERENCES

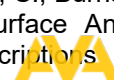
2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J211-1	Instrumentation for Impact Test - Part 1 - Electronic Instrumentation
SAE J1733	Sign Convention for Vehicle Crash Testing
SAE J2570	Performance Specifications for Anthropomorphic Test Device Transducers
SAE J2868	Pedestrian Dummy Full Scale Test Results and Resource Materials
SAE J3093	Design and Performance Specifications for a Generic Buck used in the Assessment of Pedestrian Dummy Whole Body Impact Response
SAE CAESAR	Harrison, C. R., Robinette, K. M., (2002), Summary Statistics for the Adult Population (Ages 18-65) of the United States of America, Interim Report: AFRL-HE-WP-TR-2002-0170
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Documents

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2.1.2 Government Publications

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- | | |
|---------------------|--|
| ISO 13232-4 | Motorcycles—Test and Analysis Procedures for Research Evaluation of Rider Crash Protective Devices Fitted to Motorcycles—Part 4: Variables to be Measured, Instrumentation, and Measurement Procedures |
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2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

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Pritz, H., "Comparison of the Dynamic Responses of Anthropomorphic Test Devices and Human Anatomic Specimens in Experimental Pedestrian Impacts," SAE Technical Paper 780894, 1978, <https://doi.org/10.4271/780894>

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2.2.3 ESV Publications

Available from NHTSA, National Highway Traffic Safety Administration, 1200 New Jersey Avenue, SE, West Building, Washington, D.C. 20590, USA, www.nhtsa.gov.

Detweiler, D. T., Miller, R. A., (2001), Development of a Sport Utility Front Bumper System for Pedestrian Safety and 5 mph Impact Performance, Proceedings of the 17th International Technical Conference on the Enhanced Safety of Vehicles, ESV 145-W

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2.2.4 IRCOBI Publications

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2.2.5 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41-22-749-01-11, www.iso.org.

ISO-15830:2005(E) Road Vehicles - Design and Performance Specifications for the WorldSID 50th Percentile Male Side Impact Dummy

2.2.6 SAFE Publication

Available from SAFE Association, P.O. Box 130, Creswell, OR 97426-0130, Tel: 541-895-3012, www.safeassociation.com.

White, R., Rangarajan, N., Haffner, M., Development of the THOR Advanced Frontal Crash Test Dummy, Proceedings of the 34th SAFE Association Annual Symposium, 1996, pp. 122-135

2.2.7 Other Publications

Ballesteros, M. F., Dischinger, P. C., Langenberg, P. (2004), Pedestrian Injuries and Vehicle Type in Maryland, 1995-1999. Accident Analysis and Prevention 36(1), pp. 73-81

Chandler, R. F., Clauser, C. E., McConville, J. T., Reynolds, H. M., Young, J. W., March 1975, Investigation of Inertial Properties of the Human Body, AMRL-TR-74-137

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3. DEFINITIONS

ARM: That portion of the upper extremity from the shoulder to the elbow.

FOREARM: That portion of the upper extremity from the elbow to the wrist.

HAND: That portion of the upper extremity from the wrist to the finger tips.

THIGH: That portion of the lower extremity from the hip to the knee.

LEG: That portion of the lower extremity from the knee to the ankle.

FOOT: That portion of the lower extremity from the ankle to the end of the toes.

SHALL: Used to denote specifications, performances, or requirements which must be met in order to comply with this Information Report.

SHOULD: Used to denote specifications, performances, or requirements which are recommended, but failure to comply does not constitute a failure to comply with the Information Report.

VALGUS BENDING: Bending about the fore-aft dummy axis (x).

STUB ARM: An upper extremity terminated at or proximal to the elbow (i.e., does not include the forearm and the hand).

VULNERABLE ROAD USERS: Terminology used in Global Technical Regulations, European Union regulations, and commonly used in the field of safety research (refer to ESV session guide) to describe pedestrians and the lightly protected road users.

XVERSION: Inversion: lift the medial side of the foot; Eversion: lift the lateral side of the foot.

4. SYMBOLS, SUBSCRIPTS, AND ABBREVIATIONS

4.1 Abbreviations

A(x,y,z)	Acceleration with direction noted by subscript
ATD	Anthropomorphic test dummy
AMVO	Anthropometry for Motor Vehicle Occupants Database as established by UMTRI-83-53-1 as listed in 2.1.8
ANSUR	1988 Anthropometric Survey of U.S. Army Personnel as listed in 2.2.2
C1, C2, etc.	Cervical vertebrae number 1, 2, etc.
CAESAR	Civilian American and European Surface Anthropometry Resource as listed in 2.1.1
CARE	Community database on accidents on the roads in Europe
c.g.	Center of gravity
CFR	Code of Federal Regulations
CV	Coefficient of variation defined as the standard deviation divided by the average
DAS	Data acquisition system, normally consisting of sensors, signal conditioning, and recorders
ESV	Conference on the Enhanced Safety of Vehicles
FMVSS	Federal Motor Vehicle Safety Standard
FPS	Frames per second
ICRASH	International Journal of Crashworthiness
IRCOBI	International Research Council on the Biomechanics of Impact
ISB	International Society of Biomechanics
ISO	International Organization for Standardization
LVDT	Linear variable differential transducer
M(x,y,z)	Moment with direction noted by subscript
MHD	Magnetohydrodynamic sensor used to measure angular velocity
NASA	National Aeronautics and Space Administration
NHTSA	National Highway Traffic Safety Administration

NPA	National Police Agency of Japan
PMHS	Post-mortem human subject (i.e., cadaver)
SAFE	Survival and Flight Equipment Association
THOR	Test Device for Human Occupant Restraint, an advanced frontal crash test dummy developed by NHTSA beginning in the 1990s
UMTRI	University of Michigan Transportation Research Institute

4.2 Symbols

4.2.1 Vehicle Reference System (fixed with respect to the moving vehicle) (6.9.4.1.2)

x Positive motions are forward with respect to the car

z Positive motions are down

V_r Resultant velocity in the vehicle reference system xz plane

4.2.2 Dummy Positioning Reference System (6.9.3) per SAE J211-1

X + forward from dummy

Y + right from dummy

Z + down

4.2.3 Imager Frame Reference System (6.9.4.1.2)

x_F + left in the image (assuming the image is of the left side of the car and the rear of the dummy)

z_F + down in the image

5. REQUIREMENTS

5.1 Head

5.1.1 Geometric and Mass Characteristics

5.1.1.1 Geometric Properties

The midsize male dummy head external dimensions should be approximately the midsize male head dimensions documented in AMVO (AMVO Table I.4) and shown in Figure 1, and the average of the values documented in CAESAR and ANSUR and shown in Figures 2, 3, and 4.

5.1.1.2 Mass

Based on AMVO (AMVO Table 5.8) the midsize male head mass should be $4.1 \text{ kg} \pm 0.2 \text{ kg}$.

5.1.2 Head Biofidelity

When tested per 6.1 the head shall meet performance criteria set for frontal and lateral impact requirements as defined in 5.1.2.1 and 5.1.2.2, respectively.

5.1.2.1 Frontal Drop Test

The disarticulated head shall meet frontal drop test performance criteria set out by NHTSA in 49 CFR 572.32 [October 1, 2006].

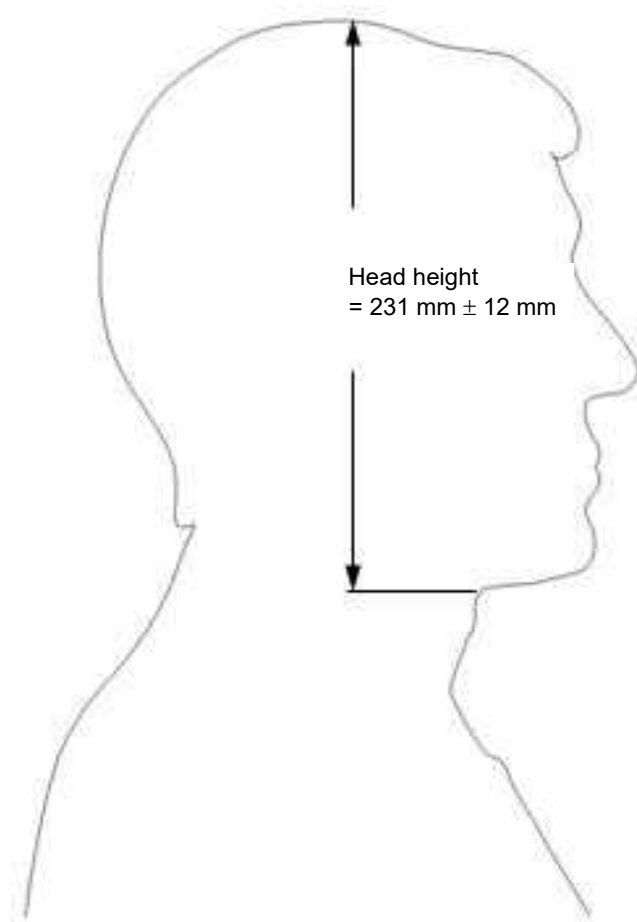


Figure 1 - Head height

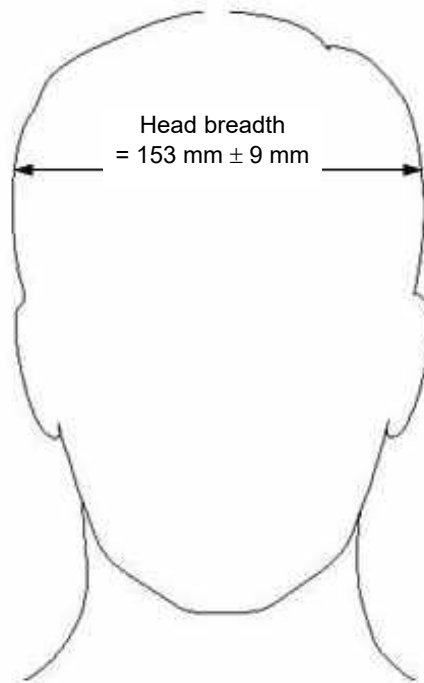


Figure 2 - Head breadth

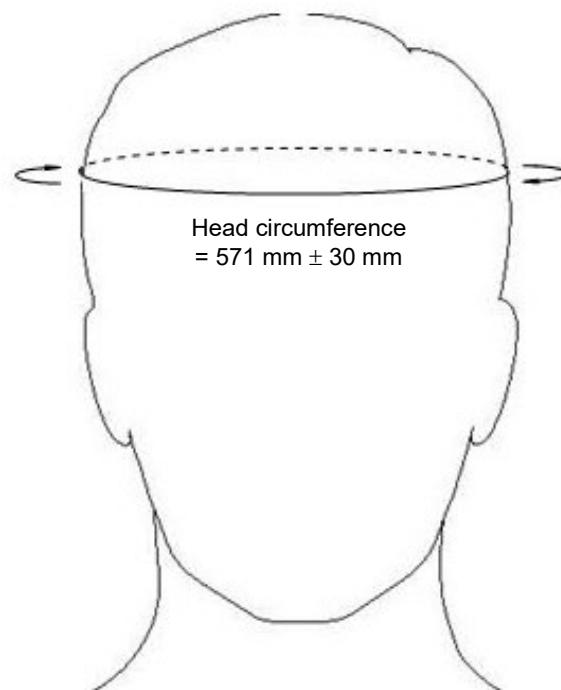


Figure 3 - Head circumference

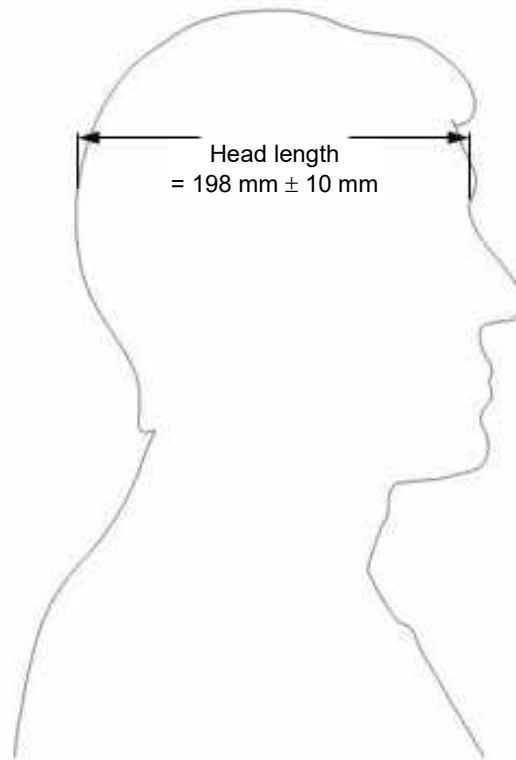


Figure 4 - Head Length

5.1.2.2 Lateral Drop Test

The disarticulated head shall meet lateral drop test performance criteria set out by NHTSA in 49 CFR 572.112 [October 1, 2006].

5.1.3 Repeatability and Reproducibility

- 5.1.3.1 The same head when subjected to three repeat tests as described in 6.1.1 and 6.1.2 shall result in a repeatability CV of 5% or less.
- 5.1.3.2 Three different heads when subjected to a single test for each part as described in 6.1.1 and 6.1.2 shall result in a reproducibility CV of 10% or less.

5.2 Neck

5.2.1 Mass Characteristics

5.2.1.1 Mass

Based on AMVO (AMVO Table 5.8) the midsize male neck mass should be 1.00 kg ± 0.05 kg.

5.2.2 Neck Biofidelity

Due to the multi-directional aspects of pedestrian to vehicle impacts, the neck design when tested per 6.2 should include at least flexion-extension and lateral bending biofidelity performance as defined in 5.2.2.1 and 5.2.2.2.

5.2.2.1 Neck Flexion Test

The disarticulated head and neck shall meet frontal pendulum test performance criteria set out by NHTSA in 49 CFR 572.33.

5.2.2.2 Lateral Pendulum Test

The disarticulated head and neck shall meet lateral pendulum test performance criteria set out by NHTSA in 49 CFR 572.113 [August 4, 1998] as amended at 66 FR 51882 [October 11, 2001].

5.2.3 Repeatability and Reproducibility

5.2.3.1 The same neck when subjected to three repeat tests as described in 6.2.1 and 6.2.2 shall result in a repeatability CV of 5% or less

5.2.3.2 Three different necks where subjected to a single test as described in 6.2.1 and 6.2.2 shall result in a reproducibility CV of 10% or less.

5.3 Shoulder

5.3.1 Geometric Properties

The midsize male dummy shoulder breadth (Bideltoïd) should be approximately the average of the values documented in CAESAR and ANSUR and shown in Figure 5.

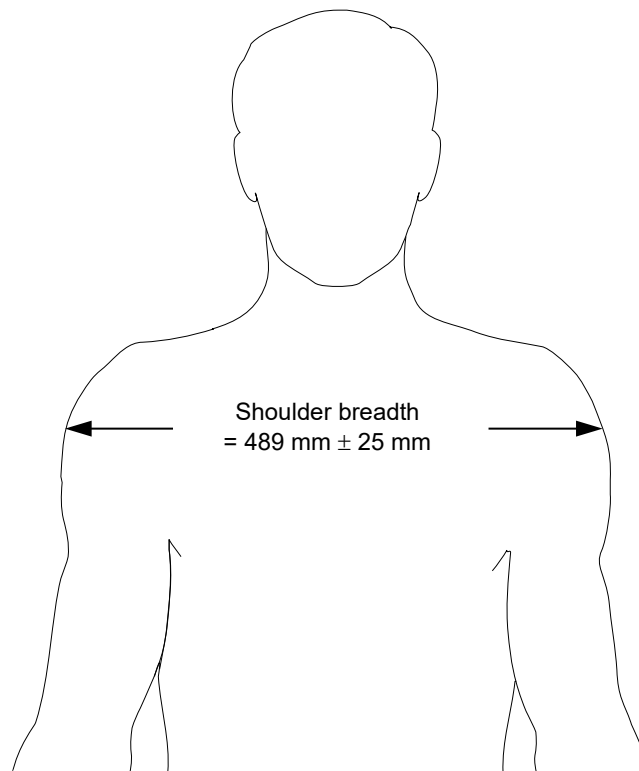


Figure 5 - Shoulder breadth

5.3.2 Shoulder Biofidelity

The shoulder design should satisfy lateral biofidelity performance as demonstrated in a lateral pendulum test. When tested per 6.3, the dummy should meet the performance criteria defined by ISO/TR 9790:1999(E) Section 4.1.4. For this test, the required force time corridor is shown in Figure 6 and defined in Table 1.

5.3.3 Repeatability and Reproducibility

5.3.3.1 The same shoulder when subjected to three repeat tests as described in 6.3.1 should fall within the corridors specified in 5.3.2.1 and the peak forces should have a CV of 5% or less.

- 5.3.3.2 Three different shoulders when subjected to a single test as described in 6.3.1 should fall within the corridors specified in 5.3.2.1 and the peak forces should have a CV of 10% or less.

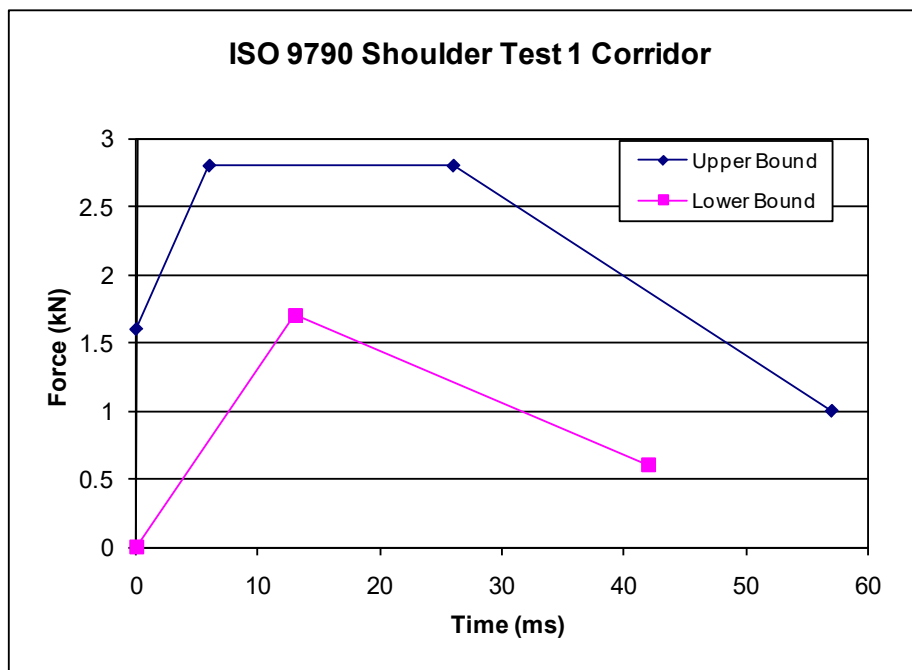


Figure 6 - Force versus time lateral shoulder corridor

Table 1 - Lateral shoulder pendulum force - time corridor

Point	Upper Bound		Lower Bound	
	T (ms)	Force (kN)	T (ms)	Force (kN)
1	0	1.6	0	0
2	6	2.8	13	1.7
3	26	2.8	42	0.6
4	57	1.0		

5.4 Thorax

5.4.1 Geometric and Mass Characteristics

5.4.1.1 Geometric Properties

The midsize male dummy thorax external geometry should be approximately the average of the values documented in CAESAR and ANSUR and shown in Figures 7 and 8.

5.4.1.2 Mass

Based on AMVO (AMVO Table 5.8), the midsize male thorax mass should be 23.8 kg $\pm$ 1.2 kg.

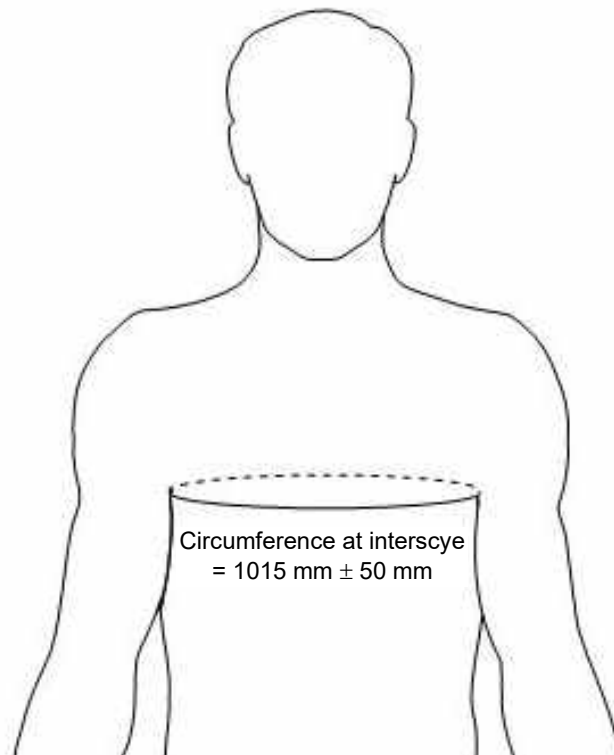


Figure 7 - Thorax circumference

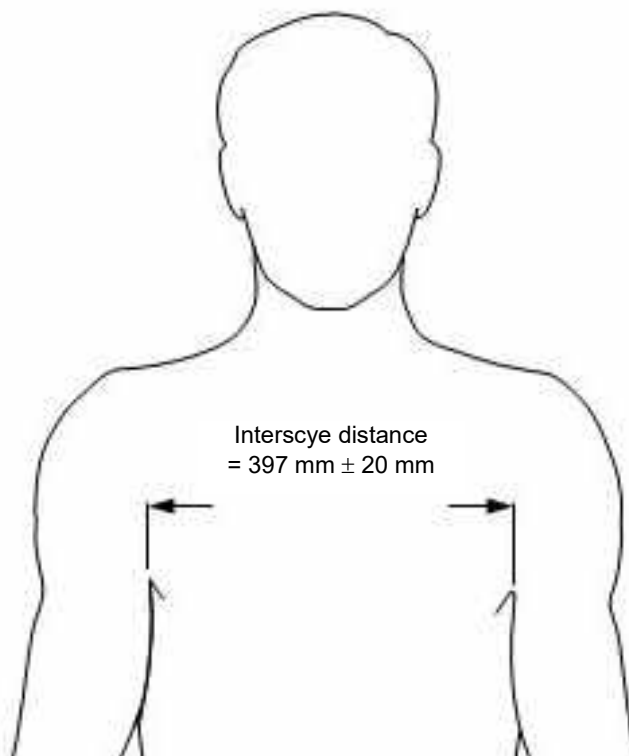


Figure 8 - Thorax interscye distance

5.4.2 Thorax Biofidelity

When tested per 6.4, the thorax should satisfy frontal and lateral performance criteria as defined in 5.4.2.1 and 5.4.2.2.

5.4.2.1 Frontal Pendulum Test

When tested per 6.4.1, the complete dummy should meet the pendulum force versus sternal deflection performance criteria specified by Kroell (SAE P-67, 1976) for 4.27 m/s pendulum impacts. For this impact speed, the required force deflection corridor is shown in Figure 9 and defined in Table 2.

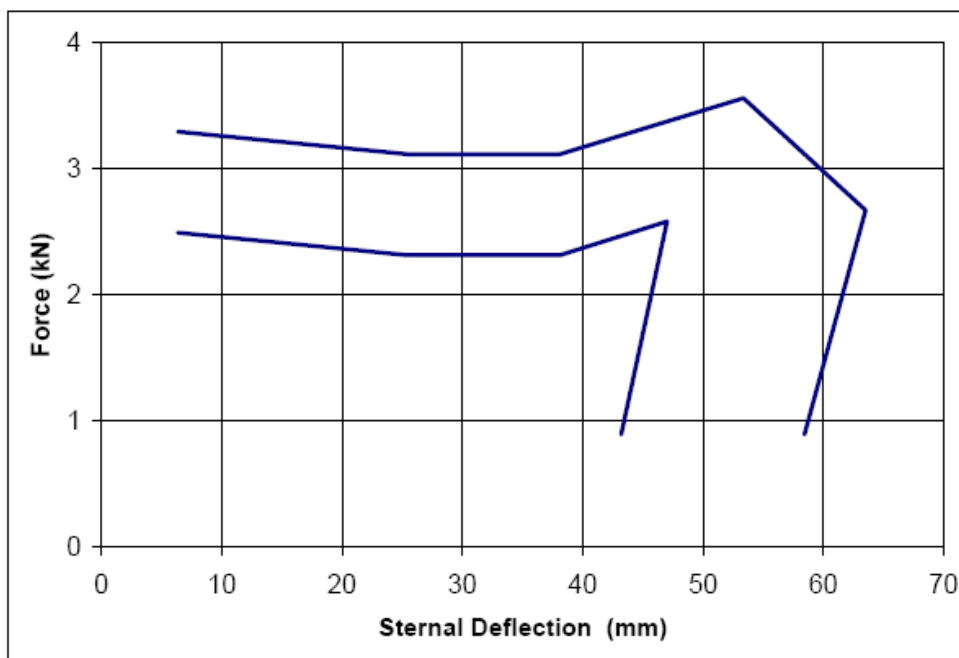


Figure 9 - 4.27 m/s frontal pendulum force-deflection response corridor

Table 2 - 4.27 m/s frontal pendulum force-deflection response corridor

Point	Upper Bound		Lower Bound	
	Def (mm)	Force (kN)	Def (mm)	Force (kN)
1	6.35	3.293	6.35	2.492
2	25.4	3.115	25.4	2.314
3	38.1	3.115	38.1	2.314
4	53.34	3.56	47	2.581
5	63.5	2.67	43.18	0.89
6	58.42	0.89	-	-

5.4.2.2 Lateral Pendulum Test

When tested per 6.4.2, the dummy should meet the performance criteria defined by ISO/TR 9790:1999(E) Section 4.2.4. For this test, the required force corridor is shown in Figure 10 and defined in Table 3.

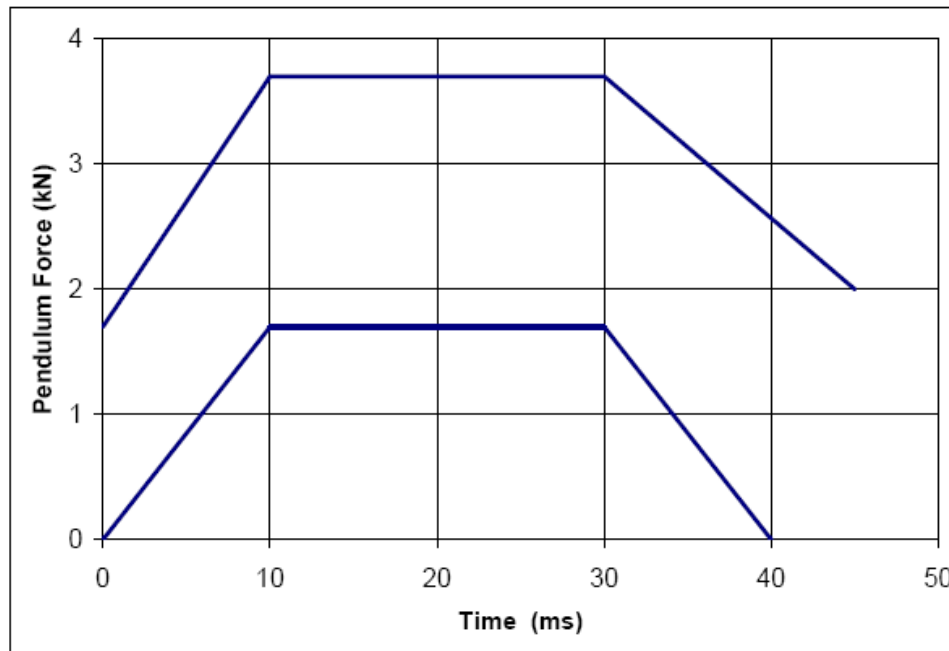


Figure 10 - ISO/TR 9790:1999(E) force versus time lateral thorax corridor

Table 3 - ISO/TR 9790:1999(E) force versus time lateral thorax corridor

Point	Upper Bound		Lower Bound	
	Force (kN)	Time (ms)	Force (kN)	Time (ms)
1	1.7	0	0	0
2	3.7	10	1.7	10
3	3.7	30	1.7	30
4	2.0	45	0	40

5.4.3 Repeatability and Reproducibility

5.4.3.1 The same thorax when subjected to three repeat tests as described in 6.4.1 and 6.4.2, should fall within the corridors specified in 5.4.2.1 and 5.4.2.2, respectively, and the peak forces in each test type should have a CV of 5% or less.

5.4.3.2 Three different thoraces, when subjected to a single test for each part as described in 6.4.1 and 6.4.2, should fall within the corridors specified in 5.4.2.1 and 5.4.2.2, respectively, and the peak forces in each test type should have a CV of 10% or less.

5.5 Upper Extremities

The dummy may be equipped with either complete upper extremities or stub arms.

5.5.1 Mass Characteristics

Based on the AMVO mass distribution (AMVO Table 5.8), the total mass for two arms should be approximately $3.5 \text{ kg} \pm 0.2 \text{ kg}$ and the total mass for two forearms and hands should be approximately $4.0 \text{ kg} \pm 0.2 \text{ kg}$. If used, the mass of dummy stub arms should be equal to the arm mass.

5.6 Abdomen and Pelvis

5.6.1 Geometric and Mass Characteristics

5.6.1.1 Geometric Properties

The midsize male dummy pelvis external geometry should be approximately the average of the values documented in CAESAR and ANSUR and shown in Figures 11 and 12.

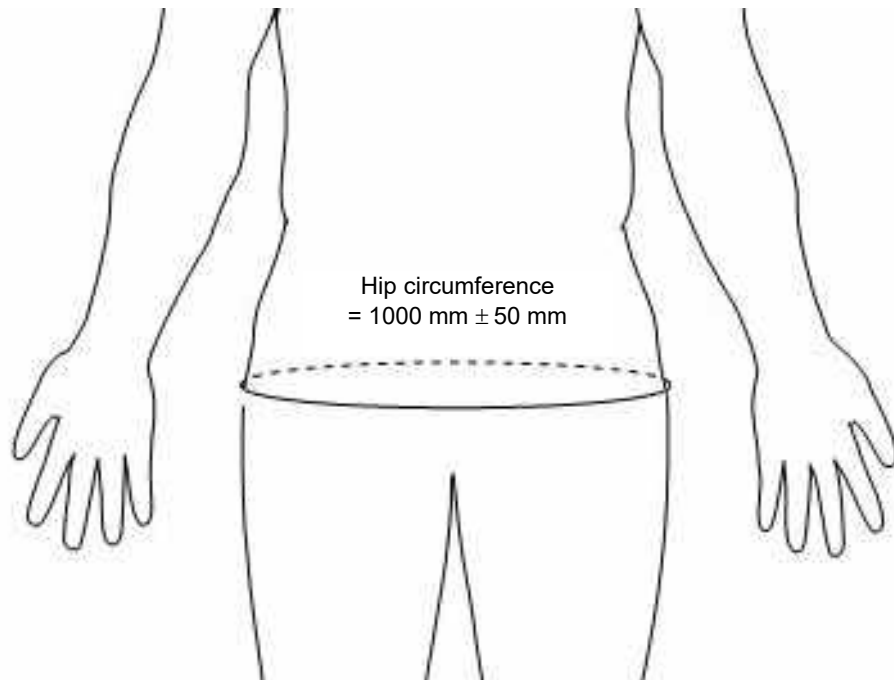


Figure 11 - Hip circumference

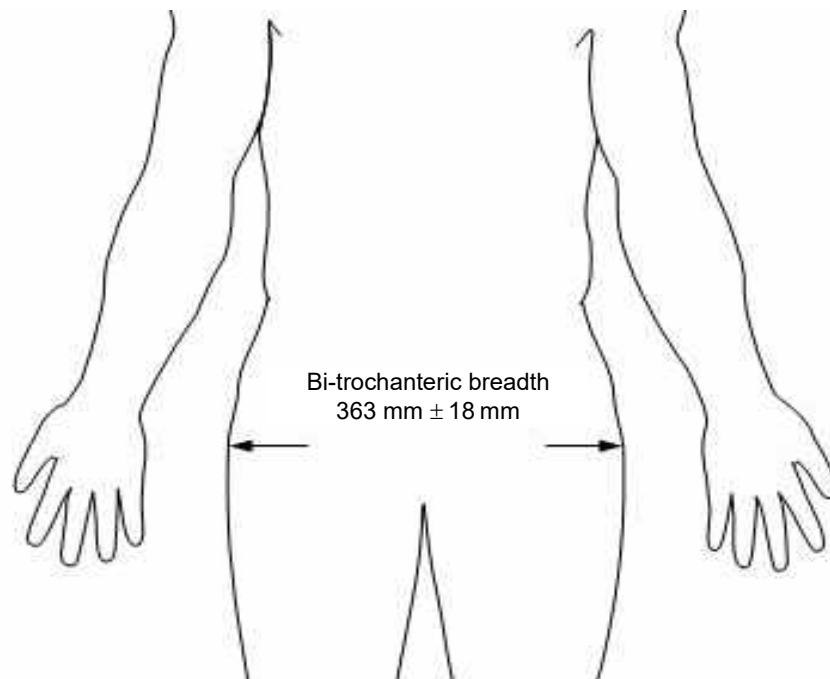


Figure 12 - Bi-trochanteric breadth