WorldSID Anthropometry Requirements and Performance

The anthropometry requirements and measured performance of the WorldSID are described herein.

1 Requirements

1.1 General

The WorldSID represents a mid-sized adult male vehicle occupant. Several anthropometry data sources were studied and compared with data from studies on anthropometry of different populations around the world. In September 1999, the WorldSID Task Group decided to accept the AMVO dataset for a 50th percentile male (Robbins, D.H., et al.[1]). This dataset describes many anthropometry details of a mid-sized adult male in an automotive posture. Included are a 3D surface description, almost 150 anatomical reference points (including joint centres), definitions of segments (head, neck, etc.), and derivation of inertial properties of these segments. The automotive posture as represented by the AMVO dataset is defined as the design reference posture for the dummy.

Communications with UMTRI revealed that some corrections had to be made since the first release of this dataset, specifically with respect to the H-point definition (yet unpublished information from the ASPECT development). FTSS corrected the dataset and created a 3D stickman diagram (lines connecting the joint centres) within the outer shell definition and anatomical landmarks. The Design Team used these as references for the WorldSID design. A detailed description of the anthropometry needs is given in Moss, S. et al.[2].

1.2 Overall landmarks

The anthropometric landmark targets for WorldSID are specified in Table 1.

Table 1 — Landmarks

Landmark	Description	*x* mm	*y* mm	*z* mm
	vertebral column			
7	C7	-264	0	499,4
8	T4	-291	0	390,4
10	T12	-244	0	156,4
12	L5	-172	0	23,4
	Pelvis			
27	Iliocristale	-78	±161	103,4
28	anterior superior iliac spine (l,r)	-23	±116	93,4
29	pubic symphysis	53	0	51,4
31	Throchanterion (skeletal reconstruction) (l,r)	22	±203	-9,6
32	h-point	0	±83,5	0
	Shoulder			
35	greater tubercle humerus (l,r)	Not specified	±218	Not specified
	joint centres			
54	head/neck	-194	0	598,4
55	c7/t1	-191	0	479,4
58	t12/l1	-175	0	175,4
60	l5/s1	-89	0	39
61	Sternoclavicular	-143	±43	443,4
62	Claviscapular	-228	±168	437,4
63	Glenohumeral	-184	±173	403,4
64	Elbow	38	±208	211,4
65	Wrist	230	±158	403,4
66	hip (h-point)	0	±83,5	0
67	Knee	408	±138	146,4
68	Ankle	686	±94	-158,6
	estimated segment centres of gravity			
79	Head	-177	0	656,4

1.3 Ranges of motion

The ranges of motion are based on several sources. Shoulder flexion, extension, abduction and adduction ranges are based upon estimates of what was to be necessary for initial positioning of the arm and motion without binding as presented in WorldSID Task Group meetings. Shoulder lateral and medial angular displacement ranges are from attachment I of the January 13, 1998 minutes of the SAE Arm-Airbag Interaction Task Group of the Human Biomechanics and Simulation Standards Committee. The elbow flexion and extension ranges match those of the SAE 5th percentile female instrumented arm. The flexion range is the maximum practical mechanical range. The wrist range of motion was provided by the University of Virginia Auto Safety Laboratory, compiled from a variety of sources.

- Shoulder flexion: 180° to soft stop
- Shoulder extension: 45° to soft stop
- Shoulder abduction: 100° to soft stop
- Shoulder adduction: 0° to soft stop
- Shoulder lateral angular displacement: 31° to soft stop
- Shoulder medial angular displacement: 91° to soft stop
- Elbow flexion: 135° to soft stop
- Elbow extension: -5° to soft stop
- Wrist pronation/supination: 80° to soft stop
- Wrist flexion/extension: 75° to soft stop
- Wrist abduction: 15° to soft stop
- Wrist adduction: 25° to soft stop

1.4 Head

Reference for the head anthropometry was the AMVO data set. The target data are specified in Table 2. The target for the outer geometry of the head was based on the Hybrid-III geometry (Hubbard R., et al.[3]), since this is a more detailed data set. Facial features from the Hybrid-III (nose, lips, etc.) were to be deleted.

Table 2 — General head anthropometry reference data (Source: AMVO Data Set)

Parameter	Target	Reference	Remark
Mass	4,14 kg ± 0,1 kg	AMVO	
Circumference.	570,6 mm ± 5 mm	AMVO 1983 Study	
Length	197,4 mm ± 2 mm	AMVO	
Width	158 mm ± 2 mm	AMVO	Hybrid-III: 155 ± 5 mm
CG location	177 mm, 0 mm, 656,4 mm (with respect to mid H-point)	Corrected AMVO	WorldSID-α anthropometry

The location of the head centre of gravity was to be indicated on the left and right exterior of the head. The tolerance of the indications was to be ± 2,0 mm.

The coordinates (x, y, z in mm), with respect to the H-point for the head CG and OC-joint were to be (–177, 0, 656,4) and (–194, 0, 598,4) respectively.

For packaging reasons, an adjustment to change the orientation of the head depending on the dummy's posture inside a vehicle could be incorporated at the head-neck junction but was incorporated into the neck-thorax bracket. An adjustable lower neck bracket allowed proper orientation of the head. The head reference plane was to be marked on the head and served as a reference to level the head (note that the head reference plane in the reference posture of the occupant as defined by the AMVO data set is at an angle of 3,7 degrees with the horizontal plane).

1.5 Neck

The neck has similar mass and mass distribution to that of the human, as available from the reference AMVO data set. The target data are specified in Table 3. Coordinates of the OC-joint and C7/T1-joint were to be (-194, 0, 598,4) and (-191, 0, 479,4). A neck shroud prevented unrealistic airbag interactions.

Table 3 — General neck anthropometry reference data (Source: AMVO Data Set)

Parameter	Target	Reference	Remark
Mass	0,965 ± 0,2 kg		Production tolerance is tighter

At the end of the ranges of motion progressive stiffness were to be built in to prevent overloading.

To allow the head to be oriented over a sufficient range of motion (angular displacement around the y-axis) with the dummy in an automotive position, the neck bracket exhibits an adjustability of at least 10 degrees forward (flexion) and 20 degrees rearward (extension) with respect to the reference posture.

1.6 Shoulder/thorax/abdomen

The anthropometry landmarks are based on the AMVO and derivative studies. Major design targets are given in Table 4. The three dimensional surface of the AMVO model was used as the design target for the outside contours of the dummy.

Table 4 — Segment masses

Segment masses	Target
Shoulder and thorax	23,763 kg
Abdomen	2,365 kg

1.7 Full arms

The arm was designed with reference to the AMVO anthropometry data set. This included approximate outside flesh contours, pivot-to-pivot lengths, component masses, and approximate centre of gravity locations.

- Pivot lengths:
    - Shoulder pivot to elbow pivot length: 295,5 mm
    - Elbow pivot to wrist pivot length: 276,1 mm
- Assembly masses: The assembly masses were to be made to match the AMVO data set target of 3,79 kg (1,77 kg upper arm and 2,02 kg lower arm). Precise segmentations were to be established during the design phase.

- Flesh contours:

    - Hand flesh contour was to be new since it is a gripping hand. Basic contour was to be from the AMVO data surface model with simplified geometry with the fingers curved into a gripping position. Left and right hands were to be mirror images of each other.
    - Lower arm flesh contour was to be based on the AMVO data surface model with simplified geometry.
    - Upper arm flesh contour were to be based on the AMVO data surface model with simplified geometry.
    - The shoulder was to be covered with flesh by extending the upper arm flesh up over the shoulder structure. The specific method for covering the shoulder with flesh was to be addressed during the design stage.

1.8 Half arms

The half arm was to be designed to meet the WorldSID anthropometry specifications, with reference to the source anthropometry data defined by the AMVO data set. The flesh contour is derived from the AMVO shell surface model, and approximated to a rectangular section to improve the arm stability during test loading.

The half arm-shoulder joint coincides with that of the full arm and was to be at or very close to the position of the gleno-humeral joint of the anthropometry data set (point 63: -184, ± 173, 403,4)[a)]

The mass property target of the half-arm is specified in Table 5.

Table 5 — Mass properties of the WorldSID half arm

Parameter (all identical left and right)	Target
Segment Mass (identical left and right)	1,769 kg

[a)] Coordinates are expressed x, y, z in mm with respect to the dummy reference position in an orthogonal reference axis system at the H-point (0, 0, 0), unless specifically specified otherwise. The designation "±" refers to left and right side.

1.9 Lumbar spine

The WorldSID lumbar spine component is defined as the connection between the upper and lower torso, and does not specifically simulate the human skeletal lumbar spine. The WorldSID lumbar spine length was to occupy the space between T12/L1 and L5/S1 according to the WorldSID anthropometry specifications in 1.2.

1.10 Pelvis

1.10.1 General

Reference for the pelvis anthropometry is the AMVO data set. In order to define the internal geometry of the pelvis, additional data is used from Reynolds, et al.[4]

1.10.2 Overall external dimensions

The external shape of the pelvis is based on the AMVO data set ("shell"), but adjusted to obtain a non-compressed buttock flesh. AMVO has defined the pelvis coordinate system at the H point with the directions of the axes along the vehicle coordinate system. Target data are given in Table 6.

Table 6 — Target data for pelvis external dimensions

Parameter	Target
Mass (only pelvis[b)])	11 kg ± 0,2 kg
Mass (pelvis + femur heads)	14,5 kg ± 0,3 kg
Hip breadth	385 mm ± 8 mm

1.10.3 Detailed internal dimensions

The internal design of the pelvis was to be primarily based on Reynolds, et al.[4]. The internal body shape (dummy skeleton) was to not represent the whole human anatomy. Only some important anatomical points were to be represented as well as the overall girdle configuration. Whereas the human pelvis skeleton mass is

b) AMVO report refers to McConville, 1980, who considered pelvis as "originates at the centre of the crotch and passes laterally midway between the anterior superior iliac spine and the trochanter landmarks along the lines of the right and left inguinal ligaments."

approximately 1 kg, the dummy uses material with higher density than human bone and was to be instrumented, and was to hence have a larger mass than the human pelvis. This also results in variation of the pelvic inertia.

Based on Reynolds' data, several bone points have been defined with respect to the (corrected) AMVO H-point definition. To achieve this, Reynolds' coordinate system has been rotated over 54° and the origin of the Reynolds' axis has been moved to the H point (see definition of Reynolds coordinate system versus AMVO system in Figures 1 and 2). Reynolds' bone markers and AMVO surface markers are shown on Figures 3, 4, and 5.

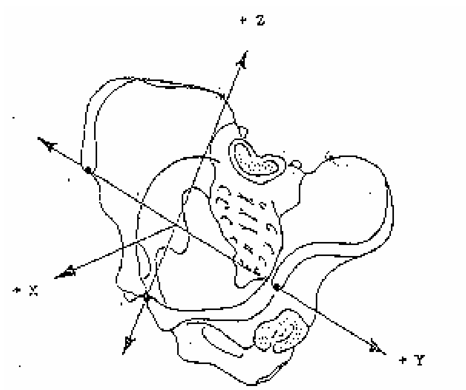

Figure 1 — Reynolds pelvis co-ordinate system

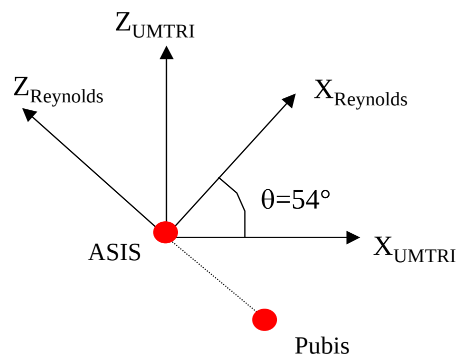

Figure 2 — Angular shift from AMVO to Reynolds co-ordinate system

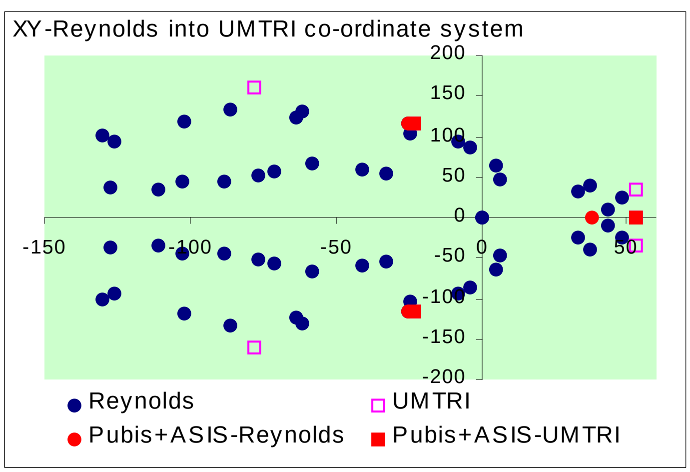

Figure 3 — Bone and surface landmark coordinates given by Reynolds and AMVO projected on XY plane

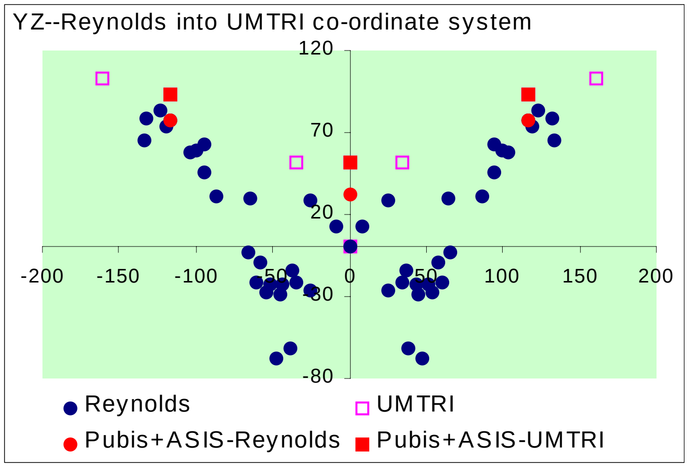

Figure 4 — Bone and surface landmark coordinates given by Reynolds and AMVO projected on XZ plane

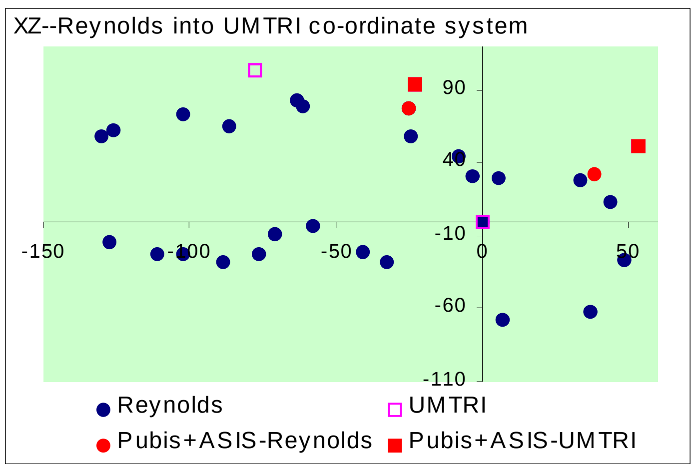

Figure 5 — Bone and surface landmark coordinates given by Reynolds and AMVO projected on YZ plane

As the difference between the Reynolds bone markers and the AMVO surface markers is surprising, other data have been searched that could give further confirmation on the pelvic bone geometry. The European Project HUMOS[c)] has produced a 3D model of a 50th percentile male (175 cm and 80 kg) in the AMVO seated posture. The 3D reconstruction is based on several cross sections obtained from the frozen cadaver subject. The dimensions of the HUMOS male cannot be

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c) Human Model for Safety – Project Programme BE 97-4169 considered statistically representative of the population, but can be used to further select the appropriate pelvic bone dimensions.

Figures 6, 7, and 8 include a comparison between the HUMOS and Reynolds bone dimensions, which appear rather similar.

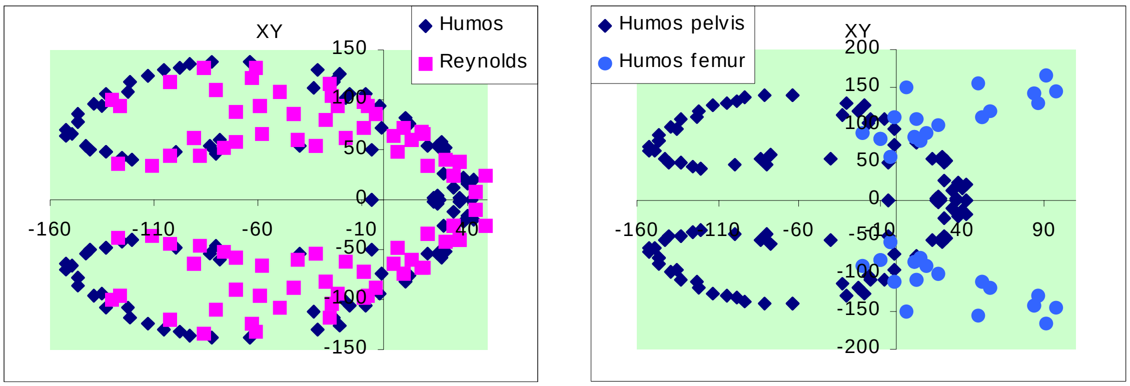


Figure 6 — Humos and Reynolds bone markers projected on xy plane

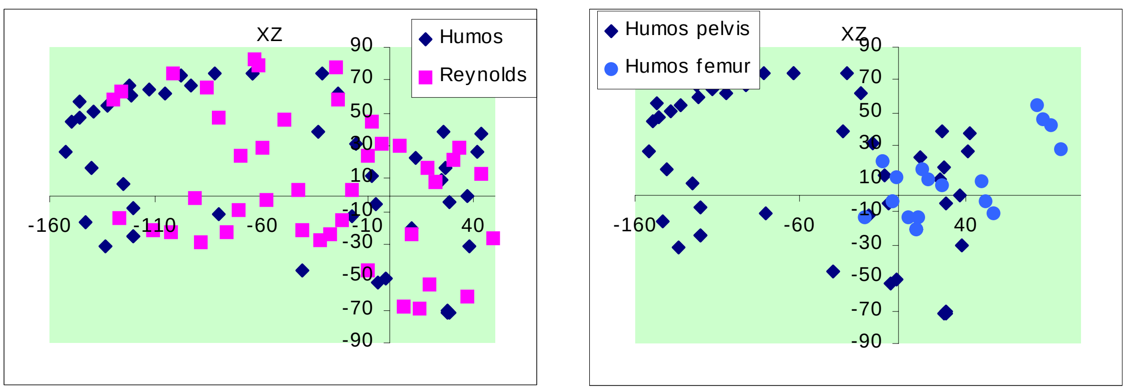


Figure 7 — Humos and Reynolds bone markers projected on xz plane

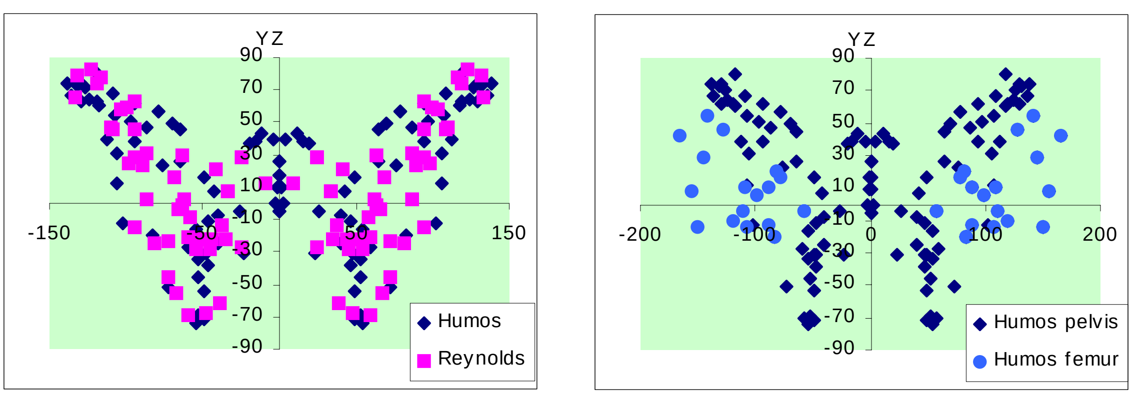


Figure 8 — Humos and Reynolds bone markers projected on yz plane

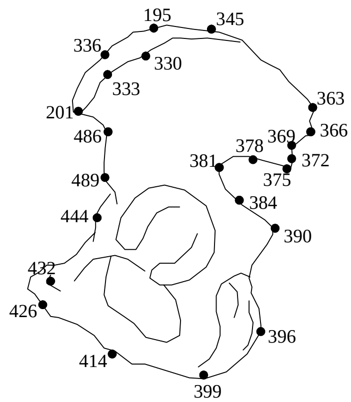


Figure 9 — Location of Reynolds' pelvis landmarks (Reynolds, et al.[4])

Table 7 — Other pelvis bony landmarks (Reynolds, et al.[4])

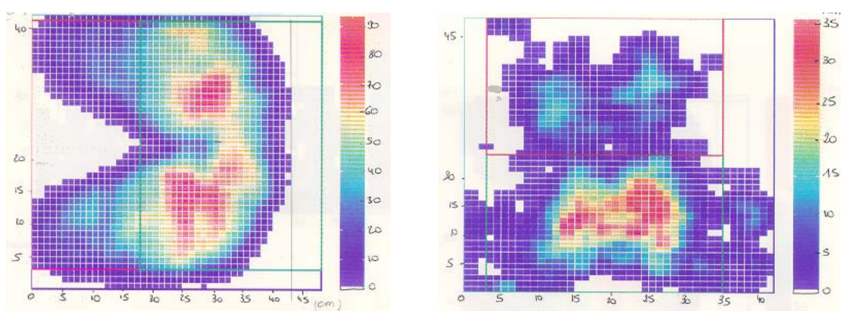
Points on left side contour	XRU-H pt	YRU-H pt	ZRU-H pt
330	-86	133	65
333	-61	132	79
336	-63	123	83
342	-130	100	59
345	-126	95	63
363	-127	37	-14
366	-111	35	-22
369	-102	44	-22
372	-89	45	-28
378	-71	58	-9
381	-58	66	-4
384	-41	60	-21
390	-33	54	-28
414	49	25	-27
444	5	64	29
486	-24	104	58
489	-8	95	45
492	-4	87	31
189-H point	0	0	0
195-illocristale summum	-102	119	74
201-ASIS	-25	117	78
204-pubis	38	0	32

Points on left side contour	XRU-H pt	YRU-H pt	ZRU-H pt
375-post-inf iliac spine	-77	52	-22
396-medial tuberosity point	7	48	-68
399-inf. tuberosity point	37	39	-61
426-ant. symphysis pole	44	9	13
432-pubotubercule	33	25	29
Trochanter	22	165	-9,6

The iliac crest points (for example point number 336 as shown in Figure 9 and Table 7) are the highest points in seated position and their coordinates are important for defining potential interaction with the abdominal ribs.

1.10.4 Detailed pelvis shape

The Ischium shape and position have to be humanlike to have a proper pressure mapping on the seat cushion (see Figure 10). The WorldSID-α pressure map was to be similar to that show below; no pressure values are specified in TG N60 Rev 2.



Dimensions in cm, pressure in g/cm^2

Figure 9 — An example of a mean seat pressure distribution obtained from 5 different subjects seated in a truck seat (Seat Angle: 4°, Back Seat Angle: 18°; Pressure Mapping of Buttock on Left and Pressure Mapping of Back on Right[d]

The HUMOS study gives the flesh thickness at different heights where horizontal cutting planes were chosen. The data given here cannot be considered

[d] Personal communication – RENAULT-RVI

statistically representative of the 50th percentile male, but constitute a first indication (Figure 11).

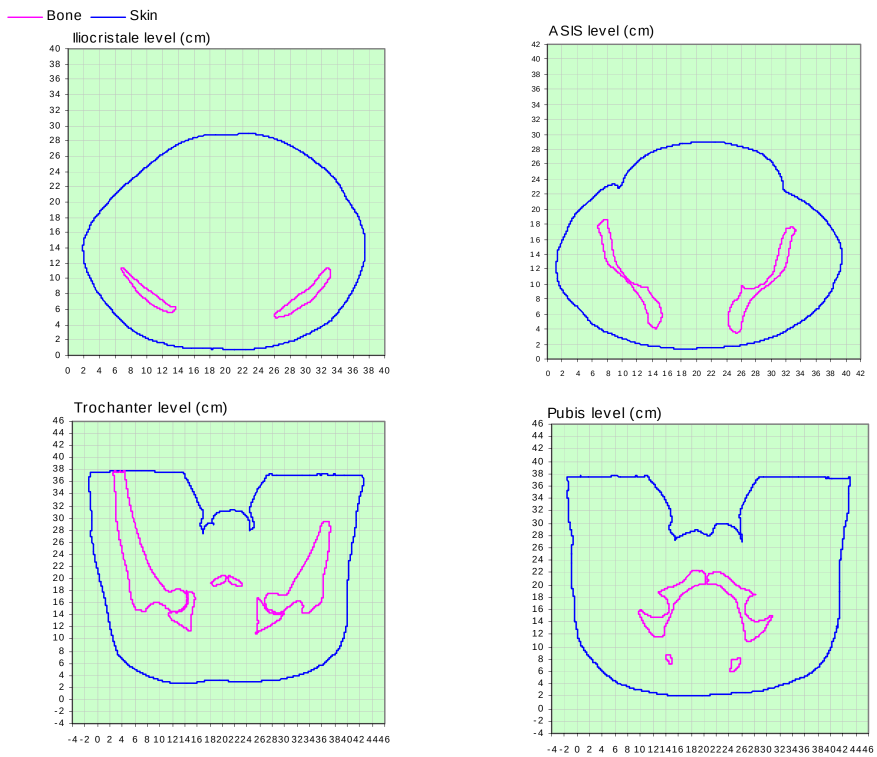


Figure 11 — Cross sections of pelvis area at iliocristale, ASIS, great trochanter and pubis level (from HUMOS)

The average horizontal flesh thickness found in the HUMOS subject, are:

- at Iliocristale: 40 to 45 mm (each side, in lateral direction)
- at ASIS: 40 mm (each side, in lateral direction)
- at Trochanter level: 40 to 45 mm (each side, in lateral direction)
- at pubis: 60 mm (in front of the pubic bone)

In conclusion:

- The Reynolds[4] pelvic bone dimension was to be considered for the main bony points of the dummy pelvis.
- The AMVO shape was to give exterior dimensions of the pelvis.

- The flesh thickness was to be derived from the AMVO and Reynolds[4] markers distance (40 mm on the Iliocristale and 30 mm at the trochanter).

1.10.5 Pelvis ranges of motion

Hip ranges of motion depend on knee position. The WorldSID was to be the seated dummy, therefore the focus was on the range of motion in seated position.

The flesh should not reduce the femur joint range of motion by more than 5°. The hip joint can be tuned by friction setting.

1.10.6 Posture

The dummy should be able to be seated in the rear of a small car. Hip ranges of motion and flesh design have to allow 53° of flexion in the upward direction. The position of the dummy pelvis (H point location) should be measurable with an H point tool. The measurement should be precise at ± 2,5 mm. The design of the WorldSID pelvis was to include a tilt sensor to measure pelvis angle ± 1°.

1.11 Upper leg

The AMVO data set was taken as reference for the anthropometry specifications. The knee pivot position and orientation were to be maintained at the AMVO coordinates (x, y, z) of 408 mm, 138 mm, 146,4 mm and 408 mm, -138 mm, 146,4 mm relative to the H-point. The segmentation locations were to be defined during the design stage. Once the segmentation is defined, the mass, target was to be defined based upon the AMVO data, correcting for the segmentation. The basic flesh shape was to be based upon a simplification of the AMVO flesh surface shell adjusted to an uncompressed state. The knee range of motion design target was to be 144° forced, based on Webb[5].

1.12 Lower leg

The lower leg was to be designed to represent the mid-sized male as represented by the AMVO data set. Major anthropometry specifications that were to be considered in the design of the lower leg are:

- The knee joint centres (points 67: 408 mm, ± 138 mm, 146,4 mm)

- The ankle joint centres (points 68: 686 mm, ± 94 mm, -158,6 mm)

The flesh system was to have a continuous outer surface when the lower leg is at or close to its reference position (according to the AMVO data set). Continuous surfaces cannot be guaranteed over the full range of motion of the ankle and knee joints.

1.13 Clothing

The suit was to be tailored to be snug fitting to the exterior surfaces of the dummy with additional material added around joints to allow full range of motion. If necessary, a soft shoulder pad was to be sewn into the suit to improve the shape of the jacket. The foam pad was not to affect the response of the dummy.

2 Performance

The anthropomorphic performance of the WorldSID is described subsequently, based on the test data, design drawings and CAD files available up through early May 2004.

2.1 Overall dummy landmarks

The actual WorldSID dummy reference locations are given in Table 8 and are compared with the original design targets.

Table 8 — Actual dummy versus design target landmarks

Landmark	Description	Design target			Actual[a]		
		x mm	*y* mm	*z* mm	*x* mm	*y* mm	*z* mm
	vertebral column						
7	C7	-264	0	499,4	-264	0	499,4
8	T4	-291	0	390,4	-291	0	390,4
10	T12	-244	0	156,4	-244	0	156,4
12	L5	-172	0	23,4	-172	0	23,4
	pelvis						

Landmark	Description	Design target			Actual[a]		
		x mm	*y* mm	*z* mm	*x* mm	*y* mm	*z* mm
27	iliocristale	-78	±161	103,4	-78	±161	103,4
28	anterior superior iliac spine (l,r)[b]	-23	±116	93,4	Not available	Not available	Not available
29	pubic symphysis[c]	53	0	51,4	Not available	Not available	Not available
31	throchanterion (skeletal reconstruction) (l,r)	22	±203	-9,6	Not available	Not available	Not available
32	h-point	0	±83,5	0	0	±83,5	0
	shoulder						
35	greater tubercle humerus (l,r) (half arm)		±218			±218	
35	greater tubercle humerus (l,r) (full arm)		±218			±222,6	
	joint centres						
54	head/neck	-194	0	598,4	-194	0	598,4
55	c7/t1	-191	0	479,4	-191	0	479,4
58	t12/l1	-175	0	175,4	-175	0	175,4
60	l5/s1	-89	0	39	-89	0	39
61	sternoclavicular	-143	±43	443,4	-143	±43	443,4
62	claviscapular	-228	±168	437,4	-228	±168	437,4
63	glenohumeral[d]	-184	±173	403,4	-169	±173	404,4
64	elbow[d]	38	±208	211,4	53,4	±211,6	212,2
65	wrist[d]	230	±158	403,4	244,2	±162,5	403,3
66	hip (h-point)	0	±83,5	0	0	±83,5	0
67	knee	408	±138	146,4	408	±138	146,3
68	ankle	686	±94	-158,6	680	±94	-158,6
	estimated segment centres of gravity						
79	head	-177	0	656,4	-177	0	656,4

[a] Some of the actual reference locations listed are very difficult or impossible to measure directly and therefore, the computer aided design (CAD) values for all points are listed as actual and are believed to be accurate.

[b] The dummy pelvis was designed with a single curvature shape to avoid a structural buckling mode that would occur with a more human like shape.

[c] Packaging of the pubic load cell required a deviation from the target location.

[d] The actual shoulder joint had to be 15 mm forward of the target to accommodate the shoulder rib design.

2.2 Range of motion

The actual WorldSID range of motion is given in Table 9 and is compared with the original design target.

Table 9 — Actual dummy range of motion vs. design target

Motion	Design target	Actual
Shoulder flexion	180° to soft stop	172º to contact, 190º forced
Shoulder extension	45° to soft stop	40º contact, 50º forced
Shoulder abduction	100° to soft stop	101, 50º
Shoulder adduction	0° to soft stop	-1º
Shoulder lateral angular displacement	31° to soft stop	31º
Shoulder medial angular displacement	91° to soft stop	91,8º
Elbow flexion	135° to soft stop	137,1º
Elbow extension	-5° to soft stop	-3,9º
Wrist pronation	80° to soft stop	81,7º
Wrist supination	80º to soft stop	82º
Wrist flexion	75° to soft stop	75º
Wrist extension	75º to soft stop	55º to flesh contact, 77º forced
Wrist abduction	15° to soft stop	15º
Wrist adduction	25° to soft stop	28,5º

2.3 Head

The actual WorldSID head anthropometry is given in Table 10 and is compared with the original design target.

Table 10 — Actual dummy head anthropometry vs. design target

Parameter	Target	Actual
Mass	4,14 kg ± 0,1 kg	4,23 kg
Circumference	570,6 mm ± 5 mm	568 kg
Height	230,9 mm	231 mm
Length	197,4 mm ± 2 mm	199 mm
Width	158 mm ± 2 mm	159 mm
CG location	177mm, 0mm, 656,4mm (with respect to mid H-point)	177 mm, 0 mm, 656 mm

2.4 Neck anthropometry

The neck is designed according to AMVO corrected anthropometry. The length of the neck design complies with the AMVO requirement, however, in order to meet the biofidelity performance requirement, the diameter of the neck itself is reduced. A neck shield is designed to simulate the skin contour of the AMVO shell. Due to the limit of the mechanical design packaging, the dummy design can not have the same split location as defined in the AMVO for a 50 percentile human. Therefore, the weight of the neck design is 1,038 kg, which is within the AMVO requirement of 0,966 kg ± 0,200 kg.

2.5 Shoulder/thorax/abdomen anthropometry

The shoulder is designed with an outer and inner rib for each side. The inner rib has damping material attached to metal rib. The shoulder rib is tilted 10 degrees upward at the front to simulate arm joint motion during an impact test. The arm to shoulder joint is designed to provide range of motion for the arm.

Three thorax ribs are designed to the represent the human thorax. The ribs are horizontal in reference to the AMVO sitting posture except for the first thorax rib, which is tilted 10 degrees upward at the front to cover the space between the shoulder rib and first thorax rib.

Abdomen is represented by two abdomen ribs. The mechanical design is similar to the thorax except for the damping material, which is thicker to meet the performance requirements.

Since the mechanical interface between the upper torso and the lower torso differs from the AMVO body segment locations, the total weight of 22,74 kg for the shoulder/thorax/abdomen, including the lower neck bracket assembly, is different from the specifications in AMVO.

2.6 Full arms

The pivot lengths were first priority. The target for shoulder pivot to elbow pivot was 295,5 mm, whereas the design measured 295,0 mm in CAD. The target for elbow to wrist pivot was 276,1 mm, and the design measured 276,1 mm in CAD. The second priority for the arm design was measurement capability and strength. The strength of the arm bone was designed to exceed the capacities of the load cells. The third priority was range of motion. The measured ROM on one arm are shown in Table 9.

The fourth priority was the external shape of the arm flesh. The upper arm flesh shape was derived by taking slices of the AMVO surface shell and drawing ellipses through the sections to approximate the area of the section. The resulting surface was smoothed and simplified somewhat, and the left and right upper arm fleshes were made as mirror images. The lower arm flesh shape was derived in a similar fashion by taking slices of the AMVO surface shell and drawing ellipses through the sections to approximate the area of the section. This surface was smoothed, simplified, and made symmetrical so that one arm flesh part could be used for the left and right arms. The hand shape was derived in a slightly different fashion. The hand was made by taking one of the Hybrid III 50th male hand shapes, bending the fingers, and mirroring it for the other side. This gave a more reasonable shape for a dummy hand than trying to use the AMVO surface data directly.

Matching the mass distributions of the arm could only be an approximation. The AMVO anthropometry data set splits body segments by defining planes through the joint centres. In a dummy these planes pass through multiple parts. The arm was designed by grouping parts that would be cut by the split planes into one of the body segments. Then, the mass targets of the flesh components were adjusted to have the dummy segments match the AMVO body segment mass targets. The final check of this process was to measure the entire arm mass of one of the arms and compare it to the full arm mass target from the AMVO data set. The actual full arm mass was 3,72 kg as compared to the target mass from the AMVO study of 3,79 kg.

Due to the many other requirements for the arm, there was no possibility to adjust the centre of gravity locations of the arm segments.

2.7 Half arms

The half arm was designed to match the AMVO upper arm weight and geometry. The actual weight is 1,768 kg. The performance of the half arm is not tested independently, but is tested in combination with the shoulder and thorax.

2.8 Lumbar spine

The lumbar design was limited by space constraints and was designed to fit within 50 mm between the thorax and pelvis. The lumbar flexibility provides shear flexibility between the upper and lower torso to simulate human response. The lumbar is approximately aligned L5/S1 and not with T12/L1.

2.9 Pelvis

The actual pelvis breadth is 384,6 mm. The actual dummy pelvis mass is difficult to compare to the target mass because the dummy mechanical split lines are different than those used for determining the target masses, however the overall dummy mass and mass distributions match the general mass targets.

2.10 Upper leg

The AMVO data set was taken as reference for the anthropometry specifications for the upper leg segment. The hip and joint centres were matched to the locations specified in the AMVO data (see Table 8). The flesh shape was split from the pelvis and is a smoothed simplified shaped derived from an approximation of what the un-deformed surface shell would be. In the knee area, the outer flesh shape was made with spherical radii on both sides and the front to give uniform surfaces to transfer load to the knee contact load cells and the front of the knee. The front knee surface radius approximated the forward location of the surface shell.

The mass segmentation between the AMVO data set and the upper leg was an approximation. The split planes in the AMVO data set pass through the hip socket and the knee centre. In the dummy, the pelvis flesh is split in a plane perpendicular to the bone well below the hip ball. The bone from the hip ball to the split above the upper tibia load cell is part of the upper leg assembly in the dummy. Due to these major differences in the splits in the dummy versus the AMVO study, the masses were adjusted by taking a portion of the mass from the AMVO study and transferring it from the upper leg to the pelvis. This made the dummy upper leg mass several kg light. The human mass of bone structure and flesh from the knee pivot to the top of the upper tibia load cell should be part of the lower leg but is included in the upper leg in the dummy. This adds to the dummy upper leg mass. As a result of such mass distributions, the average measured upper leg mass of the dummies was 6,7 kg, while the target mass was 8,6 kg.

2.11 Lower leg

The AMVO data set was taken as reference for the anthropometry specifications for the lower leg segment. The knee joint centre location is shown in Table 8. The AMVO data set specifies one joint centre for the ankle, but the dummy was designed with a split distance between the inversion/eversion and dorsiflexion/plantarflexion pivots. The dorsiflexion/plantarflexion pivot was located at the AMVO pivot shown in Table 8.

The external flesh shape was designed based on the surface shell by taking vertical slices through surface shell. At each slice, an ellipse was drawn approximating the area of the cross section. These ellipses were made symmetric about the centre of the bone so that one flesh could be used on both the left and right legs. The resulting surface was smoothed. At the knee end a spherical cut was made to mate to the upper leg flesh.

The mass segmentation between the AMVO data set and the lower leg was an approximation. The split planes in the AMVO data set pass through the knee and ankle joint centres. The dummy segmentation is very different. The split between the upper and lower legs is at the top of the upper tibia load cell. The split between the lower leg and ankle/foot is at the bottom of the lower tibia load cell for the bone structure, which is well above the angle pivot. In addition, the foot and shoe are combined in the dummy into one molded component.

These major segmentation differences make a comparison of dummy and AMVO mass targets difficult. For the dummy, the average lower leg mass was measured at 2,8 kg whereas the AMVO target was 3,6 kg. For the dummy ankle/foot assembly, the average measured mass was 2,3 kg versus a target of 1,0 kg. These differences are partly due to the segmentation differences, partly due to the inclusion of the shoe in the dummy, and partly due to the dummy ankle assembly being somewhat heavier than the AMVO mass target.

2.12 Clothing

The clothing is fabricated from 5 mm thick neoprene, and is tailored to fit the dummy according to the AMVO shell. The clothing provides smooth external contours for the dummy skin surface and does not adversely affect the joint motions. Two shoulder pads, which are not an integral part of the suit, provide human like shoulder contours.

Bibliography

[1] ROBBINS, DH. et al. *Anthropometric specifications for the mid-sized male dummy, Final report, Contract DTNH22-80-C-07502*. Washington, DC: US Department of Transportation, National Highway Traffic Safety Administration. 1983.

[2] MOSS, S., WANG, Z., SALLOUM, M., REED, M., VAN RATINGEN, M., CESARI, D., SCHERER, R., UCHIMURA, T. and BEUSENBERG, M. *Anthropometry for WorldSID, a world-harmonized midsize male side impact crash dummy*. SAE 2000-01-2202 in Proceedings of government/industry meeting, June 2000. Warrendale, PA, US: Society of Automotive Engineers. 2000.

[3] HUBBARD, RP. and MCLEOD, DG. *A basis for crash dummy skull and head geometry*. Proceedings of the Symposium on human impact response; measurement and simulation. Warren, MI: General Motors Corporation Research Laboratories. 1973. pages 129-152.

[4] REYNOLDS, HM., SNOW, CC. and YOUNG, JW. *Spatial geometry of the human pelvis.* Report AAC-119-81-5. Oklahoma City: Federal Aviation Administration, Civil Aeronautical Institute. 1981.

[5] Webb Associates. *Anthropometric source book. Volume 1: anthropometry for designers.* NASA reference publication 1024. Washington, DC: US National Aeronautics and Space Administration. 1978.