GEOMETRICAL CHARACTERISATION OF A SEATED OCCUPANT

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ABSTRACT

This paper presents the results from a project based on an anatomical study to improve the knowledge of the human anatomy for a belted car occupant.

The four phases for data collection consists of :

- the selection of a cadaver placed in a car seat.
- the realisation of a set of physical cross sections
- anatomical identification of organs seen on each section
- computer analysis and visualisation of organs.

General methods, from physical sections to 3D computer generated reconstruction were presented in [Chabert96].

The purpose of this present paper is to provide a geometrical description of a human body in the seat belt posture.

Many skeletal landmarks are viewed with reference to the H point, in the vehicle coordinate system. The pelvis and thoracic bones are seen with the seat belt below. The geometry of the spine is described by the 3D position of the centres of each vertebral body. The curvature, which is given by the angles between each vertebral axis along the spine is compared to an X-ray study performed on living volunteers. The anatomic results, which refer to a male PMHS closed to the 50° percentile, should be interesting in the fields of ergonomics, anthropometric dummy design and biomechanics.

INTRODUCTION

Human Anatomy descriptions are done according to a conventional position, which results from teaching inherent needs. New techniques in medical imaging and data-processing tools development allowed the rise of human three-dimensional representation in this position [Ackerman95]. However there are no data-bank available for the Anatomy human in seated position.

How can a study of the sitting position be conceive, which may go until the creation of a data-bank? The most adapted methodology can be neither the dissection, neither conventional radiology, nor even the nuclear magnetic imaging (CT-scan and MRI are currently unsuitable to perform examinations on people in seated positions).

The aim of our study is to provide elements for the anatomical study of human body seated on an automobile seat, this work is based on an anatomical analysis of PMHS placed in driving configuration on a usual automobile seat. The approach is based on the serial sectioning technique that has often been used in Anatomy. The elements seen on each section are placed in an initial reference frame for a geometrical description of the occupant. With a validating aim, a study by radiography on volunteer subjects in sitting position on an automobile seat was undertaken.

METHODOLOGY

Choice of the PMHS

The subject used has morphological characteristics closed to the 50th male percentile for the two parameters : body mass and height (stature of 174 centimetres for a weight of 75kg). The body was treated by Winckler conservation technique [Winckler74], which restores a muscular flexibility and maintains a good articular mobility. A complete radiological examination was carried out in order to detect any pathology.

Seated position

We use a driver's cockpit obtained from a mid sized European mass-produced vehicle. This model car includes a seat with floor mountings, a steering column and wheel, control pedals and a restraint system. The seat, provided with a head-rest, is a standard piece which has longitudinal and backrest inclination adjustments. The seat is placed in configuration to use of a tester corresponding to the PMHS morphotype (50th percentile in our case). The subject's positioning on the seat is a very delicate stage and must be carried out with a lot of attention. Indeed, the only criteria to obtain a realistic position is the manipulators appreciation. After some adjustments on seat position, the subject is placed in driving configuration, with horizontal viewing direction, hands on the steering wheel, feet on the control pedals. This stage of the experiment cannot be validate by radiological examination because of the metal elements belonging to the cockpit's and seat's structures.

We especially respect spinal column vertical alignment in the median plane of the seat and the symmetry of the position taken by the pelvis by checking the tops of the iliac crests which must be aligned on same horizontal plane. The backward inclination of the pelvis is estimated by identification of three points accessible by palpation : the left and right ASIS and the pubic symphysis. The subject is installed with a 40° backward pelvis inclination. Lastly, the pelvis is longitudinally placed on the seat cushion, in order to obtain thigh-leg and trunk-vertical intersegmental angles in the interval of least discomfort reported by anthropometric investigations [Rebiffé84].

At the level of the upper body part, hands are attached on the steering wheel in a 10.10 o'clock driving position. The lack of muscular activity in the neck forces us to support the subject's head. It is tilted to obtain a horizontal vision axis ; a 60 millimetre distance is maintained between the back of the head and the head rest. It is noted that the shoulders are slightly taken off of the seat backrest.

Figure 1 shows the result of this positioning, with visualisation of the examination reference frame.

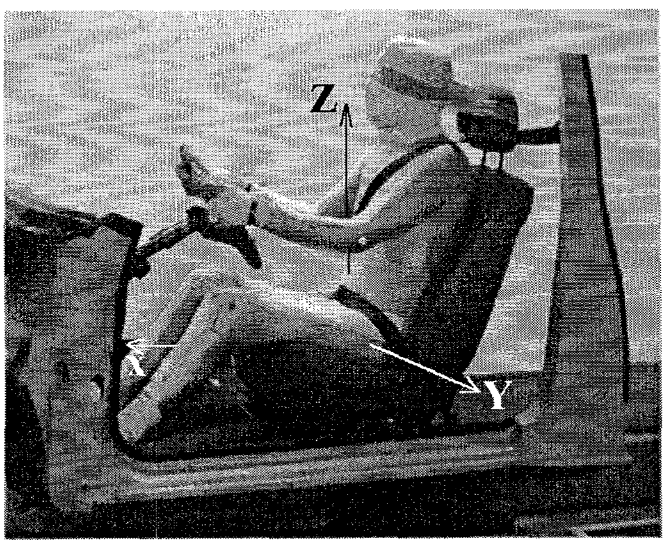

Figure 1. PMHS position in the seat.

The described position is then referenced in the cockpit by measurements of skin landmarks which coordinates will be used to replace the digital representation in the initial reference system. The co-ordinates system related to the vehicle is composed of the XOY plane which is horizontal, parallel to the vehicle support plan, XOZ which is vertical and defines the longitudinal median plane of the vehicle and YOZ which is vertical and contains the two wheels axis in front of the vehicle.

The reference frame visualised on Figure 1 corresponds to the vehicle reference system where the origin was translated in the subject's sagittal plane, between the external edges of the right and left trochanters, approximating the localisation of the H points.

Some anatomical reference points (accessible by palpation) are raised in the described reference frame.

The last stage, which completes the positioning procedure is related to the freezing step. In order to definitively fix the subject's attitude and in order to carry out serial sections, the PMHS and the seat are placed in cold room at a temperature of -23 degrees until complete freezing. This solid state will be preserved until the term of the experimentation.

Realisation of the sections

Sections are produced according to the sagittal direction (reference XOZ frame). This plane preserves in sitting position all the characteristics of the anatomy described in a conventional way of the man upright. Indeed, the sagittal plane of the individual upright crosses, in his median part, of many anatomical points such as the vertex, the spinal processes of all vertebrae, the point of the sternum or the pubic symphysis. During the passage in seated posture, only relative antero-posterior movements of body parts are involved ; the osseous points previously enumerated remain in the same median plane.

The sagittal plane is moreover very interesting for a visualisation of spinal column curvatures.

The sections are serial, with a ten millimetres interval. At the end of a complete cleaning of the surface to be analysed, a picture of the section is taken. The slides representing each section are projected on a translucent table where an anatomical diagram is carried out. This stage which consists in identifying each elementary component belonging to a section (anatomical elements and associated reference points) is necessary and is concluded by an anatomist.

RESULTS

While superimposing data coming from various sections, we bring back the entire visible elements on each section of our reference frame. The superimposition of bidimensional data allows a visualisation of some bony and skin elements (Figure 2). These numerical elements are subjected to quantitative examinations such as the measurement of angles between all the vertebrae.

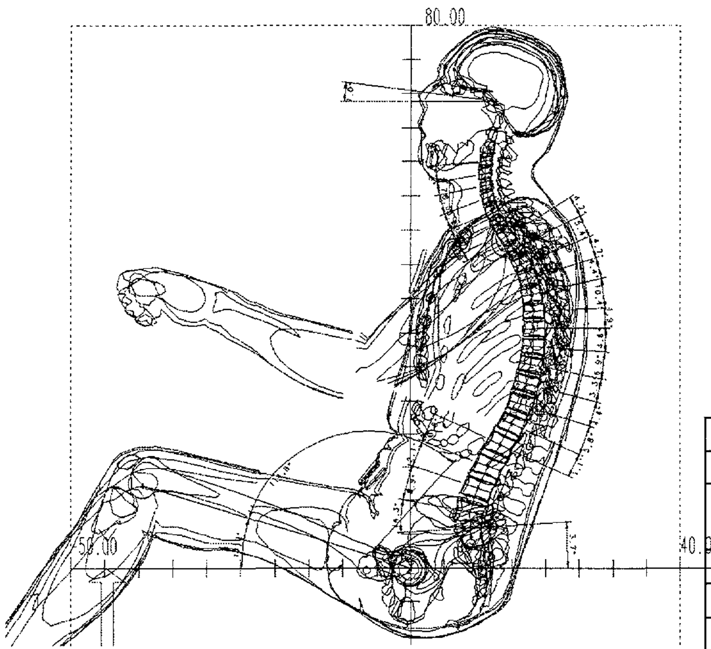

Figure 2. Contours in the XOZ plane
Only subject's right half (from the sagittal .plan) are showed, in order to facilitate the visualisation..

Characterisation of the skeleton

Pelvis

We choose two points to define the inclination of the pelvis : the first one located on the right ASIS and the second one on the former part of the pubic symphysis. The angle (measured in the XZ plane) between the line connecting these two points and the vertical characterises the pelvis slope ; this angle is equal to 41°. In natural position, prone upright, this angle is very close to 0° [Peterson88].

Angle pelvis/femur

The theoretical H-point (Hth) corresponds the femoral head centre. Let us indicate by "thigh axis" the line which contains Hth and a Knee point corresponding to the centre of lateral the condyle. The thigh axis is tilted of 17° from the horizontal axis. The angle between the pelvis and the femur (ASIS/Symphysis/Knee) is equal to 115°.

Chest slope

The chest's axis is given by Hip and shoulder and points (the last one is given by the centre of humerus head). The chest is tilted of 73.5° from the horizontal axis.

Lumbar-femur angle

We noticed first of all that the four vertebrae L1 L2 L3 L4 are almost in straightness : the former walls of L1 L2 L3 and L4 are practically aligned on the same line. The lumbar curvature appears primarily by two important angles : first between L5-S1 and second between L4-L5, other lumbar vertebrae are in straightness. The angle (measured in the XZ plane) between L1-L4 and the thigh axis is equal to 96°; a reference value, which corresponds in a state of balance, is of 135° (reported by [Keegan53]).

Complementary measures

According to Figure 2, several coordinates of skeletal points are listed below :

	X	Z
H	0.0	0.0
Superior side of the right Trochanter	1.5	1.9
Pubic Symphysis	5.2	2.9
Right ASIS	-0.8	9.5
Iliac Crest	-8.3	10.3
Coccyx tip	-7	-8.7
Ischion tip	0.5	-8.2
Shoulder (center of the Humeral head)	1-4.4	48.5
Acromion	-15.9	53.5
C1 (top of the odontoïde process)	-12.4	64.7
Vertex	-12.6	79.2
Infraorbital	-6.2	69.7
Suprasternal	-7.1	48.7
Ear	-12.7	68.9

Table 1. Measures of skeletal points
(X direction is forward)

Description of the vertebral column

Each vertebral body is compared to a quadrilateral geometry : the four points selected to represent the vertebral body are the former and posterior edges of the higher and the lower plates of each vertebra. The geometrical centre of the quadrilateral thus defined indicates the centre of the vertebral body.

The vertebral axis corresponds to the bisector of the two segments representing the higher and lower plates of each vertebral body (figure 3). The co-ordinates of the vertebral centres in the reference frame centred out of H and the angles between the vertebral axes are as following (table 2).

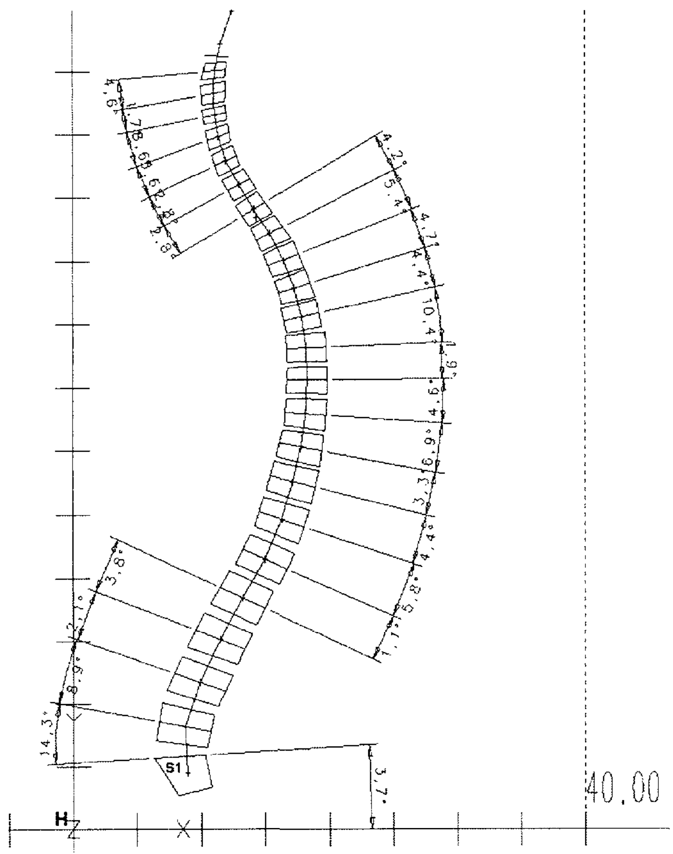

Figure 3. position of the spinal column location of the vertebral bodies and cartography of the angles between the vertebral axes

Vertebrae body	X	Y		angle
S1	8.9	4.5	S1/Horiz.	3.5
L5	8.8	8.2	L5/S1	14.5
L4	9.9	11.8	L4/L5	9
L3	11.5	15.1	L3/L4	2
L2	13.2	18.5	L2/L3	4
L1	15	21.5	L1/L2	-1
T12	16.3	24.7	T12/L1	-6
T11	17.2	27.6	T11/T12	-4.5
T10	17.8	30.3	T10/T11	-3.5
T9	18.2	33	T9/T10	-7
T8	18.3	35.6	T8/T9	-4.5
T7	18.2	38.2	T7/T8	-2
T6	17.9	40.6	T6/T7	-10.5
T5	17.3	42.9	T5/T6	-4.5
T4	16.5	45.1	T4/T5	-4.5
T3	15.4	47.2	T3/T4	-5.5
T2	14.1	49.1	T2/T3	-4
T1	13	51	T1/T2	3
C7	11.9	52.9	C7/T1	3
C6	11.4	54.8	C6/C7	5.5
C5	11.1	56.6	C5/C6	8.5
C4	11	58.3	C4/C5	1.5
C3	11.1	60.1	C3/C4	4.5
C2/C1	12.4	64.7		

Table 2. XZ Position of vertebrae and angles between vertebral axes

POSITION CHECKING

Several works based on subjects radiographs in sitting position have already been reported in [Colombini85], [Biot84], [Nyquist76]. The results presented include dispersions which are related on one hand to individual characteristics and on the other hand with the specific position adopted by each subject. Experimental protocol difficulty led the authors to limit the number of radiographs to provide only the description of the lower part of the spinal column in sitting position. Also, the seat used is always a cast solid radio-transparent matter part such as wood or plaster.

We have used the first results of a study performed by the Laboratory of Anatomy of Sousse and the radiology department of the Hospital of Sousse (Tunisia). This data where used to compare with the previously presented above.

Methodology

20 voluntary subjects, of different ages and morphologies were submitted to two successive radiographs under profile incidence ; the first carried out

on upright subject (standard radiography), the second carried out on same subject sitting in an automobile standard seat.

The sample is composed of 9 women and 11 men, the average age is 29 years (with a 19 years minimum and a 53 years maximum). Freedom was left on the subject in the choice of the various parameters of adjustments. The medical radiograph was carried out when the individual obtained the optimal configuration of comfort which corresponds to its position of usual automobile behaviour (figure 4). A receiving plate was inclined with the backrest to remain in the subject axis to provide a skeleton visualisation in the pelvic, thoracic and cervical areas (figure 4).

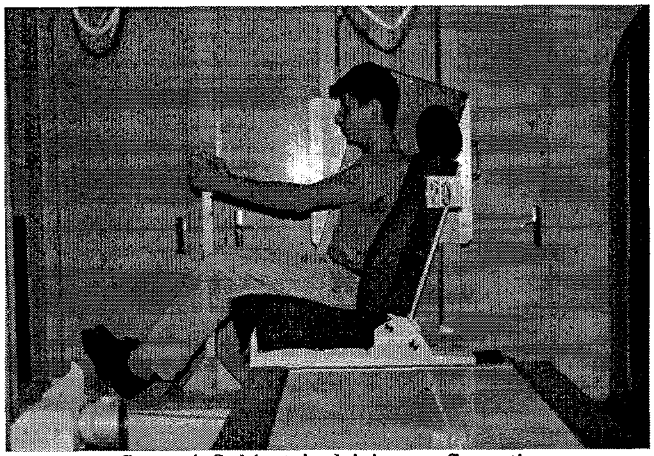

figure 4. Subject in driving configuration

Results

The vertebral bodies of the lumbar column are geometrically schematised. It makes possible to define vertebral axes. These axes allow us to measure the relative slopes of the vertebrae in the sagittal plane. The simultaneous visualisation of the angles describing the spinal column of an individual upright can be directly compared with measured obtained in seated posture (figure 5).

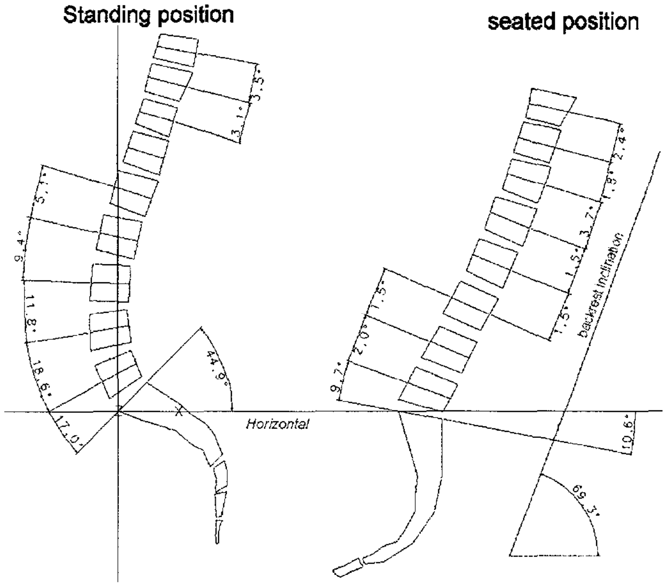

Figure 5. Schematic representation of the vertebral bodies (sacrum and vertebral axes)

In order to quantify curvature modifications, the geometrical magnitudes that we successively measured for the individuals in upright position in automobile configuration are as follow (figure 6) :

- * S1/Horizontal angle characterising the orientation of the higher plate of the sacrum compared to the horizontal line.
- * cartography of angles between vertebrae axis from T10 to L5, which provides seven angles : T10-T11, T11-T12, T12-L1, L1-L2, L2-L3, L3-L4 and L4-L5.
- * angle L5-S1 which is measured between the higher plate of S1 and L5 vertebrae axis.
- * lordotic angle L1-S1, defined as the difference in slope measured between the vertebral axis of L1 and the higher plate of S1. This angle generally characterises the lumbar lordosis of an individual upright. Let us notice that "lordotic angle L1-S1" is usually devoted to represent the angle between the higher plate of L1 and the higher plate of S1. Our quantity L1-S1 introduces little difference with the traditional angle described in the literature since we retained, for each vertebra, a transverse axis which is tilted compared to the higher plate.

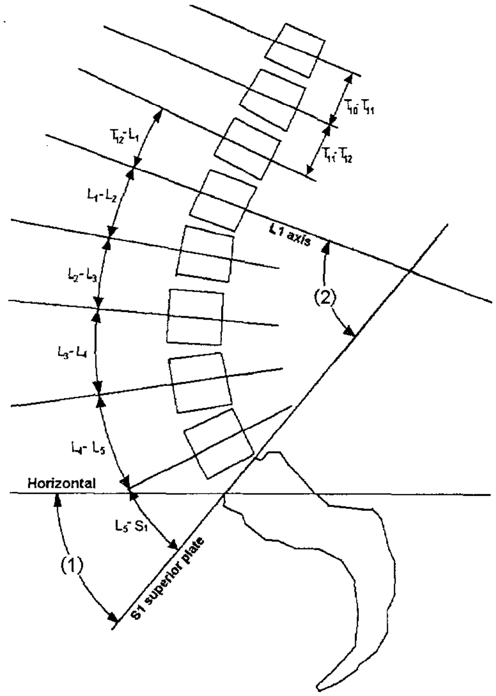

Figure 6. Angular measures
(1) sacrum orientation
(2) Lordotic angle L1-S1.

Case #	L1/S1	S1/H
1	6,8	-15,8
2	10,2	-10,6
3	9,9	-27,9
4	48,2	21,7
5	-10,2	-33,5
6	27	-1,7
7	2,4	-25,1
8	19,2	-3,3
9	11,2	-10,8
10	-0,7	-23,4
11	3,9	-15,0
12	17,9	-16,0
13	28,4	5,1
14	0,6	-20,9
15	12,5	-12,7
16	-10,9	-24,4
17	4,3	-27,0
18	20,8	-12,4
19	7,6	-20,5
20	8,2	-16,8
Mean	10,9	-14,6
Men	11,6	-13,2
Women	9,9	-16,2

Table 3. individual angles in seated position, the values are graphically displayed in the next figure.

Comparison

The PMHS lordotic angle L1-S1 is equal to 28,5°and the slope of S1 higher plate on the Horizontal plane is equal to 3,5°.

On the diagram which shows the L1-S1 lordotic angle distribution according to the inclination angle of the sacrum on the horizontal plane (figure 7), the PMHS shows a behaviour similar to the observations obtained on voluntary individuals. The pelvis position and the lumbar curve state are completely compatible with data coming from voluntary individuals. The subject position seems to be representative of a realistic position.

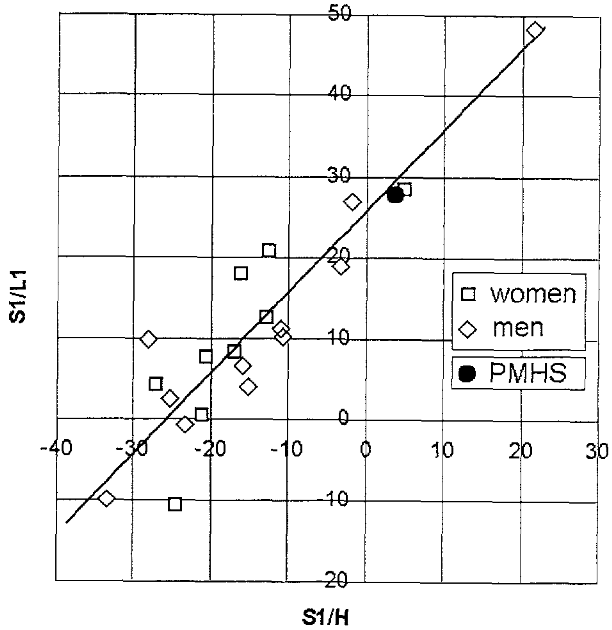

Figure 7. Lordotic angle L1-S1 function of the orientation of the sacrum (for volunteers and PMHS in seated posture)

CONCLUSION

Approaches aiming to provide descriptions of cars occupants posture were based on anthropometric approaches [Robbins83] or on analysis by radiographs [Biot84], [Nyquist76].

The technique of the serial sections is very reliable to apprehend the anatomy of human being. If radiography is easy to use, it suffers of problems involved in the 2D projection which generates uncertainties during the identification. The subject presented here was submitted to sections according to a sagittal datum-line, which is appropriate for a visualisation under side incidence. The data description in XZ plane is immediate. On the other hand, the elements location along the third axis of co-ordinates is not as easy. It requires an identification by level of section. The techniques of *three-dimensional rebuilding* make possible to take into account the third co-ordinate of space and provide a synthetic vision of initial objects. Complementary results, which provide a description in a reference frame to three dimensions are presented in [Chabert96].

This approach makes possible to consider applications in the fields of safety and comfort. Moreover among the research of less discomfort conditions in the sitting position, this approach makes possible to understand some anatomical adaptation mechanisms of the skeleton in this specific position. Moreover, in the world of safety, these results provide basic elements for anthropometry in the design of test dummies, but also for safety systems development installed around the subject, in the posture we described.

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