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Matthew P. Reed, Ronald W. Roe and Lawrence W. Schneider
University of Michigan Transportation Research Institute

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ABSTRACT

The primary objective of the ASPECT (Automotive Seat and Package Evaluation and Comparison Tools) program was to develop a new generation of the SAE J826 H-point manikin. The new ASPECT manikin builds on the long-term success of the H-point manikin while adding new measurement capability and improved ease of use. The ASPECT manikin features an articulated torso linkage to measure lumbar support prominence; new contours based on human subject data; a new weighting scheme; lightweight, supplemental thigh, leg, and shoe segments; and a simpler, user-friendly installation procedure. This paper describes the new manikin in detail, including the rationale and motivation for the design features. The ASPECT manikin maintains continuity with the current SAE J826 H-point manikin in important areas while providing substantial new measurement capability.



Figure 1a. SAE J826 H-point manikin.

INTRODUCTION

The current standard tool for measuring vehicle seats is the SAE J826 H-point manikin (1).¹ The H-point manikin was developed in the early 1960s in response to the need for a three-dimensional tool to represent vehicle occupants in the design process (2). Although the H-point manikin has been used successfully for over 30 years, the limitations of the H-point manikin in modern seats and vehicles and in the contemporary computerized design environment pointed to a need for a new manikin. This paper presents an overview of the ASPECT manikin, a new tool for vehicle and seat design and evaluation that builds evolutionarily on the success of the original H-point manikin. Figure 1 shows the SAE J826 manikin and the new ASPECT manikin. Among other features, the ASPECT manikin has a three-piece articulated torso, a single supplemental leg, a lightweight thigh segment separate from the weighted buttock/thigh pan, a revised mass distribution, new seat interface contours, and a new, less-complicated installation procedure.



Figure 1b. ASPECT manikin prototype.

HISTORY OF THE H-POINT MANIKIN – In 1955, Professor Wilfred Dempster of the University of Michigan conducted an in-depth study of skeletal kinematics to develop a three-dimensional kinematic linkage representing the seated operator (3). Dempster was on the forefront of the emerging science of engineering anthropometry, seeking to apply the human body mea-

1. Numbers in parentheses denote references at the end of the paper.

surement and data analysis procedures of physical anthropologists to the problem of workspace and equipment design. The new methods originally developed for military applications were rapidly adopted by the auto industry. Geoffrey of Ford Motor Company conducted a series of radiographic experiments to create a two-dimensional template describing a seated automobile occupant (4). In the late 1950s, Myal of General Motors completed the first prototype of a "comfort dimensioning manikin," a three-dimensional, weighted representation of an automobile driver (2, 5). The manikin was intended to provide three measures of the vehicle interior geometry that were previously unavailable. First, the manikin included a reference point at the hip, known as the H-point. When the manikin was installed in a seat and weighted, the location of the H-point provided a more useful predictor of occupant position than seat reference points on the undeflected contour. Second, the manikin torso was also weighted so that it deflected the seatback in a manner similar to the deflection produced by human occupants, providing an improved measure of seatback angle. Finally, the angles at the manikin's hip and knee joints provided a measure of leg room.

To obtain a typical seat deflection, a median male weight of 170 lbs (77.3 kg) was selected, based on available civilian and military data (2). However, because a measure of legroom was also desired, the reference stature for the manikin was established at 5'11" (1803 mm), approximately the 90th percentile for male drivers at the time. The external contours in the seat contact areas were developed from the seat interface contours of eight men who were approximately 5'11" tall and 170 lb (1803 mm, 77.3 kg). One subject's contour that was deemed to be most representative of the group was selected as the basis for the manikin contour. A contemporary examination of the contours suggests that some additional modifications were made, perhaps to improve manikin performance or because of manufacturing considerations. No record of these modifications is available, however.

In 1962, the SAE Design Devices Committee adopted SAE Recommended Practice J826, describing a weighted three-dimensional manikin with contoured shells. The new H-point manikin used the GM external surface shells, but modified the linkage geometry using input from Geoffrey and others. By 1968, J826 had been amended to specify use of longer leg and thigh segments identified as 95th percentile. A review of the calculations used to develop the longer leg and thigh segments suggests that the 90th-percentile segments developed by Geoffrey were adjusted by scaling the external buttock-to-knee and knee-to-heel dimensions to match 95th-percentile male values from the 1963 U.S. HES data (4, 6). The result is a total functional leg length (thigh plus leg plus foot) that is longer than the 95th percentile for male drivers of that time.

Since the original development of the H-point manikin, there have been a number of efforts to modify the manikin. Kohara and Sugi (7) created an articulated manikin torso intended to replicate human lumbar spine motion. Muscle tension was replicated using springs in the manikin torso. Thier (8) placed sensors in the manikin shells to record seat interface pressures. Unpublished modifications have included modified torso shells with lordotic spine curvature. Another adaptation of the manikin was recently included in SAE J826. The manikin is installed in a seat without legs, using a modified weight distribution, to measure the seat cushion angle (1).

The H-point manikin has been adapted for other uses beyond its original intent, largely because of its status as the most widely used physical representation of a vehicle occupant. SAE J1100 contains dozens of dimensions measured relative to the manikin, including measures of hip room, leg room, and headroom. International groups, including ISO, have incorporated the H-point manikin into standards. The H-point manikin has been used as a platform for other measurement devices, including a belt-fit test device (9) and a tool for measuring head restraint location (10). The U.S. Federal Motor Vehicle Safety Standards use the H-point manikin with modified leg lengths to establish reference points for positioning crash test dummies (11). Recently, a version of the H-point manikin with contours, segment lengths, and mass equivalent to the small female Hybrid-III crash dummy was created to facilitate crash testing (12).

While the widespread use of the H-point manikin testifies to the many potential applications for a physical representation of a vehicle occupant, the limitations of the current tool led human factors practitioners in the automotive industry to call for improvements. In the early 1990s, UMTRI researchers conducted a study comparing the H-point manikin measures of posture and position to data from human subjects in three vehicle seats (13). The SAE J826 H-point was found to be consistently located in the test seats relative to the human hip joint locations, but the manikin measure of seatback angle did not accurately represent human torso posture.

THE ASPECT PROGRAM – In 1993, the SAE Design Devices Committee, which has jurisdiction over the H-point manikin, convened a task group to consider improvements to the manikin. Representatives from auto manufacturers, seat suppliers, and universities determined that a research and development plan focused on the development of a new manikin was needed. Researchers from the Biosciences Division of the University of Michigan Transportation Research Institute and the Biomechanical Design Laboratory of the Michigan State University College of Engineering drafted a program description, laying out a four-year effort that would culminate in a new set of vehicle and seat design tools, including a revised H-point manikin. Eleven automotive industry companies participated via yearly contributions

coordinated through SAE's Cooperative Research Program. The research and development activities were conducted by the two university research labs, with industry consultation and coordination through an Industry Advisory Panel comprised of representatives from the funding companies. Work on the program began in July 1994, and is scheduled for completion at the end of June 1999.

The research program was called ASPECT, an acronym for Automotive Seat and Package Evaluation and Comparison Tools. The program objectives included the development of a new manikin and new statistical tools for predicting occupant posture and position (14-20). This paper focuses on a description of the new ASPECT manikin, a tool for seat and vehicle measurement intended to replace the current H-point manikin. Figure 2 shows the latest ASPECT manikin prototype, designated APM-4 for the fourth major prototype of the ASPECT physical manikin. The final version of the manikin at the conclusion of the ASPECT program in June 1999 will be slightly different, including changes in response to industry feedback regarding performance and ease of use. The final manikin specifications will be documented in SAE technical papers and recommended practices.



Figure 2. ASPECT manikin prototype (APM-4).

METHODS AND MANIKIN SPECIFICATIONS

INDUSTRY INPUT – Early in the ASPECT program, the research team led a systematic effort to obtain input from the industry regarding the uses of the current H-point manikin and the needs for the future. Two written surveys were conducted, each completed by representatives of all eleven IAP companies. The survey findings were supplemented by information from on-site visits with participating companies, during which current uses of the H-point manikin were demonstrated and the limitations discussed.

In discussions with industry representatives, three limitations of the current H-point manikin were most frequently mentioned as opportunities for improvement.

Ease of Use – The current manikin was often described as difficult to use, particularly in rear seats. The manikin itself, without the legs or additional weights, weighs over 40 lbs (18 kg) and is difficult to maneuver inside a vehicle. The attachment between the legs and the thigh section (T-bar) is cumbersome, and the installation procedure requires various rocking and pushing steps that are difficult to perform consistently.

Stability in Seats with Prominent Lumbar Supports – The current manikin has a one-piece, rigid torso shell that does not conform to the seatback. When installed in a seat with a prominent lumbar support, the torso tends to pivot around the apex of the lumbar support, resulting in unstable readings. Some of the seat suppliers participating in the program indicated that their seatback designs were restricted by a need to obtain stable H-point readings with the rigid-torso H-point manikin.

Biofidelity – Industry participants were concerned that the H-point manikin, because of the anthropometry used in its definition and the lack of articulation in the lumbar spine, does not suitably represent a modern vehicle occupant, particularly with regard to torso posture and hip location. A study at UMTRI (13) had indicated that the H-point location was fairly consistent with human hip joint locations across three seats, but that the manikin torso did not accurately or consistently represent human torso interactions with seats.

Another issue that had been raised repeatedly in meetings of the SAE Design Devices Committee and other automotive human factors groups was the undesirable linkage between seat and package measures in the current J826 manikin. Because the standard procedures for measuring H-point location and seatback angle with the J826 manikin require use of the legs and shoes, the resulting measures represent some combination of the effects of the seat and the package geometry. Further, the accelerator heel point (AHP) and ball of foot (BOF) reference points are defined by the position and orientation of the manikin shoe when the manikin is installed in such a way that the manikin H-point is at the driver seating reference point (SgRP). Any change in the SgRP location, therefore, changes the pedal reference point locations, which in turn affects driver accommodation models.

One of the goals for the new manikin design was to separate the influences of the seat and package on occupant posture. The ASPECT manikin was designed to be primarily a seat measurement tool, able to be applied without interaction with the rest of the vehicle interior. ASPECT manikin H-point locations, for example, are independent of seat height or any other package-related influence. To provide continuity with current practice, sup-

plemental leg, thigh, and shoe components are provided to facilitate package-related measures, such as hip angle and knee angle.

MANIKIN APPLICATIONS – Input from industry representatives led to the identification of three broad application categories for the new manikin. These applications guided the development of the manikin functions and features.

Defining and Measuring Reference Points – The foremost function of the new ASPECT manikin, like the current H-point manikin, is the definition and measurement of a reference point (H-point) that provides a human-centered reference relative to the vehicle seat from which accommodation-related measurements can be made. The new manikin preserves the H-point as a representation of the hip joint location of the vehicle occupant. The original objective in locating the reference point on the new manikin and in prescribing the manikin performance was to obtain the best possible match between the manikin H-point and the average hip joint center location of males who are the same stature and weight as the manikin. However, as noted below, the findings from extensive posture data analysis resulted in a change in the manikin performance objectives to provide more continuity with current practice and to improve the manikin’s usefulness as a seat measurement tool.

The J826 manikin is also used to define the accelerator heel point (AHP) and ball of foot (BOF), two reference points used to define the pedal and floor locations. The new manikin includes a supplementary shoe segment that can be used to define and measure a pedal reference point (PRP), a ball of shoe point (BOS), and an accelerator heel point (AHP). Details of the use of these supplemental segments to measure package related reference points and dimensions are published elsewhere (17).

Design of Vehicle Interiors for Accommodation and Comfort (Occupant Packaging) – Vehicle interior design applications of the manikin differ from the primary application (definition and measurement of reference points) in several important ways. The definition and measurement of the H-point are not directly useful in designing a vehicle interior. Rather, the H-point provides a human-centered reference from which measurements can be made and to which other prediction tools can be anchored. The ASPECT program encompasses both a new definition of the reference point and new use of the reference point to define interior vehicle measurements and to anchor posture-prediction tools.

For purposes of the ASPECT program, vehicle design for accommodation includes two general task categories: defining and using vehicle measurements, and predicting occupant posture and position. A clear and consistent set of definitions for vehicle interior dimensions is critical, since these measures are inputs to the models and prac-

tices used to design vehicle interiors for accommodation (e.g., SAE J1517 and J941). The manikin is used to define and measure a reference point (H-point). The H-point, in combination with other vehicle interior landmarks, is used to define measures such as seat height. Seat height is then used, for example, as input to statistical models that predict the distribution of driver-selected seat positions (SAE J1517). Importantly, the predicted “seat position” is actually the location of the seat H-point in package space. Thus, the manikin provides the essential reference used both to make interior measurements and to predict posture and position.

Seat Design for Accommodation and Comfort – The SAE J826 manikin was developed primarily as a seated position reference tool that accounts for seat deflection. It provides a reference point for positioning accommodation tools and describing consistent comparative spatial measures of vehicle interiors. Although it lacks some of the functionality that would be useful in a seat design tool, it has nonetheless been used to obtain measures relating seat design to comfort. The surveys and site visits undertaken at the start of the ASPECT program demonstrated that there is a strong desire in the industry to continue to use the manikin for seat design and comfort evaluations. One potential use of the manikin is to make pressure distribution measurements on seats, using the manikin as a standardized sitter for seat evaluation purposes. Seat surface pressure distributions produced by the manikin were monitored during manikin development, and some changes in contour were made in part to reduce unrealistic pressure patterns. However, further research beyond the ASPECT program will be necessary to determine if the ASPECT manikin pressure distribution is a reliable predictor of human pressure distributions.

A number of additional applications of the manikin beyond those listed above were noted, including those relating to vehicle safety. The H-point manikin is used for crash dummy positioning and as a platform for tools to measure seatbelt fit and head restraint location. Most of these applications involve modifications to the standard H-point manikin design and installation procedure. The manikin functionality required for these applications was considered, but not always accommodated, in the ASPECT manikin development process. Because the ASPECT manikin differs in important ways from its predecessor, both in features and performance, add-on tools such as the belt-fit test device cannot be used with the new manikin without modification. Further research will be necessary to determine how such things as seatbelt fit and head restraint location should be measured with the new manikin, or how the ASPECT manikin can be used for crash dummy positioning. In general, the ASPECT manikin is expected to provide more stable and easier-to-use measures of vehicle occupant posture and position than the current manikin, and is likely to be a better platform for other measurement devices.

ANTHROPOMETRIC DEFINITION – The current SAE J826 manikin represents an amalgam of anthropometry resulting from the range of applications for which the manikin was developed. The manikin was intended to produce a reference point relative to a seat (H-point) that represents where people would be located in the seat. The reference point previously in use was the intersection between the undeflected seatback and seatpan contours, commonly known as the bite line. A reference point obtained from a weighted manikin predicts human positions in the seat more consistently. Noting that deflections of typical seat cushions of the time were approximately proportional to body weight, the developers of the original manikin chose median male weight as the reference value (2, 5).

The J826 manikin was also intended to be used as a legroom measurement tool, so relatively long legs were desired. The original manikin design was based on men who were 90th percentile by stature, according to data from about 1960 (2). In subsequent revisions, the leg and thigh segment lengths were adjusted so that each was 95th percentile for that dimension in the male population, using reference to data from the Health Examination Survey (6). The anthropometric definition for the current SAE J826 manikin is thus a combination of 50th-, 90th-, and 95th-percentile male values, taken from different civilian anthropometric surveys from the early 1960s.

An examination of the applications for which the ASPECT manikin was intended demonstrated that any reasonable manikin size would be adequate — no specific percentile of any particular population is required. Percentile targets for the manikin are inappropriate, because (1) percentiles imply a population, raising the question of what population should constitute the basis for a manikin to be used internationally, and (2) populations are dynamic, so that even if a chosen percentile for a particular population could be identified, the values would soon be in error with shifts in demographics.

The manikin must provide a reference point and other measurements of a seat that are related to the postures and positions of human occupants in consistent and predictable ways. For example, in some seats, the vertical position of a person's hips when sitting is related to the person's body weight. If the relationship between weight and hip position is known from studies of vehicle occupant posture, then the hip location of any individual can be predicted from the hip location of any other person and the relationship between weight and hip location. For vehicle and seat design applications, the objective is to use a measure from a surrogate sitter (weighted manikin) to predict hip locations of occupants of a wide range of sizes. In the ASPECT program, the posture and position of hundreds of occupants with widely varying anthropometry have been measured to quantify relationships between anthropometry and posture across a wide range of seats (15, 18, 20). The resulting data and analyses make it unnecessary to represent any particular occupant size in the ASPECT manikin.

Several considerations indicate that an extreme manikin size is less desirable. A manikin that is excessively large might not fit in vehicles or seats that are legitimately designed for smaller populations. A manikin that is excessively small might not deflect seats into a range typical of automobile occupants. In general, a manikin that produces measurement values near the middle of the range typical of automobile occupants would be best for predicting occupant posture and position.

Having established that a midsize occupant anthropometry would be best, the dominant consideration became continuity with current practice. Anthropometric specifications of midsize U.S. males were used to develop the two tools most commonly used to represent humans in the vehicle design and development process: the current H-point manikin (with the limitations noted above), and the Hybrid III crash dummy used in compliance testing for U.S. Federal Motor Vehicle Safety Standards (11). A midsize U.S. male body size was therefore selected as the target for the ASPECT manikin, with the stated objective of continuity with crash dummies.

The anthropometric specifications for the ASPECT manikin were determined using data from the 1974 National Health Examination and Nutrition Survey (NHANES) (21). At the time, these were the best data available to describe the U.S. population.² The 1974 NHANES data also formed the basis for the development of anthropometric standards for the next generation of crash dummies. In the early 1980s, Schneider et al. (22) conducted a study supported by the U.S. National Highway Traffic Safety Administration to develop anthropometric specifications for a new frontal impact dummy. The sampling categories for that study used the median male values of stature and weight from the 1974 NHANES for the midsize-male target values. Extensive measurements from 25 men within a narrow range of the target stature and weight were used to create anthropometric specifications (23) that were subsequently used to develop components for a new crash dummy (24). Selecting median male values from the 1974 NHANES study for the ASPECT manikin therefore provides a good match to the current standard Hybrid III crash dummy, ensures considerable continuity with future crash dummies, and makes the detailed data from the Schneider et al. study applicable to manikin development.

Table 1 shows the ASPECT reference anthropometry. The ASPECT manikin geometry should not be referred to as "50th-percentile male," even though some dimensions were obtained from median male values from one survey. The values are almost certainly different from the true median U.S. values today, and would be different from

2. Since this time, more recent U.S. civilian data have become available from the 1990 NHANES study. In keeping with the rationale described above, the ASPECT reference anthropometry was not altered in response to this new information. Similarly, data from the CAESAR study, now underway, will not affect the ASPECT reference anthropometry or the design of the manikin.

median values in almost any population of interest. The ASPECT manikin is specified on three variables: stature, weight (mass), and erect sitting height. Analyses have shown that these three variables account for a majority of the variance in anthropometric variables that are relevant to vehicle interior design (20). Note, however, that none of these values is represented directly in the manikin. The manikin does not have the body segments necessary to measure stature or erect sitting height, and the manikin weight is reduced by the force required to support the heels of a sitter matching the reference anthropometry (see below). Instead, the reference anthropometry was used to select people whose anthropometry and behavior form the basis for the manikin specification.

Table 1. ASPECT Reference Anthropometry Compared to Crash Dummies

| Variable | ASPECT* | Midsized Male Advanced Crash Dummy (23)* | Midsized Male Hybrid III Crash Dummy (25) |
|---------------------------|---------|--|---|
| Stature (mm) | 1753 | 1753 | 1754 |
| Mass (kg) | 77.3 | 77.3 | 78.3 |
| Erect Sitting Height (mm) | 913 | 913 | 906.8 |

* Median male values from 1974 NHANES (21).

KINEMATIC LINKAGE – One of the primary goals in the development of the ASPECT manikin was to provide a lumbar articulation that would allow the manikin to function better in seats with contoured seatbacks, particularly those with prominent lumbar supports. From the beginning of the ASPECT manikin prototype development, methods of simulating lumbar spine articulation in the manikin were explored. Kinematic computer simulations, based on previous work of Haas (26) and Reed et al. (27, 28), indicated that a relatively simple kinematic linkage with one or two lumbar joints would adequately represent human spine kinematics for ASPECT applications. The most promising approach used two lumbar joints, located at the anatomical positions of the T12/L1 and L5/S1 joints. This provided a single mechanical segment representing the lumbar spine, and facilitated connecting the external contours (shells) to the linkage. Figure 3 shows these lumbar spine joints relative to the manikin and a midsized-male human figure.

Work with early manikin prototypes demonstrated that the three degrees of freedom provided by the hip, lower lumbar, and upper lumbar joints resulted in poor manikin performance, particularly at more vertical seatback angles. The manikin was unstable, and tended to flop forward in the seat. Two additions to the linkage were made that provided the necessary performance and stability. Figure 4 illustrates the torso linkage schematically.

First, a connecting rod was added to link the thorax and pelvis together across the lumbar joints. The effect of this connection is to distribute lumbar flexion or extension

approximately evenly across the two lumbar joints, reducing the lumbar spine to a single degree of freedom (flexion/extension). This concept was adapted from the mechanism used by Bush (29) for a two-dimensional seat design template. He demonstrated that the resulting kinematics were similar to those obtained using a six-joint lumbar spine. During the ASPECT program, prototype manikins were evaluated using a range of mechanical ratios to distribute the lumbar motion between the two joints. Ultimately, however, none of the alternatives was found to be superior to an approximately even distribution of motion.

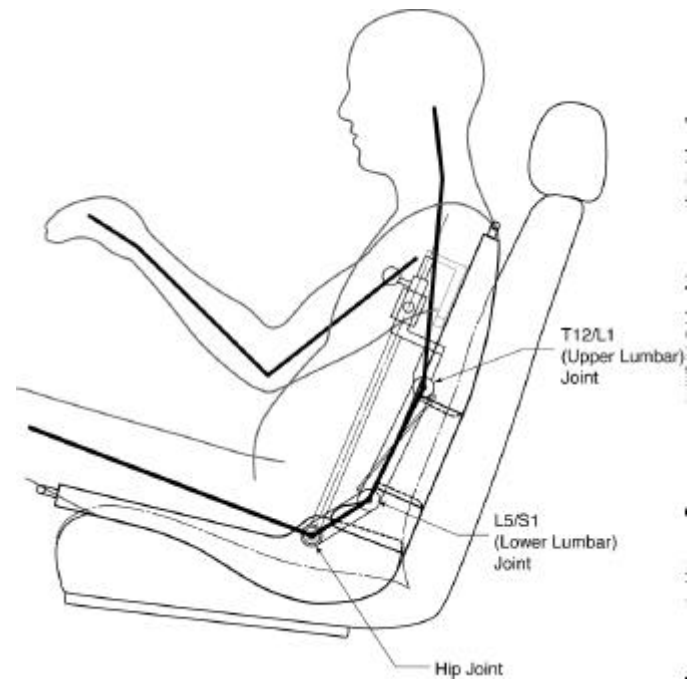


Figure 3. Sideview schematic of a kinematic model of a driver, showing hip, L5/S1, and T12/L1 joints. ASPECT manikin geometry is overlaid.

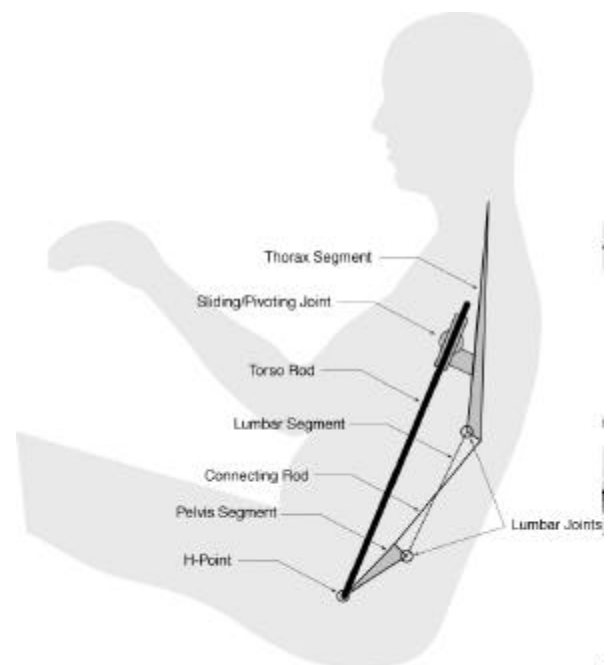


Figure 4. Schematic of ASPECT manikin torso linkage.

Second, a torso rod was added that provided a means of stabilizing the thorax at more vertical seatback angles. The torso rod, shown schematically in Figure 4, pivots at the hip joint and connects to the thorax at a sliding, pivoting joint (two degrees of freedom). The weights in the thorax area of the manikin are attached to the torso rod, rather than to the thorax segment itself. Hence, these weights create a rearward moment on the thorax whenever the torso rod is oriented rearward of vertical, which is the case for all intended manikin applications. Consequently, the manikin can successfully load the upper seatback without jeopardizing stability at upright seatback angles.

The torso rod also provides some compatibility with the current SAE H-point manikin. The torso line on the current manikin is parallel to the profile of the manikin torso shell in the lumbar area. The torso rod on the ASPECT manikin is also designed to be parallel to the lumbar shell when the manikin is in its nominal condition with a flat lumbar surface, providing geometry equivalent to the current manikin. Note that the ASPECT torso rod does not have an anatomical referent; it does not connect the hip with some other specified anatomical landmark. Figure 5 shows the manikin linkage relative to the shells.

Defining the ASPECT manikin linkage required determining the appropriate locations for the hip and lumbar joints relative to each other and to the external manikin surfaces. Extensive analyses were conducted using data collected for the ASPECT program and other previous studies. The central issues were (1) the length of the lumbar segment, (2) the length of the pelvis segment, and (3) the location of the hip joint and lumbar joints relative to the external shell. Early in the ASPECT program, techniques for estimating anatomical joint locations from external body landmark locations were developed from a synthesis of the literature and additional analysis (15). These methods were used with data from several studies to obtain the required dimensions.

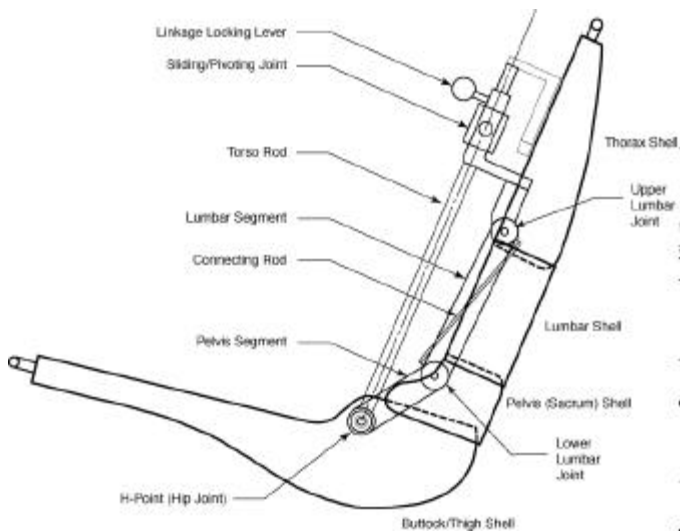


Figure 5. ASPECT manikin linkage with shell geometry.

An ideal approach to determining joint locations that would best represent the skeletal geometry of people matching the ASPECT reference anthropometry would be to use internal imaging techniques, such as radiography, with a large subject sample. However, such invasive techniques are not ethical (in the case of radiography) or are too expensive (e.g., MRI) for application to this problem. Moreover, the ASPECT manikin performance in its intended applications will not be substantially hampered if the linkage differs somewhat from the true average skeletal geometry. Consequently, the objective in linkage development was first to obtain reasonable estimates of the joint locations and segment lengths and then to revise these values as necessary to obtain appropriate manikin function.

Data on joint locations were obtained from a variety of sources. Body landmark locations from the Schneider et al. survey of 25 midsize males (22) were re-analyzed using ASPECT methods and compared to the original analysis (23). Body landmark locations were recorded from 25 men selected to be close to the ASPECT reference anthropometry as they sat in a laboratory hardseat. The resulting joint location estimates were consulted in the manikin design process.

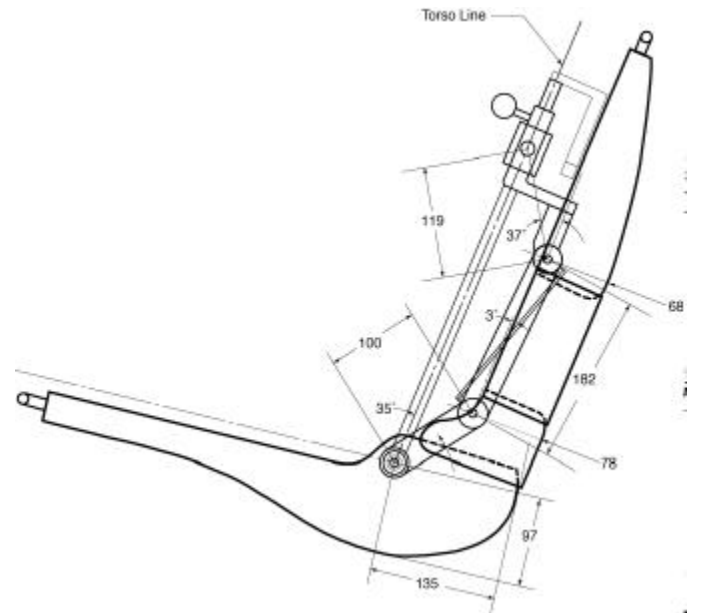


Figure 6. ASPECT manikin linkage geometry (mm).

Figure 6 shows the manikin linkage geometry. The distance from the hip joint to the posterior and inferior aspects of the contour were maintained equivalent to the current H-point manikin to improve continuity in H-point location. The pelvis segment length of 100 mm is similar to that reported by Robbins (23) for midsize males, but the lumbar segment length of 182 mm is greater than the 154-mm length estimated by Robbins. However, the large flesh margin below the pelvis in Robbin's analysis suggests that his estimate of pelvis location relative to the thorax and seat contour was too high, resulting in a shortened lumbar spine. Re-analysis of the data used by Robbins with ASPECT methods suggests a lumbar segment

length more similar to the value obtained by analysis of ASPECT data, so the value from the ASPECT analysis was chosen.

CONTOUR – New seat contact surface contours were desired for the ASPECT manikin, both to obtain greater anthropometric consistency and to improve the manikin performance. The current SAE H-point manikin has two rigid external shells that define the shape of the seat contact surface. These shells were developed from contour measurements of a man who was approximately 5'11" tall and 170 lbs (2, 5). At the time, these values corresponded approximately to the 90th-percentile U.S. male stature and 50th-percentile weight. The resulting torso was slightly taller and thinner than would be expected for men matching the ASPECT reference anthropometry. The current manikin shells also have an unrealistic contour in the buttock area that does not include the ischial prominences that are commonly observed in pressure distribution measurements of human sitters.

Consideration was given early in the program to the development of deformable manikin surfaces that would produce varying contours depending on the loading pattern. A more flesh-like manikin might be expected to produce more realistic pressure distributions and to better reflect the effects of changes in seat geometry on posture. However, repeatability, manufacturing, and durability considerations led to the selection of rigid shells of the same sort of construction used on the current manikin.

Contour measurements for the ASPECT program were conducted at Michigan State University. Details of the measurement procedures are presented elsewhere (16). After analyzing buttock and thigh contour data from seven approximately midsize-male subjects, the Michigan State researchers chose the contour of a single individual as most representative of the group. Critical dimensions, such as the distance from the hip joint to the bottom and back of the contour, were close to the mean values for the group.

Back contours taken from seven midsize males were averaged to obtain a representative contour. These data were merged with the buttock and thigh data to obtain a preliminary contour, and a full-size model of the contours was developed using computerized machining. Minor modifications to the contours were made by shaping and sanding the model. Fiberglass shells were then molded from the model and attached to a manikin prototype.

The buttock and thigh contours performed well, requiring only a few additional modifications. The back contours, however, were flatter than expected, and did not perform well in the test seats. The data were collected with the subject's upper arms positioned close to their bodies, rather than extended forward as in a typical driving posture. The difference in shoulder posture resulted in back contours that were flatter across the thorax area than the SAE J826 contour. When installed in seats designed with the current manikin, the new contour tended to bridge laterally across the seat in the thorax area, leading to unsta-

ble thorax positions as the shell contacted small areas on the side of the seat.

The undesirable performance of the flatter, more passenger-like back contour in contemporary seats suggested that a contour more similar to the current manikin was needed. A new prototype back contour was developed using contour data from the Schneider et al. study of anthropometry used for crash dummy design (22). In that study, back, buttock, and thigh contours of 8 midsize men were measured in four vehicle seats using a casting technique. The resulting data, along with body landmark location measurements and standard anthropometry from 25 midsize men, were used to create a physical three-dimensional, full-body shell representing a midsize male. The back surfaces of the physical shell were based on the measured contour data. For the ASPECT program, the shell was scanned at high-resolution and parametric surfaces fit to the resulting data. The data from the left side of the shell back were reflected to make a symmetrical contour. The resulting shape was merged with the new buttock and thigh contour data to create a new set of manikin shells.

The resulting surface shape produces more stable manikin readings than were obtained with the first prototype back contours, and provides a reasonable representation of the shape of a midsize-male driver's back. Combined with the buttock and thigh contours, the ASPECT manikin presents a surface interface contour that represents the typical deflected shape of a person matching the ASPECT reference anthropometry.

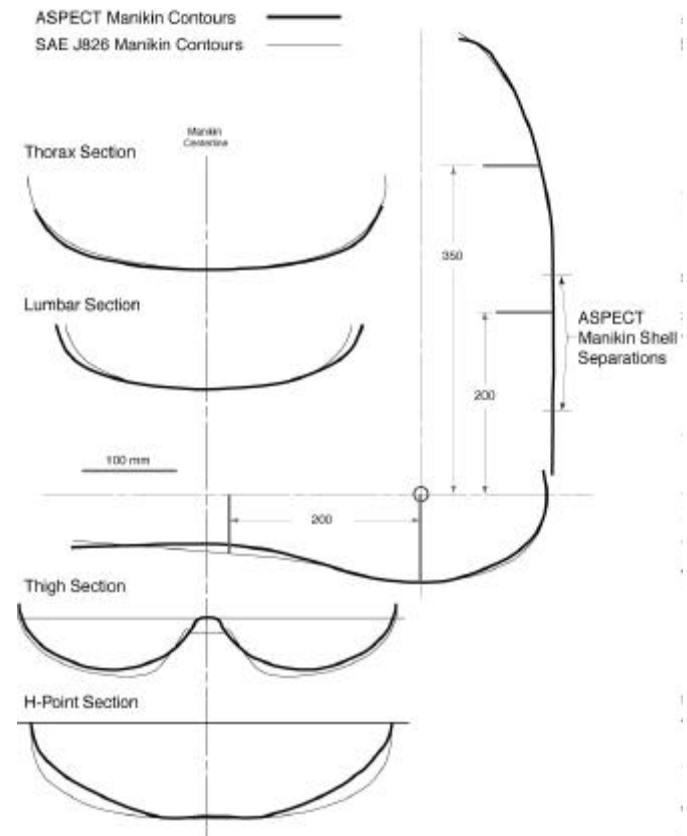


Figure 7. Comparisons of the external contours of the ASPECT and current SAE J826 manikins.

Figure 7 shows several cross sections comparing the ASPECT manikin contours with the current SAE J826 H-point manikin. In a lateral section through the H-point, the ASPECT manikin has the same overall breadth and depth, but has more pronounced ischial prominences. In profile, there is a more pronounced indentation in front of the buttocks, under the proximal thighs, than on the current manikin. The profile of the torso when the linkage is set to the nominal position is very similar to the current manikin profile, but the ASPECT manikin is wider in the lumbar area than the current H-point manikin.

The torso contour of the manikin was divided into three sections and attached to the respective linkage segments (pelvis, lumbar, and thorax segments). The sectioning planes were chosen based on linkage kinematics, so that the gaps in the external contour would remain as small as possible through a wide range of manikin spine movement. Figure 8 shows the manikin torso at a range of lumbar spine flexion levels.

MASS AND MASS DISTRIBUTION – As noted above, the ASPECT reference anthropometry specifies a stature of 1753 mm and a mass of 77.3 kg. However, the ASPECT manikin does not represent the entire body of a person, and hence cannot reasonably have the specified weight. Instead, the manikin weight was chosen to represent the reference weight minus the weight supported under the heels of people matching the reference anthropometry in an automotive posture. Studies have shown that arm support force from the steering wheel varies with arm posture and muscle activity (28), so the manikin

is weighted assuming that the full arm weight is carried by the seat. Thirty men ranging in stature (1582 to 1923 mm, average 1778 mm) and weight (57 to 141 kg, average 85 kg) sat in a typical vehicle seat with a seat height (H30) of 270 mm. After selecting a comfortable seatback angle, the subjects placed their feet with their heels resting comfortably on a force platform. The subjects' foot positions were adjusted so that there was no appreciable horizontal force applied to the platform. The vertical support force was recorded for three trials with each subject. Linear regression analysis on body weight was used to estimate the average heel support force for a person matching the reference anthropometry. The resulting value of 5.8 kg was subtracted from the reference weight to obtain the target manikin weight of 71.5 kg.

The manikin mass distribution cannot be directly representative of human mass distribution, because the manikin does not include the head, arms, and legs that comprise a substantial percentage of the body mass. Rather than attempting to relocate the head and arm masses in the thorax, as was done with the current H-point manikin, the ASPECT manikin mass distribution was determined based on performance considerations. The manikin components, without the removable weights, weigh 16.3 kg, 23 percent of the total manikin mass. Figure 9 shows the distribution of weights. Note that the thorax weights are actually attached to the torso rod and act primarily at the hip joint. This mass distribution produces stable manikin readings that meet the performance criteria established for the manikin (see below).

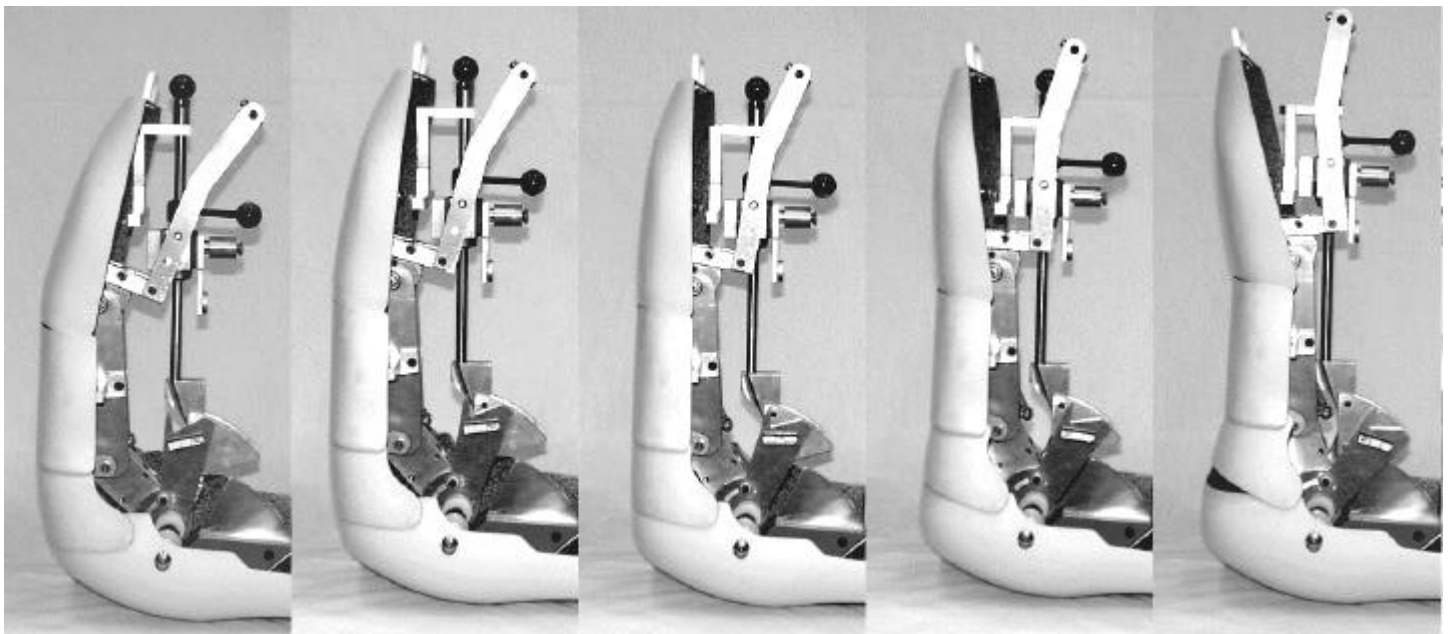


Figure 8. ASPECT manikin torso at a range of lumbar spine flexion levels (-20, -10, 0, 10, 20 mm lumbar support prominence, from left to right).

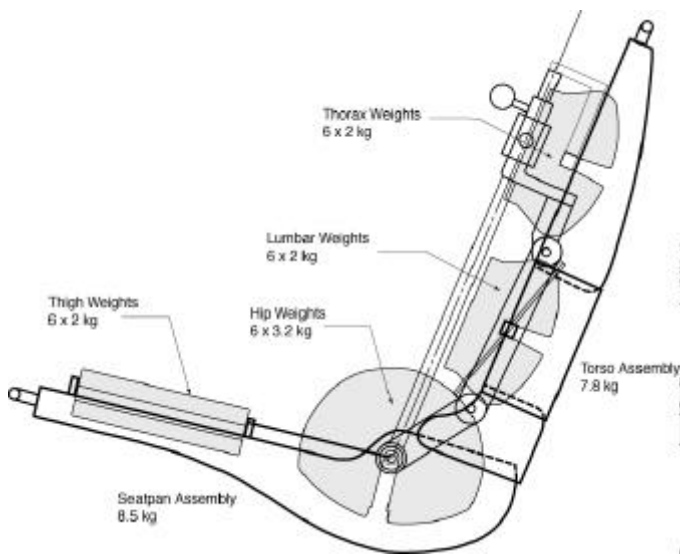


Figure 9. Schematic of ASPECT manikin mass distribution.

SUPPLEMENTAL THIGH, LEG, AND SHOE – The ASPECT manikin is designed to be primarily a seat measurement tool that can be applied independent of the vehicle package geometry. For typical seat measurements, no leg or shoe is required. However, because the leg and shoe are integral parts of the current H-point manikin, supplemental leg and shoe components are provided with the ASPECT manikin to provide continuity with current practice.

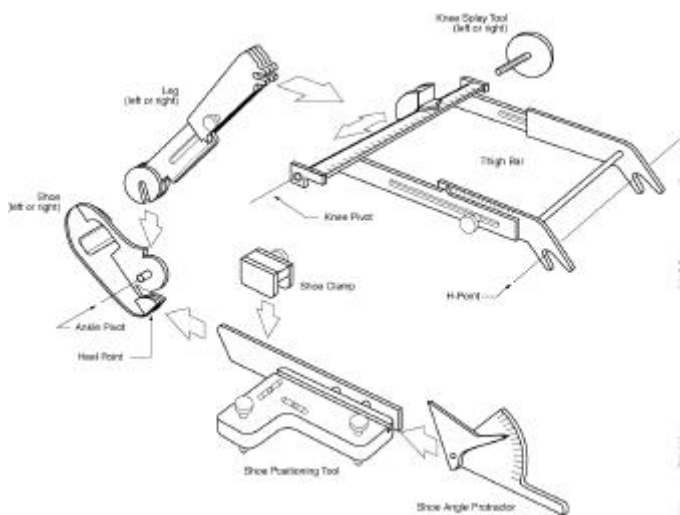


Figure 10. Supplemental ASPECT manikin thigh, leg, and shoe.

Figure 10 shows the thigh, leg, and shoe components schematically. The leg and thigh segments are adjustable in length and constructed of lightweight components. Adding the leg and thigh segments to the manikin installation in a seat does not change any of the manikin measures, including H-point location. The shoe has the same length as the SAE H-point manikin shoe, but has a symmetrical plan-view contour and has a flat sole. Only one shoe and leg segment are used for measurements. The shoe is held in place by a clamping

device, and can be used independent of the manikin to establish pedal reference points. A detailed discussion of the use of the leg and shoe in design and benchmarking applications is presented elsewhere (17).

Note that because the lightweight thigh segment is separate from the ASPECT manikin thigh section, the manikin creates two separate measures using segments analogous to the human thigh. The orientation of the weighted manikin thigh section after installation in a seat is the seat cushion angle, which is affected only by seat geometry. The angle of the lightweight thigh section after installation in a vehicle package with the seat and shoe in prescribed positions is the manikin thigh angle, which is affected only by package geometry. These values will usually be different, with cushion angle generally flatter (nearer to horizontal) than thigh angle.

EASE OF USE – An important concern of the ASPECT industry participants was that the new manikin be easier to use, particularly for in-vehicle installations. The new manikin was developed with these concerns in mind, and has a number of features that simplify installation.

- *Separate buttock/thigh and torso pieces.* The manikin separates at the hip joint, so that the buttock/thigh section can be installed separately from the torso section. Each section weighs less than 10 kg and has handles for easy manipulation.
- *Smaller weights.* The ASPECT manikin has more but lighter weights, which are designed to install easily in their specified positions.
- *Clearer readouts.* The prototype ASPECT manikin has clearer, easier-to-read scales than the current J826 manikin. Additionally, provisions have been made for using electronic inclinometers to record segment orientations.
- *Package-independent measurement.* In its primary application, the manikin measures the seat independent of the package, meaning that the measurement can be made with the seat in any seat track position. The lightweight supplementary leg and shoe tools can be added to make package-related measures without changing the H-point location relative to the seat. This means that H-point measurements can be made without having the seat mounted in an accurately configured mockup; only the seat attitude with respect to vertical is required.
- *Integrated seat cushion angle measurement.* With the current J826 manikin, cushion angle measurement requires a separate manikin installation. The ASPECT manikin measures cushion angle, H-point, and other seat measures simultaneously.
- *Easier leg installation.* The lightweight supplementary leg and shoe tools are much easier to install than the legs of the J826 manikin. Only one leg and shoe are used with the ASPECT manikin, further simplifying installation. As noted above, the leg and foot are not required for the standard H-point measurement.

- *Simpler installation procedures.* The current installation procedures are simpler and clearer than the J826 manikin procedures, and the manikin installation can be completed more quickly.

Input from industry manikin evaluations will be used to improve the manikin's useability further. Particular emphasis is being placed on the procedures, to ensure that they are defined clearly to minimize interoperator variability.

PERFORMANCE SPECIFICATIONS – The original objective for the ASPECT manikin performance was that the manikin should sit in seats in a manner quantitatively representative of people who match the manikin reference anthropometry. Specifically, the manikin H-point location should correspond to the average midsize male hip joint location, and the thigh, pelvis, abdomen, and thorax segment orientations of the manikin should match the average values obtained with humans.

During the ASPECT program, several large-scale studies of vehicle occupant posture and position were conducted, in part to develop manikin performance specifications (20). There were a number of important findings from these studies that led to fundamental changes in the manikin performance goals. The most important of these findings with implications for manikin performance are discussed here.

1. Package factors affect driver posture in ways that cannot be readily replicated in a manikin.

Specifically, the fore-aft position of the steering wheel relative to the pedals affects driver torso posture. More-forward steering wheel positions result in slightly more upright postures with slightly less lumbar spine flexion than more rearward steering wheel positions. Two potential ways to include this effect in the manikin were considered. The manikin could be physically tied to the steering wheel, for example, by use of a spring-loaded rod that would replicate the effect of the arms on the thorax. Alternatively, the manikin behavior could be altered by adjustments to the linkage made based on measures of the particular vehicle's steering wheel position. These and other potential approaches were rejected because they moved away from the basic objective of separating seat and package measures.

2. Seat cushion angle does not affect driver or passenger thigh postures in a mechanistic manner.

Prior to the ASPECT posture studies, the seat cushion angle with respect to the horizontal, measured using the legless J826 manikin procedure (1), was expected to have a direct effect on the thigh angles of both drivers and passengers. The effect was expected to be particularly noticeable with front-seat passengers, for whom the cushion angle would be the primary external constraint on leg posture. However, in two separate studies (48 and 68 subjects) in a wide variety of driver and passenger conditions,

seat cushion angle did not have a significant relationship with driver or passenger thigh angle (20, 28). Higher seat cushion angles do produce some significant postural effects, including more-forward seat positions and more reclined torso postures, but do not directly affect thigh angle. This finding meant that manikin thigh angle performance could not be reasonably specified by the average thigh angles measured on subjects.

3. Human torso posture responses to changes in seat-back geometry are too small to be useful for seat measurement.

The ASPECT manikin included, from the earliest prototypes, an articulated lumbar spine. The articulated linkage was expected to make the manikin more stable than the current H-point manikin in seats with prominent lumbar supports, and was expected to allow the manikin to replicate the effects of lumbar supports on human torso posture. However, the human subject studies in ASPECT demonstrated that differences in seatback geometry that are reasonable for production automobile seats (meaning lumbar support prominence and location) have only small effects on torso posture. For example, an increase of 40 mm in lumbar support prominence reduced lumbar spine flexion by only 1.8 degrees. Similar findings had previously been reported from other studies at UMTRI (27, 30). ASPECT studies showed that the effects of lumbar support prominence change on both driver and passenger posture are small relative to the postural variance between people.

4. Human hip joint locations are affected by seat cushion angle in ways that are difficult to replicate with a manikin.

Data from several ASPECT studies show that human hip locations relative to the seat are affected by changes in seat cushion angle. Higher seat cushion angles relative to horizontal cause people to sit with their hips more rearward on the seat than at lower cushion angles. Drivers also respond to higher seat cushion angles by moving their seats forward an offsetting amount, so that the average hip location aft of the pedals remains approximately constant. Efforts to duplicate this behavior with the manikin were unsuccessful. Seat cushion angles are highly constrained in production vehicles. In ASPECT research, a change in seat cushion angle from 11 to 18 degrees caused a significant rearward shift in hip location on the seat, but that seven-degree change in seat cushion angle is insufficient to cause any significant change in the position of a weighted manikin.

These findings necessitated a re-examination of the manikin performance objectives. The finding that the steering wheel position affected torso posture led to a redefinition of the manikin performance to replicating passenger posture. However, the findings with regard to seat cushion angle, both in its effect on hip joint location and the lack of effect on thigh angle, indicated that at

least the thigh section of the manikin could not be designed to behave in a humanlike manner. Prototype development proceeded with a focus on obtaining humanlike responses to changes in lumbar support prominence and seatback angle. As the prototype was refined, the limitations of this approach became clear.

Because the torso posture of vehicle occupants is relatively insensitive to changes in seatback contour, a manikin that behaved in a humanlike manner would be a poor measurement tool. For example, data from ASPECT and previous studies indicate that a 45-mm change in lumbar support prominence, wider than the range expected in production seats, produces an average change in lumbar spine flexion of between two and six degrees. Thus, a humanlike manikin would be required to differentiate across the full range of vehicle seats using only six degrees of lumbar spine movement. The acceptable range of test-retest variability would have to be much smaller than one degree to reliably differentiate among seats.

In light of these findings, the manikin performance specifications were redefined. The goal of the manikin remains to characterize the seat. However, the manikin posture that results when the manikin is installed in a seat is not intended to represent human posture. Rather, the manikin uses a humanlike kinematic linkage and humanlike contour to obtain measures of deflected seat surface positions and orientations that have quantitative relationships with human posture and position. The measures obtained from the manikin refer to the seat, not to human posture. The ASPECT manikin measures H-point location, seat cushion angle, seatback angle, and lumbar support prominence, rather than the analogous human posture measures of hip joint location, thigh angle, torso angle, and lumbar spine flexion.

The result of this redefinition of performance objectives is that the manikin provides more useful measures of the seat geometry than would be obtained even using a large sample of human subjects. For example, the ASPECT manikin measures cushion angle, which is poorly measured using human postural response. Yet, cushion angle has important effects on some measures of human posture and position (28, 31). Similarly, changes in lumbar support prominence are readily measured using the ASPECT manikin. Although these changes have only small effects on posture, they have large effects on comfort ratings, and hence are important for seat design (32).

The manikin performance objectives are defined as follows:

1. Obtain an H-point location that is as close as practical to the SAE J826 H-point location in seats that produce a lumbar support prominence measure of zero (i.e., result in an ASPECT manikin back profile matching the SAE manikin back profile);
2. Record a cushion angle that approximately matches the SAE J826 seat cushion angle measure across seats;

3. Record a seatback angle that is parallel to the external lumbar shell, and approximately matches the seatback angle measured by the J826 manikin, when the lumbar support prominence is zero; and
4. Fully engage with the seatback to produce a deflected measure of longitudinal seatback contour, expressed as lumbar support prominence.

When a seat produces a lumbar support prominence reading of zero on the ASPECT manikin, the manikin should produce an H-point location and seatback angle that are similar to the values obtained with the current H-point manikin. However, in all other seats, deviations between the two manikins in H-point location and seatback angle are expected, since the ASPECT manikin torso interacts with the seatback in a way that is different from the rigid torso of the current manikin.

COMPARATIVE RESULTS

The ASPECT manikin is currently undergoing extensive evaluation and validation trials, conducted both at UMTRI and at the participating companies. The evaluations focus on the repeatability of the manikin and the success in attaining the performance objectives. As part of these evaluations, the ASPECT manikin measures of eleven driver seats were compared to the SAE J826 manikin measures.

The eleven seats were among twelve seats used in a study of male driver and passenger posture (20). One seat (seat six), a heavy-truck seat, was excluded from the present analysis because the seatback angle adjustment range was sufficiently limited that many subjects could not find a comfortable seatback angle. The seats were each mounted in a generic sedan-like vehicle package for testing (seat height 270 mm, steering-wheel-to-ball-of-foot horizontal distance 550 mm). In each of the seats, thirty male subjects with a wide range of anthropometry selected their preferred driver and front-seat passenger postures. Each subject adjusted the fore-aft seat position and seatback angle to obtain a comfortable posture, which was measured using a FARO arm digitizing device. Testing was conducted with and without the steering wheel and pedals to obtain both driver and front-seat passenger postures. Details of the posture measurement and analysis procedures are found elsewhere (15, 20).

One important finding from the study is that there were no important differences in torso posture across the eleven seats. For example, the angle with respect to the vertical of a sideview line from each subject's hip joint to the eye did not differ significantly across the eleven seats in driver or passenger postures and averaged about 8.5 degrees. This finding is consistent with other studies that have shown changes in seat geometry to have only small effects on torso posture (27, 28, 30).

For subsequent manikin testing, the seatbacks were fixed at the mean preferred seatback angle for the thirty subjects. Since the subject's torso postures were the same

across the seats, on average, the mean selected seat-back angles can be considered to represent equivalent seatback angles to the subjects. That is, the seatback angles were the same with respect to the postures that they supported. This provided a useful comparison for the two manikins.

Three SAE J826 manikin drops were conducted in each seat in accordance with standard procedures. Three ASPECT manikin drops were also conducted, using preliminary procedures documented by Roe et al. (17). A FARO arm digitizer was used to record the location of targets on each manikin's segments, including the H-point, relative to reference points on the seat frame.

Figure 11 shows the location of the ASPECT manikin H-point for each of the measurements, relative to the average J826 manikin H-point in each seat. Data from each seat are plotted using a different symbol. In the plot, a symbol at the origin would indicate that the ASPECT manikin H-point is directly coincident with the J826 manikin H-point. On average, the ASPECT manikin H-points are lower and rearward, relative to the J826 manikin H-points. The ASPECT manikin measurements for each seat are also tightly grouped, indicating good repeatability.

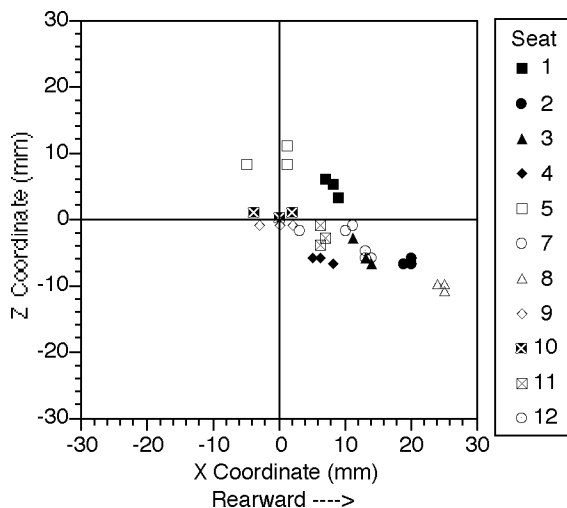


Figure 11. ASPECT manikin H-point relative to SAE J826 manikin H-point for three trials in each of eleven seats.

Further analyses of these data indicate an important relationship between the offset between the ASPECT and J826 manikin H-points. Figure 12 shows the horizontal offset between the two H-points plotted against the ASPECT manikin measure of lumbar support prominence. In the three trials in each of these eleven seats, lumbar support prominence ranged between 0 and 22 mm.

The lumbar support prominence measure is strongly associated with the horizontal offset between the two manikin H-points. This observation can be explained by considering the effect of the ASPECT manikin's spine

articulation on manikin performance. In a seat with a prominent lumbar support, the rigid torso shell of the J826 manikin pivots around the lumbar support, pushing the H-point forward. In contrast, the articulated torso of the ASPECT manikin allows the buttock/thigh shell to slide fully rearward on the seat, while the torso wraps around the lumbar support during the installation procedure. As a result, the ASPECT manikin H-point is more rearward on the seat, relative to the J826 manikin H-point, as the lumbar support prominence increases.

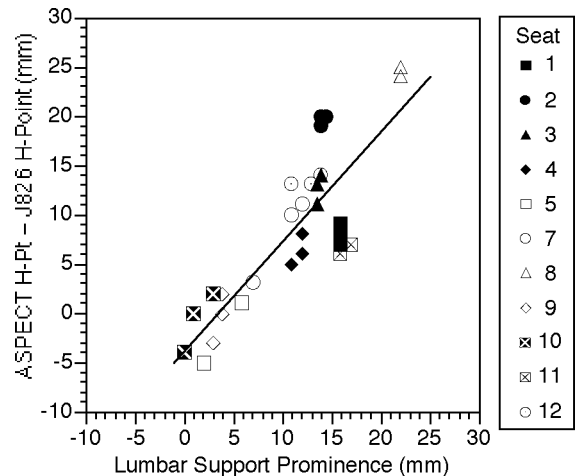


Figure 12. Horizontal offset between the ASPECT and SAE J826 manikin H-points as a function of ASPECT manikin lumbar support prominence measure.

This relationship suggests that J826 manikin H-point location can be predicted from the combination of the ASPECT manikin H-point location and the measured lumbar support prominence of the seat. Using a linear regression, the location of the J826 H-point forward of the ASPECT manikin H-point (mm) can be predicted from the equation

$$\text{ASPECT H-Pt (X)} - \text{J826 H-Pt (X)} = 1.14 \text{ LSP} - 4.3 \quad (1)$$

where LSP is the lumbar support prominence as measured by the ASPECT manikin. The equation indicates that when the lumbar support prominence is zero, the two manikin H-points are approximately coincident. This confirms that the ASPECT manikin has met one of its performance goals, which is to replicate the J826 H-point in seats that produce a flat ASPECT-manikin back profile.

Using equation 1 and a similar equation developed for the vertical offset, the effectiveness of estimating SAE J826 H-point from ASPECT manikin measures was assessed. Figure 13 shows J826 H-point locations estimated from ASPECT manikin measures relative to the actual SAE J826 locations. Note that the discrepancies are less than 10 mm, indicating that it is feasible to predict J826 H-point locations from ASPECT manikin measures.

Table 2. Summary of Manikin Measures in Eleven Test Seats (Average of Three Trials per Manikin)

| Seat | J826 H-Point (X, Z) | ASPECT H-point (X, Z)† (mm) | J826 Seatback Angle (degrees) | ASPECT Seatback Angle (degrees) | ASPECT Lumbar Support Prominence (mm) | ASPECT Seatback Angle (adjusted) (degrees) |
|------|---------------------|-----------------------------|-------------------------------|---------------------------------|---------------------------------------|--|
| 1 | (0, 0) | (8.2, 4.9) | 21.5 | 19.6 | 16.0 | 22.9 |
| 2 | (0, 0) | (19.6, -6.8) | 27.3 | 22.3 | 14.2 | 25.3 |
| 3 | (0, 0) | (12.9, -5.2) | 23.3 | 21.1 | 13.7 | 24.0 |
| 4 | (0, 0) | (6.2, -6.2) | 23.8 | 21.6 | 11.7 | 24.1 |
| 5 | (0, 0) | (-1.1, 8.7) | 23.5 | 23.2 | 4.7 | 24.2 |
| 7* | (0, 0) | (8.0, -1.9) | 25.0 | 20.9 | 10.0 | 23.0 |
| 8 | (0, 0) | (24.9, -10.5) | 24.7 | 18.5 | 22.0 | 23.1 |
| 9 | (0, 0) | (-0.3, -1.0) | 23.8 | 23.1 | 3.7 | 23.8 |
| 10 | (0, 0) | (-0.6, 0.5) | 24.8 | 22.6 | 1.3 | 22.8 |
| 11 | (0, 0) | (6.1, -2.6) | 23.7 | 20.9 | 16.3 | 24.3 |
| 12 | (0, 0) | (13.3, -5.6) | 21.5 | 17.9 | 12.7 | 20.6 |

* Seat number six, a heavy-truck seat, is omitted from this analysis because it had insufficient seatback angle adjustment range.

† Relative to the J816 manikin H-point; positive X and Z indicate that the ASPECT manikin H-point is above and behind the J826 manikin H-point.

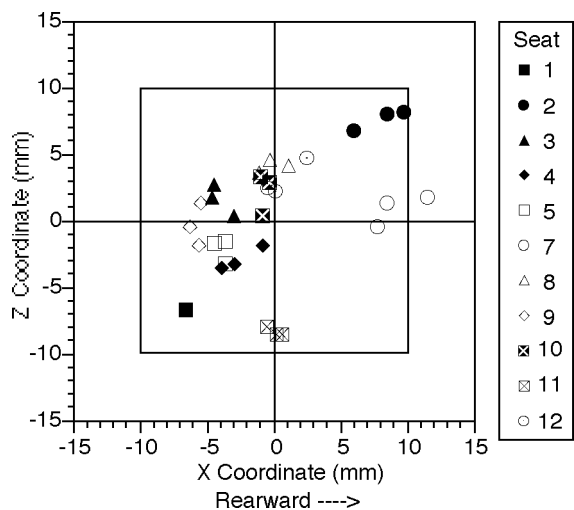


Figure 13. J826 H-point location estimated from ASPECT manikin measures relative to actual J826 H-point locations (averages of three trials with each manikin in eleven seats).

Table 2 summarizes some of the ASPECT and J826 manikin measures across the eleven test seats with each seat set to the mean preferred seatback angle. Each value represents the average obtained in three trials. In each case, the J826 H-point is defined as the origin for H-point measurements.

Figure 14 compares SAE J826 and ASPECT manikin seatback angles. The ASPECT manikin produced more upright seatback angle measures, on average. Ideally, a human-like manikin would record the same seatback angle in each of the seats, since they were each set to the subjects' mean selected angle, and each seat produced the same average preferred torso posture. However, the J826 manikin measured seatback angles between 21.5 and 27.3 degrees, a range of more than six degrees.

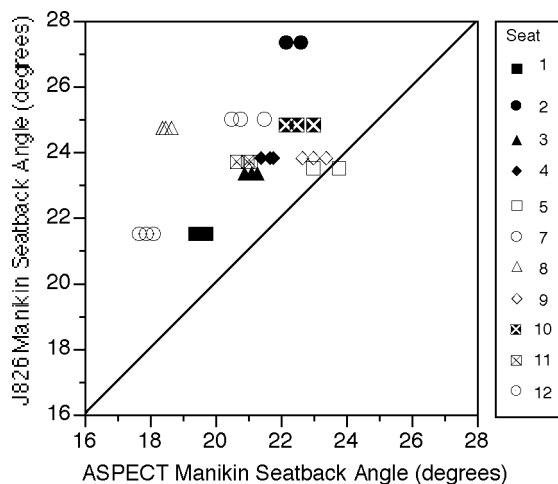


Figure 14. ASPECT manikin seatback angles for three trials in eleven seats compared to SAE J826 manikin (some points are coincident).

The ASPECT manikin seatback angles varied between 17.9 and 23.2 degrees, a similar range, but the ASPECT manikin lumbar support prominence measure provides a way of adjusting the manikin-measured seatback angle to obtain a more ideal seatback angle measure. Figure 15 shows the relationship between ASPECT manikin seatback angle and lumbar support prominence for the eleven test seats. The figure shows that increasing lumbar support prominence is associated with decreasing seatback angle measurements. This effect is produced by the buttock section of the manikin sliding rearward under the lumbar support, tipping the torso of the manikin more upright.

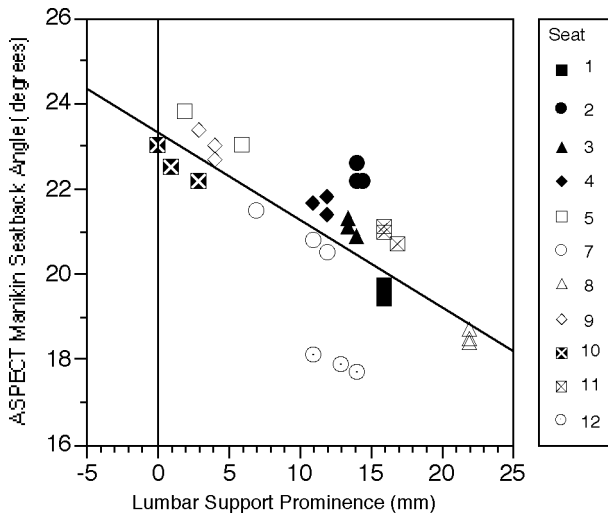


Figure 15. ASPECT manikin lumbar support prominence and seatback angle for three trials in each of eleven seats.

If the zero-lumbar-support condition is defined as the “true” seatback angle, each seatback angle measurement with the ASPECT manikin can be adjusted based on the lumbar support prominence. Using a linear relationship between seatback angle and lumbar support prominence, the adjusted seatback angle is given by

$$\text{SBA}(\text{adjusted}) = \text{SBA} + 0.209 \text{ LSP} \quad (2)$$

where SBA is the seatback angle in degrees, and LSP is the ASPECT manikin lumbar support prominence. Adjusted seatback angle values in Table 2 vary between 20.6 and 25.3 degrees, a slightly smaller range than the unadjusted values. For all but two of the eleven seats, the adjusted seatback angle measure is within one degree of 23.5 degrees, the zero-lumbar-support intercept from Figure 15. Although this approach seems to be a promising method of relating seatback angle to human posture, more testing and analysis will be necessary to determine an optimal approach.

DISCUSSION

Human factors practitioners in the automotive industry initiated the ASPECT program to address the limitations of the current SAE J826 H-point manikin. The four-year program has culminated in the development of a new manikin, along with associated posture prediction models and other design and evaluation tools (15-20).

The new manikin is based on midsize-male anthropometry, providing compatibility with the current H-point manikin and midsize-male crash dummies. However, the manikin is not intended to represent a specific percentile on any dimension for any population. In fact, the manikin applications do not require a tool that matches any particular population percentile. The ASPECT manikin is intended to produce consistent measures of seat geometry that can then be related, via posture prediction models developed in the ASPECT program, to the posture of any occupant within any vehicle package (18).

Like the current J826 H-point manikin, the ASPECT manikin does not indicate whether a particular seat or vehicle is comfortable. Instead, the manikin provides measures of the position and orientation of the support surfaces on a seat that may be related to comfort. For example, the ASPECT manikin provides a new technique for measuring the contour of the seatback under occupant loading. This measure of lumbar support prominence may be more usefully related to occupant comfort than measures of the undeflected seat contour.

The ASPECT manikin described in this paper is a prototype, subject to further revision after further testing. At this writing, the manikin is undergoing extensive evaluation at UMTRI and the participating companies. Minor changes in manikin features, including H-point location and mass distribution, may be required to meet the performance goals. The installation procedure, which is an important determinant of the manikin measures, is also subject to revision.

At the conclusion of the ASPECT program in June 1999, the SAE Design Devices Committee will begin the process of considering revisions to SAE J826 based on the ASPECT manikin and related research findings. A revised version of SAE J826 incorporating the new manikin is expected in June 2000. Implementation of the manikin into the vehicle design and development process is expected to take several years. Each company and organization will likely proceed at its own pace. The ASPECT research team will provide the supporting documentation necessary to assist companies with implementing the new tools. Although it is difficult to anticipate how any individual organization will proceed, the feedback from ASPECT participants suggests some potential paths to ASPECT manikin implementation.

The SAE Design Devices Committee will determine the other SAE practices that will be affected by changes in SAE J826. The H-point defined by the manikin is referenced in many other practices (e.g., J941, J1052, J1100, J1517). The Design Devices Committee will interact with the committees responsible for the affected practices to inform them about the new manikin and to suggest ways to make the necessary changes. Many practices will be able to incorporate the ASPECT manikin without change. In others, minor modifications may be required to account for the change in H-point location relative to the seat. Because the ASPECT manikin measures the seat independent of the vehicle package, it provides a platform for making many standardized seat-related measures that are not currently defined. A committee comprised of ASPECT participants has recently developed a preliminary list of seat dimensions based on the ASPECT manikin for potential inclusion in SAE J1100 (17).

The SAE Design Devices Committee will also interact with the U.S. National Highway Traffic Safety Administration concerning the safety applications of the H-point manikin. Minor modifications to crash dummy positioning procedures would result from using the ASPECT manikin. However, as demonstrated above, there are straight-

forward ways of estimating J826 H-point from ASPECT H-point. UMTRI researchers have already begun the process of developing new crash dummy positioning procedures that are based on up-to-date information on vehicle occupant posture and position (33). Further communication with the related SAE committees and NHTSA will be required to develop an implementation plan for safety applications.

Each automaker and supplier will need to determine the best method for implementing the ASPECT manikin into its processes. Seat suppliers may begin using the manikin in comfort and design evaluations prior to its use as the primary seat measurement tool. The new articulated spine and shell contours make the ASPECT manikin more useful than the current H-point manikin for quantifying differences between seats. For example, the new manikin provides a method of quantifying lumbar support prominence that may be related to comfort evaluations. Auto manufacturers may need to use the new manikin in parallel with the current manikin on a pilot program to explore ways in which their in-house practices are affected. Changes underway in other SAE vehicle design practices (J1516: Pedal Reference Points; J1517: Driver-Selected Seat Position; J941: Driver Eye Position; and J1052: Driver Head Location) will provide an opportunity to take advantage of the new ASPECT manikin capabilities (19, 31, 34, 35).

The current SAE J826 manikin is used with several auxiliary tools, such as the belt-fit test device and the head restraint measurement device (9, 10). As noted above, the ASPECT manikin has not been made compatible with these devices, since differences in the posture of the ASPECT and J826 manikins would change the measurement values obtained with these tools. Further investigations will be conducted to determine the best ways of including the functionality of these add-on tools in the ASPECT manikin.

CONCLUSIONS

The ASPECT manikin builds evolutionarily on the success of the SAE J826 manikin to deliver new, more useful measures of seat and vehicle geometry. The ASPECT manikin measures the vehicle seat independent of the package while providing continuity with previous package-dimensioning practice. The new manikin is easier to use than the current manikin and is more stable and consistent, particularly in seats with prominent lumbar supports. Developed through industry cooperation, the ASPECT manikin is expected to become an important new tool for vehicle and seat design and measurement.

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