

SPECIAL REPORT

Development of uniform terminology and procedures to describe wheelchair cushion characteristics

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INTRODUCTION

Assistive technology, specifically in the area of wheelchair seating, has advanced tremendously in the past decade. Over 200 wheelchair cushion models are commercially available. This increased selection brings greater options to the end user. However, having more options places greater importance on the ability to make a correct cushion selection; thus, the ultimate goal is an informed decision. Currently, no system or process exists that allows for an objective comparison of cushions across manufacturers.

The burden of making an informed decision is shared by many persons, but ultimately, impacts the wheelchair user alone. The medical model of assistive technology (AT) service delivery involves at least five parties, the consumer, his/her clinician, a vendor that sells the technology, the manufacturer of the technology, and

the funding source that pays for the device. All these interested parties will benefit from the development of wheelchair-cushion standards with the consumer benefiting most directly by obtaining the proper cushion. Based on figures from the National Health Interview Survey in 1994 and 1995, Kaye, Kang, and LaPlante (1) estimated that 1.68 million people used wheelchairs as their primary means of mobility, including 1.5 million manual-wheelchair users, 155,000 powered-wheelchair users and 142,000 scooter users. The overwhelming majority of these wheelchair users are also users of wheelchair cushions.

Cushion selection is not a trivial matter for many wheelchair users. The loss of motor and/or sensory function represents significant risk factors for pressure ulcer development. Selecting a cushion with adequate supportive properties is equally important for obtaining an optimal seated posture, with regard to function and prevention of orthopedic deformities. Therefore, the importance of maximizing the quality of resources to assist in cushion selection cannot be overstated.

A system of independent standards for characterizing and testing wheelchair cushions would improve the process of cushion selection and procurement. The

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creation of ANSI/RESNA wheelchair standards has narrowed the information gap between manufacturers, vendors, clinicians, and consumers. Disclosure of standards results is straightforward, no-nonsense advertising in its purest sense. Standards are consumer-responsiveness at its finest, and they should not stop at the wheelchair; rather, they should also include wheelchair cushions.

The development of wheelchair-cushion standards will include means to measure and describe both cushion characteristics and performance. This project concentrated only on the former, cushion characteristics. A cushion characteristic can be loosely defined as a distinguishing physical feature or attribute. Cushion performance, rather, relates to the manner that a cushion functions in its role as a support surface. Standards addressing both characteristics and performance are critical, and this project resulted in a draft of the former and laid groundwork for the latter.

For the sake of this project, cushion characteristics included *materials and construction, physical characteristics, cushion cover material, mass or weight, dimensions, unloaded or initial contour depth, and loaded contour depth.*

GOAL

The goal of this project was to develop uniform terminology and test methods to describe the physical characteristics of wheelchair cushions.

LITERATURE REVIEW

Health care in the United States is undergoing evolutionary change. Continual advances in technology, countered by relentless efforts to contain costs, are significant players in this evolution. Establishment of guidelines is key to balancing the system of providing high-quality durable medical equipment at affordable, third-party-payer costs. Within the area of seating and wheeled mobility, efforts have been made to establish such guidelines. Perhaps most significant are the ANSI/RESNA wheelchair standards, established through the efforts of a committee formed by members of the American National Standards Institute (ANSI) and the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) that was funded by the U.S. Department of Veterans Affairs and supported by

the Paralyzed Veterans of America. These standards consist of 18 test procedures describing how to measure and test manual and power wheelchairs in a standardized fashion. As described by Axelson et al. (2), the test procedures provide either a disclosure of the actual results, or suggest minimum performance criteria. Disclosure of the test results allows for a comparison of wheelchairs across manufacturers, while minimum performance criteria provides additional feedback to the manufacturers with regard to improving their product.

Virtually all wheelchair users sit on a wheelchair cushion that plays an important role in comfort, stability, postural support, and pressure ulcer prevention. Yet, the same advancements in standardized testing have not been made for wheelchair cushions as have been established for wheelchairs. Cochran and Slater (3) first identified the need for cushion standards and published a pilot study regarding an experimental testing scheme for cushions. Further development and implementation of test methods by Cochran and Palmieri (4) included testing 24 commercially available cushions and comparison to a 4-in. polyether foam reference cushion. Testing included measures of deflection, vertical and horizontal stiffness, and heat retention. Whereas this work deserves high acclaim for representing the only attempt to develop comprehensive standards for wheelchair cushions, it has several limitations for application to today's market. Most importantly, not all of the test procedures are applicable to contoured cushions, which represent a significant number of cushions available today. Of equal importance is the authors' conclusion that further clinical work was needed to determine the practical importance of each test parameter. Without determining clinical relevance, e.g., how these standards can benefit the end user, much of the incentive to carry out this type of research is lost.

Cochran grouped cushions into four major categories: foam, viscoelastic foam, gels, and fluid floatation. These categories plus the addition of viscoelastic fluid describe the components of nearly all currently available commercial cushions. Existing industry standards covering these materials provide a significant foundation for development of cushion test standards. Although limitations were identified, Cochran and Palmieri utilized American Society for Testing and Materials (ASTM) standards for foams (5,6) as a starting point. The current project drew upon foam and other standards to form preliminary guidelines for cushion-material testing.

The International Standards Organization (ISO) has established a workgroup to develop wheelchair-seating

standards. In the United States, ANSI/RESNA committee members support this effort. Draft standards documents have been developed for common terminology, description of posture and body orientation, postural support devices, and tissue integrity devices. These standards efforts are the result of voluntary contributions from many scientists, clinicians, and wheelchair users. All documentation is available for public review and comment (7).

METHODS

The employed methods included a combination of literature and standards review, and analysis and bench testing to ensure that test methods were applicable across cushion design. The resulting test methods were then applied to all wheelchair cushions that were commercially available in the United States. Only static or nonpowered cushions were included in this survey and testing. This methodology can be divided into four tasks:

1. Identify consistent terminology and definitions to describe wheelchair cushions and their covers, including materials and components. Terms and definitions were obtained from literature, published standards, trade association literature (such as the Polyurethane Foam Association), and scientific text.
2. Collect and analyze current standards that are applicable to wheelchair cushions to initiate the process of developing standards of wheelchair-cushion performance. Standards from ASTM, ISO, and SAE were searched with the use of keywords such as foam, elastomer, seat, cushion, furniture, etc.
3. Identify specific, standardized test procedures to describe wheelchair-cushion characteristics, such as overall dimensions, weight, amount of precontour, and properties of the materials.
4. Complete a survey of wheelchair cushions available on the market today.

A draft cushion characteristics document was developed based upon literature review and preliminary testing. The document was disseminated for review to 10 clinicians and scientists working in the area of wheelchair seating. All feedback was tabulated and changes were made to the document when appropriate. Tabulated feedback and the respective responses were sent back to the review group. Subsequent iterations of the Cushion Characteristics docu-

ment were disseminated during ISO and ANSI/RESNA standards meetings, and feedback was again solicited.

RESULTS

Over 75 standards and 100 manuscripts and other documents were obtained and reviewed. Terminology and definitions relating to cushions and seating were identified, tabulated, and referenced. A second document identified all devices used to test cushions, support surfaces, and materials. These two documents formed the basis for developing terminology and test methods to describe wheelchair cushion characteristics.

The compilation of this information resulted in the production of a document, "Defining and Describing Cushion Characteristics." This document contains terminology and test methods that address *material and construction, physical characteristics, cushion cover material, mass or weight, dimensions, unloaded contour depth, and loaded contour depth*. It is reproduced below with rationale added in certain sections for clarification purposes.

Wheelchair cushions were requested from all U.S. manufacturers and distributors. Identification of these sources was made through trade journal "buyer's guides" and advertisements, Internet searches, and Abledata. Samples of all cushion models were requested. The size was requested by asking for the cushion "designed to fit into a standard adult wheelchair (18 in. wide, 16 in. deep)." Over 225 cushion models were obtained. All requested cushions were acquired either through donation or loan. From this pool, 210 cushion models were tested. Untested cushions included those that were not designed for wheelchair use and duplicate models of different sizes. Another document listing the characteristics of these 210 cushions was also produced. Space limitations obviate the ability to reproduce it in its entirety, but a small sample of cushion results can be found in the table on page 460.

DEFINING AND DESCRIBING CUSHION CHARACTERISTICS

A. Material and Construction

1. Cushions Using Cellular Materials:

foam: a lightweight cellular material resulting from the introduction of gas bubbles into a reacting polymer; describes most elastic or polyurethane foams employed in

support surfaces. Foam can be open (polyurethane, latex) or closed cell (Ethafom, MiniCell, ConstructaFoam).

flexible matrix: cellular, flexible matrices employed in support surfaces (e.g., Supracore).

viscoelastic foam or matrix: foam or flexible matrix material that has both elastic (displacement-dependent) and viscous (time-dependent) properties. Since the viscous properties differentiate these materials from regular or elastic “foam,” viscoelastic foam is defined by time-dependent behaviors such as stress relaxation, creep, and hysteresis (T-Foam, Sunmate, and Tempur-Med).

nondeforming foam or matrix: support material that does not deflect or deform under clinical loads; often used in cushion bases (Freedom Designs, Jay) and characterized by high stiffness.

2. Cushions Containing Fluid:

viscoelastic fluid: relatively incompressible substance that can flow under small stresses and exhibits both elastic (ability to store energy) and viscous (resistance to flow) properties. (Cloud and FloFit use viscoelastic fluids.)

air cushion: a cushion with an impermeable membrane containing air (Roho, BBD).

water cushion: a cushion with an impermeable membrane containing water (Lotus).

3. Other Construction:

solid elastomer and solid gel: solid rubber-like, relatively incompressible polymer that resists and recovers from deformation. (Akton pads are an elastomer, while Alimed uses gel.)

cushion with displacing solid elements: a cushion made of solid, relatively incompressible components that displace under load (e.g., Vicair).

B. Physical Characteristics

1. Surface Characteristics

unloaded contour depth: the depth of contour at the site designed for buttock support in relation to the support surface thickness; measured 150 ± 25 mm from rear edge with no load applied. To determine the appropriate support surface height, this measure is taken either midline (flat and convex cushions) or at the lateral border (contoured cushions). An example can be found in the diagram of cushions on page 455.

loaded contour depth: maximum depth of contour resulting from load on the cushion’s surface at the site designed for buttock support; measured 150 ± 25 mm from rear edge of the cushion using a Cushion Loading Indentor (CLI); the loaded contour depth of flat cushions equals the deflection or displacement under load. For contoured cushions, loaded contour depth equals the amount of unloaded contour depth plus contour after loading in comparison with the lateral rear border; the magnitude of load depends on the size and type of the CLI and is based upon a 77-kg person. (See the diagram of cushions on page 455.)

contour: cushion’s surface that is shaped to fit or reflect the form of the human body, most specifically, the buttocks. Cushions may be contoured to a general or nonspecific shape or custom contoured to a particular user’s shape.

cut-out: cushion’s surface having a disruption or removal of material to alter the load-bearing characteristics of the surface or to create room for an insert of material; a cut-out, by definition, does not reflect the form or shape of the human body (Isch-Dish, Tender-Care).

segmented: material whose surface is divided into separate and distinct segments of grid top design; (e.g., Val-Med; Bioform).

convoluted foam: cushion surface composed of convex protrusions separated by depressions or sulci; often called “egg-crate” but includes checkerboard and other designs. The specifications for convoluted foam generally include the total thickness of the pad and the thickness of the base (measured from the bottom to the lowest point of the valley).

2. Features

Preischial support: bar/ridge or area of contour placed anterior to ischial tuberosities and intended to inhibit forward movement of the ischial tuberosities and pelvis; antithrust seat.

Lateral pelvic support: pad or other contact to the region defined by the posterior buttocks to slightly distal to the greater trochanter and intended to prevent lateral movement of the pelvis; hip pad, block, or guide.

Medial thigh support: pad or other contact to the adductor region of the thigh provides stability to the lower extremities; abductor pad or support pommel, leg-dividing support.

Lateral thigh support: pad or other contact to the lateral region of the thigh distal from the greater trochanter to

the femoral condyle; provides lateral stability to the lower extremity.

3. Other

bonded: adhesion of material by any means (heat, glue, etc.) (Infinity, UltiMate).

compartment or chamber: section or partition of a material; often applied to air or other fluid cushions; cushions can have single, dual, or multicompartments or chambers; may be adjustable.

stiffness: the degree of firmness of a foam or flexible matrix determined by measuring its force-deflection response; reported as Indentation Force Deflection (IFD), if known; examples include “single stiffness cushion” (Skil-Care, Hermell) or “bonded multistiffness foam cushion” (ProFoam, Seat Buddy).

flat base or curved base: describe the cushion’s bottom surface. A “curved base” is typically designed to accommodate for sling upholstery. See below for special measuring instructions for curved-base cushions.

C. Weight or Mass

Weight is recorded to the nearest 0.05 kg (0.1 lb) with an accuracy within 25 g (0.05 lb).

Rationale: Most standards call for an accuracy of 1 percent of desired value (most standards utilize standard specimen sizes); the value limits above represent an accuracy of 1 percent and a precision of 2 percent in a 5-lb cushion.

D. Dimensions

1. Support surface length and width: overall dimensions of the body support portion of the cushion; measured to the nearest one-half cm (or one-quarter in.); three measures are taken, with the median recorded. (See **Figure 1**.)

2. Footprint length and width: certain cushions have a footprint or base contact area different than that of the support surface. For example, a beveled cushion has a footprint that is less than the support surface dimensions. Dimensions are reported only if footprint differs from overall dimensions. Three measures are taken, with the median recorded.

3. Support surface thickness: measured 150 ± 25 mm from the rear border of the cushion (**Figure 1**) while applying 5–17 mmHg pressure (0.1–0.3 PSI or 0.7–2.0 kPa)

with the use of a circular foot and to the nearest one-half cm (see below for cushion loading device); three measures are taken, with the median recorded; for contoured cushions, measure is taken at the lateral border; for flat cushions and those with slight convexity, measures are taken at midline; please refer to figure of cushions on page 455 for examples; thickness reflects the available support surface thickness and does not include nondeforming space or sling-filler material used in cushions with curved bases; additional information on curved-base cushions is provided below (**Figure 2**). If different, the cushion’s overall thickness is also recorded.

4. Thigh thickness: the thickness of the cushion at the front edge, midway between lateral edge and midline, while applying 5–17 mmHg pressure (0.1–0.3 PSI or 0.7–2.0 kPa) using a circular foot and to the nearest one-half cm; three measures are taken, with the median recorded. Heights of medial and lateral thigh supports key off of this measure.

5. Medial thigh support height: height difference between the front midline section and the thigh thickness. The height of the front midline section is measured while applying 5–17 mmHg pressure (0.1–0.3 PSI or 0.7–2.0 kPa) using a circular foot and to the nearest one-half cm; three measures are taken, with the median recorded.

6. Lateral thigh support height: height difference between the cushion’s left and right lateral front sections and the thigh thickness; the height of the lateral front sections is measured while applying 5–17 mmHg pressure (0.1–0.3 PSI or 0.7–2.0 kPa) using a circular foot and to the nearest one-half cm; three measures are taken, with the median recorded.

Rationale: Many standards use specified samples so stated dimensions and measurements simply confirm that the proper size is used. Load is typically applied when measuring thickness to ensure seating of the jig. The ranges of this load vary from 1–10 mmHg (0.02–0.2 PSI) depending on the standard and material (ASTM D3574 (8), SAE J388 (9), SAE J1051 (10), Dow Corning Gel Penetration (11)), with the lower magnitude used for soft gel materials. Testing showed that pressures of 17 mmHg (0.3 PSI) do not deform cushion materials and can be used as an upper limit for wheelchair-cushion testing.

Thickness measurement taken 150 ± 25 mm from the rear border of the cushion is consistent with ISO 4253 (12) and ISO 5353 (13). This distance is used to ensure

of the cushion. They also may impact performance. Contoured cushions (those with an unloaded contour depth) and the depth of that contour affect positioning of the user on the surface and can impact transfers on and off the cushion. Additionally, the increase in contour depth under load (loaded contour depth) can also impact transfers and other clinical considerations.

Thigh support heights and unloaded contour depth can be considered as an indication of the positioning capability of a cushion. Certain cushions are designed for postural control whereby cushion material contacts body parts to encourage proper alignment and stability.

E. Method for Measuring Width and Length

Measurement of support surface and footprint length and width is done using a platform as shown in **Figure 3**. The cushion is seated between the platform's rear and lateral fences. The platform is ruled to permit reading of the dimensions. A transparent panel is slid into contact with the cushion, and dimensions are read. The panel is seated against the cushion to take up any slack in material and to increase repeatability of the measurement. Three measures of length and width are taken, with the median recorded to the nearest one-half cm.

F. Method for Measuring Thickness

A 50-mm diameter circular indenter foot is used to measure thickness dimensions. Applying initial pressure (5–17 mmHg; 0.1–0.3 PSI; 0.7–2.0 kPa) to measure thickness is done to ensure that the tool is seated properly. Values are recorded to the nearest one-half cm.

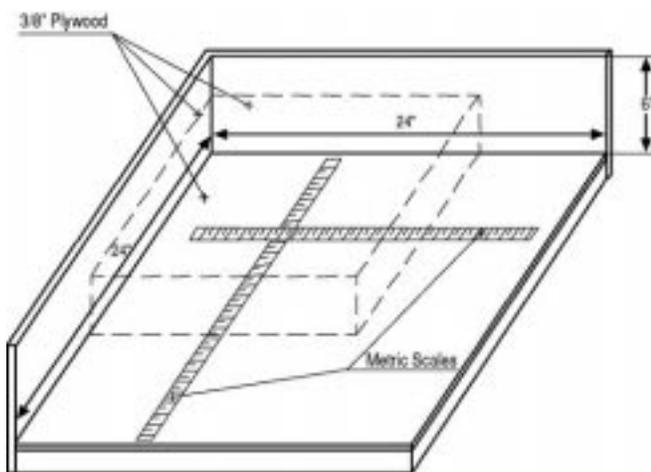


Figure 3.
Cushion dimensioning fixture.

The foot is mounted to a ruled vertical rod that slides within a bearing. The bearing housing slides along a horizontal track to properly position the foot to the area of interest (**Figure 4**). This fixture can also be fit with the indenter jig for the loaded contour depth and overload tests.

As described above, cushion thickness is taken 150 ± 25 mm from the rear edge of the cushion. In order to determine the appropriate support surface height, this measure is taken either midline (flat and convex cushions) or at the lateral border (contoured cushions). Please refer to **Figure 5**.

The fluid in certain cushions should be leveled prior to measurement. Some of these cushions have a convex

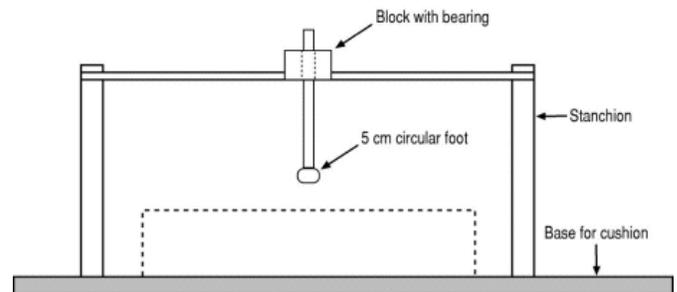


Figure 4.
Thickness and loaded contour depth fixture.

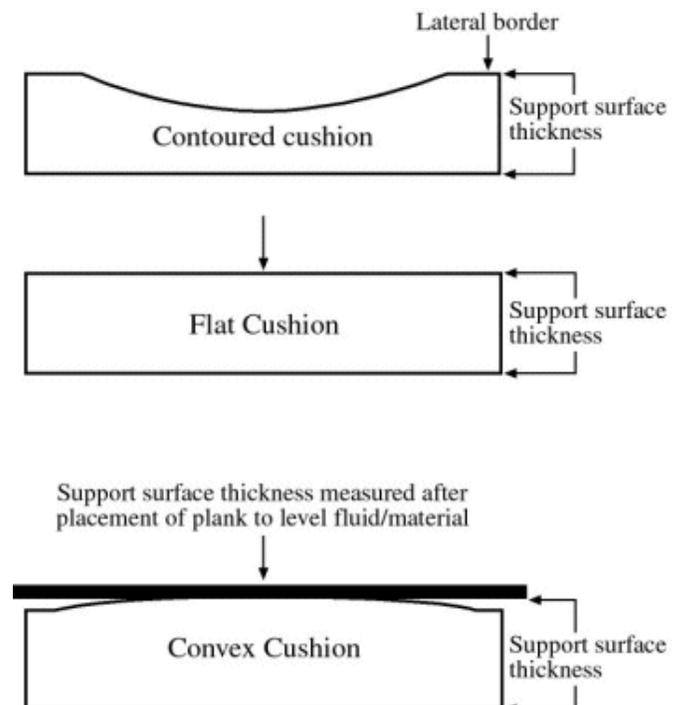


Figure 5.
Locations from which to measure thickness.

surface. Place and level a board, approximately 4 in. \times 18 in. across the cushion, 150 \pm 25 mm from the rear of the cushion. Record cushion thickness at midline, remembering to subtract the board thickness if it remains in place during the measurement.

Alternative devices: Thickness may be measured with the use of other techniques as long as the initial pressure and accuracy limits are achieved. Other devices include calipers, tape measures, and rulers.

G. Method for Measuring Unloaded Contour Depth

Definition: The depth of contour at the site designed for buttock support in relation to the support-surface thickness; measured 150 \pm 25 mm from rear edge with no load applied.

A circular indenter foot of 50-mm diameter is used to measure depth of contour. To determine the appropriate support-surface height, this measure is taken either midline (flat and convex cushions) or at the lateral border (contoured cushions). Contour depth is determined in relation to this measure of support-surface height. Three measures are taken, with the median reported. Values are recorded to the nearest one-half cm. The alignment of the loading jig should reflect the design of the cushion. Many wheelchair cushions have contour or indentation in the area intended for buttock loading. By definition, flat and convex fluid cushions will have an unloaded contour depth of 0 cm.

H. Method for Measuring Loaded Contour Depth

Definition: Maximum depth of contour resulting from load on the cushion's surface at the site designed for buttock support; measured 150 \pm 25 mm from rear edge of the cushion; the magnitude of load depends on the size and type of the CLI and is based upon a 77-kg person.

Prior to testing, the cushion is preloaded twice to 133 percent of the test load. Each preload is held for 60 s. Loaded contour is measured by applying 137 N if using the PVA loading jig or 505 N if using the ISO buttock model (see next section). Values are recorded after 5 min of loading. The magnitude of loaded contour depth equals the height difference between the inferior aspect of the CLI and the support surface height (as described above). Three measures are taken and the median is reported to the nearest one-half cm. Loaded contour depth describes the cushion's capability to contour and takes into account

both the initial contour and contouring produced by loading.

I. Overload Test Method

A cushion is considered to be "bottomed-out" when an increase in load does not impart an increase in deflection. One means to measure this situation is to increase load from the "loaded contour" test and determine if an increase in deflection results.

The Overload test requires that a cushion will deflect a minimum of one-half cm when loaded by 33 percent over that of the Loaded Contour Depth test. The Overload test can be run immediately after the Loaded Contour Depth test by adding the appropriate amount of weight. Deflection is recorded after 1 min of overload to the nearest one-half cm.

PVA loading jig: 31 lb (or 137 N) is used for loaded contour, so 10.25 lb (or 45 N) will be added for 33-percent overload.

ISO buttock model: 112 lb (or 505 N) is used for loaded contour, so 37 lb (or 165 N) will be added for 33-percent overload.

Rationale: One means to measure this situation is to increase load from the "loaded contour" amount and determine if an increase in deflection results. An overloaded condition mimics several clinical situations that underscore a need to avoid a bottomed-out condition.

For example, A person should not "bottom-out" his or her cushion when seated in a typical posture; this situation would lead to high interface pressures, because the cushion could not adequately support the body. Furthermore, a cushion that is bottomed-out in a typical posture could not accommodate to the slight weight shifts experienced during sitting, thus further elevating the tissue-interface pressures. Certain functional movements such as leaning and reaching effectively overload an aspect of the cushion. These transient events overload a cushion and may lead to a bottomed-out condition. The amount of overload is related to the magnitude of the postural sway (an extreme lean would overload a cushion more than a slight lean).

Ensuring that a cushion does not bottom-out during overloading adds assurance that the cushion can weather normal fatigue without becoming dangerous. Many new materials have a "break-in" period during which they soften up when being stressed for the first time. After this break-in period, cushion stiffness will remain fairly constant until material fatigue occurs (development of

fatigue will vary across cushion design). Testing a cushion with a nominal overload helps ensure that the cushion will not “bottom-out” during the initial break-in period and will not bottom-out at the early stages of fatigue. Basically, an overload test helps ensure a longer useful cushion life.

J. Cushion-Loading Indentors

Loaded Contour and Overload tests are simulation tests that use models to represent the human buttocks. These tests utilize a CLI to impart load onto a cushion.

PVA Loading Jig: A loading jig (**Figure 6**) was designed to represent buttock loading. Overall dimensions are based upon anthropometric data. Ischial tuberosities are modeled by two 50-mm-diameter indentors, spaced 12 cm apart; trochanters are modeled by 25-mm-diameter indentors at 38-cm spacing; the vertical height difference between the tuberosities and trochanters is 40 mm. A 50-mm-wide strap spans the jig to impart a more continuous load typical of sitting. The spacing described above approximates those of a person who uses a standard adult wheelchair (18-in. seat width and 16-in. seat depth). Jig dimensions for other users will vary.

Loading of the jig was based upon a 77-kg person (worldwide average plus 10 percent to account for variability) and the fraction of the buttocks represented by the jig. Values rounded to integers.

upper body weight on buttocks = 66 percent of body weight or 51 kg

buttock depth averages 7.4 in, therefore a 2-in strap represents 27 percent of buttocks

$51 \text{ kg} \times 27 \text{ percent} = 14 \text{ kg-f}$ or 31 lb or 137 N

ISO Buttock Model: The buttock model described in ISO7176 (16) can be used for testing (**Figure 7**). It shall be mounted to the testing apparatus with a 5° rearward tilt. The buttock model shall be positioned over the test cushion so that the area of the cushion designed for the ischial tuberosities can be aligned with the analogous part of the buttock model. This location is approximately $150 \pm 25 \text{ mm}$ from the rear edge of the ISO model.

Loading of the model is based upon a 77-kg person (worldwide average plus 10 percent to account for variability) and the fraction of the buttocks represented by the jig. Values rounded to integers.

upper body weight on buttocks = 66 percent of body weight or 51 kg or 505 N

K. Method to Support Curved-Base Cushions

Cushions with a curved base must be stable during dimension and contour measurement testing. One approach to support cushions with curved bases involves the use of bags or bladders filled with polystyrene pellets (**Figure 8**). The cushion is placed upon the testing surface, and a level is positioned on the top surface. The “bean bags” are then slid under the edges of the cushion and conform to the specific shape and slope of the curved base. When correctly placed, the centermost portion of the cushion bottom will remain upon the test surface with the bean bags filling the lateral edges; the cushion should be level and should not move during testing.

Test Method Validation

During development, all test methods underwent repeatability testing. In addition, loaded contour depth measurements underwent cross validation with values reported in the literature.

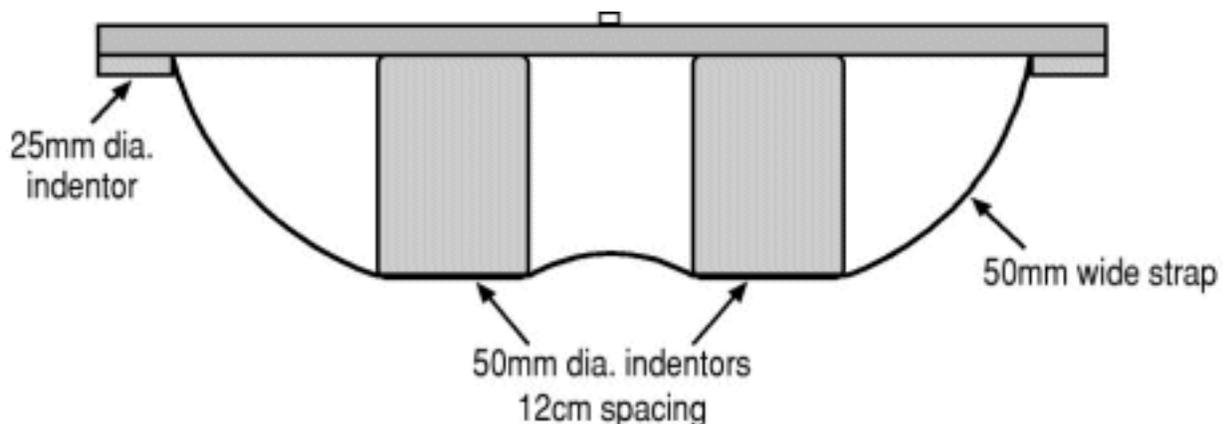


Figure 6.
Loading Jig: Modeling ischial tuberosities and trochanters.

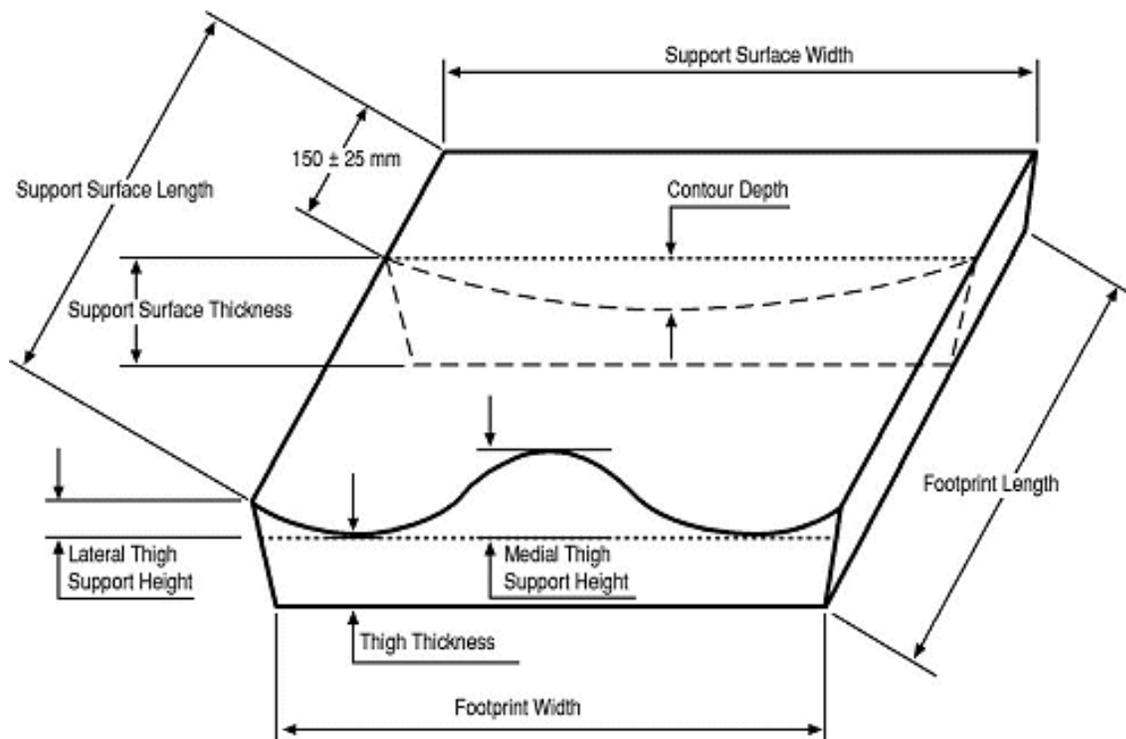


Figure 1.
Cushion dimensions.

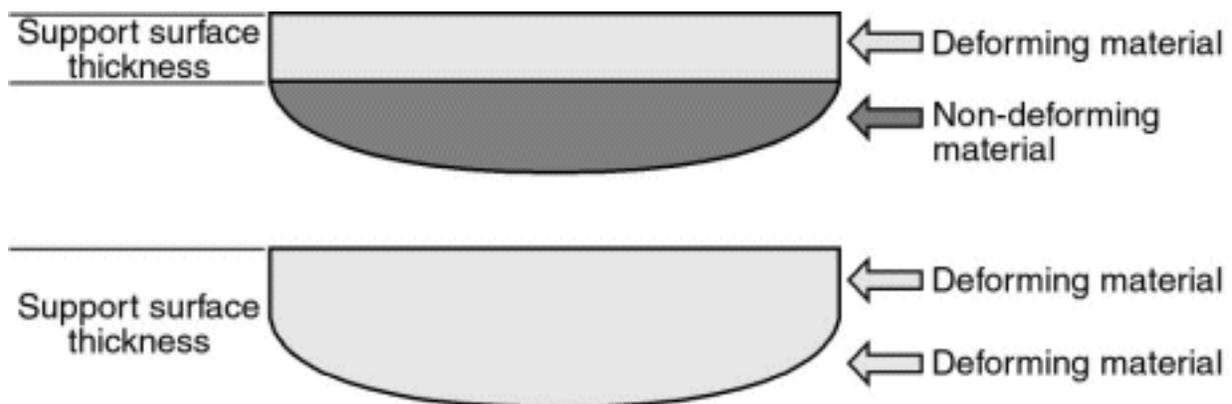


Figure 2.
Support surface thickness of curved-base cushions.

thickness is measured in the load-bearing region of the cushion.

Dimension accuracy also varies across standards, including: ± 1 mm for 25 mm and ± 2 mm for 38-mm specimens in ASTM D-412-87 (14); ± 3 mm for thickness measures of specimen >40 mm, ± 10 mm for length and width measures from 150 mm to 300 mm and a 3-percent accuracy allowed for specimens >300 mm in ASTM 1667 (15).

Rounding width and length to 5 mm can produce an error of ± 2 mm, which is well within the accuracy of ASTM 1667. Rounding thickness to the nearest 5 mm can result in an error of ± 2 mm, or a 4-percent error in a 50-mm cushion. Both errors are within the guidelines of other ASTM standards.

Unloaded and loaded contour depths are considered characteristics because they are features that impact use

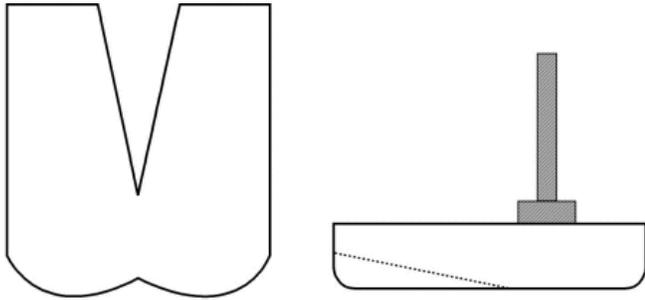


Figure 7.
ISO Buttock model.

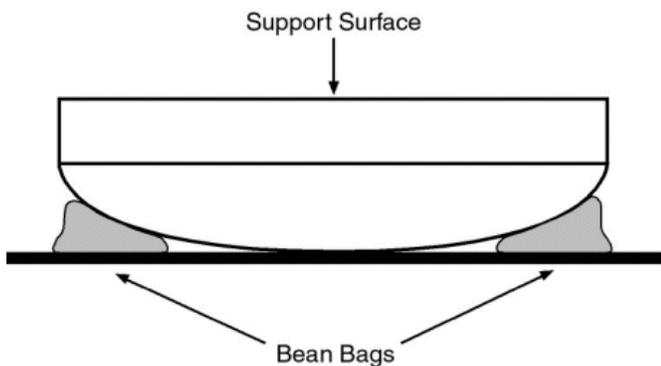


Figure 8.
Supporting curve-base cushions.

Loaded Contour: Validation of the loaded contour depth test method was done via comparison of values of human subjects to that from the CLI tests (Table 1). Two sets of data were found that measured the contour depth as wheelchair users sat upon cushions (17,18). Both sets of data used nondisabled subjects and sub-

Table 1.
Comparison of loaded contour depth to human subject trials.

	75 mm 45 ILD	Roho
Chung (16 SCI & 8 control)	32.7	45
Sprigle, et. al (11 SCI & 6 control)	37.7	–
combined	34.3	–
PVA jig	30	45
ISO model	31 1/2	44 1/2

jects with SCI and had a 66–75-kg range in mass. The Loaded Contour Depth test was run using both the PVA and ISO CLIs that are modeled on a 77-kg person. Two cushions, foam and Roho, comprised Chung's data and a single foam cushion comprised Sprigle and colleagues' data. Given the different measurement methods and variability within and across subject groups, the data similarity is evident.

Reliability of the loaded contour depth across CLI was performed using five cushions (Table 2). The cushion selection varied considerably in construction and surface characteristics and included block foam (45 and 70 ILD), contoured foam (Fundamental and No Sorz), a combination contoured foam and viscous fluid cushion (Personal Seat), and a segmented air cushion (Roho).

Reliability of the measurements across time and tester was done using two investigators who each measured a sample of cushions at two separate times. Over 25 cushions were measured in this manner using the PVA jig. The overwhelming majority of measurements matched with rounding error attributed for all discrepancies. Thus, the measurements were all within one-half cm.

Selection of the PVA Jig

The PVA jig was selected as the loading indenter for the project. This decision was based upon practical and philosophical reasons. Neither indenter mimics a human buttock, since indicators are rigid. However, both are buttock models.

The PVA jig uses the ischial tuberosities and greater trochanter as load-bearing sites. All four sites are designed and spaced according to anthropometric measurements. The design of the jig allows for easy accommodation of different pelvic sizes. By changing the spacing of the ischial cylinders and trochanteric buttons, one can model wheelchair users with different-sized pelvises. The ISO buttock model does not permit a simple means to change size, but the possibility exists that a family of buttock models could be designed.

One benefit of the ISO buttock is that it incorporates an entire buttock-and-thigh loading area. This increases its face validity. The lack of face validity of the PVA jig could also be looked upon as a positive feature. Because it is a mechanical analog of load-bearing prominences, a cushion designer is very unlikely to design to this jig. Designing to a test is a potential drawback of standardized test methods.

Table 2.
Comparison of loaded contour depth across CLI.

	75 mm 45 ILD	75 mm 70 ILD	ROHO	Maxus NoSor ^z	E&J Fundamental	Invacare t Personal Sea
PVA jig	30	18	45	32	29	69 1/2
ISO model	31 1/2	20	44 1/2	34	26 1/2	74 1/2

Cushion Characteristics

Table 3 contains the cushion characteristics of 11 cushions. These cushions comprise a convenient representation of the entire 210 cushions in that they vary greatly in construction and characteristics.

Not surprisingly, foam and air cushions are much lighter than cushions with solid gel or viscoelastic fluid. One of the listed cushions, the Tem Pro Seat, had a nondeforming foam base, so both its support surface thickness (7 cm) and overall thickness (12 cm) are listed. The Quadro cushion has a border around its support surface, so footprint dimensions are listed in addition to its support surface dimensions. Two cushions, Xact-Contour and Saddle, had substantial thigh contouring that resulted in medial and lateral thigh supports exceeding 2 cm. Five of the cushions in **Table 3** are flat (0-cm unloaded contour), and of the six contoured cushions, three had unloaded contours exceeding 2 cm. Loaded contours of the cushions listed in **Table 3** varied between 2 cm and 6 cm. Some cushions are designed to significantly contour under load, because their loaded and unloaded contour depths are quite different, whereas others (i.e., Xact-Contour) deflect a lesser amount under load but use precontouring to achieve a significant loaded contour.

CONCLUSIONS

This project resulted in the identification of common terminology that can be used to describe wheelchair cushion characteristics. The use of common terms to describe material construction and physical features will permit better understanding by and communication between clinicians, vendors, and wheelchair users. The development of test methods that describe cushion characteristics will also be useful to these groups by permitting better comparison across cushion types throughout the wheelchair-cushion selection process.

Because close communication was maintained with the ISO and ASTM/RESNA standards workgroups, all terminology and test methods are consistent with the draft standards under development. However, certain differences may result as draft standards documents are modified during the review and adoption process of each respective standards organization. Even if minor differences develop, this project produced useful information by documenting the characteristics of 210 cushions available in the U.S. market.

Table 3.
Cushion characteristics.

Name/Manufacturer	Cushion Construction	Cover Construction	Weight (kg)	Dimensions W × L (cm)	Support Surface Thickness (cm)	Thigh Thickness (cm)	Med & Lat Thigh Support Height (cm)	Unloaded & Loaded Contour Depth (cm)	Overload Displacement (cm)
Xact-Contour/ Action Products, Inc.	Segmented solid elastomer pad atop contoured foam base with viscoelastic foam insert	Inner: fabric-backed vinyl; outer: lycra top, fabric-backed vinyl bottom	3.00	45 1/2×41	9 1/2	8 1/2	M: 2 L: 2 1/2	Unl: 3 L: 4 1/2	1/2
Latex Wheelchair Cushion/AltiMed, Inc.	Perforated latex foam	Polyester double knit fabric	0.85	46 1/2×41	5	5	M: 0 L: 0	Unl: 0 L: 3 1/2	1/2
VariLite Evolution/ Cascade Designs, Inc.	Bonded multistiffness polyurethane foam encased in adjustable single valve air cushion	Vinyl-coated polyolefin bottom; polyethylene film coated stretch lycra top; nylon sides	0.95	48×40	10	10	M: 0 L: 0	Unl: 1 1/2 L: 4	1/2
Infinity Maximum Contour/Invacare Corp.	Viscoelastic foam bonded atop polyurethane and non-deforming foam with optional solid gel insert	Inner: fabric-backed vinyl; outer: lycra top, fabric-backed vinyl bottom	1.60	45×43 1/2	10	9	M: 3 1/2 L: 2 1/2	Unl: 0 L: 3 1/2	1/2
Jay Basic Cushion/ Sunrise Medical	Contoured urethane foam	Fabric-backed vinyl bottom - coated stretch knit top	0.75	45×42	5	5	M: 1 1/2 L: 0	Unl: 1/2 L: 2 1/2	1/2
Tem Pro Seat Buddy/Profex Medical Products, Inc.	Bonded viscoelastic and urethane foams with curved base	Fabric-backed vinyl	0.70	45 1/2×42 1/2	7 1/2 overall: 12	7 1/2	M: 0 L: 0	Unl: 0 L: 3 1/2	1/2
Quadtro/ROHO, Inc.	Single valve, four chamber adjustable air cushion	Stretch lycra top; nylon sides; open-mesh nonskid fabric bottom	2.10	45×41 fprint: 48×44 1/2	10	10	M: 0 L: 0	Unl: 0 L: 5 1/2	1/2
Econo-Gel Pad/ Skil-Care Co.	Viscous fluid bladder between bonded foam layers	Sealed vinyl	3.15	45 1/2×40 1/2	8	6 1/2	M: 0 L: -1/2	Unl: 0 L: 3 1/2	1/2
GeoMatt Contour/ Span America Medical Systems, Inc.	Segmented foam bonded atop polyurethane foam encased in polyethylene	Coated ripstop nylon top; fabric-reinforced vinyl bottom	0.85	45 1/2×41 1/2	8	6 1/2	M: 1 1/2 L: 1 1/2	Unl: 3 L: 5	1/2
Saddle Zero Elevation/ The Comfort Company	Viscous fluid bladder encased in multistiffness with cutout	Fabric-backed vinyl bottom; stretch lycra top	2.30	44 1/2×46 1/2	11 1/2	9	M: 3 1/2 L: 2 1/2	Unl: 4 L: 6	1/2
Advantage/ Otto Bock Rehab	Segmented multiple viscous fluid bladders atop dual stiffness urethane foam	Neoprene-coated stretch lycra top; coated nylon sides and bottom with nonskid panel	1.40	W: 45×40 1/2	8	7	M: 1/2 L: 1	Unl: 0 L: 3	1/2

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This manuscript is presented here as a Special Report, not a peer-reviewed scientific or technical note. The information represents many years of outstanding investigation on the subject by George Van B. Cochran, MD, reaching back into the early 1980s at the now-named Center for Rehabilitation Technology at Helen Hayes Hospital. This work is relative to wheelchair characteristics and the development of uniform terminology and procedures used to describe those characteristics.

The Journal Editors agreed that this information would be of special interest to the multidisciplinary readership of the Journal, and it is therefore presented here as a Special Report.

Tamara T. Sowell
Editor

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