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BIOENGINEERING METHODS OF WHEELCHAIR EVALUATION

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The Veterans Administration undertakes the responsibility for evaluation of a variety of orthopedic devices such as braces, artificial limbs, wheelchairs, and patient lifts. Its primary purpose is to provide an intelligent basis for selection, procurement, and application of those devices which can be of greatest benefit to disabled veterans. This program also serves to guide the manufacturers of orthopedic devices along lines of development that are of particular interest to the Veterans Administration. The evaluation may therefore range from analysis of the design and materials to a full-scale biomechanical analysis in the laboratory, as well as a field study in several hospitals and clinics around the country. Laboratory studies are generally delegated to the VAPC Bioengineering Laboratory, and field studies are usually conducted by the Prosthetic and Sensory Aids Service.

Orthopedic braces and artificial limbs for both the upper and lower extremities have been the subject of evaluation programs for many years, and relatively useful methods and techniques have been evolved. The parameters which provide the most useful assessment of these devices are fairly well established. In addition, there exists a body of basic data on normal human locomotion from which useful criteria for evaluating performance can be drawn.

A somewhat different situation prevails in an approach to the evaluation of such items as lift aids and wheelchairs since there is available little basic information about their performance factors. Such standards as do exist are descriptive in nature and relate primarily to dimensions and materials of the devices. A meaningful evaluation, however, depends on tests not only of hardware but also of the human factors that enter into efficient use.

To provide a basis for an adequate assessment of orthopedic lift aids and wheelchairs, there has evolved in the Bioengineering Laboratory an evaluation program that takes into account the man-machine combination that is both descriptive and functional. This program consists of specifically designed test procedures to provide information on:

1. Analysis of mechanical design, adequacy of materials, and durability.
2. Convenience and ease of operation.
3. Patient acceptability in relation to appearance, utiliztion in the home, and the availability of other similar devices.
4. Stability and safety.
5. Force and energy requirements.

A careful analysis of the design of an orthopedic device illustrates the extent to which the fundamental idea or purpose has been translated into appropriate mechanical features. A consideration of the mechanical design in relation to all aspects of the intended application frequently discloses serious limitations. In designing an orthopedic lift for extreme stability, for example, one developer failed to realize that the broad base of support was a grave handicap in confined areas where lifts are frequently used. Materials used in an apparatus strongly influence comfort, safety, and durability. These features are assessed in the light of good design principles and on the basis of some standards which, although not entirely adequate, can be usefully applied. Durability is frequently determined by means of cycling tests.

Convenience and ease of operation are not only important considerations for the therapist who may use the devices, but they are especially critical factors for the patients of limited strength and mobility who must operate them. Use tests are devised to assess these matters. In some cases, observation of several appropriately selected patients may suffice; in other cases, longer-term hospital use may provide the basis for judgment.

To continue reading, please visit http://www.rehab.research.va.gov/jour/64/1/1/77.pdf

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COMMENTARY ON BIOENGINEERING OF WHEELCHAIRS: THE PAST 50 YEARS

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It was a pleasure to become reacquainted with the landmark article "Bioengineering methods of wheelchair evaluation" by Peizer et al. from the 1964 *Bulletin of Prosthetics Research*. As is to be expected, in some areas, there have been tremendous advances since the article was written and, in others, our understanding remains limited. Probably the three most profound aspects of the Peizer et al. article are that (1) much of the wheelchair engineering research at the time could be summarized in a single article, (2) the Department of Veterans Affairs Prosthetics Center was on the leading edge of multidisciplinary team research, and (3) far fewer people were conducting wheelchair-related research. The breadth of the research described by Peizer et al. is remarkable for its time, but the depth of the knowledge was much less than we know today.

Most would agree that the greatest changes that have taken place over the past 50 years are in the areas of ability to image the upper limbs; biomechanics (kinematics, especially kinetics) of wheelchair propulsion and transfers; design of wheelchairs from the materials, electronics, software, and fabrication to the style; and human-to-wheelchair interfaces for both manual and power chairs. The most profound difference is that the wheelchairs of today are vastly superior to the wheelchairs of 50 years ago. At the time of publication of Peizer et al.'s article, there was one dominant manufacturer and very few options to include sizes. People could literally memorize the entire catalog. Today, there are more than 100 companies and thousands of models with literally hundreds of thousands of options.

Manual wheelchairs are much lighter, efficient, ergonomic, and socially acceptable. A growing number of clinicians understand the need for matching the design and configuration closely to the needs and abilities of the user. Electric powered wheelchairs (EPWs) share very little in common with their ancestors of 50 years ago. EPWs today have computer-operated interfaces and power controls that were unthinkable at that time. Further, the EPW seat and chassis systems have been separated to be more like a car than a "wheeled chair." EPW chassis often have independent suspension, and seats can range from simple "captain chairs" to fully articulated with power elevation, leg-rest angle, tilt, and recline. Fifty years ago, sports wheelchairs (e.g., racing, rugby, basketball, and hand-cycling) did not exist. Athletes competed in essentially the same chairs that they used everyday. Now, nearly every adaptive sport uses custom-designed wheelchairs and athletic performances are astoundingly better than 50 years ago. People who use wheelchairs are healthier and live longer because science has led to better understanding of the benefits of exercise, adaptive sports and recreation, nutrition, smoking cessation, upper-limb preservation, pressure ulcer prevention, and skills training.

A number of barriers still remain. Although international wheelchair standards exist, they are seldom used in decision making or uniformly applied, leading to high variability in the quality, efficacy, and safety of wheelchairs. Reimbursement policies still vary widely, and the majority of insurers still severely limit access to appropriate quality and functioning wheelchairs. There remain millions of people without access to wheelchairs or the ability to operate current wheelchairs. There remains much to be learned about designing optimal wheelchairs, preventing secondary conditions, matching wheelchairs to user needs, evaluating the interaction of wheelchairs with the built environment, and infusing that knowledge into user and clinical communities.

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