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Testing of manually-propelled wheelchairs

The need for international standards

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Abstract

The Veteran's Administration Rehabilitation Engineering Centre (VAREC), and others in the United States have been involved in work associated with improving the wheelchair since early in the 60's. United States Veteran's Administration standards for the "push" wheelchair have been promulgated based on a number of tests, some simple and some requiring complex equipment. A draft of a standard for electrically powered wheelchairs has also been developed by VAREC. Nevertheless, such efforts as those which have taken place in the United States on both the "push" wheelchair and electrically powered systems have so far not been related to the work in other nations; certainly the definitive action toward the development of international standards recently started should employ mechanisms to include the work of all.

International standards—when and how?

Although we in the United States and our colleagues in Canada, Germany, Scandinavia, Great Britain, Japan and perhaps elsewhere have for years worked on developing standards for wheelchairs and have designed and used test procedures associated with the standards, we have only recently seen some meetings to bring all this work together to develop international standards. But how encompassing have those meetings been? We have no way of knowing the details of what has been started except that starts occur and that only those who can get to a meeting are able to contribute or know what was contributed. Although such conferences are valuable, we appeal for the communications that are independent of the meetings, for the publication of the activities now underway nationally and internationally. We appeal for the involvement of the interested international professional bodies, the International Commission on Technical Aids and the International Society for Prosthetics and Orthotics.

This paper is aimed at all those who have developed and used test procedures for manually-propelled wheelchairs and who should now look to international standard setting through the International Standards Organization (ISO) and its technical committee ISO/TC173. We offer this to encourage work on the manually-propelled or "push" wheelchair as a priority for ISO using the facilities and capabilities made available by the national efforts. Since we are also urging that wheelchairs become freely sold in international markets, we now seek to reinforce the work started only recently by ISO.

Wheelchair deficiencies

For years the persons most concerned with the functional and durability characteristics of the wheelchair, the users, have been repeatedly reminding the manufacturers, the professionals in the clinic and in the marketing network, the counsellors, the designers, and representatives of large purchasers like Government agencies, to work to improve this essential mobility device. We interpreted the demand as being directed first to making improvements in the push "hand-propelled" wheelchair, then to do the same for the electric wheelchair.

Clearfield (1976) strongly recommended that technology be applied to improve wheelchairs. He urged the VA to take actions quite similar to those taken in rigorously employing standards for hand controls on personal licensed vehicles.

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In his opinion similar VA action was needed on wheelchairs. He also pointed out that "awareness of the . . . . . potential of . . . . . technology and its use and demand by the disabled can result in products that meet the requirements of durability and effectiveness". Although we would have chosen different words, we agree in principle.

As Clearfield pointed out repeatedly, breakdowns of wheelchairs and the required maintenance hinder the life-style of the user. We of the VA, before Clearfield, had demonstrated our concern about wheelchairs and had done a significant amount of work. It was obviously not enough; nevertheless we responded anew, particularly to enlist the disabled in promoting improvements.

A historical perspective

Let us review the recent past. In 1964 Peizer et al presented the first discussion of wheelchair studies in the VA Prosthetics Center (VAPC now VAREC). Evaluation methods were proposed; this was the real beginning of the work in the VAPC—then mainly aimed at quality improvements that were sought by a small number of "consumers" served in our own clinical programme. Performance factors such as propulsion characteristics, stability, and design quality were the major concerns of these first efforts. These early activities also responded to the opinions of users concerning the dimensions of wheelchairs and their durability. Mainly though, tests to show performance differences among several kinds of wheelchairs were presented; energy studies and measures of coronary response and pulmonary ventilation were cited.

In 1965 the American Rehabilitation Foundation and the Vocational Rehabilitation Administration sponsored a wheelchair conference at the Kenny Institute of Rehabilitation in Minneapolis. Organized to enhance contacts between the manufacturers of wheelchairs and those who were concerned about wheelchair use, particularly the clinicians, the conference keynote expressed the concern that there was no *regulatory* agency holding wheelchair manufacturers to particular standards.

But Peizer (1965) there and then offered a plan for the development of such standards and for the specifications to meet such standards. Although not proposed as regulatory in the strictest sense, the concept presented was that an agency such as the VA as a large consumer in screening for quality of materials and for function, safety, cost, and durability could indeed employ higher quality standards than those used at that time by the VA supply system. Function, energy demands, and key physical characteristics were mentioned particularly as part of the philosophy based on *performance* standards rather than the previously used dimensional standards. In fact some precise indices were given at this time about wheelchair stability, weights, and structural requirements for acceptable durability.

Then in 1969 Peizer and Wright published draft standards for push or hand-propelled wheelchairs with their report on 5 years of wheelchair evaluation in VAPC/VAREC. The standard presented tests to check wheelchairs for ease of operation, manoeuvreability, durability, weight and so forth. At that time the authors also gave preliminary criteria for powered wheelchairs. Subsequent evaluations reported in the Bulletin of Prosthetics Research displayed refinement and expansion of these criteria.

In 1977 VAPC published slightly modified draft standards for "push" wheelchairs in the U.S. Federal Register. These were then reviewed both at a workshop WHEELCHAIR I, and then by a Committee of the American Society for Testing Materials—(McFarland, 1978). Later Peizer (1979) in a paper presented to a second workshop, WHEELCHAIR II, reported the scope of much of Lipskin's work on wheelchair evaluations in VAPC. This report mainly showed the wide spectrum in powered wheelchair design which standards need to encompass. At WHEELCHAIR II, Stout (1979) offered a very detailed analysis of the requirements of high performance wheelchairs.

Most recently the VAREC has contracted with Wright State University of Dayton, Ohio to support the development of performance standards based on comparative evaluations of metabolic, muscular and cardiorespiratory demands (Glaser, 1980). A commonly used "push" wheelchair is used as a control for performance comparisons with subjects in other (test) wheelchairs being considered for purchase and use by the Veterans Administration. Findings of this type help guide prescription.

The Paralyzed Veterans Association have

always been concerned as consumer-users; its members have urged the VA to give priority to the improvement of structure and performance of wheelchairs. Much of the input came from our constant contact with members of the Eastern Paralyzed Veterans of America, particularly those members involved in wheelchair sports where performance and structural demands are the greatest.

The VA Rehabilitation Engineering Center working with colleagues of the Rehabilitation Services Administration (RSA)* organized two national wheelchair workshops to focus on the problems of wheelchairs as viewed by a larger number of interests including especially the users. Manufacturers, developers, clinicians, marketing firms, and representatives of purchasers such as Governments participated.

The first of these workshops termed WHEELCHAIR I, was held in 1977; the report gave a number of very specific recommendations which came out of its panel discussions of wheelchair design (Wheelchair I, 1977). WHEELCHAIR I also reviewed the VA draft standards. Recommendations made were:

I. Review of VA Draft Specification.

A. Specific recommendations for change in the draft, item by item, were made by two panels.

B. It was recognized by all that the draft standard prepared by the VA includes chairs for only a portion of the population of wheelchair users, and chairs for children, special models, etc. need to be covered. Also, standards for seat structure, brake locks, tyres, etc. are not included.

C. The draft standards should be forwarded to Committee F–19 of the American Society for Testing and Materials, along with the suggestions made at the workshop for changes.

D. The VA/RSA should conduct a continuing programme on validation of the laboratory tests by feedback of clinical performance and repair records.

*Currently (March 1981) U.S. Government rehabilitation engineering research, development, and evaluation efforts among the non-veteran population are overseen by the National Institute for Handicapped Research (NIHR) of the U.S. Department of Education.

II. Design Refinements.

A. Stronger mounts are needed for the handrim.

B Improved design to support the spokes properly is needed.

C. Tyres presently provided are not completely satisfactory with respect to durability and maintenance of proper inflation. The use of foam-filled tyres and puncture sealants should be studied for effectiveness in ameliorating inflation problems.

D. Critically damped casters for front wheels should be provided for all "active" wheelchair users.

E. Frames need to be strengthened at strategic points. An analysis of failures is needed for determination of the weak points in the present system.

F. Chairs narrower than those presently available should be made available.

G. More appropriate wheel bearings are available to wheelchair manufacturers and they should be used to improve useful life of the chair.

H. More attention needs to be given to the seat, seat fabrics, and accessory cushions to make seating more functional, comfortable, and durable.

Priority should be given to the development of the basic data needed to carry out the recommendations listed above.

III. Design Innovations.

Some of the more interesting ideas offered concerning manually propelled wheelchairs were:

A. With advent of smaller cars, storage en route requires even more attention than it has had in the past.

B. A study of the feasibility of use of automobiles with rear entry possibilities should be initiated.

C. The idea of Chair-E-Yacht or front-wheel "scooters" where the wheelchair can be driven onto the power package seems to have merit and should be explored.

D. Retractable arm rests would be helpful.

E. The efficiency of arm-propulsion should be investigated to determine optimal arm and body motion patterns for various disability groups.

F. The use of materials other than those presently used should be studied for all the parts of a wheelchair.
G. A lap tray that stays with the chair at all times, yet is not in the way, is needed.
H. Use of 3-speed hubs for gearing manually propelled chairs should be evaluated.
I. The use of "ski-boot" technology to provide custom seating should be studied.
J. The use of a "bendable" structure or "adjustable chair" for initial fitting is suggested.
K. A modular system that can be assembled and dismantled quickly might prove to be more efficient than the present-day collapsible system.
L. Pneumatic foam-filled tyres may be useful and should be evaluated.
M. Wheelchair systems that enable the user to stand up, squat, and assume other normal posture configurations should be investigated.
N. Stored energy to assist in standing, curb-climbing, ramp-climbing, and change in seat position should be investigated.

WHEELCHAIR II, a second workshop, was held in 1979 to look closely at the special problems of powered wheelchairs (Wheelchair II, 1979). In April 1981—in Dallas, Texas another wheelchair workshop (WHEELCHAIR III) will be held to respond to current needs and to review accomplishments since 1977. VAREC will there propose newly developed (Dec. 1980) draft standards for electrically powered wheelchairs as developed by Lipskin; these cover performance, electrical characteristics and requirements, the drive system, stability, controls, power supply and charging, as well as many of the structural requirements of the "push" wheelchair.

During recent years VAREC and the Rehabilitation Services Administration also sponsored two rehabilitation engineering conferences (The Interagency Conference on Rehabilitation Engineering 1978 in Washington, D.C. and the Interagency Conference on Rehabilitation Engineering 1979 in Atlanta, Georgia). At these conferences, all aspects of rehabilitation engineering were covered in courses, open-paper sessions, and symposia. All disciplines including the consumer participated. It is expected that such conferences will continue to be held in future years and wheelchair development and evaluation will be major concerns.

Persistent problems with wheelchairs

But we know without further input that manually propelled or "push" wheelchairs continue to demonstrate maintenance problems, due perhaps to very rough handling but nevertheless based on the reasonable needs of the user. Breakdowns are extremely inconvenient to the person who depends on the wheelchair for ranging, from and to his home or place of employment. This "inconvenience" can be a near disaster economically with the dependence on getting to and from a job.

In response to a charge in a recent VAREC contract, Joe Silverman of the Center for Independent Living in Berkeley, clearly pointed out the kinds of irksome problems of repairs and of the frequencies of various repairs, these based on studies in and around that Center. Silverman (1977) reported to WHEELCHAIR I:

"*Front tyres, rear tyres, upholstery, and bearings were the most frequent classes of repairs.* From the economic point of view, however, it is of greater importance to compute the frequency of each repair multiplied by the cost of that repair. *In these terms, the most serious repair problem was tyres. Thirty cents* of the dollar spent for repair of manual chairs was spent on fixing flats and replacing tyres or replacing tyres with wheels. *The second greatest expense was rear wheels. Fixing spokes, trueing wheels, and replacing rear wheels accounted for 22 cents of the pushchair repair dollar. Replacing worn upholstery was the next costliest category.* The total for seat, back, and armrest upholstery was 14 cents of the dollar. The fourth major item was replacing worn bearings, which cost 12 cents per wheelchair repair dollar."

The American Society for Testing and Materials in its 1978 review performed a paragraph-by-paragraph analysis of the VAREC testing procedures and other aspects of the standards; this analysis will assist in the development of useful international standards; such critiques after appropriate secondary review may be helpful in developing a second-stage national (U.S.) standard, but perhaps it is time for a direct thrust at the international level.

In its analysis ASTM endorsed the VAREC approach in stating that the purpose of a standard for wheelchairs is to assure "that the user is enabled to operate a wheelchair with safety and reliability by identifying *performance* characteristics of adaptive devices which have been shown to create safety and service problems".

The proposed standards of 1977

The standards proposed by the VA Rehabilitation Engineering Center in 1977 have been published (Peizer and Wright, 1969; VAPC, 1977). The entire standard will not be presented here. Some tests are described to show the nature of the measures employed. The several tests presented here show the coverage and thrust of the current "draft" and most importantly, project some positive attributes as well as the limitations in the test programme.

Wheelchair testing

The sample of tests shown in Figures 1 to 5 from the Veterans Administration draft represents attempts to control quality and durability during periodic reviews for initial approval and subsequent purchases on VA contracts. Some of these tests can be readily performed in the manufacturer's setting; others require special equipment.

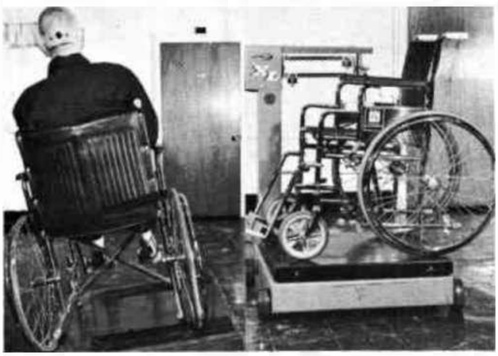

Fig. 1. Left, "The wheelchair must resist toppling on a surface with a 9° slope. The wheelchair shall be loaded with a 200 lb (91 kg) test load and positioned on the 9° slope with the front of the chair pointed upslope and locks on the drive wheels engaged. The standard 200 lb (91 kg) test load shall consist of a rigid 14 in (36 cm) cube with its centre of gravity (CG) at the intersection of the anterior-posterior and medial-lateral planes at a height of 4 in (10 cm) above the bottom surface. It shall be covered with a 0·5 in (1·25 cm) thick layer of 2 lb/ft (32 kg/cm) density, 30 durometer, foam rubber or (alternatively, the test can employ) an anthropomorphic 95th percentile dummy with movable joints such as the Sierra automotive test dummy in compliance with DOT, part 572." Right, "The gross weight of the chair, including all basic accessories such as footplates and armrests, shall not exceed 48 lb (22 kg)" (The seat, the backrest, and the legrests are also measured for certain dimensional requirements.)

Fig. 2. Left, "One year of normal use shall be simulated by driving a chair 360 hours with a 200 lb (91 kg) anthropomorphic dummy on a series of drums that provide a surface velocity of 5 mph (8 kph) and an alternating surface angulation of 9° both drum slope to the right, inward, to the left and outward." Right, "The chair shall be driven on 6 in (15 cm) curb drop simulator with the anthropomorphic dummy for 1,800 drops one way and 1,800 in a reverse direction" to subject the wheels and frame to equal impact loading over the 3,600 drops.

Clinical evaluations of wheelchairs

Standards should not inhibit innovation; thus a standard must be clearly associated with a class of device, and the classification used must be realistic in embodying a clearly related family of devices. Only in this way will there be fair and equitable compliance testing without including

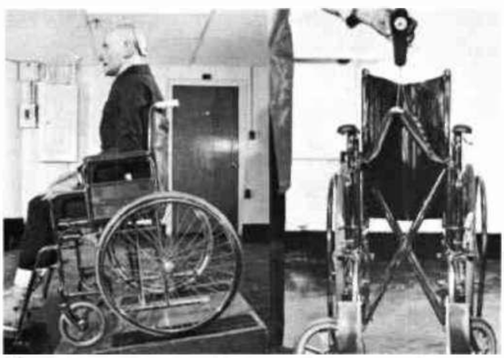

Fig. 3. Left, "Locks shall prevent wheel rotation when the wheelchair is loaded with a 200 lb (91 kg) test load and positioned on a 9° slope with the front of the chair pointed down-slope. Wheel movement with the locking device engaged shall be considered a failure". Right, "Measure force required to fold chair. The average of five readings shall not exceed 15 lb (66 N)."

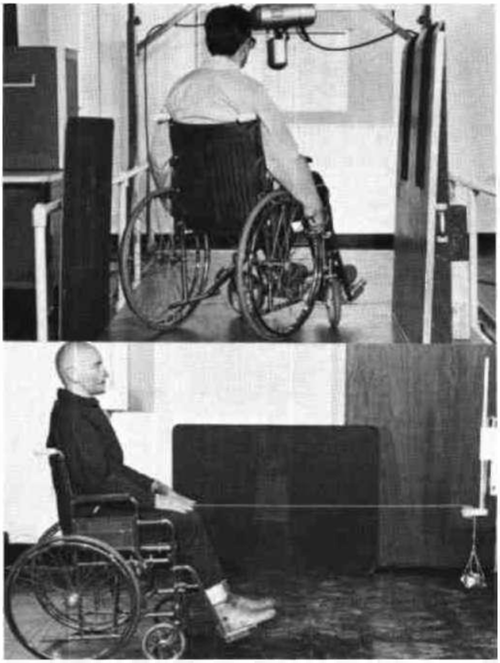

Fig. 4. Top, "Trials of turning 180° in an area 48 in (122 cm) wide, and through a 28 in (71 cm) opening." Bottom, "The wheelchair is loaded with the 200 lb (91 kg) load. One end of a light cable which passes over a pulley is attached to the wheelchair at its centre of gravity and the other end is connected to a weight. The weight used to produce a continuous movement of 12 in (30 cm) is recorded. The average of five such tests shall not exceed 5 lb (22 N)."

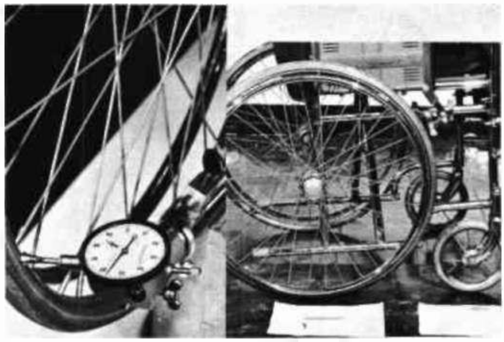

Fig. 5. Left, "With the chair supported on its lower frame members, check the wobble of the drive wheels using a displacement indicator. Remove the supports and apply the 200 lb (91 kg) test load. While pushing the chair, check the wobble with the displacement indicator. The difference between the first and second reading is the wobble due to the payload; 0·0625 in (1·5 mm) is the maximum acceptable wobble." Right, "Tyres are marked with a soft crayon and the wheelchair loaded with a 200 lb (91 kg) test load is placed on a sheet of paper. Upon removal of the chair, the area of the tyre imprint on the paper is measured. A drive wheel tyre mark shall not be less than 0·75 sq in (4·84 sq cm); a caster wheel tyre mark shall not be less than 0·5 sq in (3·34 sq cm)."

those devices which because of special character deserve another family grouping and therefore another type of testing.

In rehabilitation engineering generally, and with wheelchairs specifically, there is also a need to "evaluate", to determine the utility of a device. Since there are differences even within a family of devices, the differing characteristics must be valued and associated with performance, function, or comfort and then linked with classes of disability to give prescription indices.

Compliance testing against a standard is part of the evaluation process; it presents the framework for assessing mechanical durability and other values easily measured in a laboratory. But rehabilitation engineering devices also require clinical assessments, on new designs or new versions of older design or with model changes or manufacturing process changes. Performance measures as with the Wright State University tests mentioned earlier need now to be part of an "evaluation standard". Moreover, user tests and subjective analyses arrived at thereby are absolutely essential; mechanical testing alone is insufficient.

To illustrate some features of the current VAREC programme and particularly the variability among devices seen we cite some wheelchairs now undergoing evaluations:

Lightweight wheelchair "A"

This lightweight wheelchair (Fig. 6, left) is a conventional folding manual wheelchair with fixed arm rests, hard rubber tyres and removable foot rests. The 22 in spoked wheel rims and hand rims are made of annodized aluminium. The 8 in front swivel casters have special aluminium caster stems and the upholstery is a lightweight nylon. Two units were submitted to VAREC for evaluation.

The samples underwent laboratory tests at VAREC, New York and failed the structural durability standard which states," . . . . shall be of materials and construction which does not deform permanently under the stress of normal usage." The failure occured while undergoing the simulated 6 in (15 cm) curb drop test with a

Fig. 6. Left, Lightweight wheelchair "A." Right, structural failure in "A" as a result of curb drop test.

load (Fig. 2, right). The force generated caused a break in the back support above where it was welded to the frame (Fig. 6, right). The testing was terminated at that point.

Lightweight wheelchair "B"

This lightweight wheelchair (Fig. 7, left) has conventional wheelchair features such as hammock seating, pneumatic tyres, chrome-plated steel hand rims, removable arm and foot rests. However, two main differences are the woollen upholstery and roller cam braker. The overall weight is 38·75 lb (17·57 kg). Attached to the wheelchair is a repair kit (tools) and a tyre pump. One unit was submitted to VAREC for evaluation.

Compliance tests in accordance with the VA Standards yielded the following; the chair when loaded with the 200 lb (91 kg) test load and mounted on-the-ground reaction cycle tester (cycled at three miles per hour) showed excessive tyre wear after 144 hours. Also the leg strap provided became disengaged while performing the curb drop.

Lightweight (Carbon Fibre) wheelchair "C"

The Lightweight Carbon Fibre wheelchair (Fig. 7, right) of Japanese origin is a manually propelled wheelchair constructed of carbon-fibre-reinforced epoxy with a resultant weight of 19·8 lb (8·9 kg). This weight is lighter than the lightest commercially available wheelchair, now approximately 30 lb (13·6 kg), on the market.

Fig. 7. Left, Lightweight wheelchair "B." Right, Lightweight (carbon fibre) wheelchair "C."

VAREC's testing so far has been based primarily on the curb drop carousel shown in Figure 2, right. The wheelchair passed the test; no deformation, cracks, or other failures occurred suggesting that this structure should hold up under normal wheelchair use.

The wheelchair incorporates pneumatic tyres on the rear wheels and solid rubber tyres in front. In contrast to the conventional wheelchair, it is without hand-brakes and employs a cloth-like material as a foot support. The arm rests are fixed to the frame as with some conventional wheelchairs; however, they are positioned somewhat higher. Without hand brakes, swing-away foot rests, and removable arm rest at proper height, there are apparent limitations which clinical evaluation projects are used to discern.

Push rod propulsion wheelchair

This wheelchair (Fig. 8, top) has a spring-loaded push rod apparatus that replaces the conventional handrim for propelling the wheelchair.

If a wheelchair occupant has restricted use of the hands, he may be able to use the conventional handrim for propulsion. The use of special purpose handrims as on this chair with its rod projections are alternate choices.

The occupant pushes on the tip of the uppermost push rod (this can be done without grasping the tip). As the wheelchair moves, that push rod moves away from the occupant while the following push rod moves into its upper position. Continuation of this process provides movement in the desired direction.

As the spring-loaded push rod reaches its lowermost position, by use of the eccentric cam shown, the push rod is retracted to clear the floor.

In order to ensure the safety of the occupant when the wheelchair is moving, particularly downhill, this development also provides a spring-loaded brake. This braking system can reduce the speed (and can control direction) without locking the wheels. Brake levers are positioned near the top of the armrest, one on each side, for easy access by the occupant.

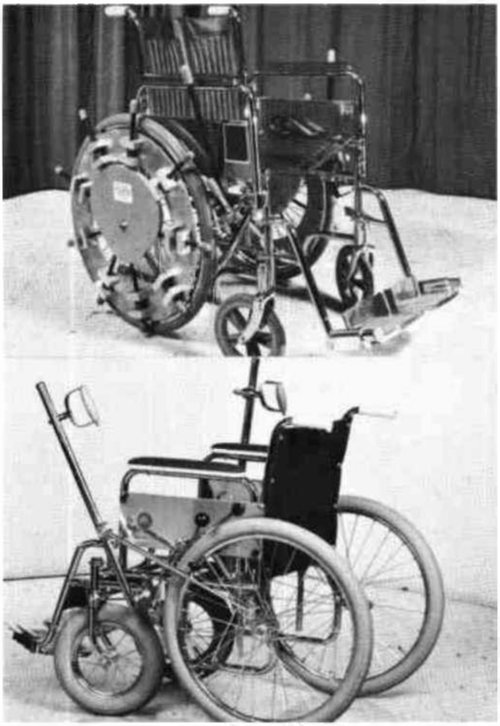

Fig. 8. Top, Push-rod propulsion wheelchair. Bottom, lever drive wheelchair.

Tests for metabolic and cardiorespiratory responses of disabled persons using this chair are particularly important but other laboratory and clinical trials will also be used.

Lever-drive, manual wheelchair

A lever-drive wheelchair (Fig. 8, bottom) is available using either one or two levers for propulsion. This system utilizes a bell crank mechanism which turns one or both drive wheels when the operator alternately pushes and pulls on the lever(s). Steering is achieved by turning the handle on the end of one lever which, through appropriate linkages, steers the free-spinning front wheels.

Braking of the two lever-drive unit is achieved by offering resistance to the reciprocal action of the levers. Braking the one lever-drive unit is achieved by squeezing a caliper type handle located within the steering handle. Both units also contain parking brakes which are positive acting friction mechanisms acting on the rear drive wheel(s).

Again tests for metabolic and cardiorespiratory response will be highlighted in the evaluation of this wheelchair.

The Mobilpodium Mark III

The Mobilpodium is designed to allow a paraplegic person both horizontal and vertical mobility ranges similar to that of the able-bodied person. This device (Fig. 9, left) was developed by the Center for Orthotic Design under the sponsorship of the Veterans Administration Rehabilitation Engineering Center.

The Mobilpodium is a mobility system designed to perform as an indoor wheelchair with the addition of a standing feature allowing mobility in any position (Fig. 9, right). The joints of the lower torso and extremities are stabilized in the unit which also has a specially designed and contoured seat, backrest, knee and footrest to support the body. A person's balance over the base of support is maintained, freeing the hands for activities.

The horizontal mobility is short range such as within one or several (connected) rooms.

Fig. 9. Left, Mobilpodium in its full down mode. Right, Mobilpodium in its erect mode.

The occupant can squat, to pick up objects from the floor; adjust to a sitting height, or stand up to reach overhead to get items off shelves.

The device has a two-speed drive mechanism which the occupant can operate from any position from standing through squatting. It has two parking brakes on the rear wheels. Two positions for the feet are provided: for standing, the feet are placed on a footrest underneath the person and secured with an ankle strap. For seating, the feet rest on the front frame where there are heel loops on the front frame for support.

There is an upper torso strap which can be used either across the shoulder or around the waist. A pneumatic cylinder is the primary *energy source* used for standing.

The Mobilpodium has two speeds: the slow speed is engaged when the hand crank is in the upper-near propulsion socket, recommended for use when standing; the fast speed is engaged when the hand crank is in the lower-forward socket.

The VAREC evaluation procedure includes:

Laboratory tests for durability, safety and performance

Metabolic and cardiorespiratory responses

This testing and clinical trials conducted by VAREC at various VA centers throughout the United States demonstrated that the unit performed adequately mechanically; however, it did not provide the comfort demanded by the majority of paraplegic individuals who tried it. The primary problem was a slightly forward inclination of the standing occupant.

As a result of VAREC's laboratory tests and evaluation, which included very carefully controlled clinical use by one paraplegic, modifications in design had to be made.

The metabolic and cardiopulmonary data indicated that the unit was more stressful to operate than a control wheelchair under all test conditions; this was in part due to its additional weight. It appears that the biomechanical and physiological benefits which can be derived from use of an arm crank propulsion system may have been negated by the location of the cranks, the internal resistance or other design characteristics. The unit, however, does increase the wheelchair-dependent individual's vertical accessibility and may be best suited for short term use within the confines of the home or office.

Next steps for wheelchair standards

The "draft" specifications for manually-propelled wheelchairs require improvement. Publishing this information internationally can stimulate the mechanism needed to compare these methods with others in Western Europe and Japan. Since it is essential that an international standard be developed and that this should be based on testing and evaluation procedures agreed to by manufacturers and many national bodies, we propose that the process already begun in ISO include detailed review and comparison of current national standards and associated evaluation and testing processes. The ISPO programme is particularly important to the U.S. Veterans Administration which has been assessing wheelchairs not only from U.S. manufacturers but from Europe and Japan. Work really should start with the manually-propelled wheelchair; not far behind should be analyses of the efforts already begun on electrically-powered chairs.

These projects should engage the support of national governments; wheelchair manufacturers, and organizations of the disabled for all will benefit; however for this work to proceed most efficiently and effectively, funds will be needed from all parties involved.

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