# Clinical Perspectives on Wheelchair Selection

## Prescription Considerations and a Comparison of Conventional and Lightweight Wheelchairs

*by Kristjan T. Ragnarsson, MD*

**Dr. Ragnarsson is Dr. Lucy G. Moses Professor and Chairman of the Department of Rehabilitation Medicine at the Mt. Sinai Medical Center, New York, NY.**

### INTRODUCTION

Despite its obvious benefits to the user, the wheelchair represents a changed and intensely disliked lifestyle. It identifies the user as disabled and is a constant reminder of the disability. Moreover, the wheelchair becomes part of that person's self-image. For the prescribing physician or clinician, it is a frustrating reminder of an inability to cure the condition. An appropriate wheelchair prescription for a permanently disabled person demands the utmost attention and care, involving the assessment and integration of the user's needs with the most currently available technology. Since each user's needs are unique and scores of basic wheelchair types, each with numerous options, are available, hundreds if not thousands of possible combinations and choices exist.

Over the past few years, available technology for wheelchairs has been changing rapidly. This trend is expected to continue. Wheelchairs, component parts, and even new concepts of wheelchair usage are changing radically. Thus, excellence of practice makes it imperative for the prescribing physician and clinician to be aware of new technology and trends.

An example of both the application of new technology and new concepts of wheelchair use is provided by what are now called lightweight wheelchairs. Lightweight wheelchairs, originally designed exclusively for athletes, have had a dramatic impact upon the very image of a wheelchair, and are now preferred by users with a wide range of non-athletic needs and interests. However, conventional wheelchairs are still the most appropriate choice for many individuals. Thus, the prescriber must consider and evaluate the latest engineering trends along with input from the users and their families, as well as from nurses, physical therapists, occupational therapists, and knowledgeable suppliers in order to write the optimal wheelchair prescription.

This article traces the primary and ongoing concerns of the wheelchair prescriber in meeting the individual physical and environmental needs of prospective users. It also presents a comparative description of conventional and lightweight wheelchair components and functional characteristics to help the prescriber and user make the best choice.

### INITIAL RESPONSIBILITIES OF THE CLINICIAN

The most important factors the clinician must take into consideration when writing a wheelchair prescription are summarized in **Table 1**. The principal wheelchair features and options selected are based on the individual's characteristics and needs. In order to avoid unnecessary cost, the wheelchair prescribed should have only those optional features that are useful and necessary to

**Table 1.**
Considerations for a Wheelchair Prescription

1. User's age, size, weight, etc.
2. User's disability and prognosis
3. User's functional skills and preferences
4. Indoor/outdoor use
5. Portability/accessibility
6. Reliability/durability
7. Cosmetic features
8. Options available
9. Service
10. Cost
11. Level of acceptance (total environment)

achieve optimal functioning. The wheelchair must fit the user properly in order to be comfortable, to provide maximum mechanical advantage and energy expenditure efficiency, and also to prevent medical complications. Incorrect fit may result in poor posture, joint deformities, restriction of joint movement and general mobility, pressure sores, circulatory impairment, and actual pain.

Many clinicians work in institutions where there are wheelchair clinics. Here the user can discuss his needs with a clinician and other professionals in the rehabilitation field. The setting allows the opportunity to test and evaluate various wheelchair types, sizes, and options before an actual selection is made. Special prescription forms listing the options for each wheelchair type are frequently used to facilitate the process and ensure accuracy.

## Functional disability considerations

The nature and extent of a user's disability obviously will influence the prescription. For example, extensive paralysis or musculoskeletal problems of the upper extremities may make manual propulsion impossible and warrant the prescription of a powered wheelchair. Extensive paralysis of the trunk and neck requires a reclining backrest of extra height, perhaps with a neck extension. Elevating legrests are indicated for users who may not or cannot bend their knees or who have dependent edema of their feet. In order to prevent backward tipping, a person with lower extremity amputation, especially bilateral above-knee, requires a wheelchair in which the rear wheel axles are posteriorly placed. Those with triplegia require a one-wheel-drive manual wheelchair. Disabled people capable of ambulating with assistive devices, but with significant gait deviations, not only ambulate at slower speeds but also have significantly increased energy expenditures. Physiological responses to wheelchair propulsion, i.e., heart rate, respiration, and blood pressure are greater when using the upper extremities than the lower extremities, as is cardiac work and metabolism, a clinical fact to be considered when prescribing a wheelchair for persons with a known heart condition.

## Mobility needs and preferences

Several questions need to be addressed regarding the potential user's mobility needs and personal preferences. People with the same disability may function very differently, especially with respect to transfer techniques. For example, questions arise when considering a user's upper extremity strength and hand skills. Will a motorized wheelchair be needed? Will the user propel the chair or will someone else push it? Will the user require detachable armrests or footrests, or will fixed wheelchair components be sufficient? Will the wheelchair be used at home, at work, or both? Indoors or outdoors? For recreation and sports? Will the chair be used when traveling? Will it be used extensively on a daily basis by an active and/or heavy person, demanding increased durability of the device? Does the user have the skill to maintain the chair or have access to people who repair chairs?

And not inconsequentially, the wheelchair needs to reflect the user's personal preferences for appearance—its style and color. Ultimately, the most important factor in the success of a wheelchair prescription is the user's total level of acceptance and satisfaction with his chair as it combines looks, comfort, and function.

## Purchasing concerns

Once the user's needs have been established, the clinician directs the user to a knowledgeable and reliable supplier who can help to finalize the prescription and deliver the product without undue delays or extra costs. The supplier should stock a variety of wheelchairs and options available for lease or rent when there is a delay in delivery or extensive repairs are required. The supplier should also provide a reliable maintenance and repair service at a reasonable cost.

Without compromising quality, and in order to avoid unnecessary cost, the wheelchair prescribed should have only those options that achieve optimal

functioning and user satisfaction. Finally, the user's means and ability to pay for the chair that serves his needs must be addressed. For example, will the insurance company agree to pay for the wheelchair which most closely matches the user's needs? If not, how can an affordable wheelchair best be prescribed without compromising function?

### Adjustments for proper fit

Wheelchair fit is the next consideration. The clinician should carefully examine the chair for proper fit and make appropriate adjustments when the wheelchair is delivered and on follow-up visits as well.

The components of the wheelchair system should be adjusted to the user in order to obtain the optimum biomechanical advantage necessary for efficient propulsion. This means that the muscles should be close to the resting length in the starting position. Therefore proper measurement of the user's dimensions prior to prescription is of great importance. It is also important that *the chair and the seat cushion be fitted as a unit, rather than as separate units*, to ensure that the final wheelchair is neither too high nor too low, too narrow nor too wide. For example, a wheelchair that is too wide results in poor posture because insufficient support is provided, frequently causing a person to lean to one side and have ineffective bimanual propulsion. On the other hand, if the wheelchair is too narrow, pressure on the trochanteric regions results in pressure sores or discomfort.

Excessive seat depth results in pressure on the popliteal region. This in turn results in restricted blood flow or in poor seating posture because the user may slide forward in the seat. Inadequate seat depth results in excessive pressure on the ischium since there is less distribution of weight on the thighs. Generally, when the user is properly seated, there should be a clearance of 1-2 inches between the anterior edge of the seat and the popliteal regions.

Excessive seat height impedes effective propulsion and reduces stability as the center of gravity is elevated. But a seat that is too low or footrests that are too high also increases ischial pressure due to less weight bearing on the thighs. Excessive height of the backrest restricts shoulder and trunk motions whereas a low backrest provides inadequate body support and results in poor posture.

## CONTINUING CONCERNS AND RESPONSIBILITIES OF THE CLINICIAN

The clinician's responsibilities do not end with ensuring that the delivered wheelchair matches the prescription. On each follow-up visit the user's overall condition needs to be reassessed. Sitting posture and mobility should be checked. The wheelchair's condition and service to the user should also be reevaluated.

Since clinical conditions affecting the upper extremities may interfere with operation of a manual wheelchair, they need to be regularly monitored. For instance, after many years of propelling a wheelchair and performing all ADL with the upper extremities, symptoms of degenerative changes of the musculoskeletal system may appear, e.g., osteoarthritis of the shoulders, elbows, and wrists; rotator cuff tears; bursitis; lateral epicondylitis; and tenosynovitis.

It is also the clinician's responsibility to see that the user is properly trained in the operation of the wheelchair, not only on level surfaces and inclines but on curbs and steps, indoors and outdoors, performing various kinds of transfers in and out of the chair, falling safely from the chair, getting back into the chair from the ground, pulling the chair into an automobile after transfer, and so on.

The user's environment must be made as accessible as possible to the wheelchair. This may require widening of doorways, expanding space to allow wheelchair turning, and the building of ramps.

Finally, the importance of wheelchair maintenance should be stressed. Regular lubrication of the chassis and detachable items, fastening of bolts and screws, adjusting of casters and wheels, changing of flat tires, and cleaning of the entire wheelchair often become highly developed skills and routine tasks of the user.

## COMPARISON OF CONVENTIONAL CHAIRS AND LIGHTWEIGHTS

The vast majority of wheelchairs prescribed are manually propelled. In recent years, manual wheelchair design has been significantly modified to meet the demands for better performance in daily activities and recreation. The newer lightweight and ultralight designs have been frequently referred to as

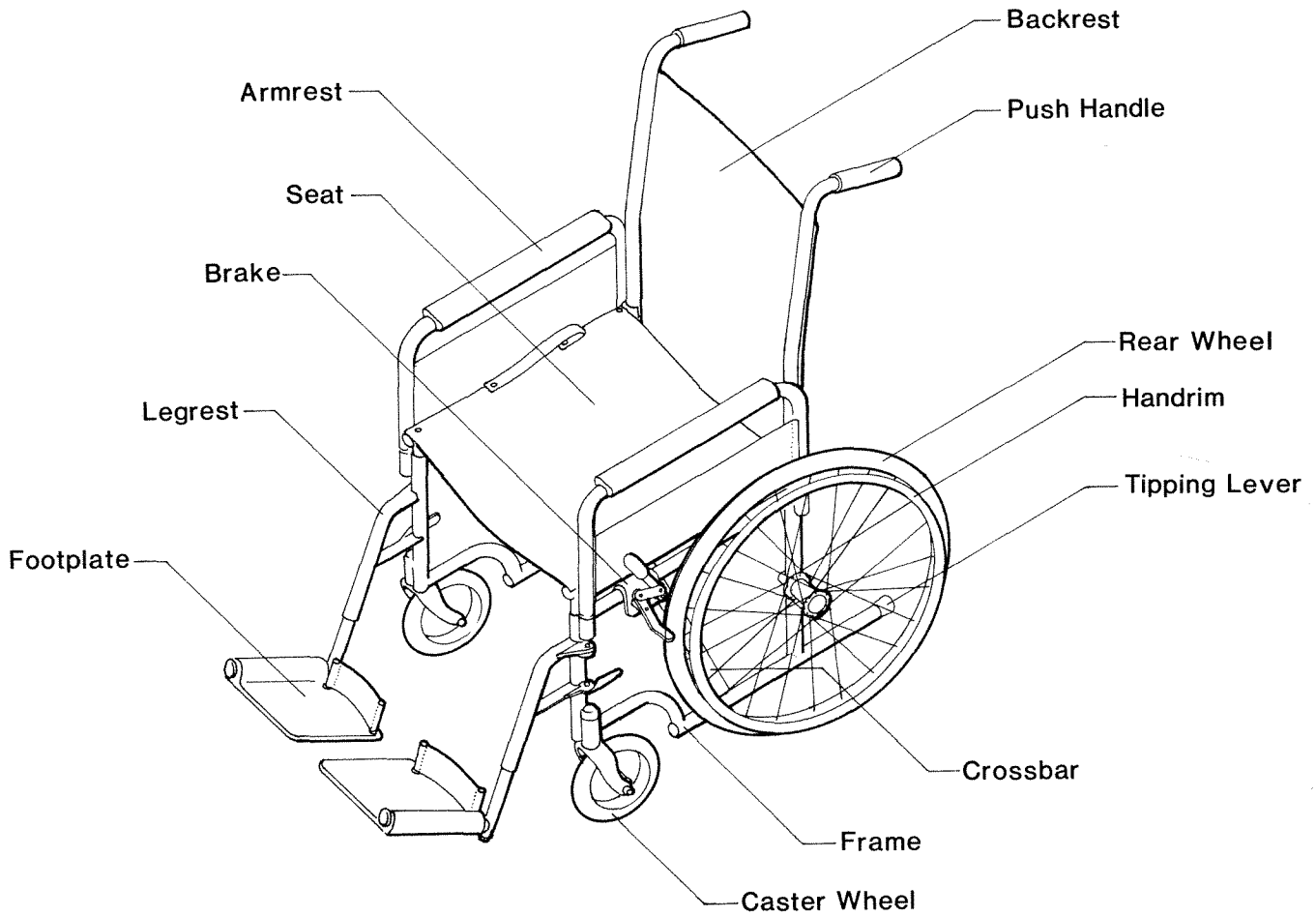


**Figure 1.**
The conventional wheelchair. *(Drawing by Samuel McFarland)*

"sports" wheelchairs. Presently, however, these chairs are prescribed for use by an increasing number of individuals who are not necessarily involved in sports, but who find that the modifications provide for better and more varied mobility. The sporty look of the lightweight and ultralight chairs is appealing and has contributed greatly to their popularity. Although these designs are in many ways technologically superior, they are not the best choice for every individual. Conventional wheelchairs have features that still warrant prescription for certain people and circumstances. Each case should be considered individually using the factors presented in **Table 1** as guidelines.

## The Conventional Wheelchair (Figure 1)

1. The *frame* is made of chrome-plated, cold-rolled steel. Colors are not available. The *weight* averages 50 pounds. In 1967, a stainless steel model weighing approximately 40 pounds was introduced and was often referred to as a lightweight wheelchair.

2. *Push handles* are always in the back. The axle for the large rear wheels is positioned directly underneath the backrest.

3. The height of the *backrest* is fixed and usually measures 16 1/2 inches. An extended and manually reclining adjustable backrest is optional.

4. The *armrests* may be either full length or desk type, fixed or removeable, and adjustable in height. They are sturdy, attached to the wheelchair frame in 2 places, front and aft, with a metal skirt to prevent the user's clothes from being soiled by the tires or caught in the spokes.

5. The *seat* is a sling seat and made of vinyl like the rest of the upholstery. The upholstery is usually available in several colors.

6. The *front rigging,* with or without legrests, though fixed in the less expensive models, can be detached. Detachable front rigging generally has a swing-away feature and may have an elevating mechanism and a legrest.

7. The *footrest* (footplate, footpedal) is adjustable for length and rotation. It is available in 2 sizes and has the option of heel and toe loops.

8. With the conventional wheelchair the front *caster wheels* are usually 8 inches in diameter, although occasionally, they are 5 inches in diameter. The tires are made mostly of solid rubber. Pneumatic tires are now recommended for outdoor use.

9. The frame has *crossbars* underneath the seat to allow easy folding. There are no locks on the conventional wheelchair that securely maintain the open position.

10. *Brakes* are located in front of the large rear wheels and are either of the toggle or lever types.

11. The *rear wheels* measure 24 inches in diameter and have *handrims* for pushing that are attached to the periphery. The handrims are made of chrome-plated, cold-rolled steel and do not have a covering. Pneumatic tires or solid rubber tires can be used.

12. In the rear of the wheelchair, below the frame, are short *tipping levers.* They are used to negotiate curbs. Anti-tipping extensions can be attached to these levers to prevent backward tipping of the wheelchair.

### The Ultralight or Sports Wheelchair (Figure 2)

1. The *frame* is made of lightweight metals such as aircraft aluminum alloys, titanium, or graphite. The entire wheelchair generally weights about 25 pounds, which is half the weight of a conventional wheelchair. (Some racing chairs weigh less than 15 pounds.) The lighter weight makes propulsion more energy-efficient, and lifting and handling easier. Many models have as many as 12 to 24 frame colors to choose from; none are in chrome. Initially, these models all had rigid frames. This made them sturdier and resulted in better performance for active individuals. Without crossbars, the weight of the wheelchair was reduced. However, it made transportation more difficult because the wheelchair could not collapse. In order to transport the chair, the backrest folded forward and the large rear wheels were removed, allowing the wheelchair to fit into the trunk of most cars. Recently, several manufacturers have produced folding frames, with or without crossbars, usually fitted with locks to prevent even minor folding during activity (e.g., the Quadra in 1979, the Quickie in 1983, and the Rolls in 1984). This has further eased the transportation of these wheelchairs.

*Push handles* may or may not be present but, more frequently, straps are added to the backrest upholstery for grabbing. Some active and independent individuals choose not to have push handles because they add to the weight and some users find them demeaning.

2. The *rear wheel axle* on the conventional wheelchair is located directly underneath the backrest, below the seat. The newer wheelchair designs have multiple axle positions that can be adjusted up or down, forward or backward. If the axle is moved forward the wheelbase is shortened. Many users find that when the axle is in this position the wheelchair becomes easier to maneuver and a shorter turning radius is needed. Likewise, it is easier to push the wheelchair when the large wheels are placed forward. A disadvantage of forward placement is less overall stability because the chair becomes lighter in front and is more prone to tip backwards. As the axle is moved backwards, stability is increased. If the axle is moved upward the seat is lower and the center of gravity is lowered. This results in increased stability of the wheelchair. The stroke propulsion also becomes stronger, a fact recognized by wheelchair racers who frequently have the top of the wheels right underneath their axillae. When the axle is moved upward, the seat tilts backwards unless the caster height also is adjusted. Such backward tilting elevates the knees and raises the thighs off the seat. This may increase trunk stability, but also increases pressure on the buttocks and the risk of pressure sores. Instead of moving the axle some models have moveable seats

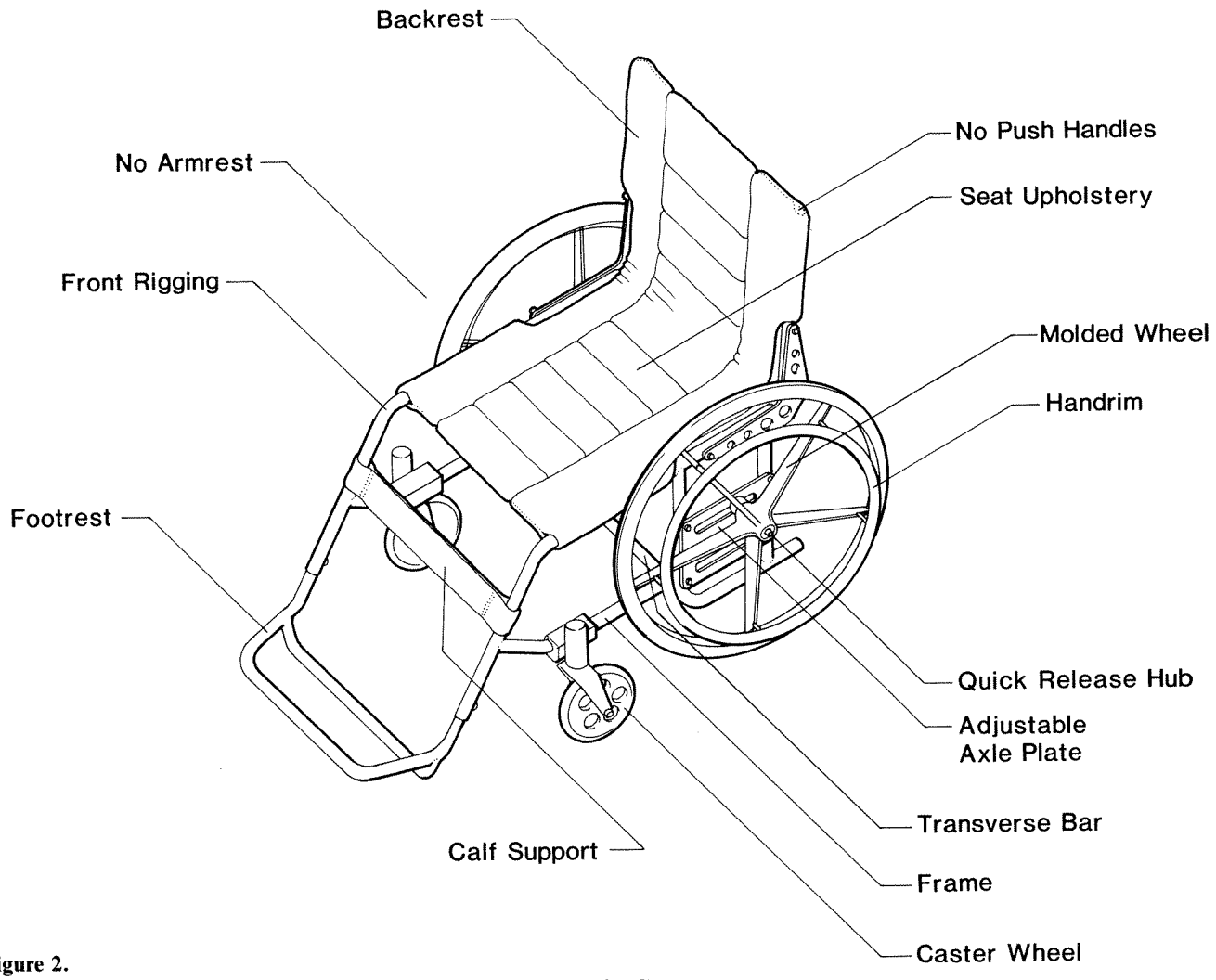


**Figure 2.**
The ultralight or sports wheelchair. *(Drawing by Samuel McFarland)*

(up and down, forward and back) and the results are similar.

3. On the newer wheelchair designs the *backrest* height is generally adjustable, most commonly between 11 and 15 inches, although adjustable backrests between 7 and 11 inches and between 15 and 19 inches are also available. The backrest is generally used in a position that is lower than on the conventional wheelchair, giving the upper body more mobility, although trunk stability may be reduced. The *upholstery* is usually made of reinforced nylon or dacron and is light, strong, and stretch resistant, but more difficult to clean than vinyl. The upholstery may be available in many colors.

4. *Armrests* are frequently missing on the newer models. This reduces the weight of the wheelchair and also increases the range of lateral movement of the user, a definite advantage during wheelchair basketball and tennis. When the armrests are used, they are usually of adjustable height, swing-away and removeable, simply designed, and attached only to the posterior part of the wheelchair frame. The armrests are not sturdy enough to sit on, thus they cannot be used for transfers to higher surfaces. Sometimes skirts are not attached to the armrests and clothes can be soiled or caught in the wheels. However, some of the newer designs do provide skirts as part of the upholstery that extend diagonally from the backrest to the front of the seat.

5. The *seat* is frequently adapted for wheelchair cushions by providing velcro straps that are used to

attach the cushion to the seat, or by a pouch in which the cushion fits. As previously noted, lowering the back of the seat results in the elevation of the knees. This provides for better trunk stability during racing.

6-7. *Front rigging with footrests* was originally part of the wheelchair frame and not detachable. This made the wheelchair sturdier and prevented mechanical failures, but made some transfers and turning in small spaces more difficult. On some of these chairs the footrests are closer to the frame than those on the conventional wheelchairs, and this reduces the turning radius. The footrest is adjustable for leg length, but in order to provide calf support a soft sling often extends between the bars. Recently, certain designs have provided swing-up footrests and even swing-away detachable legrests. Many paraplegics feel that detachable front rigging is only useful when transfers are difficult.

8. The *casters* are generally made of solid polyurethane, although occasionally they may be fitted with pneumatic or solid rubber tires. Usually 4 to 5 inches, they are smaller in diameter than the casters on conventional wheelchairs. However, some users choose the regular 8-inch diameter caster and on some racing wheelchairs, 12 to 18-inch diameter casters are chosen. The 4-inch polyurethane caster, which is common on the newer wheelchair designs, is in many ways, similar to the wheels on a skateboard: it turns quickly, handles well with minimal flutter, and is very durable. However, the ride is somewhat rougher than on a pneumatic tire. The 8-inch polyurethane caster rolls easily over obstacles and an 8-inch pneumatic tire gives a smoother ride outdoors. Some designs provide a soft urethane in the liner of the caster for a puncture-free tire and a smooth ride.

9. *Crossbars* on rigid frames have been replaced by transverse bars. The recently developed folding frames are equipped with locks.

10. *Brakes* are optional because many users of the newer wheelchairs find them unnecessary. Some users do choose toggle brakes or the so-called scissors brakes. The scissors brakes are mounted lower on the frame, away from the fingers, and have become popular among very active users because fingers may accidently hit the toggle brakes during rapid propulsion. A way to prevent this problem is seen on some recently designed toggle brakes that have added space between the wheel and the brake when in the disengaged position.

11. The *large rear wheels* measure 24 inches in diameter as on the conventional wheelchair, although some racing chairs have wheels that measure 27 inches in diameter. The hub of the wheel is designed like the one used on a racing bike, lighter in weight with sealed precision bearings that give very low friction resistance. The hub can also have a quick release mechanism for removing the wheel when changing axle position or facilitating transport of the chair. The detachable wheels have hubs that protrude 1/4 to 1/2 inch on each side, thus adding to the total width of the chair. The spokes of the wheels are similar to the conventional models, although some designs use molded wheels.

The *tires* are generally pneumatic, not solid rubber, and may allow higher pressure, up to 160 pounds of pressure per-square-inch (PSI) on racing models. The pneumatic tires give a cushion effect for outdoor use. As on racing bikes, racing wheelchairs frequently have narrow tires that provide reduced resistance. Occasionally, the tires are made of soft polyurethane.

The *wheel camber* is adjustable on the newer wheelchair designs. As seen on many sport cars, the bottom of the wheels may be further apart than the tops. This has several advantages. The wheels are brought closer to the body for more effective propulsion. The wheelchair is easier to steer and is more stable, especially when turning. This is because the lateral width of the base is increased. However, it is more difficult to get through narrow doorways or, even when collapsed, to fit the wheelchair in the trunk of a car. Many of the newer models also have an adjustable "toe-in" on the rear wheels, thus more distance separates the wheels in the back than in the front.

The *handrims* for pushing are made of metal but are plastic foam coated with vinyl and are often available in assorted grip sizes. Although this gives the user a firmer and more comfortable grip, the vinyl coating increases the friction coefficient which may result in finger burns when the hands are used to stop the wheelchair. Handrims are available in many sizes, but are usually small on racing wheel-

chairs. The smaller handrims may give a slower and more difficult take-off, but they provide for a higher top speed and require less effort to sustain high speed. This is an advantage for strong people. Different handrim diameters are analogous to the different gears on bicycles, i.e., the highest gear (rim) has the smallest diameter. This makes starting and ascending inclines difficult, but, once momentum is reached, it can allow for the highest speed and greatest distance to be travelled with each stroke. Likewise, the lowest gear (rim) has the largest diameter, which makes starting and acceleration easier.*

12. Step-on *tipping levers* are shorter and part of many chairs. Anti-tipping extensions, although optional, are generally not included on the newer wheelchair, especially on wheelchairs prescribed for skillful individuals.

13. *Seatbelts* are an option. They are used in the same manner as in the back of an automobile or seatbelt in an airplane. For high level paraplegics and quadriplegics, safety vests and harnesses are available. It may be enough support to use the same arrangement used in the front seat of today's automobile. For those clients that experience severe extensor thrust spasticity of the lower limbs, it is absolutely necessary to have a seatbelt.

*Summary.* Perhaps the most important aspect of the newer wheelchair designs is that they promote self-confidence, a better self-image, and a greater feeling of acceptance by the public. These factors can help facilitate community reintegration and greater life accomplishments, which indeed, are the ultimate goals of rehabilitation.

## RACING WHEELCHAIRS

A wheelchair meant for sports use exclusively is not a prescription item, but can be purchased directly by the user from a supplier or builder. The clinician, however, should have some knowledge of the options for a wheelchair athlete.

The serious wheelchair racer frequently has a custom-built chair designed with numerous features that are used to obtain optimum energy-expenditure, efficiency, and high speed. The rear wheels are large, 26 to 27 inches, and the set is low so the top of the wheels almost touches the axillae. The wheel camber is variable. The handrim is small in diameter, approximately 12 inches, and is attached to the spokes with clips. The pneumatic tires are narrow with 160 PSI. The front casters or wheels are large—12 inches in diameter, with spokes and a hub with low friction, and sealed, precision bearings to facilitate rolling. Attached to the front wheel mechanism are steering handles and brakes. The seat is low to lower the center of gravity and thus, increases stability.

## MOTORIZED WHEELCHAIRS

Motorized wheelchairs are prescribed for persons who cannot propel a wheelchair with their hands or feet or who have a medical condition, or other reasons that contra-indicate the energy expenditure associated with such exertion. Generally, a motorized wheelchair would not be prescribed for a person with a temporary or minor disability. It is frequently prescribed for people with severe neuromusculoskeletal disabilities or poor endurance due to cardiopulmonary diseases. Some might use the motorized wheelchair only in a given situation, e.g., to travel long distances, but might be capable of ambulating or propelling a manual wheelchair for shorter distances at home. Obviously, the prospective user must be mentally competent and observant, have adequate sitting balance and adequate vision. Coordination and strength of some muscle groups in the upper extremities, neck or face, is required to operate the wheelchair control mechanism. However there are special control systems for individuals with poor hand/arm function, i.e., people with cerebral palsy.

In recent years, the designs of motorized wheelchairs have improved in many ways. Although a motor, batteries, and control mechanisms can be added on virtually any heavy-duty wheelchair, most motorized wheelchairs prescribed today are designed and built with these components as integral parts.

**Editor's Note.* Handrims: For clients with limited use of their upper limbs, particularly quadriplegics, vertical or oblique projections may be mounted on the handrim to assist in propulsion. These are pushed against by the radial border of the forearm or hand or by the hypothenar eminence of the hand in supination.

This has resulted in a cosmetically improved appearance. Since people requiring motorized wheelchairs tend to be more severely disabled than those requiring manual chairs, certain aspects of the prescription require special attention. A detailed description of motorized wheelchairs is presented in Chapter 6, "Powered Mobility and Its Implications."

## CONCLUSION

The wheelchair is the single device that can most radically improve the mobility and functional independence for a disabled person. Although most wheelchairs appear similar, relatively minor modifications in design, components, and appearance can have a major impact on the user's self-image and ability to function.

Wheelchair prescription for a permanently disabled person should never be based on limited knowledge. It should be done by rehabilitation professionals who know both the disabled user and the current wheelchair technology, and only after careful observation and evaluation that combine the user's personal preferences, skills, and lifestyle as well as his/her medical needs.