REHABILITATION MANUAL 18

MANUAL FOR ADAPTATION OF POWERED WHEELCHAIR AND OPERATION PRACTICE

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JAPAN

(WHO COLLABORATING CENTRE)

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National Rehabilitation Center for Persons with Disabilities
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March 29, 2006

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PREFACE

In recent years, we have been surprised by the remarkable progress of technologies such as personal computers, mobile phones and digital cameras. It is no exaggeration to say that these technologies have drastically changed our everyday life. Naturally, technologies are also having an impact on welfare related equipment. In particular, powered wheelchairs are a good example of such remarkable technological progress. Some powered wheelchairs have high performance and enable the user to operate them not only with a joystick, but also to operate with the head or chin, raising or reclining the seat and programming travel modes.

One of the factors for the recent spread of powered wheelchairs is the QOL concept. Previously, the mainstay approach was encouraging persons with disabilities to improve their remaining abilities through practices even in everyday life by moving their hands as long as they could manage to move their hands. In contrast, the QOL concept is to reserve the remaining abilities and utilize them for social activities, or more specifically, for their occupations. Selection between the two concepts will largely depend on an individual view of life.

It is true that powered wheelchairs have significantly expanded the field of activities for persons with disabilities. The major advantage of powered wheelchairs is that they enable the user to acquire traveling ability by operating the controller as long as the required environment is secured, and this splendid benefit would have an impact on the lifestyle of the user. However, if a person with a disability thinks about how to actually operate a powered wheelchair, he/she may have concerns such as "Can I operate this wheelchair without having an accident?" and "Can I operate it carefully?" In addition, the disability of the user varies from person to person as does the level of wheelchair functions. Effective use of a powered wheelchair can be achieved only if a wheelchair appropriate for the environment and the user is selected and the selected wheelchair is adapted to meet specific requirements. Therefore, the capabilities of the wheelchair model to be adapted are important.

Although the powered wheelchair is equipment, it is not just a tool. For the user, a wheelchair is feet and shoes. We are not overstating the situation when we say that the powered wheelchair could be a lifelong partner. Consequently, the powered wheelchair must be one appropriate for the user.

This manual has been compiled based on data that therapists have collected through clinical experience concerning the adaptation of powered wheelchairs for individuals with injured cervical cords. I hope that these individuals with injured cervical cords using powered wheelchairs will be appropriately treated and run though the basics, applications and practices, and that they will be able to lead a social existence.

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CONTENTS

Introduction

The powered wheelchair1 is equipped with an electric motor to enable it to travel. It is used for ambulation of those who have lost their ability to walk and those who are unable to operate wheelchairs with their hands. The powered wheelchair is not just a means of ambulation. More importantly, it provides benefits such as increased freedom in everyday life movements, expanded fields of activities, expanded human interaction and enhanced motivation to participate in society through ambulation. These benefits would impact each other to produce further benefits.

Since the powered wheelchair is welfare equipment, it cannot be effectively used in everyday life unless it meets and adapts to user needs. For those providing instructions about prescription and operation of powered wheelchairs, it is necessary to acquire knowledge, such as evaluation of powered wheelchairs, product characteristics and required practices, to prescribe an optimal powered wheelchair that meets the functions of the user, instead of just helping the user to move in a powered wheelchair. The descriptions in this manual focus on persons with injured cervical cords, many of whom use powered wheelchairs.

Chapter 1.
Basic Issues

1. Status of Responding to Users of Powered Wheelchairs

1) Barrier free

Moving indoors and outdoors without help, meaning ambulatory independence has huge significance also from the viewpoint of user mental independence. However, even if the user can operate a powered wheelchair, whether or not the environment allows the user to move indoors and outdoors is an important issue. Recently, means to transfer powered wheelchairs have been being improved, although gradually, through barrier-free approaches such as use of wooden floors indoors, improvement of road surfaces outdoors, public transportation accessible with wheelchairs and spread of wheelchair-lift buses.

2) Improvement of the Equipment

Formerly, speed control was the only function that corresponded to operational ability, and the user had to adapt himself/ herself to a powered wheelchair. Recently, foreign made high-performance powered wheelchairs have been introduced. These high-performance wheelchairs are capable of adapting to individual abilities through programming input methods, traveling modes, and programs etc.

3) Increase in rehabilitation-related facilities, hospitals and firms that support powered wheelchairs

Recently, welfare and rehabilitation firms are adding or enhancing divisions that sell and repair powered wheelchairs, and local municipalities are also responding to powered wheelchair users through contractor firms.

Since powered wheelchairs are machines, they may have initial failure or breakdown, and it is also important for these firms to have techniques for repairing the wheelchairs. These firms are not medical professionals, and may not have sufficient medical knowledge. Therefore, prescribers must be able to identify the state of the functions of the user, instead of leaving everything to the firm.

2. Structure and Characteristics of the Powered Wheelchair

Figure 1 shows the structure of a standard type powered wheelchair. The powered wheelchair is operated with a battery as the power source. The power components consist of three systems: an operation input system, a control system and a drive system. These three systems are connected through cords to enable the whole wheelchair to function.

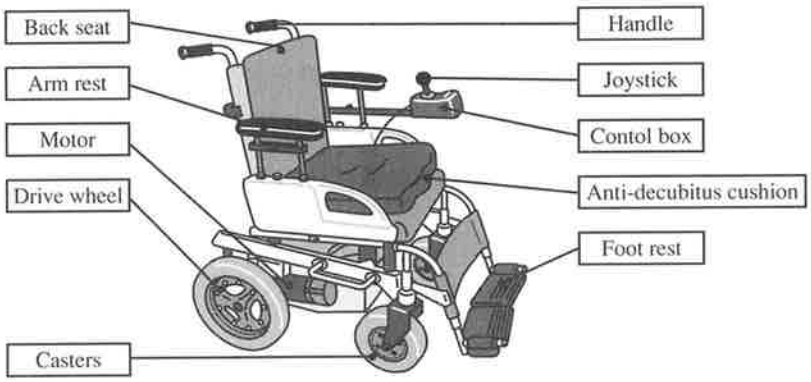


Figure 1 Standard wheelchair structure

1) Operation input section (controller)

This system converts user operational intent such as startup, stop and turn into an electric signal. The items to be operated are divided into traveling-related items and seat position-related items. Traveling-related items are startup, stop, turn and speed, while seat position-related items include the angle of the seat back, angle of the seat and angle of the footrest.

In general, a joystick, which can be operated with a hand, is used as the input device. The joystick (Figure 2) allows the user to input two conditions: traveling direction and speed, and the user adjusts the traveling direction by tilting the joystick in the corresponding direction, and adjusts the speed with the tilt angle.

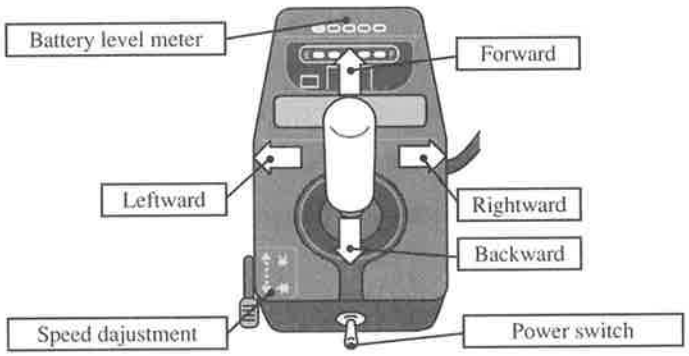


Figure 2 Joystick and controller

The user selects a method for operation input of the powered wheelchair in accordance with his/her physical abilities. If the user cannot use his/her upper limbs, he/she performs input operation with his/her chin or head (Figure 3). The chin control (Figure 3a) is operated with the chin. The push switch (Figure 3b) enables the wheelchair to advance in a desired direction only when it is pressed, and stop if released. The head control (Figure 3c) determines the traveling direction based on the positions of the sensor attached to the cap and the other sensor on the wheelchair. For example, if the user bends forward, the wheelchair advances forward, and if the user bends rightward, the wheelchair travels rightward. Since these input devices are selectable depending on the extent of the user's disability, the user can determine which input device to use by finding the device that enables him/her to operate it most stably through evaluation.

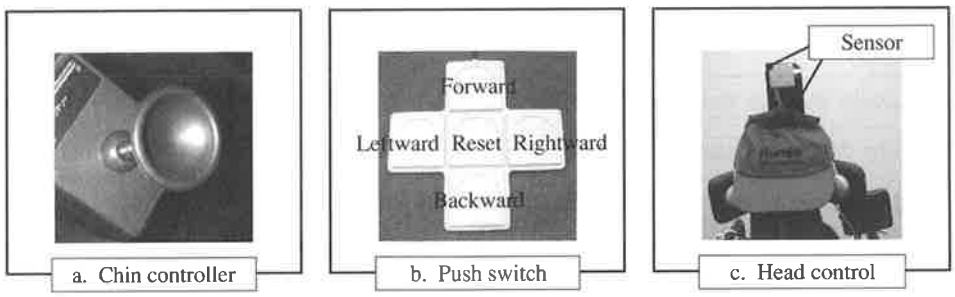


Figure 3 Input system

2) Control system

This system allows the user to properly communicate a transmitted signal to the drive section by moving the controller. If the wheelchair is well controlled, the user will feel as if he/she is freely moving on his/her own will.

3) Drive system (electric motor)

The electric motor operates in response to a signal from the control system. The majority of powered wheelchairs are equipped with one motor on each of both wheels.

When the wheelchair turns around ,the two tires rotate at different rotation speeds. For example, if the wheelchair turns right, the rotation speed of the right wheel is smaller than that of the left wheel. If the wheelchair makes a turn on the spot (minimum turning), the right wheel turns backward while the left wheel turns forward.

4) Chair section

For those users capable of maintaining their sitting positions, this section is the same as the chair of a manual wheelchair. If the user has difficulty in maintaining the sitting position due to lateral curvature, significant joint limit of limbs, deformation of the pelvis, etc., a sitting position retainer is attached.

5) Battery (chargeable battery)

A standard powered wheelchair contains two 12-V, 35-A batteries in series. The batteries are available in two

types: a sealed type and an open type battery. The sealed battery does not require fluid replenishment. The open type is based on a fluid type, and requires replenishment of the fluid, which decreases as the battery is used. When the user travels by air, the sealed type can be carried in an airplane, but the open type cannot be brought in. In general, battery charging does not have to be done immediately after wheelchair use. If the wheelchair is used indoors, it is appropriate to charge the batteries approximately once a week although the actual charging interval depends on frequency of use and travel distance. If the batteries are charged after the wheelchair is used only for a short period, the memory function of the batteries will be activated to lower the battery capacity. However, it is safe to charge the batteries the day before an outing as a cautionary measure. Depending on the wheelchair type, a charger is built-in or a dedicated charger is used.

6) Clutch

The clutch is a device used to disconnect the drive wheels from the electric motor. Generally a clutch is installed on both wheels. Since the method for operating the clutch (Figure 4) varies with wheelchairs, it is necessary to understand the operating method in advance. When the wheelchair travels, the clutch connects the motors with the drive wheels. If an assistant pushes the wheelchair, the clutch should be disconnected to release the link between the motors and the drive wheels so the assistant can lightly push the wheelchair. As a precaution, the clutch operations must always be performed on a flat place. This is because disconnecting the clutch will make the braking mechanism in the motors inoperable, which on an incline would be dangerous.

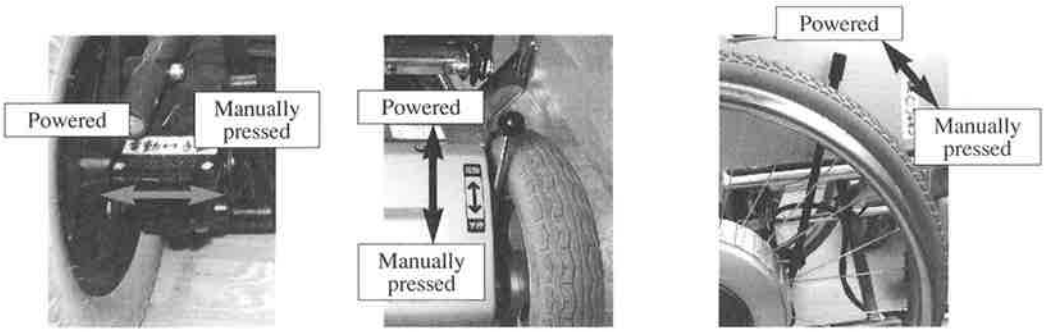


Figure 4 Method for operating the clutch

7) Brake

Many powered wheelchairs are not equipped with brakes on the tires as opposed to ordinary wheelchairs, and powered wheelchairs require braking through clutch operation. The brake is activated while the power is turned off and the clutch is connected. If the controller is in an intermediate position when the power is turned on, an electromagnetic brake prevents the wheelchair from moving backward even on an incline.

3. Types of Powered Wheelchairs

1) Standard powered wheelchair

This type is operated with a joystick, and has motors on the rear wheels. By law, the maximum speed of domestic powered wheelchairs must not exceed 6 km/h for indoor types, and 4.5 km/h for indoor-outdoor types.

The maximum speed of some foreign made types can be set at approximately 12 km/h.

2) Simplified powered wheelchair

This type is also called a "powered and manual operated wheelchair," and has a motor unit on the frame of a standard type wheelchair to make it serve as a powered wheelchair (Figure 5). It is smaller than the standard type in external dimensions and weight and easier to carry, and allows switchover between powered and manual. Since the motor is less powerful and the battery is smaller than the standard type, the traveling time is shorter. Therefore, if the user goes out, he/she must carry a spare battery.

When prescribing this type, the prescriber needs to include an electromagnetic brake. This is because the wheelchair would move on an incline without an electromagnetic brake.

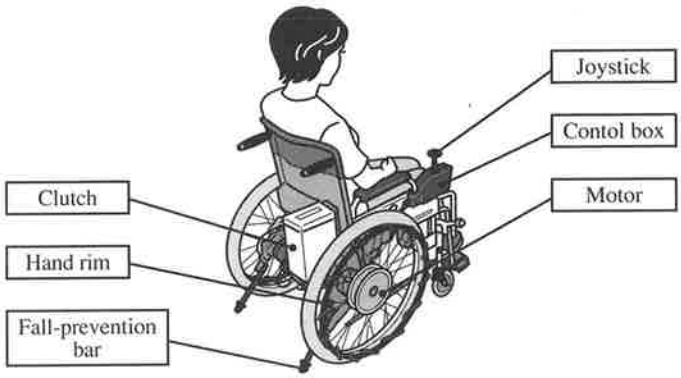


Figure 5 Powered and manually operated wheelchair A(uead by C5)

3) Relining powered wheelchair

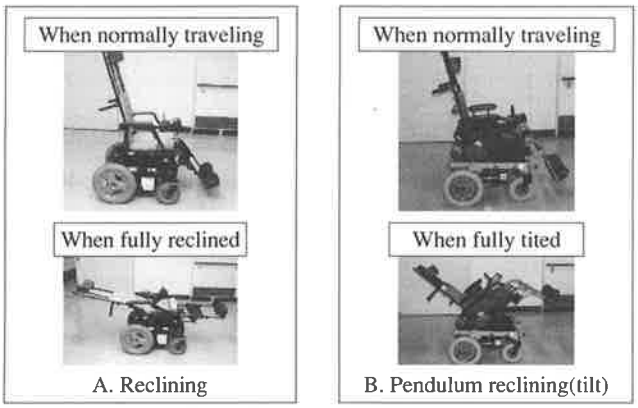
This type of powered wheelchair has a reclining mechanism that enables the user to easily change the angle of the seat back by hand.

4) Powered-reclining standard wheelchair

This type is a powered wheelchair equipped with a motorized reclining mechanism to allow the seat back angle to be changed (Figure 6a). The type is used in cases where sitting tolerance is low or the user has orthostatic hypotension, or used for pressure reduction to prevent decubitus.

If the user cannot operate the control switch by hand, he/she can use his/her chin, cheek or head to operate the switch. The disadvantage of this type is that the user's body is displaced and the posture collapses if the seat back is reclined. A heavier type is also available with a mechanism that allows the seat back to be displaced together with the trunk when reclined to reduce the displacement of the body.

The heavy type has a function called a pendulum reclining tilt (Figure 6b) that prevents the trunk from being displaced by tilting the whole chair without changing the angle between the seating surface and the back. This will prevent the posture for persons with severe disabilities using sitting position retainers from collapsing, making it unnecessary for them to restore their postures, thus lightening the assistance load as a result.

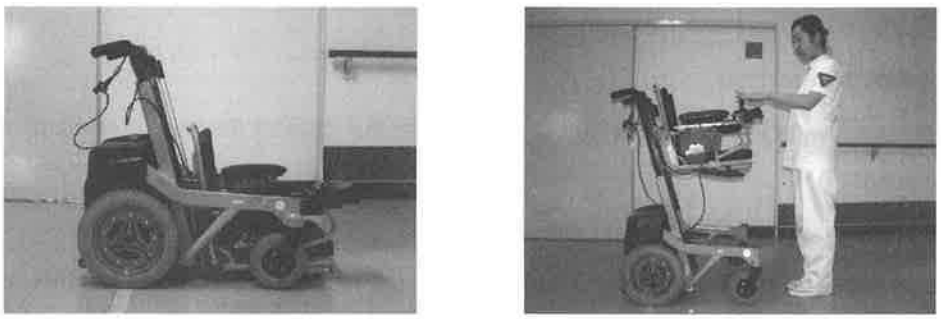


A. Reclining B. Pendulum reclining(tilt)

Figure 6 Powered reclining

5) Standard powered wheelchair with a powered lift

This is a wheelchair with a mechanism for lifting and lowering the seat (Figure 7), and it enables the user to take an item from a high place without rising from the seat or raise the seat so that the user's eyes are at the same level as the listener. This wheelchair is very useful in a workplace where multiple desks with different heights are placed. In addition, persons with disabilities living in homes with tatami mats or wooden floors and moving by crawling on their knees can easily get on and off the wheelchair because the seating surface can be lowered to the floor.



a. The seat in the lowest position b. The seat in the highest position

Figure 7 Standard powered wheelchair with a powered lift

6) Scooter powered wheelchair

This type is divided into 3-wheel (Figure 8) and 4-wheel wheelchairs. Generally, 3-wheel rear-drive wheelchairs are used. This wheelchair is operated with handlebars. Since it has a large turning circle, it is not suitable for indoor use. Many wheelchairs of this type have turnable seats that allow the user to easily get on the wheelchair. The 3-wheel type may fall in steep turning. It is suitable for individuals whose abilities to walk a long distance and whose trunks are stable enough to operate the handlebars. Recently, traffic accidents involving scooter-type powered wheelchairs have frequently occurred. Therefore, it is necessary to instruct users about the operating method and manners on the road.

Figure 8 Three wheeled scooter powered wheelchair

7) Wheelchair with auxiliary power

This wheelchair is used if the user's upper limb muscles required for driving the wheelchair by himself /herself are weak to supplement the muscles with an auxiliary motor. In this type, a motor unit (Figure 9) is attached on the frame of a standard type wheelchair. As the user tries to drive the hand rims, the motor is activated to supplement the driving force. Although this wheelchair has auxiliary power, it is not equipped with an electromagnetic brake as opposed to standard powered wheelchairs, and the user may have difficulty in operating the wheelchair depending on the environment such as on an incline. Therefore, this type of wheelchair requires careful use.

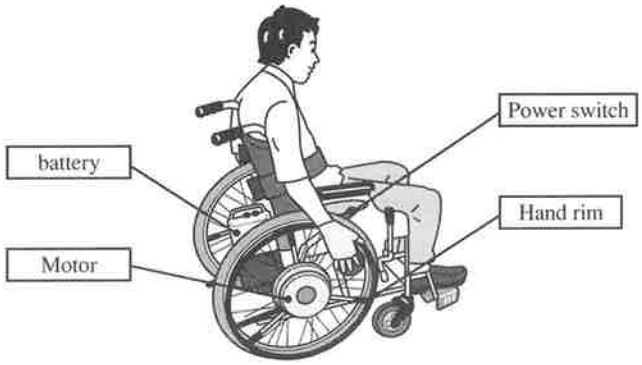


Figure 9 Powered and manually operated wheelchair B (C5)

8) Powered wheelchair for assistance

This wheelchair is driven with a motor in place of the assistant who would push the wheelchair. It is applicable if the assistant's physical strength is minimal or if the wheelchair is used in hilly places. However, it is important that the assistant has a high operating ability to perform speed control and turnaround from behind.

9) Powered wheelchair with a small turning circle

This wheelchair is divided into 4-wheel and 6-wheel types (Figure 10). In both types, the drive wheels are close to the center of the seat and the wheelbase is short. Therefore the turning circle is small. Since the wheelchair requires only a small space for turning, it is suitable for indoor use such as in the workplace or home. There is also a type with a seat lifting mechanism that enables the user to reach a high place in indoor work.

4-wheel type

Figure 10 Powered wheelchair with a small turning circle

4. Application of Powered Wheelchairs

This section describes disorders of patients using powered wheelchairs and the characteristics of powered wheelchairs.

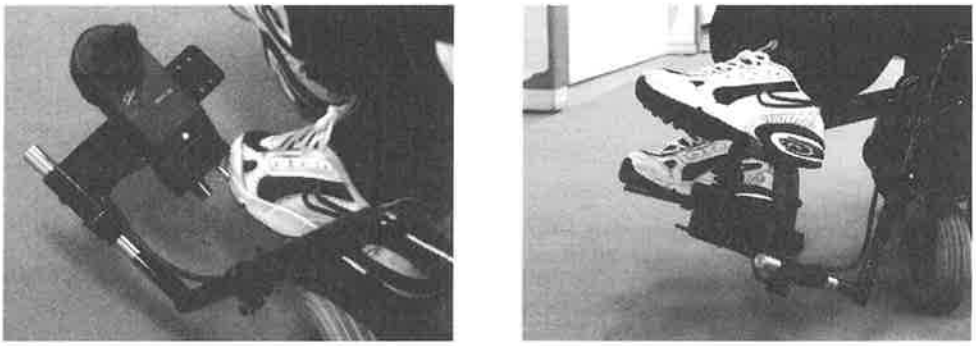
1) Cervical cord injury

Powered wheelchairs are applicable to persons with cervical cord injuries at functional level (hereafter "C") 5 or higher, whose muscles for driving the wheelchair are weak. At level C3 or higher, the patient's diaphragm does not move, and therefore, a ventilator is used. Consequently, it is necessary to install a ventilator on the powered wheelchair. At level C3, since the sitting posture is not stable, a sitting position retainer must be attached. This wheelchair is operated with the chin. At level C5 or below, the patient is able to manually operate the wheelchair on a flat place indoors. However, for outdoor use, a standard powered wheelchair, a simplified powered wheelchair or a powered wheelchair with an auxiliary power may be prescribed in order to achieve safe travel while taking into account the road conditions such as hills and bumps and the durability. At level C5, the user wears an upper limb orthosis and places his/her palm of the controller to operate the wheelchair.

In prescribing a powered wheelchair for a person with cervical cord injury, the prescriber must not forget including a cushion with good pressure dispersion due to risk of decubitus.

2) Cerebral palsy

For cerebral palsy, powered wheelchairs are prescribed mainly for patients with spastic and athetoid cerebral palsies. In general, operation with the upper limbs is common. Some patients with athetoid cerebral palsy have better voluntariness in their lower limbs or toes than in the upper limbs. In such a case, place the controller on the footrest (Figure 11). In addition, to achieve practical operation, the sitting posture needs to be stable. Therefore, it is preferable to prescribe a sitting position retainer.



a. The user operating the switch　　b. The user operating the joystick

Figure 11 Powered wheelchair operable with a foot

3) Muscular disorders

For muscular disorders, powered wheelchairs are prescribed in cases where the patient is unable to walk a long distance or manual operation for long-distance travel is impractical. If the patient is unable to maintain the sitting posture for a long period, a powered reclining wheelchair should be applied. If a lightweight or compactness is required for indoor travel or for outing, a simplified powered wheelchair should be prescribed.

4) Rheumatoid arthritis

Depending on the operating environment, the level of limb joint contracture or the level of the ability to get on the wheelchair, a standard powered wheelchair, a scooter powered wheelchair or a powered wheelchair with a small turning circle is prescribed. Additionally, a powered wheelchair with a powered lift may be selected to help the user get on the wheelchair.

5) Multiple limb amputation

If three limbs of the patient are amputated, including an upper limb in addition to both lower limbs, the patient can use a manual wheelchair driven with one hand. For long-distance travel, it is appropriate to select a simplified powered wheelchair or a standard type powered wheelchair given the patient's fatigue or the like. If all limbs are amputated, it is necessary to alter the controller of a standard powered wheelchair.

6) Internal disabilities

For patients with respiratory disorders or cardiac disorders that restrict walking, standard powered wheelchairs are applied.

Chapter 2.

Adaptation of Powered Wheelchairs

1. Environment of the User

When introducing a powered wheelchair, it is important to identify the environment, such as why a powered wheelchair is needed and how and where it will be used, instead of just helping the user operate the powered wheelchair and move in it.

1) Identifying needs

① Who: identify whether the patient or the caregiver needs the wheelchair.

② Where: identify the place where the wheelchair is used for long time, such as home, facility, hospital or workplace, and its space.

③ Time: identify how long the wheelchair will be used.

④ What: identify whether ambulation is the only purpose or whether it will be used for work.

2) Identifying the present state

① If a powered wheelchair was produced in the past, when was it made?

② What is the problem now?

④ Who has the problem?

3) Identifying the living environment

① Family environment: identify whether the residence is a detached house or a condo, and identify the size of the elevator, etc.

② Automobile used: identify the span of the entrance, indoor height, etc.

④ Accepting structure: identify whether understanding/cooperation of the hospital, facility, workplace, school, assistant, etc. can be gained.

2. Evaluation of the Sitting Posture

For the operation of a powered wheelchair, stability of the sitting position is also an important factor although it is subject to the muscle and joint range of motion. To acquire stable operational ability, it is necessary for the user to attach important to the sitting posture and maintain a stable posture. To achieve this, it is important to evaluate the posture.

1) Evaluation of the sitting position ability

Evaluation of the sitting position ability2) of the user is performed with the user sitting on the end of the bed. Observe the sitting posture and analyze the problem. For example, if a lateral difference in the shoulder heights of the user in the wheelchair is observed, the possible causes include the lean of the pelvis, lateral

spinal curvature and lateral difference in muscle tone of the trunk. Or, the wheelchair might be the cause. In particular, if the seat of the wheelchair is a sling seat, the sitting position varies depending on where on the seat the user sits. Thus, it is difficult to evaluate the sitting position ability of the user in a wheelchair.

Observing the sitting ability will enable you to identify the sitting ability of the user, and to easily assume what kind of supporting ability the equipment must have. First, have the user take a sitting position. In doing so, arrange evaluators in front of and behind the user so that the user will not fall. If the user can freely move his/her hands after you release the hands, it is appropriate to only apply a cushion. If the user holds the bed end and cannot release it, it is necessary to support the seat and the back, and especially the back needs a supporting mechanism such as a pad. It the head and the body fall from the sitting position, a device capable of supporting the pelvis, trunk and head and neck is required.

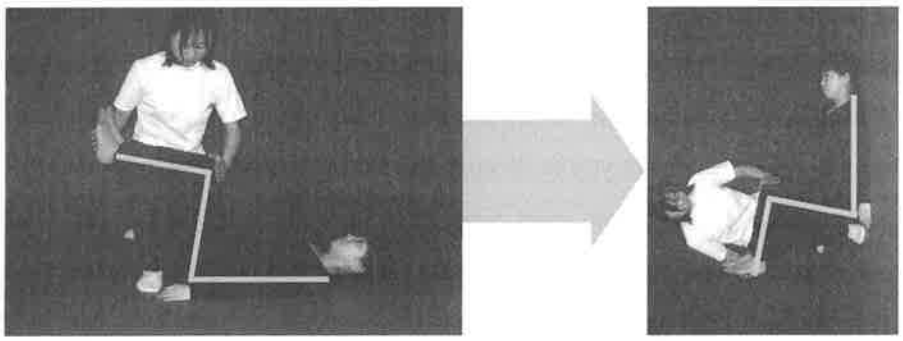
2) Evaluation in a supine position (Figure 12)

Evaluation in a supine position[2)] is performed with the user lying in the bed. The head and the body of a human are heavy, and in cases where the ability to support the weight is lowered, the body will be deformed if it is raised. Therefore, the purpose of the evaluation in a supine position is to assess the state of the user after removing those weights once. In addition, it is possible to see the level of the muscle tone and the mobility of the user by moving the spine and the pelvis. Secondly, see if the user can maintain the basic posture. In the basic posture, the user lies in a supine position, a rolled up towel is inserted under the waist in order to lightly bend forward the lumber spine, while the trunk is held upright and the thighs, knees and foot joints are held at 90°. Check if the user can maintain such a posture. Then, flex the hip and knee joints further from 90° to check whether the user has pains. If the user feels pain in maintaining the posture for a long period even though he/she has no pain, slightly loosening the posture will make the user feel comfortable.

The angle between the trunk and the thighs in a comfortable state as indicated above is regarded as the angle between the seat surface and the back. A footrest should be placed in the place where the feet are positioned.

If the hip joints are too stiff to allow 90°, gradually change the angle until the user feels comfortable. This will enable you to roughly determine the angle between the seat surface and the back. In practice, you start with this angle, and adjust it while observing the state of the user.

Where the user shows a lateral curvature in the wheelchair, the trunk will be held upright in a supine position. If the pelvis of a person with spinal cord injury is leaned due to the seat surface because the trunk muscle does not effectively function, the result is a compensatory lateral curvature in order to adjust the balance.



a. Basic position

b. If the above picture is turned 90°, the user look sitting on the seat.

Figure 12 Evaluation with the user in a supine position

3) Evaluation in a sitting position (Figure 13)

Following the evaluation in the supine position, have the patient take a sitting position2). The examiner should serve as the sitting position retainer to evaluate the posture. Use a footrest and have the patient place his/her feet on it. As opposed to the supine position, a gravitational force is applied in the sitting position so that the examiner can observe the actual state of the sitting user.

The most important factor in observing the sitting position is the pelvis, followed by the spine. In the basic posture, the examiner sits behind the patient with the pelvis in a horizontal position. Subsequently, the examiner fixes the pelvis of the subject. For example, if the spine is bent, the examiner supports the trunk with both hands to correct the bend. The examiner must see which part of the trunk he/she should support to correct the spine upright. It is considered that the position of the hand equals to the position of the pad that supports the body on the seat, and the strength of the pushing hand approximates the force of the pad supporting the trunk.

If the pelvis and the spine are deformed and the trunk is not in a horizontal position regardless of the position at which to fix the trunk, insert a towel under the buttocks to stabilize the pelvis. The thickness of the towel supplements the height of the seat. Then, find the optimal position for supporting the trunk with the hands again, as stated earlier.

The therapist can identify the muscle tone and the strength required to hold the trunk by actually touching the trunk, and he/she should study the extent to which he/she can stabilize the posture on the seat. In addition, when holding the trunk in the predefined posture, she/she should study whether the desired position can be actually reproduced with a sitting position retainer.

You must not forget to have the impression of the user concerning the posture. If the user says "hard" or "painful," you should change the angle from the relevant region to see any improvement. If it is difficult to communicate with the user, you should infer the user's impression from his/her facial expression.

Through the evaluations indicated above, you can assess the conditions of the trunk and the pelvis, and set the seat back of the sitting position retainer.

Figure 13 Evaluation with the user in a sitting position

3. Measure to Cope with Orthostatic Hypotension

Some powered wheelchair users have autonomic disorders. In particular, if a person with cervical cord injury maintains the sitting position in a wheelchair for a long period, his/her blood will be retained in the abdomen and lower parts of the body due to disruption in the vasoconstrictor mechanism of the abdomen and the lower limbs, and he/she may eventually develop orthostatic hypotension. If the user can solve the problem by himself/ herself, for example, by bending the trunk forward, the seat may be the fixed type. However, if he/she cannot, a mechanism for tilting or reclining the seat with a motor is required. In most cases, tilting mechanisms are introduced from the viewpoint of pressure reduction and seating. Although orthostatic hypotension may not be fully prevented with a backward tilt at 45°, there will be no problem in everyday life for patients with functional levels C3 to 5.

4. Selecting a Method for Preventing Decubitus

If the patient maintains a sitting position for a long period, the vessels in tissues surrounding the ischial bone are compressed, and the blood flow to the tissues dominant with vessels will be blocked. Symptoms include numbness and pains. However, if the patient has cervical cord injury, he/she develops anesthesia and does not sense numbness or pains, and therefore, it is necessary to recover the blood circulation through pressure elimination or reduction of the compressed region by regularly changing the posture or providing pushups or the like.

When prescribing a wheelchair, the prescriber must pay attention to the following two points. First, an anti-decubitus cushion should be included. If the risk of decubitus ulcer is high, the cushion thickness must be 10 cm, and if the risk is low, prescribe a 5 cm thick cushion. The second point is the function of the wheelchair. The type of the wheelchair to be selected varies widely depending on whether the user can release and/or reduce pressure by himself/ herself.

If the user can release and/or reduce pressure by himself/ herself, the seat part may be the fixed type. If he/ she cannot, a model capable of tilting or reclining the seat with a motor (Figure 14) is required. The reclining mechanism allows the back and feet to be tilted together to almost horizontal level, and the user can feel relaxed. On of the disadvantages is that the posture is easily changed even if it is maintained with a sitting position retainer due to a strain caused by expansion of the trunk. Another disadvantage is that the posture correction is required when

the user rises and the clothes will become untidy. The pressure is reduced around the ischial bone and the sacrum, but it is not sufficient (Figure 14a). Since the tilt mechanism does not ensure complete flatness, the user cannot feel relaxed. However, the user is tilted together with the seat, the posture will not collapse and the clothes will not become untidy. For the pressure, if atrophy develops in the soft tissues of the trunk or the lower limbs as with cervical cord injury, the body weight will notably transfer to the seat and the depressurizing effect is high (Figure 14b).

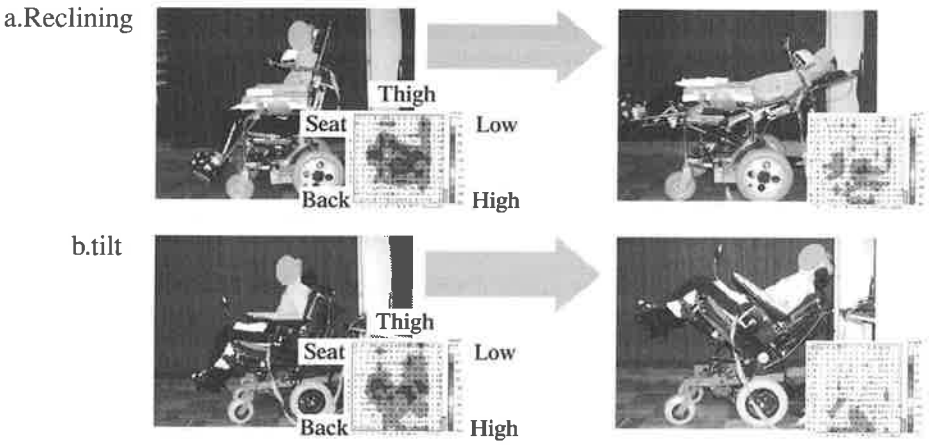


Figure 14 Contact pressure for the tilt and the reclining types

5. Studying the Operation Input

When selecting a controller, it is important to match the equipment to the operation ability of the user, not to the user.

1) Operation input method

It will be effective if the examiner observes the operation ability of the user by moving the user's hand while standing in front of the user. However, it is also very important to estimate the operation level of the powered wheelchair in evaluation with a sitting position. This can be done by judging how the user's body moves in the sitting posture, which is the basic operation posture. For example, if joystick operation is performed with the right upper limb, the shoulder joints will make abduction and medial rotation during direct advance. If the user operates the stick rightward, the examiner serving as the seat from behind will clearly notice the reaction such as rightward bend of the trunk. This indicates that the method has the advantage of being able to sense with the body how to support the trunk. For the order of precedence with the operation input method is the upper limbs, lower limbs, chin, head, tongue and breaths. This is because the operation ability requires delicate control and the order of precedence is based on the level of skillfulness. Another issue is the cost. For upper limb operation, a large number of off-the-shelf articles, such as joysticks, are available and their shapes are also varied, to respond to different disabilities.

The important factor in observing the operation is that the user can release his/her hand or foot from the controller without fail when stopping the wheelchair, and can place his/her hand or foot on the controller when starting the wheelchair. This is because the time in which the user operates the controller is shorter than the

time in which he/she takes a rest, and the wheelchair may suddenly start and could lead to an accident through contact with another person unless the user's hand is off the controller. In addition, since the user requires assistance of another person if the user cannot place his/her hand or foot on the controller when traveling, he/she will not be able to independently travel.

2) Operation input devices

In clinical practices, a joystick, switch-input joystick, pushbutton input device and single-input operation are used. The operational performance decreases in this order, and the traveling performance of the wheelchair also decrease in this order.

With an ordinary joystick, the tilt direction corresponds to the traveling direction while the tilt angle represents the speed. Thus, adjustment of the rotation and the traveling speed can be performed with a single stick. The switch-based joystick is not capable of adjusting the speed. With the push-button type, the wheelchair is unable to continuously travel, or perform smooth traveling such as turnaround after stopping once. The single-input method takes time since the traveling direction is determined through scanning.

Selection of an operation method is an important factor for persons with cervical cord injury, who have fewer muscles and less physical endurance. Previously, the most common mode was a momentary mode. In the momentary mode, the wheelchair keeps traveling while the user is performing operations such as touching and pushing the controller, and stops if the user releases the controller. In this mode, however, if the chin control is used during traveling outdoors, the chin may come off from the controller due to external disturbances such as impact from the road. In addition, prolonged operation involves fatigue.

A latch mode makes prolonged operation easier. In this mode, the user can achieve direct travel with a single operation, and can keep the chin away from the controller during travel. To stop the wheelchair, the user touches the controller. For lateral travel, the user has only to touch the controller in the traveling direction. Thus, the operation is simple. The result is stable outdoor travel for an extended period.

Chapter 3.

Selection of Equipment and a Controller for Cervical Cord Injury

1. Operation Device for Patients Capable of Operating with the Upper Limbs

This requires functions at level 3 or higher in shoulder blade lifting, and level 3 or higher in elbow flexion (brachioradial muscle), of MMT (manual muscle testing). If the level of wrist joint dorsal flexion is 3 or below, use a wrist joint splint.

1) Powered and manually operated wheelchair (powered assist) (Figures 5 and 9)

This requires physical endurance of the muscle surrounding the shoulder blades and no lateral difference. In many cases even patients having difficulty in manually operating the wheelchair indoors can pass over electric cords and thresholds indoors if using a powered assist. Operating with the remaining muscles is effective in maintaining the functions. At function level C6, the patient can improve his/her ambulatory ability, and therefore is able to perform outdoor travel without problems.

Although this makes the operation easier, there is a limit since in principle the user has to use his/her muscles. In addition, while the wheelchair is suitable for indoor use, the user may become unable to operate it from fatigue in long-distance ambulation outdoors. In our country, a person with a disability can be supplied with one wheelchair under the Law for the Welfare of Physically Disabled Persons. Therefore, it is necessary to consider the intended use when prescribing this wheelchair.

2) Joystick (Figure 15)

Although joystick shapes vary, this section describes those used in clinical practice. The stroke (neutral to maximum incline) of the joystick-based controller varies with the knob length. Its angle ranges from 7° to 10°. If the length from the controller shaft to the end is 10 cm, the stroke will be approximately 1 cm and the front-to-back span will be approximately 2 cm.

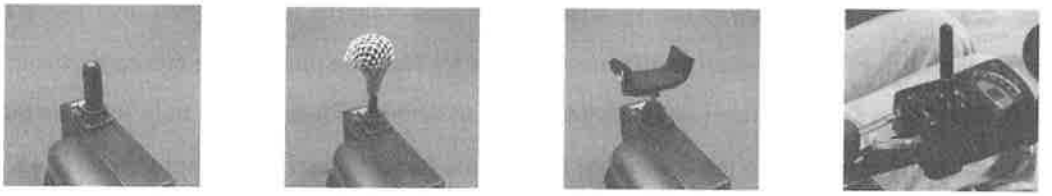
The names of shapes are not formally defined. In this section, the names utilized in clinical practices are used.

(1) Normal (stick) (Figure 15a): Used for patients capable of easily grabbing articles or patients capable of operating the controller by holding it with a palm.

(2) Ball (Figure 15b): With a round end, this type can be used for patients having finger contracture.

(3) Palm (forearm pronated/ supinated) (Figure 15c): Patients with wrist joint dorsal flexion at level MMT 3 or below use a splint to secure the wrist joint to transfer the force of the shoulder and the elbow efficiently.

(4) Tapered (thin candle) (Figure 15d): Although the operation method is the same as the stick type, the length is larger than the previous type, and therefore, the user can easily perform control operation based on the principle of leverage. For example, if the patient unable to reach a normal-length controller due to muscle weakness is tilted backward, he/she can operate this controller to raise the seat forward.



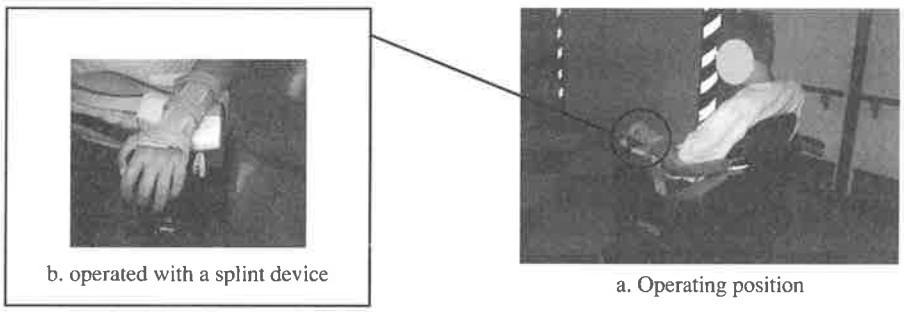
a. Standard (stick) type b. Ball (slip resistant) c. Palmar (slip resistant) d. Tapered (thin candle)

Figure 15 Types of joysticks

3) Adjusting the joystick

If the shoulder blade of a patient at level C5 in joystick operation wearing a splint on the fingers, with the shoulder joint set at an intermediate position and the elbow joint at 90°, is elevated during the operation, the shoulder will be abducted and externally rotated and it will result in "cannot exert the strength because the armpit opens" since the set position is too high. In such a case, operating the controller by pressing it with the weight of the raised upper limb will enable the user to operate the controller even with the elevated shoulder blade. To stabilize the motion, it is preferable to produce a forearm support (Figure 16).

Even for patients operating the controller in a sitting posture with the shoulder joint in an intermediate position and the elbow joint at 90°, it is easier to operate a low joystick by using the weight of the upper limb.



b. operated with a splint device a. Operating position

Figure 16 Adjustment of the joystick (scene showing practicing by C5)

2. Operation device for Patients Unable to Perform Upper Limb Operation 2)

(1) For level 3 or below in elbow flexion and level 3 or higher in neck flexion/extension, a chin controller or a head controller is used, and the tile and reclining seat operation is based a puff or a button.

(2) For level 3 or below in neck flexion/extension, a chin controller or a head controller is used, and the tile and reclining seat operation is based on switchover or breaths.

The chin control (Figures 17, 18 and 19) is designed to be performed with the chin, and operable without problem as long as the user can move his/her face, especially the lips and the jaw. Since the chin control has a controller on the front face, it will interfere with operation. As an alternative, a head control is available. However, the wheelchair is delicately controlled with the position of the head, and more time is required to master the head control as compared with the chin control.

Chin operation is unexpectedly easy. When indicating a direction, the user points to the direction right or left simply with the chin. The user's chin naturally moves towards the intended direction.

For patients at level C3 or higher who use ventilators, you may imagine that they can only move their faces. However, in fact their trapezius and sternocleidomastoid muscles function through the eleventh cranial nerve (accessory nerve). Yet, they cannot perform any anti-gravitational activity. Therefore, to help the user move his/her neck and chin efficiently in operating the controller, tilt the seat back, set at 95°, by approximately 15° backward to transfer the weight of the head onto the seat back, and use the headrest to leave a one-finger space to the left and right of the head. The purpose is to lessen the weight applied on the head, restrict the backward and lateral movements with the head rest, and enable the neck to bend forward from the occipital bone as the fulcrum even if the neck flexion and extension muscle is at MMT level 2 or below, thus allowing chin control.

a. Chin contioller with a bib
Manufactured by company of
the United States

b. Cup-type contioller
Manufactured by company of
japan

b. Fin-type contioller
Manufactured by company of
the United States

Figure 17 Chin controller

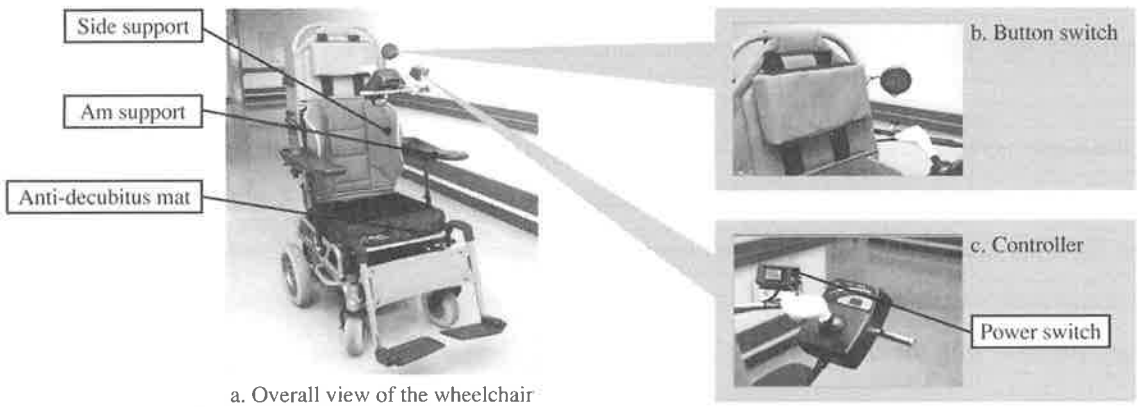
a. Control operating position

b. Mode display section

c. Puff operating position

d. Puff

Figure 18 The operating section of a chin-controlled powered wheelchair with a tilt mechanism (operated with a puff)



a. Overall view of the wheelchair

Figure 19 Chin-controlled powered wheelchair with a reclining mechanism (operated with a button switch)

In setting the controller for level C3 or higher (Figure 20), separate the controller from the chin by one finger wide (approximately 1 cm). If the overall stroke including the control operation is only about 3 cm, it will be sufficient for operation. This means that the user only has to push out the chin forward while bending the neck backward. In actually instructing the user, saying: "push out the lower lip" would make the motion easier.

Concerning the angle of the seat during operation of a powered wheelchair, many have said that the trunk must be upright to secure vision and for safety. If the trunk were upright during travel, it would provide good vision. However, doing so may transfer vibrations of slight road bumps to the trunk and cause forward slip, resulting in collapse of the posture. Even if the user wears a belt, forward slip will occur in the belt. This is because the trunk muscle of persons with high cervical cord injury does not function, and they do not have muscle to react against disturbance despite balance reaction to it. Ss a result, they cannot maintain the posture.

As a measure to solve the problem, tilting the seat backward in advance will shift the weight of the head and the trunk to the seat back and stabilize the posture. In addition, the trunk will also absorb the shock to reduce the forward slip and lessen the rocking of the head.

You might fear that titling the seat backward could make difficulty for the user to look ahead and secure safety. However, normally the user becomes able to smoothly operate the wheelchair even in small areas through practicing. If you drive a car, you cannot see the front end and the side faces, but you can keep driving partly through visual judgment. This also applies to powered wheelchairs.

Controller position adjustment:secure a space about the width of one finger
Set the system so that the wheelchair will stop if an impact is applied and the chin contact the controller

Figure 20 Method for setting the chin controller (C3 using a ventilater)

3. Summary of Input Methods

The input methods can be summarized as shown in Figure 21. This will enable you to select an input method even if the functional level is unknown.

① For MMT level 3 or higher in shoulder blade elevation, level 3 or higher in elbow flexion and level 3 or higher in wrist joint dorsal flexion, use a joystick.

For level 2 or below in wrist joint dorsal flexion, use a wrist joint securing splint and use a joystick.

② For MMT level 3 or higher in shoulder blade elevation, level 2 or below in elbow flexion and level 3 or higher in neck flexion/extension, use a chin control, and an air puff for head operation, or use a switch to adjust the reclining/tilt seat and the speed. For level 2 or below in neck flexion/extension, use a chin control. Use the same controller as the chin control to adjust the reclining/tilt seat and the speed.

③ If the upper limbs do not move at all, use a chin control. Use the same controller as the chin control to adjust the reclining/tilt seat and the speed.

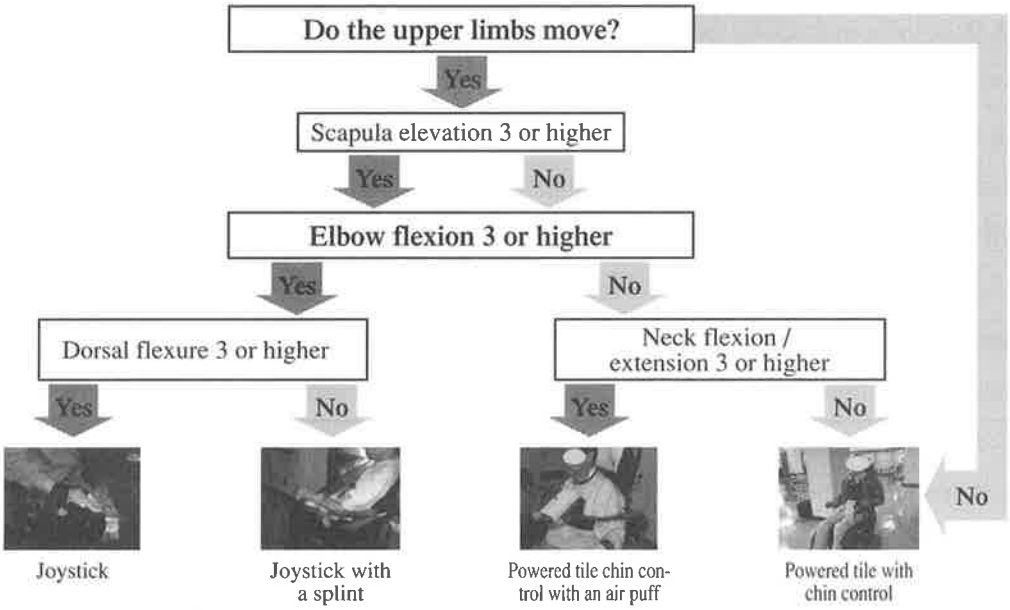


Figure 21 Method for determining the operation input

Chapter 4.

Practicing Operations

Before using a powered wheelchair, it is important for the user to become able to operate it well. Furthermore, just selecting a model and practicing the operation is not sufficient since it is also necessary to secure safety as an accessory condition.

1. Safety

When the user judges it safe to use a powered wheelchair, the most important factor is the wheelchair's ability to stop without fail. In addition, in terms of safety of the powered wheelchair, ? it does not run out of control, ? it does not hurt a person or an object, ? it provides the sense of security to a third parties, and ? the user will be able to cope with an unexpected accident.

In our country, the functions and strength of powered wheelchairs are defined under JIS (JIS T 9203). However, it is necessary to pay attention to the following points when traveling. In terms of stationary ability, a powered wheelchair may likely fall backward on an incline at 10° or higher. In terms of tilt stability, the wheelchair must not fall on an incline at 20° forward/backward and 15° sideward. However, this JIS standard does not assume the physical functions such as balancing of the user. Therefore, even within the functional standard, the posture in the wheelchair may collapse and the user may not be able to operate the wheelchair in an unfavorable condition. To solve this problem, it is necessary to instruct each user on his/her safety range.

For actual safety consideration, it will be necessary to cover all possible issues assumed at present and in future. For serious or special cases, it is particularly necessary to consider safety.

2. Operability

1) Appropriate equipment and functions

The latch mode and the program as described in the section concerning the input devices.

Using a program will enable you to control the forward/reverse speed, controller sensitivity, motor torque, etc. High-function wheelchairs are provided with programs. Effective use of the program will allow the user to operate the wheelchair relatively safely and easily. For example, if the carpet is thick-piled, starting the wheelchair will require a large torque. If the wheelchair is programmed so that the torque is increased without increasing the speed, the wheelchair can gradually start. However, if only the speed is adjusted, the wheelchair will suddenly move in starting operation.

The posture is an important factor for safe operation. A stable posture will enable automatic motion to be efficiently achieved. The prerequisite for the operation method, the controller and the program described earlier is the posture.

2) Method for practicing to improve operability

Having the user get on the wheelchair and instructing him/her to "run here" or "turn here" would be an effective training method for the user to learn the driving sense. However, it is preferable to conduct a training method with which to encourage the user to acquire and learn the sense required for traveling in order to become skilled.

1 Acquire the traveling sense in linear travel, stop, turn, sudden start and sudden stop.

2 Acquire the distance sense at 10 cm, 20 cm, 50 cm, 1 m, 3 m, 5 m and 10 m.

Stand in front of the wheelchair and ask the user about the distance from the front end of the wheelchair. For example, ask questions such as "1 m is this length" and "Is the distance from the front end of the wheelchair to me longer than 1 m or shorter?" to have the user think about the distance.

3 Learn the size of the wheelchair such as the length, width and height. For example, ask "The width of this wheelchair is 60 cm," "Is this width larger than 60 cm?" or "With your operating ability, you can safely pass a passage if its width is 90 cm," "Can you pass a passage with this width?" while instructing the user to have him/her acquire the sense of the width at which the wheelchair can pass.

4 Learn the motion of the casters. Since the user in the wheelchair cannot see the casters, use a mirror or another wheelchair to show the motion of the casters. Perform this in the order of linear travel, turn from stationary state, and reverse from stationary state.

5 Teach the user about accident situations and preventive measures. The places where accidents frequently occur are door entrances, automatic doors, roads and railroad crossings.

a. The cause of accidents at entrance doors is that the user enters the entrance at a slant approaching angle without considering the rotary difference of the powered wheelchair, and lets the rear wheel hit the entrance wall. The preventive measure is letting the powered wheelchair approach straight toward the entrance.

b. The cause of accidents at automatic doors is that the timing of speed adjustment/stopping is inappropriate, and the user advances before the automatic door opens and collides with the door. The preventive measure is stopping in front of the door once, and advancing after confirming that the door opened.

c. The cause of accidents on roads outdoors is the unstable driving posture and inadequate control ability in advancing forward. On most roads, the center is higher and both sides are lower than the average level for good drainage. This is called a single-flow structure. If the user tries to move straight without performing fine control, the wheelchair will drift toward the roadside. The preventive measure is stabilizing the sitting posture in the wheelchair so that it does not tilt toward the roadside. In addition, have the user learn how to fine-adjust the controller leftward if the user keeps to the right in order to move straight.

d. The cause of accidents at entrances/exits of intersections is that there is a level difference between the sidewalk and the street at intersections, and forward slip occurs due to impact from the road surface in ascending/descending a level difference and the posture collapses, resulting in inability to operate the wheelchair. The preventive measure is decelerating when approaching the level difference and shifting

the center of gravity toward the seat back using the remaining functions.

e. The cause of accidents at railroad crossings is that the user is afraid of closure of the crossing and he/she passes on the side of the crossing to avoid cars, and then mistakenly operates the wheelchair, causing it to fall from the passage. As a result, the wheelchair becomes inoperative. In the worst case, the user will fall. The preventive measure is, when passing a narrow railway crossing in the wheelchair, allowing a margin from the side end so that the wheelchair does not fall while considering safety in order to prevent an accident, although doing so may hinder traffic of cars.

As indicated above, it is necessary for the user to practice the required actions in advance.

3) Practice menus

Table 1 shows a checklist for practice menus. In an ideal system, practices are regularly performed, the user runs through the menus from easier to advanced ones, and the instructor provides advice at each course.

The following are the purposes and points of practice menu items.

(1) Setting the equipment

Many powered wheelchair users are supported by assistants in transfer motion, sitting posture retention and position adjustment of the controller because of the nature of the functions. To operate the wheelchair in a stable posture, it is important for the user to understand the requirements by himself/ herself. In addition, it is also necessary for the instructor to verbally practice on a daily basis to appropriately provide instructions since the assistant may be changed.

(2) Explanations of the operation

The purpose is to understand the basic operation method. It is necessary to understand the characteristics of the wheelchair to be used since the forward and the reverse are opposite for some chin controllers.

(3) Operation learning in large places

The purpose is to check how the user understands the operation method and have the user understand the characteristics of the controller. To achieve this, keep the controller inoperative so that it does not function even if it is operated, and provide instructions such as "advance straight ahead," "advance rightward" and "stop the wheelchair."

If you feel all right in the operations with the clutch disconnected as indicted above, activate the controller and set the speed at the lowest level, and then have the user actually experience the operation.

The user in the powered wheelchair spends more time when stationary than when moving. Therefore, it is necessary for the user to be safely stationary. The user needs to remain stationary and must not erroneously operate the controller even if something hits the powered wheelchair.

The user is required to acquire the operation ability to accurately stop the powered wheelchair so that it does not hit a person or object. For example, it is important to approach an elevator without hitting a person or the

door.

Although the operations indicated above are not required in everyday life, the user needs to understand the operational characteristics of the wheelchair and acquire the ability to reliably change direction.

With wheelchairs whose speeds and torques can be changed, identify how the wheelchair behaves after the settings are changed.

(4) Traveling in hallways

The purpose is to acquire the ability to safely travel in hallways in facilities and hospitals.

Since hallways are narrow and provide two-way traffic, it is important to advance straight. With unstable travel, the wheelchair may hit the wall or the like. Therefore, the user should steadily practice straight advance operations. If making a U turn is inevitable, the user must stop temporarily. Then, the user must identify the surrounding environment and confirm safety in performing the U turn. If there are people around in doing so, saying: "I am turning" will keep the surrounding people away, and the user can safely make a U turn.

(5) Traveling indoors

The purpose is to acquire the ability to safely operate the powered wheelchair in possible situations in public and at amusement facilities.

Automatic doors may not open if the wheelchair approaches at normal traveling speed. Therefore, the user must briefly stop or slow down before entering the door.

In narrow hallways, the user should take a favorite center, left or right line while traveling.

Since people walk in a flow, it is necessary to join the flow. Therefore, if the user cannot turn left or right unless stopping before truing with the present operation ability, he/she may block traffic flow, and followers may become worried. To prevent such a problem, the user is required to be able to smoothly operate the wheelchair.

If the user is unable to travel due to a level difference or the like, he/she should ask assistance instead of trying too hard. If the user asks the assistant to lift the front wheel, he/she should ask the assistant to hold the stable frame, and it is important to mark the part with a tape or the like in advance. Then, the user should instruct the assistant "please hold the taped part."

(6) Traveling outdoors

The purpose is to acquire the operation ability at parks, roads with no distinction between sidewalks and streets, and railway crossings. If the user keeps to the right in advancing straight on a single-flow road, he/she should fine-adjust the controller in order prevent the wheelchair from drifting rightward.

If passing on soil, lawn or gravel, the casters may receive resistance from the road surface, and the wheelchair cannot advance straight, or the user will have difficulty in operating the wheelchair. In particular,

gavel will get into the wheels to stop them, and should be avoided. However, if traveling through gravel is inevitable, the user must hold the controller firmer than usual. If the speed is decreased, the wheelchair will stop due to the resistance of the road surface. Therefore, it is important to maintain normal speed or accelerate to pass through the graveled area.

When passing a railway crossing, the user tends to travel near the side in order to avoid hindering the automobile traffic. However, if the wheel falls, the result may be a disaster. Therefore, it is important to travel while allowing a margin from the side end.

If it is difficult to travel on a road due to traffic of cars and people or bicycles or luggage placed on the road, the user should briefly stop, and then identify the status and find the best route.

(7) Practicing fine movements

Placing the wheelchair beside the bed and the table is an action performed in everyday life all the time. Therefore, the user must acquire the ability so that he/she can accurately operate the powered wheelchair to place it beside the bed and the table with the appropriate direction and distance.

3. Inspection items in everyday life

To use the powered wheelchair safety and comfortably, it is essential to inspect it on a daily basis. Since the wheelchair user cannot inspect the wheelchair by himself/herself in many cases, he/she should ask a family member or an assistant to perform inspection. Inspection should be performed both when the wheelchair is stationary and traveling.

If the traveling time becomes shorter even if the batteries are charged and if frequent charging is required, promptly replace the batteries. The batteries have service lives, and the preference is to replace them every 2 to 3 years.

If an anomaly is detected in inspection, promptly contact the firm and ask the firm personnel to handle the problem. Never regard the wheelchair as without a problem just because the wheelchair can move. It is important to perform daily inspection on the following items in prevent any accident.

1) When stationary

1 Is the remaining battery level sufficient (be sure to charge the batteries before outing)?

2 Is the air pressure of the tires appropriate (less air, flat tire)?

3 Is the controller properly placed (not loosened, bent)?

4 Can the clutch be properly connected and disconnected (too stiff to move)?

5 Can a stable driving position be taken?

6 Can the power be turned on?

2) During traveling

1 Does the wheelchair advance straight in response to controller operation?

2 Does the wheelchair accurately stop in response to controller operation?

3 Does the wheelchair accurately turn left and right in response to controller operation?

4 Can the speed adjusted?

5 Does the wheelchair generate noise?

6 Does the driving feel the same as usual?

Table 1 Checklist for Powered Wheelchair Operation Practices

Name: Sex: Male / Female Age: Disability type:

Items	/ /	/ /	/ /	Remarks
1. Setting up the wheelchair				
1) Understand how to set up a wheelchair and how to sit. Adjust the wheelchair by oneself, or ask a caretaker to adjust it.				
2. Explanations on operations				
1) Turning it on/off				
2) Operations for moving forward				
3) Operations for stopping				
4) Operations for changing directions				
3. Learning operations in a large space				
1) Turning it on/off				
2) Learning operations when power is turned off				
3) Turning it on				
4) Learning operations when clutch is disengaged				
5) Moving forward (short distance), stopping, moving backwards (short distance), and rotating at the spot while maintaining the minimum speed when clutch is engaged				
6) Stopping for a long time				
7) Practicing turning right and left while moving forward				
8) Practicing moving forward to a target place and stopping in front of it				
9) Moving back along the line				
10) Practicing moving in the form of a big eight				
11) Practicing moving in a big circle				
12) Moving back along the straight line				
13) Practicing turning right and left while moving back				
14) Experiencing driving when the settings are changed				
4. Driving in a corridor				
1) Practicing moving straight along the center line of the corridor				
2) Practicing moving straight along the wall				
3) Practicing a U-turn while judging the circumstances				
4) Practicing moving to the side of the corridor and then stopping				
5) Experiencing driving when the settings are changed				
5. Driving indoors				
1) Going through an automatic door				
2) Getting on/off an elevator				
3) Going through a narrow aisle (Target: 70 cm)				
4) Going through the crowd				
5) Driving on different floor materials including a carpet				
6) Driving on the slope				
7) Going through a hand-operated door				
8) Adjusting speed while judging the circumstances				
9) Learning driving rules				
a. Keeping right				
b. Moving to the side for to stop and rest				
c. Checking safety at an intersection				
d. Giving way to others				
e. Adjusting speed with the other people in the crowd				
10) Making an appropriate request to a caretaker				
6. Driving outdoors				
1) Checking physical endurance in relation to the temperature and outdoor environment				
2) Moving forward on the one-sided tilt				
3) Driving on a slightly uneven surface				
4) Driving on a sidewalk (width, braille blocks, slope)				
5) Climbing up steps (moving forward/backwards)				
6) Driving on the slope (moving forward,stopping, turning right/left, rotating on the spot)				
7) Driving on the off road (soil, lawn, sand, etc.)				
8) Crossing the road (pedestrian crossing, signal)				
9) Crossing the railroad crossing (simulation)				
10) Making an appropriate request to a caretaker				
11) Deciding the direction for driving safely in a dangerous place				
7. Practicing detailed operations				
1) Stopping beside a bed or a chair				
2) Sitting at a table				

○: No problem △: Almost all right ×: More practice required

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