Clinical Guide

to Powerchair Controls

LiNX®

INVACARE®

Yes, you can.®

Contents

Allow powerchair users to be independent and in control

Main author

Sofie Vercaemer
Occupational Therapist,
Product Manager, Belgium

Contributors

Rhona Moot
Occupational Therapist,
Clinical Specialist, Europe

Ezequiel Filipe Silva
Occupational Therapist,
Group Product Manager
Seating & Positioning, EMEA

Samantha Hatchett
EMEA Marketing Communications
Executive, Europe

Controls

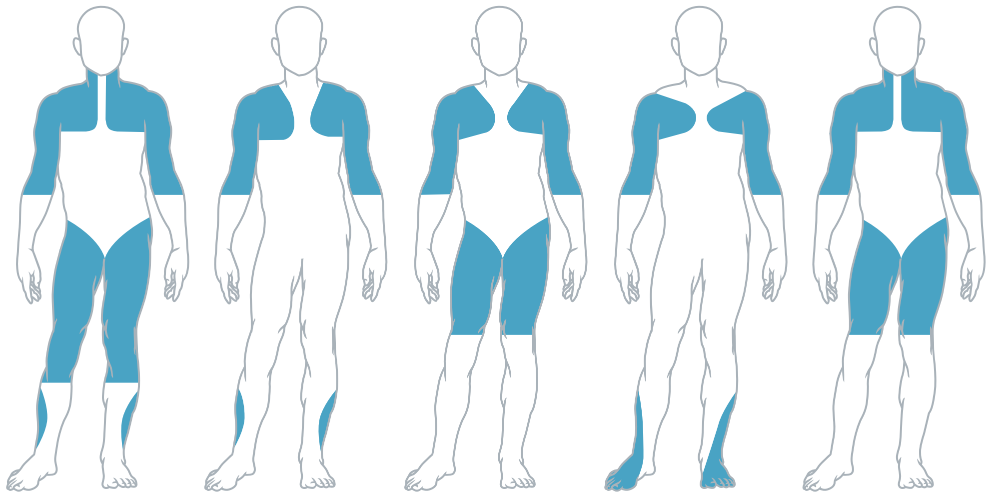
▶ When it comes to choosing a **control interface for a powerchair** the options available on the market are vast. It's the job of the clinician to match the appropriate control interface to the motor and cognitive abilities of the user, considering the size and activation method of the control interface itself and which control will match most effectively with the functional capabilities of the individual.

a Skills for using a control interface

▶ To select the right control interface for an individual, it is important to identify their functional skills and where the control interface needs to be placed to ensure proper operation. Skills to look for are:

1. Motor control
2. Range of motion (ROM)
3. Strength
4. Endurance

Types of Muscular Dystrophy and their affected areas



Motor control

▶ Motor control is the human process by which we use our cognition to activate and coordinate the muscles and limbs involved in the performance of a motor skill. It is a function that involves the precise movement of muscles with the intent to perform a specific action.

Fine motor control is the **coordination of muscles, bones and nerves** to produce small, exact movements. An example of fine motor control is picking up a small item with the index finger and thumb. The opposite of fine motor control is gross motor control. An example of gross motor control is waving an arm in greeting.

Problems of the brain, spinal cord, peripheral nerves, muscles or joints may all decrease fine motor control. People with **Parkinson's Disease** are likely to have trouble speaking, eating and writing because they have lost fine motor control.

To have fine motor control, we need:

- **Awareness and planning**
- **Coordination**
- **Muscle strength**
- **Normal sensation**

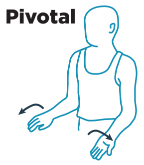
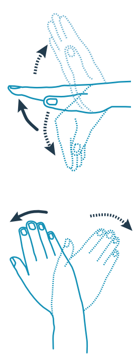
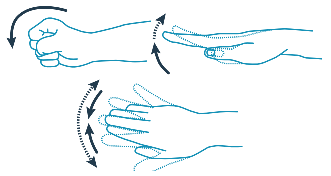
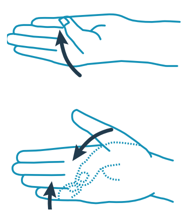
Depending on the ability of performing fine motor control, a user will be able to handle a specific control interface or target buttons with a certain spacing.

For example, for some types of Muscular Dystrophy, like Duchenne, the proximal muscle groups are affected and cause issues in voluntary gross motor skills of the arm over time. As small distal movements are still possible, a joystick option that supports these small movements will be required.

The standard joystick in the standard position on a powerchair (at the end of the armpad) might not be an option over time. To be able to use it, the user not only needs fine motor control to be able to grab the joystick, but also gross motor skills for the joystick throw: elevation, extension and maybe a small abduction of the arm. With a smaller and lower force joystick, it can be activated by using only finger and hand movements. However, it is still important to remember that the position of the joystick is crucial.

Range of motion (ROM)

▶ **Range of motion is the measurement of a movement around a joint. The arc through which active and passive movements occurs at a joint is created during a movement.**

Body Part	Type of joint	Type of movement	Range (degrees)	Primary muscles
Elbow	**Hinge** 	**Flexion**: bend elbow so that lower arm moves towards its shoulder joint and hand is level with shoulder	150	Biceps brachii, brachialis, brachioradialis
		Extension: straighten elbow by lowering hand	150	Triceps brachii
Forearm	**Pivotal** 	**Supination**: turn lower arm and hand so that palm is up	70-90	Supinator, biceps brachii
		Pronation: turn lower arm so that palm is down	70-90	Pronator teres, pronator quadratus
Wrist	**Condyloid** 	**Flexion**: move palm toward inner aspect of forearm	80-90	Flexor carpi ulnaris, flexor carpi radialis
		Extension: move fingers so that fingers, hands and forearm are on the same plane	80-90	Extensor carpi ulnaris, extensor carpi radialis brevis, extensor carpi radialis longus
		Hyperextension: bring dorsal surface back as far as possible	89-90	Extensor carpi radialis brevis, extensor carpi radialis longus, extensor carpi ulnaris
		Abduction (radial flexion): bend wrist medially towards thumb	Up to 30	Flexor carpi radialis, extensor carpi radialis brevis, extensor carpi radialis longus
		Adduction (ulnar flexion): bend wrist laterally toward fifth finger	30-50	Flexor carpi ulnaris, extensor carpi ulnaris
Fingers	**Condyloid hinge** 	**Flexion**: make fist	90	Cumbricales, interosseus volaris, interosseus dorsalis
		Extension: straighten fingers	90	Extensor digiti quinti proprius, extensor digiti quinti proprius, extensor digitorum communnis, extensor indicis proprius
		Hyperextension: bend fingers back as far as possible	30-60	
		Abduction: spread fingers apart	30	Interosseus dorsalis
		Adduction: bring fingers together	30	Interosseus volaris
Thumb	**Saddle** 	**Flexion**: move thumb across palmar surface of hand	90	Flexor pollicis brevis
		Extension: move thumb straight away from hand	90	Extensor pollicis, longus, extensor pollicis, brevis
		Abduction: extend thumb laterally (usually done when placing fingers in abduction and adduction)	30	Abductor pollicis brevis
		Adduction: move thumb back toward hand	30	Abductor pollicis obliquus, adductor pollicis transversus
		Opposition: touch thumb to each finger of same hand		Opponeus pollicis, opponeus digiti minimi

Some tasks require a larger range of motion, like pushing a hand rim on a manual wheelchair, while some tasks require a smaller range of motion, such as handling a joystick. For some, their range of motion can be so limited that using a joystick is impossible.

Evaluating impairment of ROM will include consideration of the following:

- **Arthrokinematics: the intra-articular movement of bones**
- **Tissue extensibility: the length and movement of a muscle and tendon**
- **Muscle tone and spasticity**

Spasticity is seen in a number of different conditions like Cerebral Palsy, Traumatic Brain Injury, Spinal Cord Injury, Stroke and Multiple Sclerosis. It arises as a result of damage to bundles of neurons in the brain or spinal cord.

Over time, spasticity can lead to **muscle stiffness, atrophy and fibrosis** which will influence the range of motion in a certain joint. Limited range of motion, for example, in the extensors/flexors of the fingers and the opposition of the thumb, will mean the user can't grab a standard joystick. An alternative joystick knob might be a solution, where the muscle movements are less pronounced or the movement required is changed from the fingers to the palm of the hand. If the limitation in range of motion is situated more proximal in the elbow or shoulder joint, it may be that the user is unable to deflect the joystick completely. Positioning the joystick closer to the body or in midline might help, alternatively programming the throw of the joystick could be a solution.

Examples of upper limb spasticity

Strength

Muscle strength can be reduced, normal or increased.

Reduced strength

▶ **Due to paralysis, the use of certain muscle groups may be restricted.** For example, a Spinal Cord Injury, depending on the height of the injury, may prevent a movement at full strength due to the failure of certain muscles.

Paresis or partial paralysis will not prevent the movement, but the muscle will be weaker. The same goes for atrophied muscles, caused by disuse of the muscle or a defect in the enervation of the muscle. Through degeneration of the muscle, the function is still there, but reduced in strength.

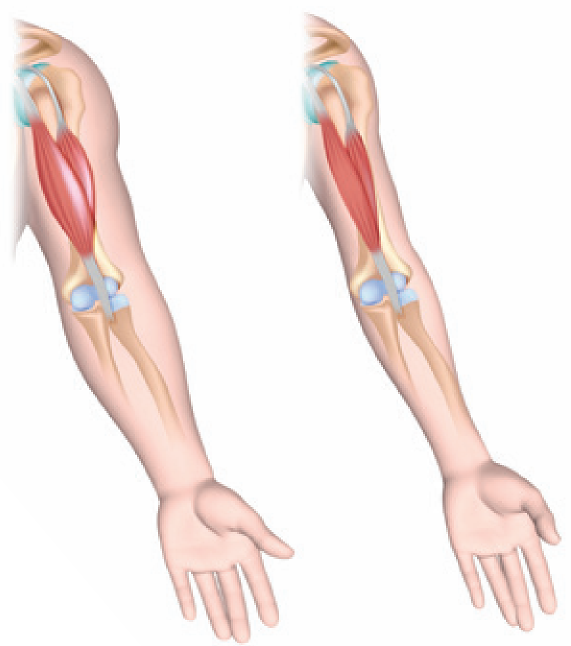
Muscular dystrophy gradually results in the same symptoms, but is a progressive hereditary disorder caused by genetic mutation.

To compensate for reduced strength when operating a joystick, different force joysticks are on the market.

The joystick used on remotes of the Invacare LiNX system, all require a force of 1.9N to operate. This force is much lower than other standard remotes on the market and makes them suitable for a range of users, preventing them from having to opt for an alternative joystick with lower force.

Driving with a proportional joystick means users have to have the ability to control the force they use to operate it, as the powerchair will go faster or slower depending on the throw of the joystick. However, if the user has poor strength, it might not always be possible to do so. In these cases, it is possible to programme the joystick so that any force applied will result in activation.

Normal biceps | **Muscular dystrophy**



Strength

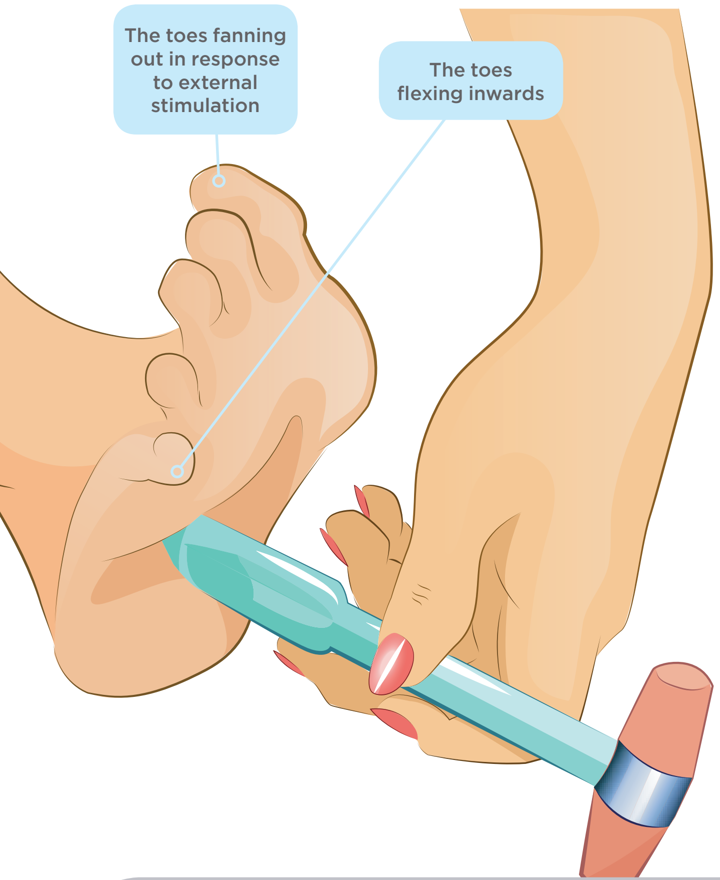
Increased strength

▶ **An injury to the brain or spinal cord can lead to changes in muscle tone.** This affects people who suffer from Cerebral Palsy, Traumatic Brain Injury, Spinal Cord Injury, Multiple Sclerosis or ALS, for example. Impaired muscle tone can cause flaccidity, spasticity and rigidity. A reduction in muscle tone is referred to as flaccidity or hypo-tonicity. When muscle tone is increased, it is referred to as hyper-tonicity or spasticity. For both flaccidity and spasticity, there is an imbalance in tone between muscle groups. The agonist muscle causes the movement through contraction; the agonist opposes this movement by slowing it down and controlling the movement.

When the muscle tone is increased in both antagonist and agonist muscles, we call it rigidity. When rigidity is present, even passive ROM can be hard to achieve.

Babinski Reflex

Plantar Reflex Displayed by Adults

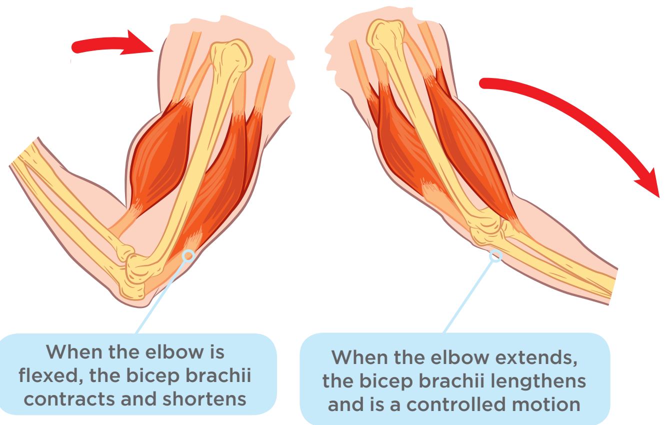


▶ **Over time, spasticity will cause changes in the muscle composition: shortening of the muscles, limited range of motion in the joint, permanent fixation or contracture and ankyloses.** The constant contraction of "spastic muscles" renders the antagonists inactive, resulting in the development of muscular atrophy because of disuse. These effects can notably increase fatigue and make performing daily activities hard.

Handling increased strength or spastic movements can be a challenge, not only for the driving, but also the seated position in the powerchair. Proper posture and positioning are important for people in wheelchairs, to reduce spasms.

The position of the joystick for the user can prevent triggers for spasticity. For example, certain joint positions can be avoided in order to prevent hyperreflexia, or intentional movements can be induced in alternate directions to compensate for unintentional movements, oscillating towards a desired target.

Agonist **Antagonist**



Spasticity is only one of several components of the upper motor neurone syndrome which is characterised by muscle over-activity. Other components can be:

- **Tendon hyperreflexia: overactive or overresponsive reflexes**
- **Clonus: involuntary, rhythmic, muscular contractions**
- **Clasp-knife phenomenon: sudden increase in tone when rapidly and passively contracting antigravity muscles (e.g. extensors upper limb)**
- **Flexor and extensor spasms**
- **Babinski sign**
- **Spastic dystonia**

Endurance

▶ **Endurance refers to the ability to sustain a force over a period of time, like deflecting the joystick whilst driving, but also being able to repeat the action several times a day.**

Sometimes the initial strength will be in the normal range, but after repeating the action a couple of times, there will be a continual decrease in performance until total fatigue occurs.

Fatigue can have multiple causes from mental state to poor blood supply or metabolic illnesses. As described above, spasticity can be very tiring for people and will affect their performance over the course of the day. Poor positioning, or not being able to reposition over time, can also cause fatigue.

The presence of pain can influence the endurance level of an individual. That pain can be consistent, but can also change during the day in response to the activity. To help overcome a lack of endurance whilst using a powerchair, a lower force joystick is suitable as it requires less travel to activate it. Another option can be to activate the "latched mode". This drive mode only needs one initial input to activate it and keeps going until a second input brings it to the next speed up/down or to a stop. This is very useful, for example, if a sip 'n' puff control is chosen as the user would have to puff constantly, leaving them breathless within a couple of minutes. This option is applicable for any control method, as long as safety is taken into consideration. The user needs to be able to deactivate the action or driving at any time. It is recommended to use a mechanical switch for this action but in certain circumstances a proximity switch can also be chosen. For example, sip 'n' puff

users can have a proximity switch positioned close to their mouth so for any reason the control is pulled away from the user, the wheelchair can be deactivated and come to a stop.

On the Invacare LiNX control system, 6 latched drive modes are offered: cruise control, 1 step up, 3 step up, 5 step up, 3 step up/down and 5 step up/down. This offers the user the possibility to make the driving and the transition between different driving speeds as smooth as possible.

Depending on the skill set of the user at the chosen anatomical site, it is the decision of the clinician to select a control interface that best suits the user. Every powerchair supplier has a range of remote options, including alternative controls.

We, at Invacare, want to help make the process of finding the appropriate control interface easier and so we have developed an application, where clinicians can select the skills of the user and the chosen anatomical site. A suggestion for the control interface (with an image and description) along with programme considerations will be provided.

Visit our Powerchair Controls Guide App for recommendations and support on which control is best for the user: **www.linx4you.com**.

The app is also available to download free on the Google Player App Store.

b Control interfaces

▶ Every powerchair supplier has a range of standard remotes so it's good to know the differences and how to identify them.

In 2016, Invacare launched a revolutionary control system, which following customer insight, gives the user control and an enhanced drive experience, whilst also providing simple and easy programmeing abilities for professionals. The Simple Smart technology brought with it a range of remotes options to suit different user needs.

Standard remotes - The Interface

▶ **The group of items (buttons, switches or joystick) on a standard remote provide input to control an operation of the powerchair.**

The joystick will provide the movements forward, reverse, left and right. Other buttons on the remote will give direct access to different functions such as seat functions. The complete set of items that can be selected and the way it is set-up, forms the selection set.

Physical properties of the remote are:

- The size, the weight, the texture or hardness of the remote and the buttons/joystick
- How clear and visible the display is
- The mechanical force required to use the interface; not only the buttons, but also the force needed to operate the joystick

Dimensions

- **The dimensions of the remote - the number of targeted buttons and the spacing between them - are an important part of interface selection or choice.** Buttons that are set widely apart, fewer buttons or even a single button, will work well for people with gross (large) range of motion (ROM) and limited fine motor control. Buttons that are set close together will work well for people who have limited or reduced ROM and require a smaller distance between buttons.

In developing our new LiNX platform, 76 users with a variety of physical conditions were assessed, using a control interface to determine their preferred means of operating the controls and what range of motion they had linked with their condition.

The research showed that the position of the on/off button and the joystick was the most important, closely followed by accessibility of the speed control and ease with which both could be operated.

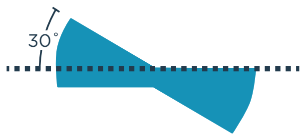
Activation

- **How a control is activated can vary, not only with regard to choice of control, but also the amount of force needed to activate it i.e. the amount of force needed to move or hit the joystick or button.**

The **Invacare LiNX REM100** and **REM200 series** have been designed so that all the remotes in the range look alike, giving them a really intuitive feel when in use.

The force needed to operate the standard joystick on all **LiNX remotes** is 1.9N, much lower than other Invacare standard remotes on the market, making it a suitable for a range of users.

The large centrally mounted speed dial can be operated using both fine and gross hand movements. Buttons are located in such a way to eliminate the possibility of mistakenly activating two buttons simultaneously. No buttons have been placed directly in front of the joystick to ensure ease of access.



Tactile impairment (the loss of touch) and the inability to accurately perceive kinesthetic feedback, can impair an individual's ability to grasp and manipulate objects. **Our sense of touch plays a crucial role in how we identify, interpret and perform grasping tasks, therefore, a choice of buttons can be crucially important.** The force needed to activate a push button, can't be too low so incidental hits are diminished. The recommended button resistance is 3.1 Newton of force. When using a rocker switch, the travel of the switch needs to 30° before it is activated.

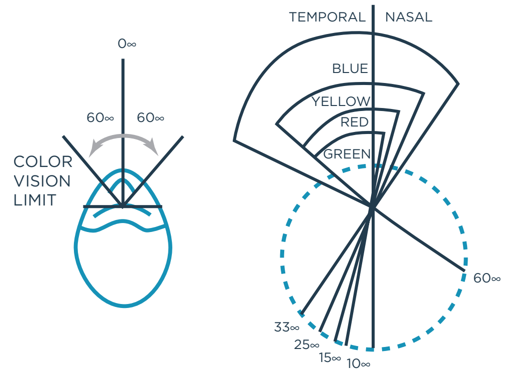
Sensory

- **For every action we do, we receive sensory feedback from our environment.** This is no different for the use of a control interface. Deflecting the joystick will make us move forward and if not, it means something is wrong. The lights used on the remote or the indication of the battery all give us relevant information of what we do or need to do.

On standard remotes, the sensory feedback will mostly be visual. When switches or an alternative control are used, the remote display will give the visual feedback. If vision is severely limited, auditory clicks can help guide the user through the menu. In 90% of the individuals with visual impairments, there is still some usable vision.

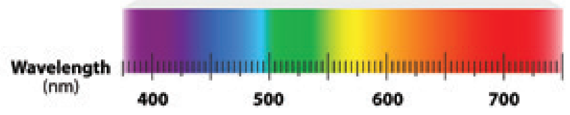
Our eyes are sensitive to colours but they are not equally sensitive to different colours. Our range of vision has an influence on colour differentiation. Choosing the appropriate display and positioning it within the correct range of vision for somebody with visual field loss will determine if they can use the remote or not.

Red objects are seen more readily in the central visual field and, therefore, a red object may be more visible to an individual with peripheral field loss. Conversely, an object that is towards the blue part of the spectrum may be more visible for someone with central field loss and intact peripheral vision.



If an individual has low vision, there are certain things that can be taken into account:

- **Use colours that differ as little as possible in brightness**
- **Avoid colours from the ends of the spectrum (violet and red)**
- **Avoid white or grey with any colour of the same brightness**
- **Avoid colours adjacent to each other in the colour spectrum**
- **Avoid using pastel colours**
- **Spatial considerations**



The Invacare LiNX REM400 and REM500 remotes, with their interactive 3.5" colour touchscreens, have been designed in a way to accommodate people with low vision impairments as much as possible:

- The brightness of the touchscreen can be adjusted to the user's choice or just use the "auto adjust" function. This function ensures the brightness of the screen adapts, whether the user is inside or out in bright sunlight.
- The three main colours used in the colourway of the display indicate drive, seating and connectivity: green for drive, orange for seating and blue for connectivity. Each colourway is distinctively different: the colours of the battery gauge have a different tonality compared to the colours of the display. All the colours used in one colourway complement each other and contrast with the colours of a different colourway.
- All the colours used have been revised for various types of colour-blindness.
- The background used in the display is white, because black will create more reflection and drown out the content on the screen. This is of major importance, as users will not always be able to change their head position.
- The white background is a better contrast with the orange, green and blue.
- The colours used on the screen might not appear to grab people's attention and that is the intention. Users do not want to have a display that draws attention all day.
- Invacare has chosen to work with white letters on the coloured backgrounds as it gives a better contrast than using black on certain colours like orange or blue.

The Invacare LiNX platform currently has five remotes in its portfolio:

- **REM110** This is a drive only remote with a speed dial, on/off button, horn and battery gauge.

- **REM211** This remote looks aesthetically like the REM110, but has more buttons. It has two rocker switches for access to multiple drive functions, seating functions and connectivity

- **REM216** This remote is similar to the REM211, but also has buttons for lights and indicators.

- **REM400** This remote has a touchscreen colour display of 3.5" to navigate through the menu using swipe or tap. If preferred, the joystick or buttons can be used to navigate through the nested menu list.

- **REM500** This remote is a standalone display with the same features as the REM400, except there is no joystick. Instead, an alternative control can be chosen.

Key components of the control system

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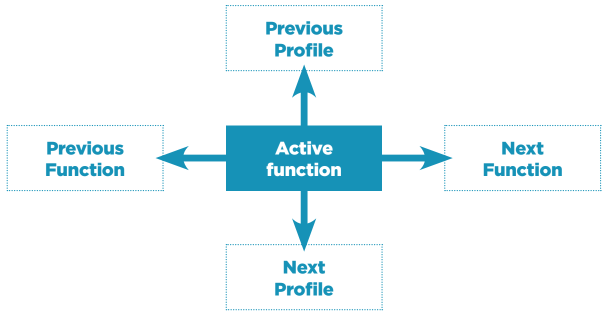
Commands

For a powerchair, the basic commands are forward, reverse, left and right, but there are other commands like tilt, recline, lights, horn etc. The more commands available on the system, the more flexible for the user, however, the more commands, the more complex the system gets.

On the LiNX REM400 and REM500, the chosen commands can be ordered in a way to suit the user. Everybody is different and wants things to be easy, so by having the ability to tailor commands to best suit the user's needs, is a great feature. For example, "I use my tilt function the most and it needs to be easy to access. Next to that, I want fast access to my indoor profile and outdoor profile."

With the **REM400/500**, the user is only one action away from their next function, without having to go through the complete menu:

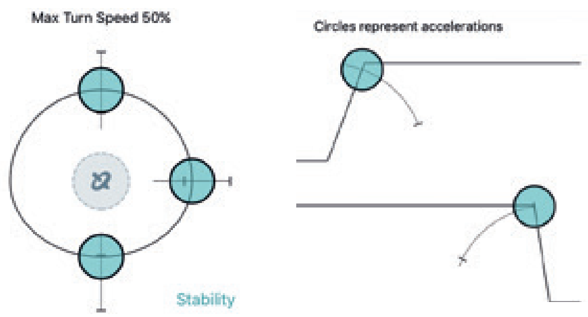


- **Transitioning from one function to another is triggered by either a swipe, a tap, joystick movement, button press or via an alternative control.**
- **The destination function is entirely predictable based on the arrangement of the functions and profile defined.**
- **The arrangement of functions and profiles is configurable for the needs of each individual.**
- **A transition may be blocked due to system status or conditions.**
- **The user input operation is determined by the function.**

Control parameters

The control parameters in LiNX allow adjustments to be made to the system. For example, the forward or reverse speed can be adjusted. The control parameters also make it possible to switch between different applications, like using the joystick for controlling a communication device. Again, as for the commands, the more parameters that can be altered, the more complex the system becomes. It is important to find the right balance between flexibility and simplicity for the user.

Adjusting the drive parameters of a powerchair will affect the speed and responsiveness of the chair. The importance of adjusting the parameters is that it will increase the driving efficiency and that it allows for a customised driving experience.



What common parameters can be adjusted in the LiNX system?

- **Speed:** forward, reverse and turns
- **Acceleration:** how quickly the chair reaches full speed
- **Deceleration:** how quickly the chair gets to a stop
- **Torque:** increase power without increasing speed e.g. carpet
- **Sensitivity of the joystick:** the responsiveness of the joystick e.g. tremor dampening
- **Joystick throw:** shorten the distance to get to full speed or activation
- **Deadzone of the joystick:** change the size of the 'neutral zone' of the joystick
- **Directional movement:** change the function of the direction or eliminate directions
- **Proportional or not**: make a proportional joystick non-proportional like a switch

Data

As the powerchair is being used, LiNX allows information to be collected and stored. For example, when the powerchair is expanded with a new LiNX control, the system will recognise the device and offer a 'standard' program set-up so the provider doesn't have to start from scratch. This action is not commanded by the user or provider, but is a result of the internal system data.

The output of the powerchair, or the activities the chair performs for the user, can be measured in:

- **Magnitude:** Does the chair have enough torque or force to climb my driveway?
- **Precision:** Is the load compensation adjusted to my exact situation?
- **Flexibility:** Is the system expandable over time?

Alternative controls

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When a standard remote with joystick is not suitable for the user, alternative access to the system is required.

An alternative control is any control other than the standard remote. Sometimes it is called a secondary control, which indicates it is an expansion to the standard control. The reason to move to an alternative control can be because the control site or anatomical site is too difficult to reach with a standard remote or the access method of the standard proportional joystick is too difficult to handle and can't be altered by changing parameters.

Between the user and the powerchair itself, information is exchanged. The boundary between the user and the technology, is the place where information is exchanged or the place where they control the powerchair.

Two factors influence this transaction of information for the process to be as smooth as possible:

1. **The anatomical site:** The part of the body that can be used to control a device.
2. **The control interface or in this chapter the alternative control:** The device that is used to control the technology. The control interface can be primarily used to activate the system to allow the chair to drive, but also used to interact with other technologies such as communication devices or environmental controls.

The anatomical site

An anatomical site of the body is capable of performing a variety of movements or actions, which will make it possible for the user to operate the powerchair. As a clinician, the area of the body that gives the most consistent access for independent control needs to be identified. The interaction between the user and the powerchair involves relatively fine control. The hand and fingers are the preferred anatomical site because we typically use the hand or fingers for manipulative tasks. Even if the hand function is limited, the remote can accommodate for limitations in fine motor control through the programmeming of the control system or adaptations of the joystick on the standard remote.

If the fine motor control limitations prevent the use of the hand for the standard remote or any alternative hand control in multiple directions, the use of the head as an anatomical site is also an option, because multiple movements are very likely possible and it is possible to obtain relatively precise control using head movements such as tilting side to side or a forward and backward movement. The control interface isn't limited to the traditional head control (which is not proportional), but is also applicable for the chin or forehead, if that is preferred.

Another possible control site where multiple movement is possible, but not used very frequently, is foot movement. For driving a powerchair, the foot is less desirable because there is no visual monitoring and the foot is generally not as finely controlled as the hand. However, some individuals are able to develop fine control.

After deciding on the anatomical site, the clinician will always look at all proportional joystick options first. If nothing is suitable, non-proportional switches will be looked into.

d

Alternative controls options

The control interface that is used to access the powerchair system can be classified as either proportional or non-proportional.

Proportional controls

A proportional control will provide the user with the most control over their powerchair in all directions of travel and are dependent upon the amount of pressure, or force, applied to the control. The most common proportional controls are:

- **A standard joystick**
- **A mini proportional or minimal-throw proportional joystick**
- **A variety of differently configured proportional joysticks**

Joysticks are classified by their pounds/grams of force or newton's units of pressure; the smaller the amount of pressure required the less force the individual has to exert to operate the powerchair base or any other function that has been programmened in the interface. A proportional input device can be placed virtually anywhere as long as the user has the control to access at least three directions of movement — forward/reverse, left, right — or ideally, four for full access.

It is advised that before moving beyond a proportional control, try making programmeming adjustments to the following features as they may solve control issues:

- **Tremor damping**
- **Three-direction proportional control**
- **Throw**
- **Centre dead band**
- **Reassign direction**

- **The position of the remote doesn't have to be at the armpad.** For many users, they might not even be able to reach the remote on the standard armpad let alone operate it with any level of control. Think of it this way: when performing a controlled movement with your hand – (think of any activity, it doesn't matter what) - when is that hand activity ever in this straight 90° angle in front of you?

When moving away from the armpad, it is often easier to go for an alternative remote or joystick. As these tend to be smaller, the mounting is easier and keeps the access to the front of the chair open which can be helpful when transferring.

Common reasons to move to an alternative control is because of an increased muscle tone, a decrease in motor control, muscle weakness or paralysis. It means the user is not able to balance their flexors and extensors or grade the force and the distance of movement in all directions. Also fatigue throughout the day can be a variable factor.

A midline drive option can be offered to those using alternative controls as it can, for a lot of users, feel more intuitive and offer a significant advantage. The joystick comes more in the line of sight and it also centres the body and takes away the need for the user to lean to one side to reach a joystick mounted on an armrest.

This improves pressure distribution and helps prevent skeleton deformation, such as scoliosis, in the longer term. A midline mount can be prescribed when the user has a limited range of motion or to prevent worsening of postural problems.

If joysticks on a standard remote are not accessible because of its shape, different joystick knobs can be used. Common joystick alternatives are:

- **Standard cone shaped knob:** forearm in mid pronation and grasp of the hand or a more open hand, with the joystick between thumb and forefinger.
- **Vertical slim knob:** mid pronation and bigger grip surface for the hand.
- **T-bar handle:** forearm in pronation.
- **U-bar handle:** forearm in pronation, but the ends of the T-bar facing up to hold the hand in position.
- **Foam ball:** more open grasp of the hand.
- **Arm trough:** better support of the forearm while holding the joystick.

- **The position of the remote itself will be of major importance to make the joystick functional.** For example, it can be difficult for some users to achieve full pronation or it will cause the elbow to stick out, which results in lack of support of the forearm on the armpad. Therefore, sometimes it is necessary to change the position of the remote on the vertical or horizontal axis, but also in angle.

Invacare LiNX proportional alternative control options

▶ **Compact remotes (DLX-CR400/DLX-CR400F)**

Compact joystick with access to multiple profiles and functions, ideal for users with a limited range of motion; also available in a low force joystick version. Similar interface as the REM200 series for consistency.

Alternative joystick options for Invacare LiNX

▶ **Extremity control joystick (ASL138)**

Very small profile joystick with a resistance of about 1/3 of a standard joystick. Ideal for chin control due to the outer shell being resistant to saliva and other foreign objects. Comes with a headrest and an egg switch to allow function and profile changes.

▶ **MEC joystick (ASL130)**

Designed for users with muscle weakness or fine motor control that require a very low force joystick, which can be operated with a limited range of motion. Has a built-in mode change function and a choice of joystick tops and mounting features.

▶ **Compact joystick single switch (ASL133)**

A specially shaped and sized joystick that makes it easier to grab and manipulate. Has a single function switch in the top of the joystick cap and a textured end for a tactile feel, making it easier to hold. The cap of the joystick is moulded to the base, making it ideal for users with high muscle tone/uncontrolled movement.

▶ **Paediatric compact joystick (ASL132)**

A joystick in a compact package designed for paediatric users. Its shallow base makes it ideal for midline mount.

Non-proportional alternative controls

▶ **After ruling out proportional controls, it is time to look at non-proportional – switch or sensor – type devices that drive without a progressive increment from an OFF and ON state i.e. activating a switch will move the powerchair in a particular direction and releasing the switch will stop it – non proportional control.**

Switches are non-proportional – that means when the switch is activated, the powerchair is going at the top speed and the moment the switch is no longer engaged the chair immediately stops. Speed and direction are programmemable of course. Proportional drive systems, such as joysticks, allow users to gradually increase or decrease speed by how far the joystick is deflected from neutral.

The benefit of switches is that they can often be placed in locations that a proportional type device will not easily fit. This is ideal for users who have an exact location with little space for that particular access point. Some examples of switched inputs are a head array, mechanical or electric switches (single and multiple), and sip 'n' puff.

Some non-proportional controls behave like a semi-proportional control, as they allow users to change sensor state or activate functions in a more progressive and smooth increment. For example, when a switch is activated, the powerchair will drive the speed the drive profile is programmemed to and there will be four directions of control — forward, reverse, left and right — with a switch assigned to each direction. Veering directions often can be achieved by activating two switches at the same time, resulting in the powerchair veering forward to the right.

When considering a switched control access, **physical aspects of the switch** to think about are:

- The pressure required to activate the switch: dependent on the user's strength and tone.
- The size of the switch: depends on the movement that will be used to activate it. In general, the smaller the movement, the smaller the switch needed.
- The shape of the switch: dependent on the body part used to activate it.
- The feedback that is given from the switch e.g. auditory click. Consider switches without feedback for users that continually activate for the feedback rather than control of the device.
- The robustness of the switch.
- The tactile perception of the switch and robustness.

Also the activation of the switch should not cause a dramatic change in the pelvic position as this will change the positioning of the rest of the body.

Switch options available include:

- **Mechanical switches**
- **Electronic switches**
  – Proximity switches
  – Fibre-optic switches

The placement of the switch will be key in the process. A misplaced switch can be very frustrating for any user. A consistent switch site needs to be determined. Here is our advise on locating **the ideal switch location:**

- Consider the user's **preferences** and input. They know their own body and motor control best. Also, social aspects may determine where to put a switch, for example, placing a switch close to the head.
- The location of the switch should not cause **fatigue**. The control will only be functional if it is repeatable. Choosing a switch that needs less force, like fibre optic switches, can prolong the use during the day.
- The switch should not increase **muscle tone**. Increased muscle tone will reduce the accuracy and speed to operate the switch.
- The switch should not use or elicit **abnormal reflexes**, unless no other option is available.

Using an asymmetrical tonic neck reflex for activation can reduce accuracy, speed and visual contact with the control as the eyes move in the direction of the reflex and may impede the ability to release the switch.

AOTA Continuing Education Article "Assistive Technology and Switch Access: Occupational Therapy Evaluation" by Michelle L. Lange, OTR, ABDA, ATP, February 2002.

Mechanical switches

▶ **These type of switches must be physically activated to initiate a control command.** The user must depress a surface to cause an activation of the switch. A mechanical switch may be appropriate for several reasons, such as the need for tactile feedback as reassurance that they have activated a switch. In addition, a user may benefit from having switches in different colours to help with learning/recalling the function of each switch. This can be very helpful if a user would be successful in identifying red for forward, black for reverse, and yellow for reset/function change or any combination of the available colours.

Electronic switches

▶ **These require a power source for operation and the need to depress a switch is eliminated.** No force or contact is required to activate, just motion across a field, beam or sensor. Therefore, electronic switches are useful for people that have difficulties with the activation force or release of a mechanical switch. That can be the case if there is limited movements and/or limited strength. Examples of electronic switches are proximity switches and fibre optic switches.

Proximity switches

▶ **Proximity switches require require a body part to enter the field of the switch.** They can be placed in any position required that the user can reach and will operate through most materials, depending on the thickness. Proximity switches do not require pressure to activate. The user only needs to move some part of their body near the switch to activate it. For example, these switches can be mounted on the underside of a tray and the user simply moves their hand on the tray from switch to switch to operate the wheelchair.

A good application of proximity switches can be found in the ASL head arrays:

ASL ATOM head array (ASL104)

▶ The head array has three innovative proximity sensors mounted in the headrest which allow the user to control the direction of the powerchair with ease.

- **Inside the back pad** = Forward (or forward and reverse depending on how the chair is programmed)
- **Left wing** = Left;
- **Right wing** = Right

A key benefit of sensors over switches in the ATOM Head Array is their superb reaction to proportional input, ensuring a more intuitive drive if the user is driving through a busy street and needs to change direction frequently, for example. Veering can also be easily accomplished by activating the sensor in the back pad along with either the right or left sensor.

If more than five functions are needed (including the three in the head array), an additional switch is required.

The ASL PROTON Head Array (ASL104P) also comes with proximity switches, but has adjustable wings to allow for better functionality:

- **Extend and retract**
- **Side panel movement**
- **Move close to or away from the head**
- **Pad rotation**
- **Swing away for transfers**

There is also the ASL Four Switch Proximity array (ASL106) which has four proximity sensors mounted on a tray to allow the user to operate a powerchair with only a defined range of motion and no force.

It is desirable to have several switch sites, because every site will have one function

▶ **Fibre optic switches are thin transparent fibres (plastic) that emit an invisible beam of light (works through internal reflection) that can be positioned to be broken by a body part for switch activation.** A fibre optic switch would be suitable to operate a single switch scanning system.

Common locations for a fibre optic switch could be the chin area and the tray top. For example, holes would be cut into a tray top with beams directed up.

The user would move a finger across the hole corresponding to the direction of choice to move the wheelchair. Direction and speed are set, but programmemable.

The clinician will assess the user for usable single movements they can perform with their body.

The movement needs to be able to activate the chosen switch. Control sites can be in the:

- **Hand:** switches positioned at an angle are often easier to activate than those in a horizontal position.
- **Head:** head arrays or attachments to the wheelchair headrest.
- **Mouth:** e.g. sip 'n' puff.
- **Other upper extremity locations:** may use gross movement with arm, switch can be attached to multiple locations on a wheelchair or the table tray.
- **Foot:** attached to footrest or legrest.
- **Other lower extremity locations:** knee-ab/aduction, hip flexion-mounting under table tray.

It is desirable to have several switch sites, because every site will have one function. The use of switches will take more time compared to using a proportional joystick. If there is only one or two switch sites available, the user will probably need scanning to go from one function to the other.

A combination of both mechanical and electronic switches available with LiNX is the ASL Sip 'n' Puff control.

ASL Sip 'n' Puff Head Array (ASL109)

▶ The sip 'n' puff head array is an alternative powerchair control designed for users with absent upper and lower-extremity function and poor head control, but do have lateral head movement and weak breath control volume.

Any puff on the sip 'n' puff head array can equal forward and any sip equals reverse as the right and left turns are controlled by proximity sensors located in the lateral pads of the head array. Non sip 'n' puff head array systems rely on differentiated hard and soft sips and puffs to operate all four directions.

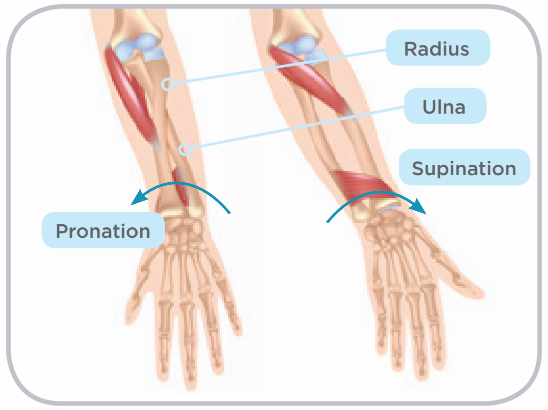
The lip switch is used to change the function or profile on the powerchair E.g. short press equals function change and long press equals profile change.

This set up allows for intuitive steering and veering, which can be achieved by rotating the head toward the left or right pad sensor while going forward in the latched mode.

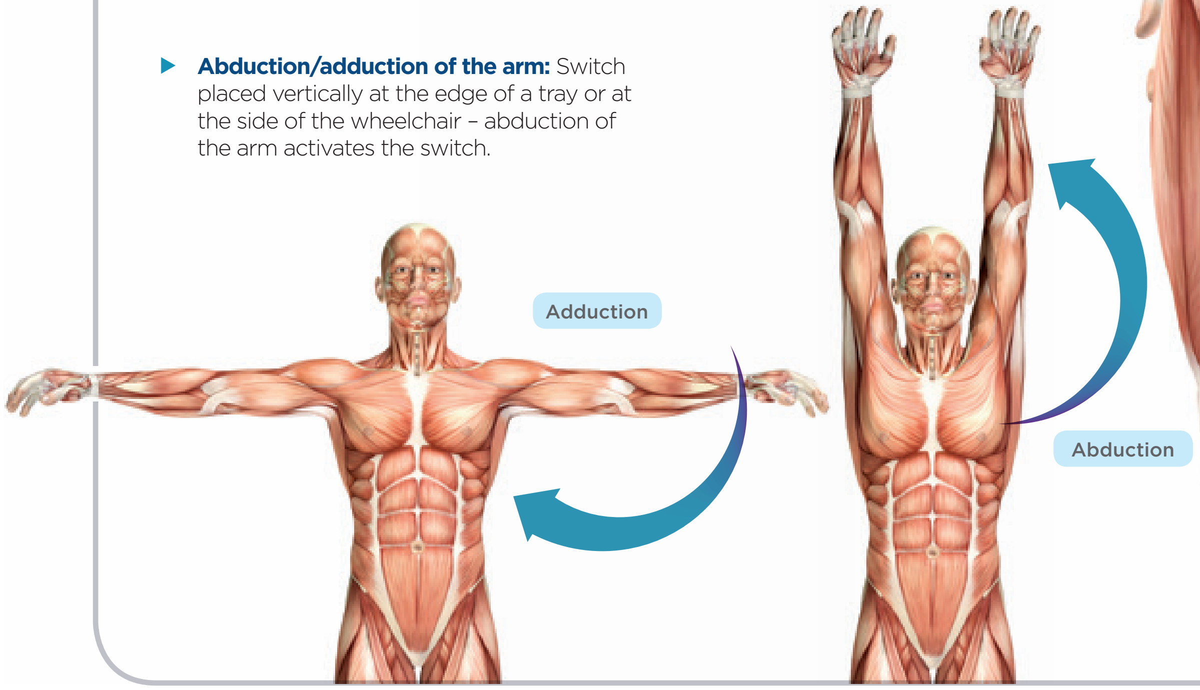
For every possible controlled movement there are switch options. Some examples include:

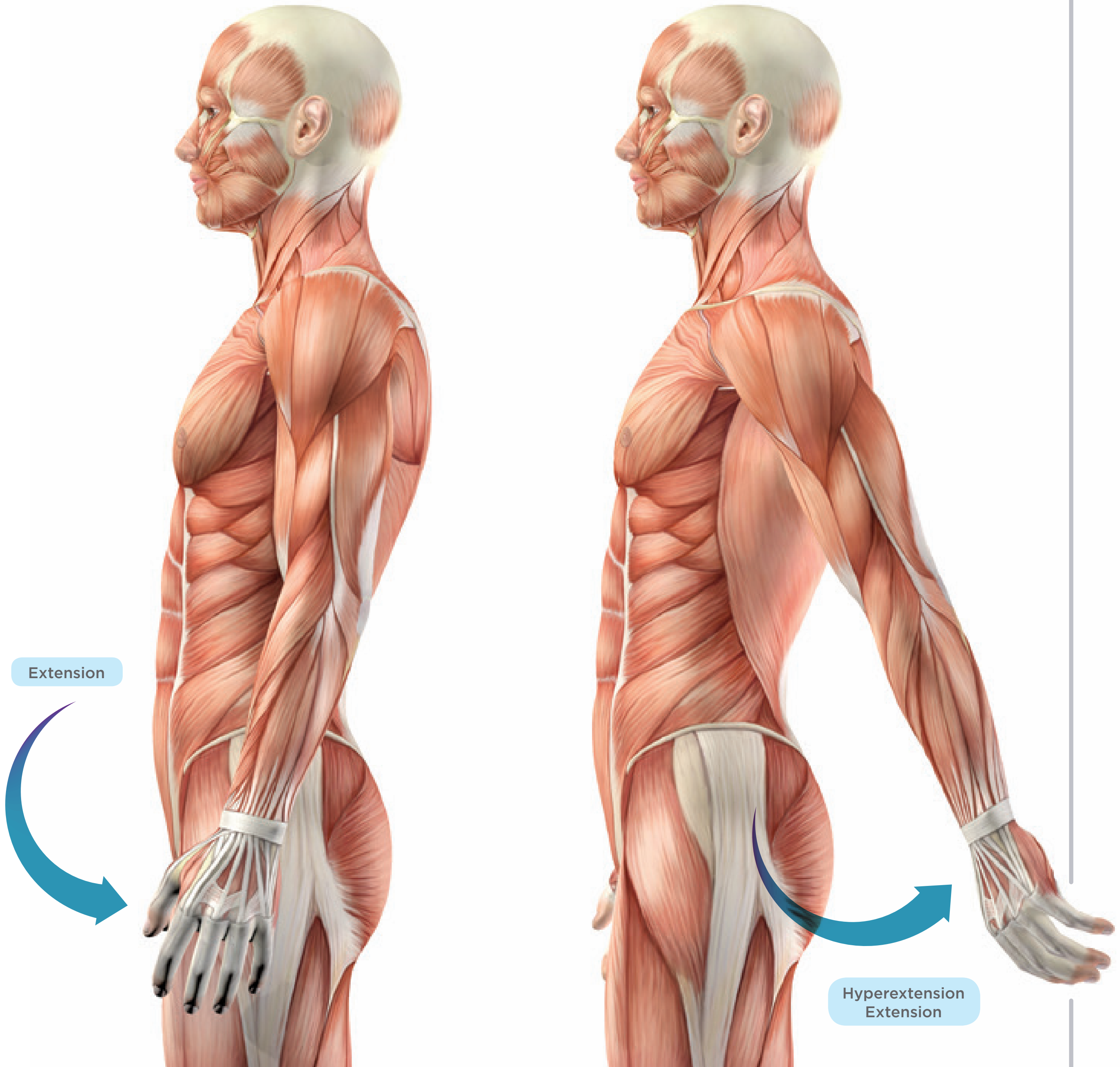
- **Shoulder flexion/extension:** A switch placed vertically in front of the resting hand. The arm moves forward with shoulder flexion to activate the switch.
- **Lateral neck flexion:** Switches on the sides of the head.
- **Neck rotation:** Switches on the sides of the head.
- **Hip/knee adduction/abduction:** Switch placed vertically to the outside of the knee.
- **Adduction/abduction of the foot:** Switch placed on the sides of the foot.
- **Knee flection/extension:** Switch placed in front of the foot; extension will activate the switch.
- **Forearm flexion/ extension or wrist flexion/extension:** Switch placed above the hand/arm can activate the switch.

- **Pronation/Supination of the forearm:** Switch placed at the lateral side of the hand; palm down (or in mid prone), turning the hand to palm up in supine will activate the switch.

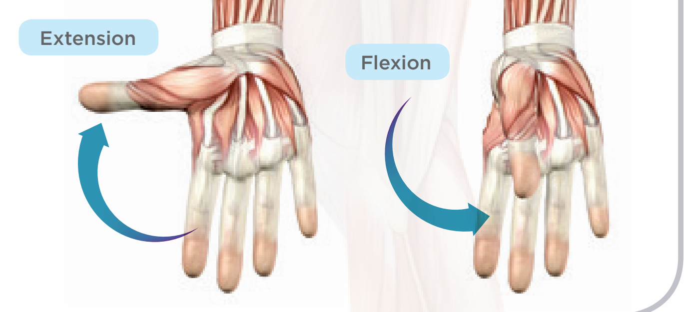


- **Abduction/adduction of the arm:** Switch placed vertically at the edge of a tray or at the side of the wheelchair – abduction of the arm activates the switch.





- **Thumb extension/flexion:** Hand resting on a tray, fibre optic switch is placed in the tray on the thumb side of the hand; extension of the thumb will activate/deactivate



Scanning

e

- When all proportional and non-proportional multi switch controls are ruled out and there is access to one or two switches, scanning is an option.

Controlling a powerchair through scanning is not the easiest choice as a function needs to be scanned, then selected and then activated, followed by scanning for the next function, selecting and activating etc. It is very time consuming. Imagine using scanning for driving. Every deviation from a straight line, is a different direction/function.

With scanning, all functions are presented on a display and each function is sequentially indicated. When the particular function that the individual wishes to choose is presented, the user activates the switch. Depending on the needs of the user, scanning can vary in the format.

The advantage of scanning is that it requires very little motor control to make a selection and a switch can easily be placed at ANY location.

Skills:

- **Good visual tracking system**
  - The display must be within the field of vision for the user, but not interfering with the vision for driving
  - The user must be able to track the scanning on the screen and in all kinds of environments
- **High degree of attention** is needed
- **Ability to sequence:** The user must hit the switch at the appropriate time. Timing is everything. In most cases, training is really important and the scanning time is programmemable.
- **One movement:** Only one consistent movement is needed, but the user must be able to hold the movement and be able release the switch also in emergency situations.

Maximising the scan rate:

If the scan rate is too high, it will be impossible for the user to make accurate selections.

If the scan rate is too low, it can be really frustrating for the user that he is slower than his potential.

A reliable and systematic method for selecting the most appropriate scan rate for single-switch scanning, is the "0.65 rule" (Simpson et al., 2006):

Reaction time of the user / 0.65 = scanning rate per second

Example: the reaction time to hit a switch (this can easily be measured) is two seconds.

2 seconds / 0.65 = 1.3 seconds scanning rate

Scanning with LiNX REM400 and REM500

To use scanning the selection of the appropriate controls is important. With the new LiNX control system, we have created features that will make the use of scanning less time consuming and easier.

Display

▶ **Developing the coloured display of the REM400 and 500, a lot of research and considerations were made to come up with the right colours and visibility in all circumstances.**

Apart from the standard icons that are displayed on the screen to visualise the functions, the user has access to a **nested menu navigation**. A drop down list that makes step scanning easy.

An example: They have three profiles – **house**, **outdoor** and **school**

First scan through the profiles and select the one needed. After that, go through the different functions in that profile.

1. Profile selection → 2. Function selection

House → Indoor slow, Tilt, Recline

Outdoor → Cruise, Tilt

School

The scanning can be programmemed to start from the top of the list or to start where it previously ended. There is also the option to add or delete profiles to the users needs.

Profile set-up

▶ **The standard Drive and Seating profiles are no longer a fixed factor thanks to ability within LiNX to mix and match the drive, seating and environmental controls.**
Please see the table below for examples of what is available:

Example 1

Profiles:	Drive 1 Drive 2 Drive 3
Functions:	Tilt Recline Elevate Riser LNX (legrests)

Example 2

Profiles:	*Indoor*	Low speed drive Tilt Recline Legrest
	Outdoor	Maximum speed drive Riser Tilt

Profiles can also be set by remote options i.e. head control, chin control, attendant control plus the name of the profiles can be changed to something more memorable.

For scanning, this means that each profile can be set up individually – functions not used in a certain environment can be invisible. One of the profiles can be called 'my house' with the functions set up to the user's preferred way.

An example: As you approach your house, you lower your speed. To access the door, you have to go down a ramp. You always tilt your chair back. Once you entered the house, you tilt back and go check out your mail on your computer.

The setup of the 'house' profile can be:

- Driving at lower speed – **indoor slow**
- Tilting to take the ramp – **tilt**
- Driving of the ramp – **indoor slow**
- Tilting back after the ramp – **tilt**
- Driving to the computer – **indoor slow**
- Accessing the computer – **connectivity**

Functions can be added or repeated in the same profile which means, using scanning, the order of the function sequence can be personalised without the need to go through all the seating or driving functions.

Evaluation of the controls

▶ During the assessment, it is important to identify and look possible body movement to control the interface.

The goal of the body function evaluation is to determine the most functional position for the individual and evaluate their ability to access the wheelchair controls independently.

What needs to be evaluated?

- **Motor control: fine and gross motor skills**
- **Range of motion: both the passive and the active range of motion**
- **Muscle strength**
- **Endurance**
- **Muscle tone and the presence of primitive reflexes and reactions**

It is important to note that the presence of a neurologic disorder will affect both range of motion and strength. The 'standard' procedures for the evaluation might be influenced, because the position of the person affects his muscle tone and as a result their range of motion and strength.

Muscle tone and the presence of obligatory movements are important considerations for individuals with neurologic disorders. The position of the individual affects the available movement. Muscle tone must be assessed in various functional positions, like prone, supine and sitting.

Reflexes and obligatory movements also need to be assessed to determine how they affect the movement or function. Key tone reflexes to assess are:

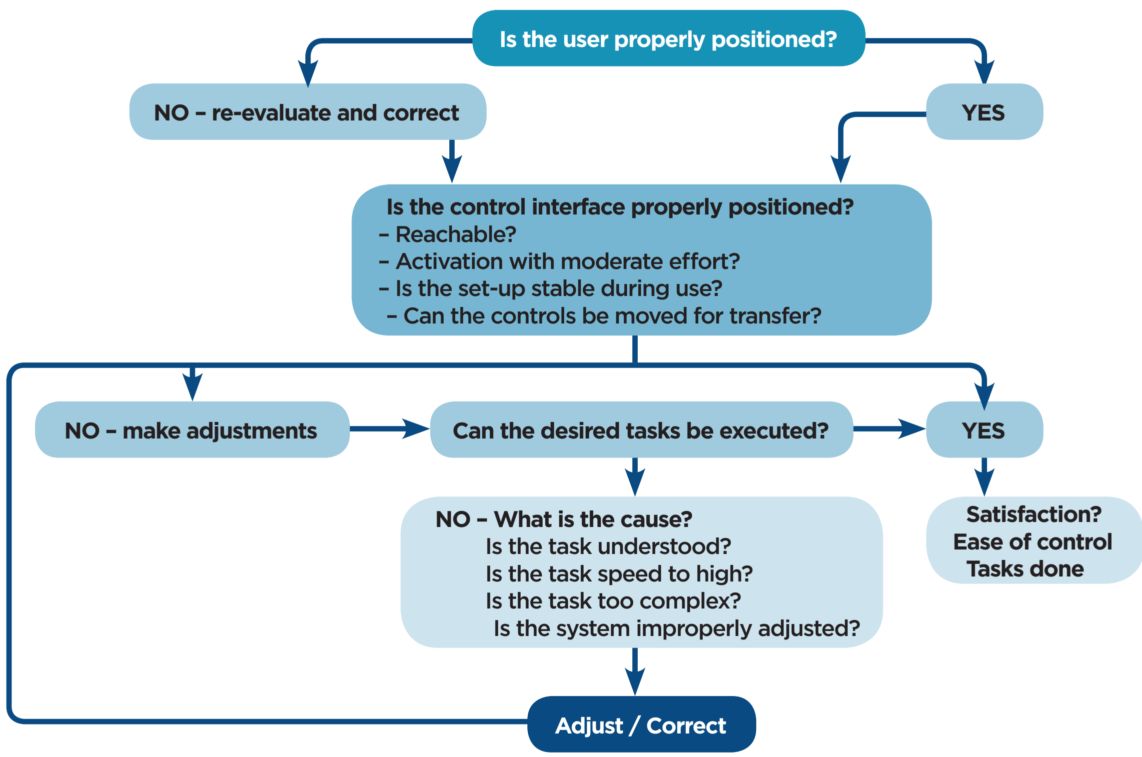
- Asymmetrical and symmetrical tonic neck reflexes
- Tonic labyrinthine reflex
- Extensor thrust
- Bite reflexes
- Grasp reflexes

The ability to right the head when moved out of a vertical alignment, either lateral or in the anterior-posterior plane, is another component. Postural control is a related component that refers to the ability to maintain the trunk in a vertical alignment.

When completing an assessment to determine function in various positions, it is important to handle the user and to challenge the balance and postural control, to determine the degree of support that is needed to work in a given position and the movement available in that position.

Fine and gross motor assessments generally test higher level motor skills. Gross motor skills include balance exercises with symmetrical and asymmetrical movements and coordination.

Evaluating the effectiveness of the controls set-up



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Invacare International Sàrl
Route de Cité-Ouest 2 - 1196 Gland
Switzerland
Tel: +41 (0)22 354 60 10
Fax: +41 (0)22 354 60 11
hqeurope@invacare.com
www.invacare.eu.com

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