Al-Mustaqbal University

Biomedical Engineering Department

Class: 3rd

Subject: Rehabilitation Science

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2nd term – Lect. 4: Seating and Mobility.

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The Global Need for Wheelchairs

- The WHO (World Health Organization) estimates that 1% of the world's population, approximately 75 million people, needs or could benefit from using a wheelchair as their primary means of mobility.
- This need will become more pressing in future years due to the global increase of chronic health conditions and the aging of the world's population.
- In the United States alone, 3.6 million people are wheelchair users.
- Unfortunately, the WHO estimates that only between 5% and 15% of people who actually need a wheelchair have access to an appropriate one.
- Discrimination against people with disabilities, a lack of funding, and a lack of trained personnel are significant barriers to the human right of personal mobility.

Appropriate Wheelchair Provision

- The ability of people who require a wheelchair to successfully participate in their community and regain independence depends entirely on access to appropriate and adequate wheelchairs.
- An appropriate wheelchair is defined as one that meets the user's needs, provides optimal fit and postural support, meets the demands of the environment, and is maintainable and repairable.
- When a wheelchair is not appropriate, it is likely to cause secondary complications such as pressure sores or repetitive strain injuries.
- Inappropriate wheelchairs can lead to a decrease in independence and self-esteem, leading to the abandonment of the technology and wasted resources.

Wheelchair Service Delivery Frameworks

- In 2008, the WHO published Guidelines for the Provision of Manual Wheelchairs in Less Resourced Settings to help countries develop formal systems of provision.
- WHO WSTP (World Health Organization Wheelchair Service Training Packages): The 2008 guidelines served as the foundation for these training packages. The WHO WSTP aims to expand wheelchair service provision, focusing on developing countries where the need is greatest, and supports the minimum skills required by personnel (managers, rehabilitation professionals, and technicians).

Wheelchair Service Delivery Frameworks

- The WHO WSTP describes eight critical steps needed for appropriate wheelchair provision: (1) Referral, (2) Assessment, (3) Prescription, (4) Funding and ordering, (5) Product preparation, (6) Fitting and adjusting, (7) User training, and (8) Follow-up, maintenance, and repairs.
- ISWP (International Society of Wheelchair Professionals): Founded in 2015 with the specific goal to professionalize the wheelchair sector globally. Because there is currently no internationally accepted way to measure competency in providing wheelchair services, the ISWP works to coordinate education and training initiatives.

AT Service Delivery Team

- A successful AT (Assistive Technology) service delivery model includes multidisciplinary collaboration.
- The person with a disability must be at the center of the process and holds the final decision-making authority.
- A model AT assessment team consists of the client, a physiatrist, a physical or occupational therapist, a speech and language pathologist, a rehabilitation engineer, and a certified equipment supplier.

AT Service Delivery Team

- The AT team must understand how physical capacity and limitations affect mobility and the conduct of ADL (Activities of Daily Living).
- ATP (Assistive Technology Professional): A specialized training certification. Ideally, the physical/occupational therapist and the wheelchair supplier should both have their ATP certification.
- RESNA (Rehabilitation Engineering and Assistive Technology Society of North America): This organization provides a searchable list of certified ATP providers (therapists and suppliers) across the United States.

Transportation for Wheelchair Users

- Driving is essential for many adults to participate in meaningful activities, carry out valued roles, and be mobile outside their home environments.
- CDRS (Certified Driver Rehabilitation Specialists): These are trained professionals who aid in determining the type of adaptive driving technology best suited to a client's goals and ability. Their assessment includes the client's wheelchair, transfer skills, functional abilities, and vehicle type.

Transportation for Wheelchair Users

- Vehicle structural modifications are indicated when barriers impede vehicle ingress or egress, or affect safe wheelchair transport and securement.
- Examples of significant structural modifications include lowered floor mini-vans with side or rear entry ramps and side entry hydraulic platform lifts installed on trucks.
- Kneeling systems can be added to lower the vehicle floor closer to ground height and decrease the angle of a ramp entry system.

Adaptive Driving Equipment & Safety

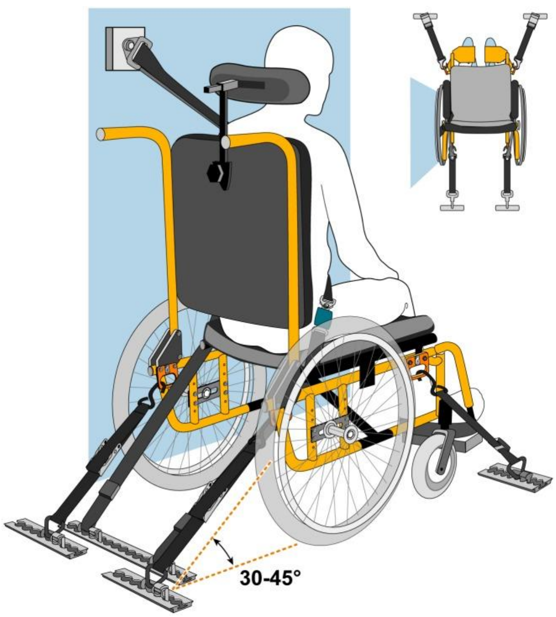
- High-tech adaptive driving devices can control vehicle functions with a designed logic system or integrate with the electronic system of the vehicle.
- Low-tech modifications include manual gas and brake hand controls, parking brake extensions, and transmission shifter levers.
- OEM (Original Equipment Manufacturer): This abbreviation refers to the original components built into the vehicle. High-tech systems may interface with OEM electronics, and low-tech options may be extensions for OEM turn signals.

Adaptive Driving Equipment & Safety

- When traveling in a vehicle, it is generally safest for wheelchair users to transfer to a standard vehicle seat and use the OEM seatbelt system.
- If transferring is not feasible, the wheelchair should be forward-facing and secured to the vehicle with tiedowns (a 4-point system), and the rider should use a crash-tested lap and shoulder belt.
- A WC-19 compliant wheelchair is optimal due to its specific design and testing for use as a seat inside a moving vehicle.

Wheelchair Tiedown and Occupant Restraint System (WTORS)

WTORS consisting of two tiedowns securing the front of the wheelchair, two tiedowns securing the rear of the wheelchair, and including both a lap and shoulder belt for occupant restraint.



Basic Seating Principles

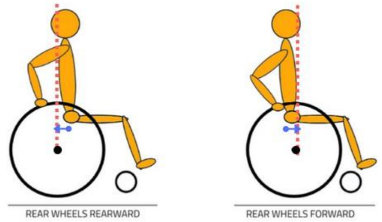
- Understanding the user's physical presentation allows the clinician to determine the selection of the wheelchair base and frame.
- Seating systems can be mounted to a "static" frame, where all seat angles are fixed, or to a "dynamic" seat frame with adjustable features such as tilt and backrest recline.
- A "dynamic" sitter is someone who is able to conduct independent, functional transfers and independent, effective weight shifts for positioning and pressure relief.
- For a "dynamic" sitter, a "static" seat frame, such as a manual wheelchair or a push rim-activated power-assist wheelchair, is appropriate.
- A "static" sitter is someone who has lost the ability to conduct independent weight shifts and is at increased risk of pressure sores.
- For a "static" sitter, a "dynamic" seat frame containing a power seating system (power tilt, recline, seat elevator) is highly indicated.

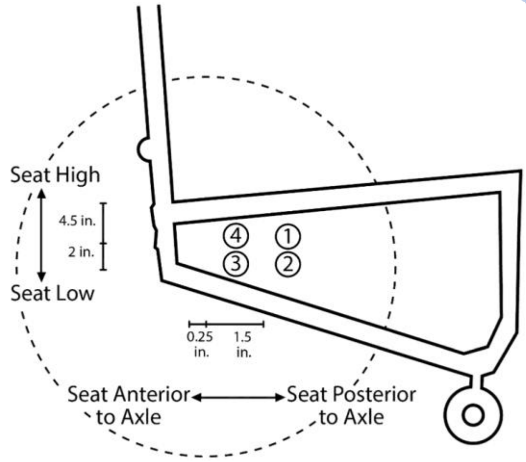
Manual Wheelchair Classifications

- Manual wheelchairs are typically classified into three categories: standard/depot, lightweight, and ultra-lightweight.
- Standard/depot wheelchairs weigh more than 36 lbs, are non-adjustable, low-cost, and intended for indoor hospital use or multiple-user transports.
- Lightweight wheelchairs weigh 34-36 lbs, are minimally adjustable, and are intended for short-term use.
- Ultra-lightweight wheelchairs generally weigh less than 25 lbs.
- RSI (Repetitive Strain Injuries): Because manual wheelchair propulsion is like "walking on your hands" and is not a natural phenomenon, people who propel manual wheelchairs have very high incidences of upper extremity RSI that significantly impair function.
- Ultra-light manual wheelchairs feature an adjustable axle position, camber, and seat angle; proper fit and alignment of the rear axle position can significantly reduce the potential for RSI.

Manual Wheelchair Classifications

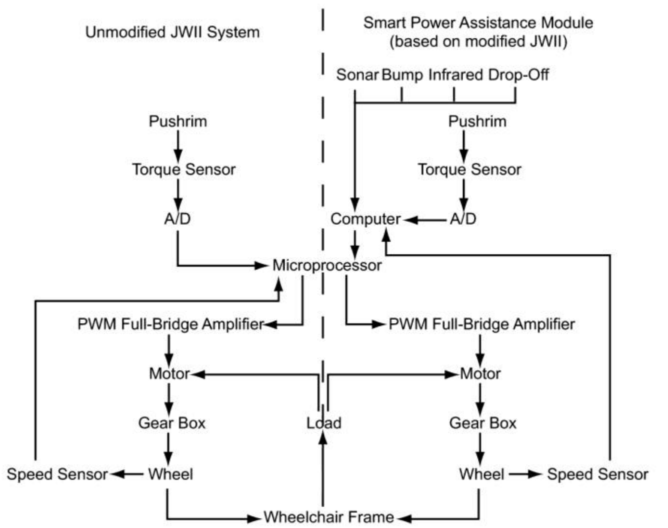
- Significant differences in the speed with axle position 1 (1.57 m/s) versus 2 (1.55 m/s) and position 2 (1.55 m/s) versus 4 (1.52 m/s).
- Modifying the rear axle position can improve propulsion speed and alter the shoulder range of motion during wheelchair propulsion of individuals with spinal cord injuries.





Power-Assist Technologies (PAPAW)

- PAPAW (Pushrim-Activated Power-Assist Wheelchairs): These are hybrid devices requiring users to stroke the hand rims to activate small, lightweight motors that drive the wheels for a brief period of time (seconds).
- The PAPAW provides the benefits of a lighter frame equipped with quick-release wheels for ease of stowage, allowing for continuation with active self-propulsion.



A prototype power assist wheelchair that provides for obstacle detection and avoidance for those with visual impairments

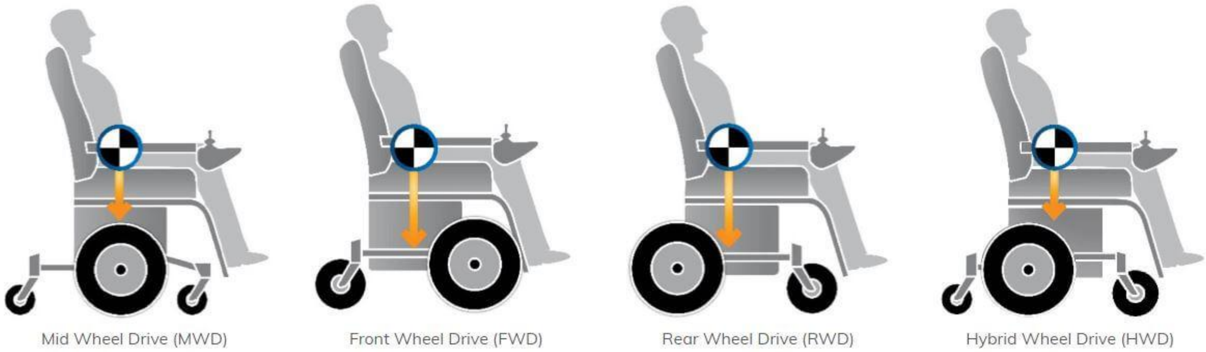
Power-Assist Technologies (PAPAW)

- Research studies have found that power assist wheels reduce stress on upper extremities, reduce metabolic energy expenditure, and improve mobility and participation.
- The "SmartDrive" is a specific power assist system designed to provide auxiliary power to manual wheelchairs to reduce the pushing power and push frequency.
- The SmartDrive system is lightweight, attaches to the back of a manual wheelchair, and assists the user in going up the steepest ramps and thickly padded carpets.

Powered Wheelchairs

- Power wheelchairs are motorized devices that are operated by a joystick or an alternative input device.
- The location of the drive wheels determines how the chair will steer, handle various terrain, and how stable it will be.
- CoG (Center of Gravity): The relationship between the drive wheels and the wheelchair's CoG defines its classification.
- RWD (Rear-Wheel Drive): The drive wheels are located toward the rear of the frame, behind the CoG. RWD provides good directional stability at higher forward speeds.
- FWD (Front-Wheel Drive): The drive wheels are located toward the front of the frame, in front of the CoG. FWD chairs are excellent at climbing obstacles, but they are prone to "fish-tail" on ramps.
- MWD (Mid-Wheel Drive): These chairs have a six-wheel design with the drive wheels directly in the center of the frame, close to the CoG. MWD provides the most intuitive maneuvering in tight areas due to its small 360-degree turning radius.

Powered Wheelchairs



Powered Wheelchairs

Rear Wheel Drive (RWD)

Mid Wheel Drive (MWD)

Front Wheel Drive (FWD)

Power Seating Features

- Power seat features accommodated on a power wheelchair base include tilt-in-space, recline, elevating leg rests, and seat elevation.
- Power tilt-in-space maintains the backrest angle while shifting orientation; 45 degrees of tilt is recommended for effective pressure relief and preventing the user from sliding out.
- Power recline provides up to 120 degrees of pressure relief and safely accommodates limited hip flexion.
- Power-elevating leg rests assist of managing lower extremity edema and allow adjustment to fluctuations in muscle tone.
- The seat elevator adjusts seat height to accommodate limited upper extremity range of motion and elevates the user to eye level for healthy social interactions.
- Control systems are typically joysticks, but users with limited extremity strength can use alternative controls such as sip-and-puff, head control, and chin control.

Power Seating Features

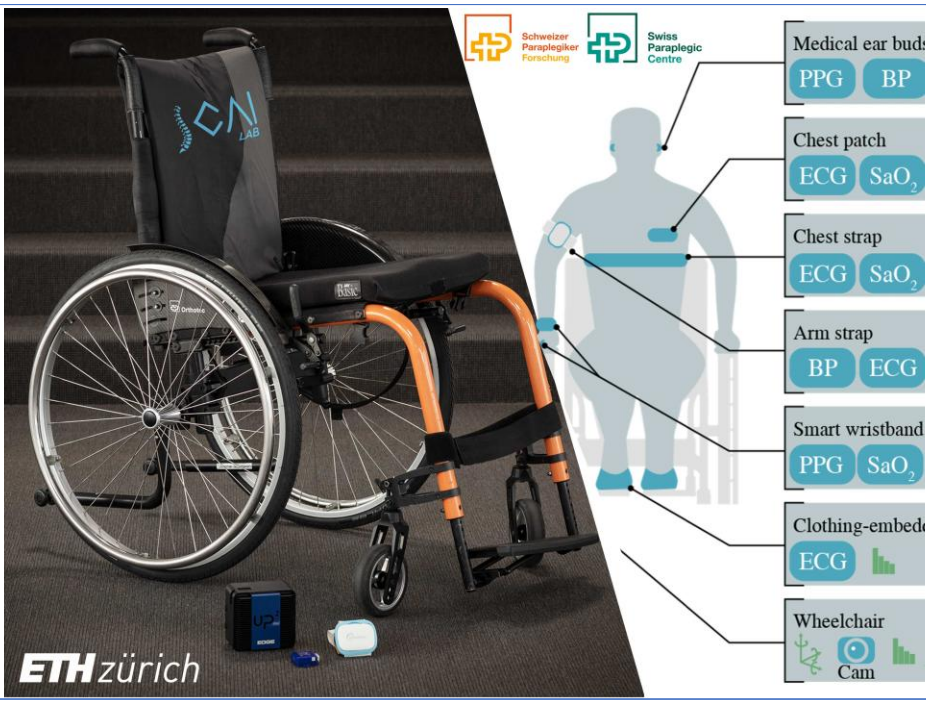
- Wheelchair “Rea Dahlia 45” (Invacare®) in the upright reference posture (a) and the maximum tilted/reclined position (b). The pivot point of the backrest is highlighted in red.

(a)

(b)

Robotic & Smart Wheelchairs

- EPW (Electric-Powered Wheelchairs): In the United States, about 15% of wheelchair users utilize EPWs.
- Current commercial EPWs are still unable to overcome many architectural barriers, such as curbs, steps, and significant slopes.
- Advanced powered wheelchairs are divided into two basic categories: devices that sense and respond to their environments (smart wheelchairs), and devices with mechanical configurations that perform difficult tasks like stair climbing.
- Smart wheelchairs incorporate technologies for navigation and obstacle avoidance, including machine vision, sonar, and infrared sensors.
- LRF (Laser Rangefinder): A critical sensor used in advanced models. For example, a Toyota MOBIRO personal mobility robot was fitted with a sweeping LRF to detect and map stationary obstacles, allowing the wheelchair to navigate autonomously.

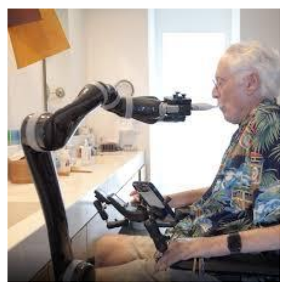


Stairclimbing Wheelchairs

- Obstacle-negotiating wheelchairs have been designed with several mechanisms.
- The simplest implementations involve exceptionally large wheels or tank-like treads, though they struggle to navigate indoors and can damage surfaces.
- Leg-wheel hybrids consist of wheels mounted at the end of structures that use sliding or swinging motions to position wheels on different surface levels.
- Spider wheels comprise small wheels mounted radially around a central hub; when an obstacle is encountered, the hub turns to place a new set of wheels on the higher surface.
- The famous iBOT 3000 used a balancing mode to lift the user to standing eye level and a stair-climbing mode that rotated the wheel clusters to step up and down stairs.

Assistive Robotic Manipulators

- In the US, about 19.9 million people have difficulties with physical tasks related to upper extremity functioning like lifting, grasping, dressing, and eating.
- ARM (Assistive Robotic Manipulators): These devices provide enhanced assistance to people with impairments in completing ADLs independently while a care attendant is not on site. ARMs can be mounted either on a powered wheelchair or a standalone mobile base.
- Two highly notable commercialized ARMs include the iARM (with a two-finger gripper) and the JACO manipulator (with a three-fingered hand).
- PerMMA (Personal Mobility and Manipulation Appliance): This is the first wheelchair to integrate bimanual manipulation. PerMMA integrates a smart powered wheelchair and two dexterous robotic arms to assist users in completing essential mobility and manipulation tasks.
- PerMMA aims to improve functional performance with three control interfaces: local control, remote-control, and an assistive interface.



Transforming Lives with the Jaco Robotic Arm

Assistive Robotic Manipulators

Transforming Lives with the Jaco Robotic Arm

Wheelchair Design Principles

- The most important principle in wheelchair design is a thorough understanding of the user's characteristics and needs of the exact user.
- Design considerations must include demographics, physical/mental limitations, preferences, environmental conditions (dry/humid), and driving surfaces (smooth/rough).
- Rigid Frame Designs: Customized to perfectly fit the body of the user, optimized for performance, and allow for easier turning by placing more weight on the rear wheels.
- Rigid frames weigh very little (as little as 5 kg), place less stress on shoulder joints, and have fewer moving parts, making them highly durable.
- Folding Frame Designs: Utilize an X-style frame allowing them to fold for transport, but this requires casters to be behind footrests, placing a heavier weight on the front casters.
- Folding frames are heavier, not as durable, and require more maintenance due to the movable parts.

Four Ergonomic Principles

1. Weight: The lowest possible weight is a primary design goal to reduce the force required to propel, maneuver, and transport the device.
2. Stiffness and Strength: Frames should be extremely strong and highly stiff so that user energy is transferred directly to motion without being dissipated.
3. Resistance: Rolling resistance is minimized by careful wheel and bearing selection, while internal friction (frame flexing) must be minimized as much as possible through the structural design.
4. Ergonomics: The biomechanical goal is for the fitting and positioning of the user to maximize control of the wheelchair with minimal physiological effort.

Wheelchair Maintenance

- The WHO strongly recommends that wheelchair users receive training on wheelchair maintenance at home and have access to repair services.
- A wheelchair in a state of disrepair becomes a barrier to social participation and can cause severe secondary injuries like abrasions, head injuries, and fractures.
- Research shows that up to 99% of inspected wheelchairs needed some level of maintenance to perform correctly.
- Over 63.8% of users reported needing at least one repair in a six-month period, and 27.6% reported suffering an adverse consequence because of the breakdown.
- Common adverse consequences included injury, being stranded, and decreased quality of life.
- When maintenance is properly performed, accidents and injuries to users are significantly less likely.

Digital Fabrication & Customization

- VA (United States Department of Veterans Affairs): A federal agency that employs clinical rehabilitation engineers who have successfully introduced digital design and fabrication directly into rehabilitation clinics.
- These engineers use digital design software and additive manufacturing (3D printing) to create custom solutions when commercial options fail to meet a client's specific needs.
- FDM (Fused Deposition Modeling): This is the most readily implemented additive manufacturing method in clinical settings because printers are small, easy to operate, and produce functional parts for client use.
- SLA (Stereolithography) and SLS (Selective Laser Sintering): These are additional, though more expensive, additive manufacturing methods that offer different material selections suited for different applications.
- Giving clients the chance to co-create custom assistive technology tailored to their exact needs fosters greater ownership, reducing the likelihood of abandonment.
- Engineering examples include printing ergonomic adapters for wheelchair joystick toggle switches to allow users with quadriplegia to reliably actuate controls.

Thank You
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