

White Paper

Evidence based development CoMoveIT Smart



In this white paper you will learn how KU Leuven's research groups have combined clinical and technological expertise to tackle the critical challenges of enabling independent mobility for individuals with complex movement disorders, such as cerebral palsy (CP).

This exploration addresses key questions, including:

- How can we achieve the fundamental right to independent mobility for those with CP and other complex movement disorders?
- What technologies allow us to analyze movement patterns and provide a driving tool at the same time?
- How can we accurately assess the severity of movement disorders?
- What insights can we gain from clinical evaluations conducted during driving, and how can these findings be translated into actual mobility solutions?

Join us on the path from research to impactful solutions, advancing independence and mobility for those with complex movement needs.

In short

CoMoveIT Smart is a head-foot steering system intended to enable users with complex movement disorders to control a powered wheelchair. The CoMoveIT Smart is an intelligent device that translates scattered involuntary pressure and movements of the users into a smooth driving of the wheelchair. As such, the system brings the highest possible independency in personal mobility when the user has insufficient control to steer a powered wheelchair with joystick or other conventional navigation systems.



CoMoveIT Smart has been launched in 2021 after years of research within Belgian University, KU Leuven. This new innovative head- of head/foot navigation system is based on pressure sensor arrays and real-time algorithms, capable of accurately identifying user's intent, taking into account evidence-based clinical insights and a variability of personalized parameter settings.

Cutting-edge mobility solution



The right for independent mobility

Having the ability to move around by yourself sounds obvious, doesn't it? Think about how often you move independently in a day and what the impact would be if you were unable to do so, and especially the opportunities that are unlocked by independent mobility.

According to the World Health Organization (WHO), over 80 million people worldwide are likely to require a wheelchair to assist their mobility. **Movement and mobility are essential** for human health and well-being, and for people who rely on wheelchairs for mobility, an appropriate wheelchair is essential to ensure **physical and mental health and development, function, participation and inclusion**.¹

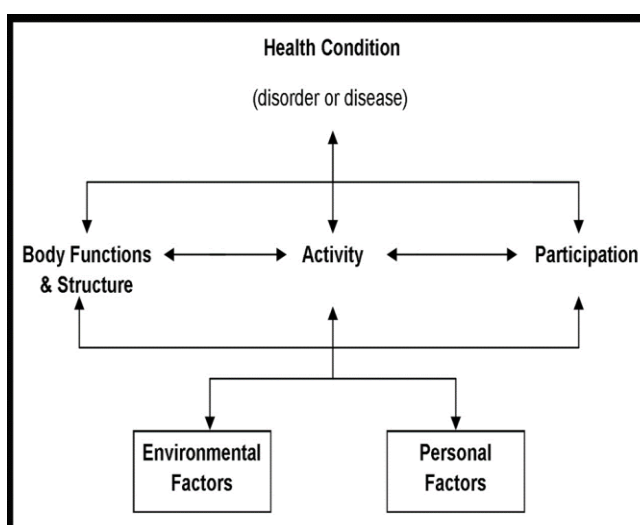


The United Nation Convention on the Rights of Persons with Disabilities states that effective measures regarding personal mobility with the greatest possible independence for people with disabilities should be taken. Furthermore, **personal mobility** should be facilitated and **access to quality mobility aids, devices and assistive technologies** should be promoted combined with **suitable training**.

Wheelchairs are one of the most important therapeutic tools in rehabilitation. Literature has documented several benefits of the use of wheelchairs such as improved mobility, improved participation, and reduced caregiver burden.

People with severe motor disabilities, such as people with cerebral palsy (CP) are confronted daily with the impact of their complex movement disorders on their mobility and are often unable to move independently. Therefore, providing them with the most appropriate, user-friendly mobility aids is a must and a basic human right.

Choosing the **right wheelchair** for people with **complex movement disorders** is crucial but multiple barriers exist, resulting in wheelchair users either not having a wheelchair or potentially receiving an inappropriate wheelchair steering system with associated risks. Therefore, **insights in health condition** as complex movement disorders are necessary placed within the framework of the International Classification of Functioning, Disability and Health (ICF)² with **evidence based underpinning**.



Importance of head control in CP

Almost 1/500 live births in high-income countries and higher elsewhere are diagnosed with cerebral palsy (CP).³ Worldwide this means approximately 17 million people of which 5,39 million have complex movement disorders which makes they cannot walk and are not able to steer conventional joysticks or control a mouse cursor in an acceptable qualitative way.^{3,4} Luckily most of them have enough control with their head to steer the CoMoveIT Smart.

To better understand this, let's go back to normal development. Everyone is born with basal or basic head control. The first thing a baby can do, is to lift and turn the neck and control the head to drink the bottle or be breastfed. In children with normal development, motor control increases by developing postural control, learning to sit up straight, maintaining stable trunk posture, controlling the muscles around the shoulder, later around the elbow and wrist, and at the end of the normal development process controlling the finger muscles resulting in fine motor skills, the highest level of the motor development ladder. Unfortunately, normal development of motor control stops or develops abnormal in those with complex movement disorders.

Because of presence of basic head motor skills, this is the main reason for people with complex movement disorders to opt for head steering control – whether or not with an extra foot function.

Research towards CoMoveIT Smart

Several mechanical or other alternative steering systems have been used over the past decades, but all too often we have seen that only a small majority provide acceptable driving performance. Additionally, they have a very long learning curve and, even worse, over time a decline in driving ability and an increase in pain and musculoskeletal deformities.

To better understand this, a research project was initiated. Three research groups at KU Leuven University (Belgium) joined forces with experts from the Department of Rehabilitation Sciences, Department of Industrial Engineering and Department of Biosystems.

In this research project, several children and young adults, able to drive a powered wheelchair with a mechanical head/foot steering system were included.

Their level of performance and years of age of experience differed and were subject of an instrumental and clinical evaluation during standardized driving tasks with increasing difficulty over several measuring points during two years.

During driving tasks:

- (1) pressure sensors -placed on the left/right head pads and left/right foot pads- measured the given pressure and the place where pressure was given.
- (2) inertial measurement units -placed on arms, legs and head- measured the involuntary, uncontrolled movements.
- (3) heartrate variability was measured using smartwatch, able to measure heartrate.
- (4) the clinical DIMS (Dyskinesia Impairment Mobility Scale) scale measured the severity of involuntary and uncontrolled movement.

Research focus was split into (1) sensor research and pressure pattern analysis; (2) clinical and instrumented evaluation of movement disorders and (3) clinical pattern analysis in relation to functional activities, driving performance and participation and found evidence for sensor driving, real-time measurement, real-time adaptive algorithms and relaxed therapeutic driving.

(1) Sensor research and pressure pattern analysis^{5,6}



The used sensors were able to measure pressure with 160 sensing elements, delivering not only very precise data about given pressure by the driver on the pads, but also how movement patterns changed during given pressure over the surface of the pads. In this phase we found and proved the ability that the used measurement sensors couldn't only be used to as a measuring tool, but also can be used as driving tool, in other words the pressure signal can be used as signal to drive the powered wheelchair.

And as the pressure sensors deliver digital data, we were able to develop a reliable and valid way to log sensor data in a microcontroller unit and as such to capture the way how the driver is pressing and how the wheelchair is reacting on given pressure by head or feet. This means

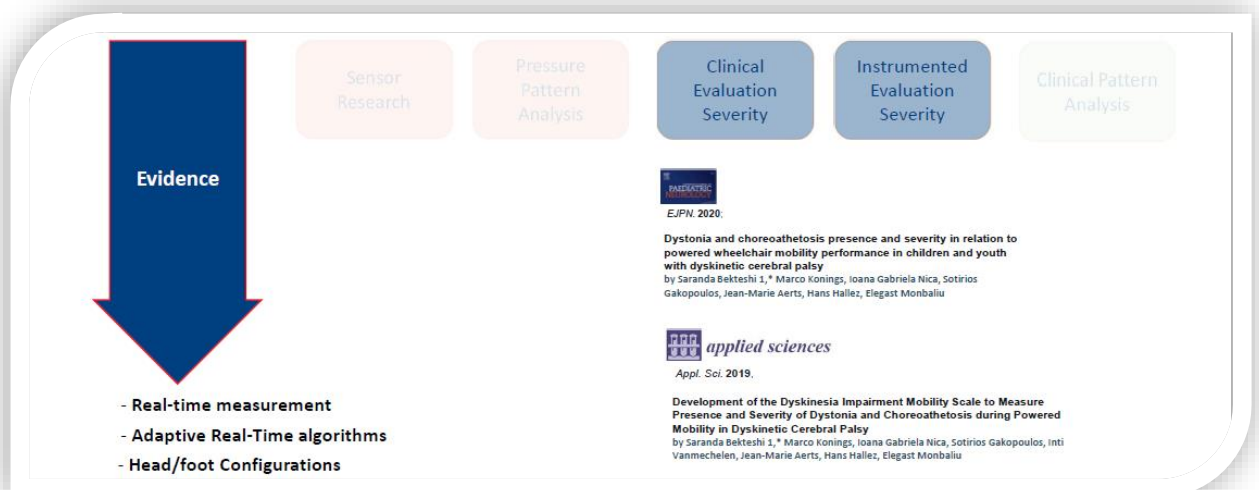
that all data the driver's steering and accelerating actions to move the wheelchair are logged in a digital way.

This digital data logging opened the window to adapt the behavior of the wheelchair in such a way that involuntary movements of the driver, resulting in scattered, fragmented movements could be adapted and filtered out by an algorithm.

This is best to compare with driving a car. If the driver pushes the gas pedal of the car with jerky, fragmented movements, the car will drive in a fragmented way.

As an answer to this fragmented driving, the KU Leuven researchers developed a software algorithm in the microcontroller unit between the head/foot sensors and the motors of the powered wheelchair, which filters out the fragmented involuntary movements and translates them into a smooth driving.

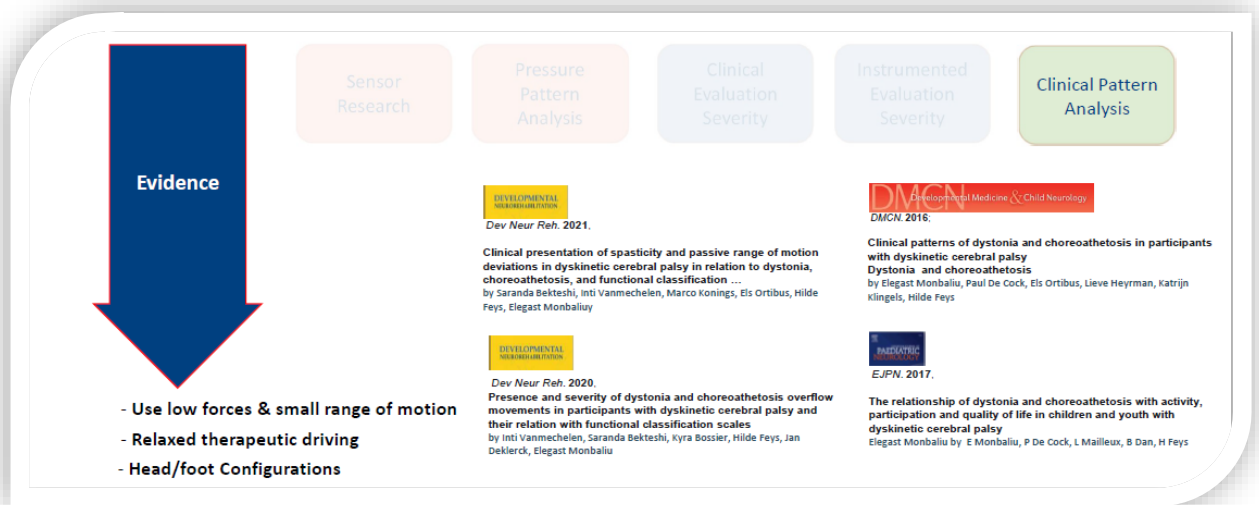
(2) Clinical and instrumented evaluation of movement disorders^{7,8}



Reliable, valid and sensitive measurements are essential to evaluate movement disorders. For this reason we developed and validated clinical and instrumented evaluation tools, giving us the opportunity to evaluate movement disorders as dystonia and choreoathetosis during driving. Further research assessed quality of driving performance of several driving tasks (e.g. start-stop task, straightforward driving, turning, veering, driving through sliding doors,..) in relation with the presence and severity of complex movement disorders.

For the first time we were able to relate severity of movement disorders with driving performance and delivered the software engineers a way to develop an adaptive real-time algorithm. This means that the developed algorithm filters out the uncontrolled, fragmented, involuntary signal and translates it into a smooth driving of the powered wheelchair.

(3) Clinical pattern analysis⁹⁻¹³



In clinical research, we assessed the clinical patterns of movement disorders in CP in relation to functional activity, societal participation, and quality of life.

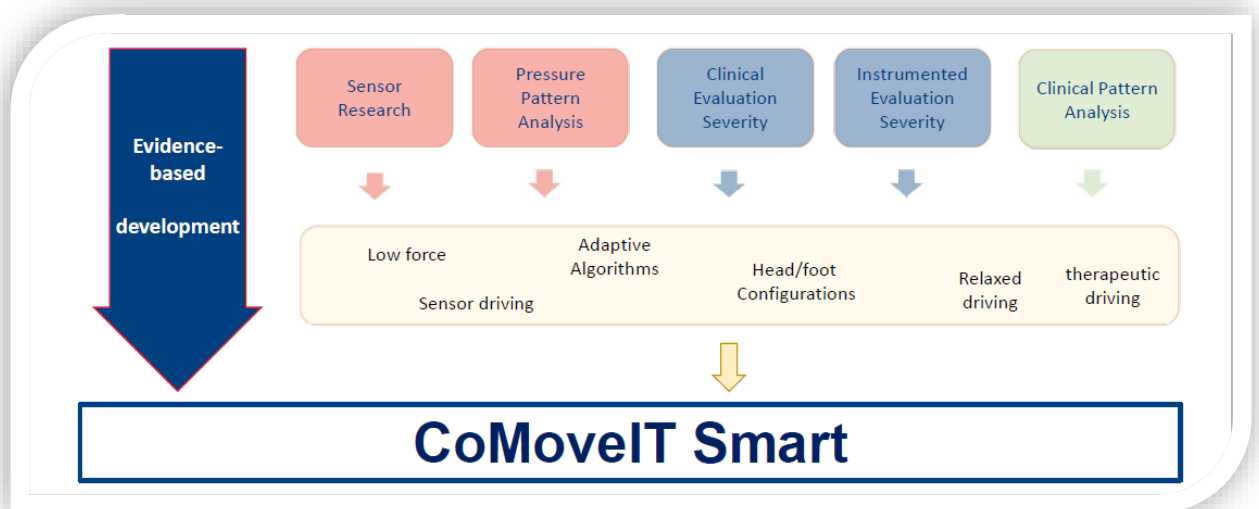
These studies showed:

- (1) the higher the severity of complex movement disorders as dystonia, choreoathetosis and spasticity in people with severe CP, the lower their functional activities, societal participation and quality of life become;
- (2) the more difficult functional activities are executed, the higher the severity of the movement disorders becomes. This results again in worsened functional activities at fine motor function and driving performance. And, the higher the severity of movement disorders, the more these lead to increased musculoskeletal deformities, pain, decreased quality of life and in turn decreased functional control.
- (3) increased difficulty of activities in people with complex movement disorders are closely related with use of high forces during function and movement patterns, with high range of motion, which in turn results again in increased severity of complex movement disorders.
- (4) the lower the used force and range of motion needed for functional activities, the better the control of complex movement disorders and the better the driving performance.

Based on new insights in the clinical head/foot patterns during driving, the combination of head/foot configuration is recommended answering the difficulty of complex movement disorders in severe CP.

Evidence-based underpinning

The evidence-based insights in (1) sensor research and pressure pattern analysis; (2) clinical and instrumented evaluation and (3) clinical pattern analysis of movement disorders, has led to an underpinned development of CoMoveIT Smart based on sensor driving, adaptive algorithms, use of low forces and small range of motion resulting in a relaxed and therapeutic driving.



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