Wheelchair Stability & Tuning
6th March 2018, Hilton Hotel, York

PROGRAMME

10:00 – 10:25  Coffee and registration
10:25 – 10:30  Introduction
10:30 – 11:00  Powered wheelchair stability
Terry Owens, East Kent Hospitals University NHS Foundation Trust
11:00 – 11:30  The development of a model for simulation of dynamic stability
Graham Henderson, Newcastle Upon Tyne NHS Foundation Trust
11:30 – 12:00  Wheelchair stability and related wheelchair performance: moving clinical practice forward
Simon Fielden, Birmingham Community Healthcare NHS Foundation Trust
12:00 – 13:00  Lunch
13:00 – 13:30  Analysis of the Centre of Gravity Measurement of Occupied Wheelchairs
John Colvin, NHS Greater Glasgow & Clyde
13:30 – 14:00  From a manufacturer’s perspective the demands and constraints of bio-mechanical stability settings
Andy McLaren, Otto Bock Healthcare
14:00 – 14:30  Isn’t the wheelchair meant to move?
Dave Long, Oxford University Hospitals NHS Foundation Trust
14:30 – 15:00  Coffee
15:00 – 16:00  Panel discussion: Bringing it all together - How can we apply this in our practice?
16:00  Close

Organised by IPEM’s Rehabilitation Engineering & Biomechanics Special Interest Group
# Powered Wheelchair Stability

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Kent and Medway Communication and Assistive Technology Service (KMCAT).

## Background:
- KMCAT are involved in supplying and maintaining communication aids and equipment to patients living within the Kent and Medway areas. A high percentage of these patients are wheelchair users who require this equipment to be attached to their wheelchairs.

## Current Standards:
- MHRA advice (2004) states that every wheelchair issued to a patient must be risk assessed for stability with the patient seated in it and that if any modifications are made to the chair which are likely to affect the stability, a risk assessment must be carried out. The stability risk assessment can be checked by carrying out a TILT TEST in which the wheelchair is placed on a bellows controlled ramp in various ways to see if it will tip.

## Challenges:
- Present methods of stability testing carries its own risks regarding transportation of equipment and manual handling issues as well as the potential of causing distress to the patient involved.
- Is the current method of static stability testing useful? What does it prove?
- Wheelchair services may require evidence of a formal stability test.

## Clinical Evaluation:
- Assistive technology has been used by the Department of Medical Physics for over 20 years, where communication aids have been attached to wheelchairs, static seating and standing frames. The service is accredited and works with ISO9001 & ISO13485.
  1. Where possible stability testing was carried out as described within the current MHRA standards. There were no reported incidents to the service relating to the wheelchair tipping over or injuries to the client or any third parties.
  2. Over the past 3 years the service has been using history of previous works, with photographs, carried out on similar wheelchairs to provide evidence of stability. These are mainly powered wheelchairs where the equipment is sited within a close range of the footprint of the wheelchair. The service is also involved in gathering evidence when carrying out work relating to manually propelled wheelchairs and Therapy chairs. There have been no reported incidents to the service relating to the wheelchair tipping over or injuries to the client or any third parties within this time period.

## Conclusion:
- By using this evidence, carrying out a simple localised risk assessment, providing suitable user instructions on delivery, employing and training staff to a suitable level of competence, through knowledge and experience, the service appear to be able to minimise the amount of stability testing previously carried out.
- The service annually maintains, reviews and documents the equipment provided ensuring it is safe and fit for purpose.
- The service is considering that if the fitting is undertaken by evidence based competent members of staff and the mounting equipment is provided by an approved supplier who is advertising products that are commercially available and CE marked then this equipment may be considered to be a simple accessory thereby eliminating the need for stability testing.
The development of a model for simulation of dynamic stability

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Thousands of wheelchair incidents occur each year with the most common incident being a tip or a fall [1]. To reduce the likelihood of these incidents it is important to test the stability of a wheelchair and its configuration. Current stability testing in the clinical environment consists of static testing via platform tilt testing or using load cells, however, in the real world most tips and falls occur in dynamic situations [2]. In the international standard ISO 7176-2:2017 there is a protocol for dynamic stability testing of electrically powered wheelchairs, however, it involves the use of a large tilt ramp and dummy which are impractical for use in the clinical environment. Additionally, there is no standard for testing manual wheelchairs. An alternative way to test dynamic stability is to do it in simulation. This enables any number of dynamic scenarios to be tested and static testing can also be undertaken without any of the risks of current stability testing methods.

To undertake dynamic stability testing a model was developed in the software OpenSim, which uses the SimBody multibody dynamic engine [3]. The model consisted of a standard OpenSim 23 degree of freedom human model, a basic manual wheelchair, and an adjustable platform. The manual wheelchair mass, centre of mass, and inertia properties were imported from a CAD file. To model the interaction between the rear wheels, the castors, and the platform Elastic Foundation mesh-based forces [4] were used. The model was setup so that four parameters could be varied: the angle of the platform, the configuration of the wheelchair, the position of the user, and the torque applied to the rear wheels. A script was developed in Matlab to enable batch running of forward dynamic analyses to test which parameter combinations lead to the wheelchair tipping. To validate the model, the maximum angle before a tip occurred was compared between real world testing with a tilt platform and testing in the simulation environment. This work is on-going, and the results will be added when available.

Future work is to further validate the model by comparing tipping scenarios between the simulation environment and the real world when varying the other three parameters. Additionally, real world scenarios will be created and tested for example negotiating curbs and colliding with obstacles causing sudden deaccelerations. The effect of mounting equipment to wheelchairs for example communication aids and ventilators will also be tested. If the validation proves successful then the simulation could be a valuable tool for clinical services and wheelchair manufacturers to determine the tipping risks posed by a wheelchair and its particular configuration.


Wheelchair Stability and Related Wheelchair Performance: Moving Clinical Practice Forward
Simon Fielden and Mike Heelis, West Midlands Rehabilitation Centre. Birmingham Community Healthcare NHS Foundation Trust
Paul Hewitt, Ace Centre North, Ace Centre South

Background

The use of objective measurements related to wheelchair stability and performance is recognised as providing repeatability, accuracy, a means of auditing and evidence for accountability in order, ultimately, to improve clinical outcomes.

Similar to the use of other clinical tools (eg pressure mapping, propelling wheelchair force measurement), there are a number of factors that result in the tools not being used as often as they could be, or not used altogether. These include initial costs and training, competency in performing, interpreting and acting upon the measurements, ease of use and portability.

In terms of available tools, the Coventry University led Wheelsense Project, despite significant effort and protected IP, was unable to secure commercial interest in developing a wheelchair stability product. Reasons for this include the small market, likely sales price, and a requirement to fund further development work. The IP protection has now lapsed, thus further reducing the commercial value of the project outputs, however, this presents an opportunity to pursue, an open source design approach.

Software and hardware collaborative open source design methods will be discussed, together with a proposed way forward to launch such an approach.

Ultimately hardware designs would be available to download and use, either to construct a platform in house, or sub-contact the manufacture and testing of the design.

Software would be created to download and use a suite of modules from running a basic stability test system through to more sophisticated meta–data analysis and advanced clinical applications.

We will propose a vision of the future of what a wheelchair clinic in 10 years time – using the technology available today. This vision will inform those developing a clinical tool on the direction of travel as we highlight the steps required to realise this vision.
The Centre of Gravity of the occupied manual wheelchair will affect how easy the wheelchair is to push and how easy it is to tip. Although the traditional static ramp tests of 12° for attendant controlled manual wheelchairs and 16° for occupant controlled and powered wheelchairs are no longer considered good practice no alternative quantitative measure or guidance has replaced them. Additionally, in the West of Scotland the rate of adverse incidents associated with powered wheelchairs is disproportionately high compared to manual wheelchair users. More robust investigations of these incidents have revealed that incidents that would typically have been attributed to driver error, tipping or castor failure are often associated with poor configuration of the Centre of Gravity (CoG).

Aims

1. To establish a “normal” dataset for Centre of Gravity of occupied wheelchairs using standard wheelchair configurations.
2. To test the hypothesis that special seating users and those with modified wheelchairs are more at risk than other wheelchair users.
3. To analyse Centre of Gravity data for the occupied wheelchair against assumed prescribing practices.
4. To compare drive wheel loading of occupied powered wheelchairs to manufacturer’s guidance.
5. To investigate the relationship between drive wheel loading and probability of tipping or traction related incidents.

Method

A simple roll on/roll off device was developed to allow measurements to be gathered using a 4 load cell method. A standardised protocol was developed to minimise the most sensitive errors. The Centre of Gravity is calculated using the method described by Wawrzinek & Boenick [1] and from that a theoretical Rearward Braked Tipping Angle (RBTA) is calculated. A “normal” data set was gathered from 87 wheelchair users from routine wheelchair clinics. Only users who had simple wheelchair configurations with no significant postural equipment were included in this data set.

A retrospective audit was carried out on data gathered using this method in WestMARC by the bioengineering team to record the stability of 245 wheelchair users that had been supplied bespoke seating systems or following an identified stability concern.

The two independent groups of normal wheelchair users and the special seating group were compared. The data was further analysed to see if the rearward braked tipping angle could be correlated with wheel size, postural skills, risk awareness, backrest type and history of rocking behaviour.

Drive wheel loading of occupied powered wheelchairs is typically gathered by bioengineering when providing bespoke seating solutions or when investigating tipping or traction related incidents. A retrospective audit was carried out on data gathered from Jan 2016 to Dec 2017 and compared to manufacturer’s guidance on configuration of occupied powered wheelchairs (n=212).

Results

Manual Wheelchairs

The “normal” wheelchair group had a mean rearward braked tipping angle of 15.0° and a standard deviation of 3.6°. The bioengineering group of wheelchair users with special seating had a mean RBTA of 14.9° and a standard deviation of 4.7°. An independent sample T-Test showed there was no significant difference in the RBTA between the two groups (p=0.84).
People using wheelchairs with transit wheels had a mean RBTA of 15.5° and a standard deviation of 4.9°. Those using wheelchairs with larger self propelling wheels had a mean RBTA of 14.2° and a standard deviation of 3.7°. This showed a significant difference (p=0.001).

Further analysis of the data showed no significant difference in RBTA based on postural skills (p=0.07), risk awareness (p=0.14) or history of tipping (p=0.86). There was some evidence of a significant difference in the RBTA depending on whether the type of wheelchair used included tilt feature (p=0.00) and an ANOVA analysis showed a difference based on the type of backrest used (p=0.03).

**Powered Wheelchairs**

Manufacturers typically recommend that the loading of the drive wheel of an occupied powered wheelchair should be between 60% and 70% of the total load. Analysis of 212 measures taken over a 2 year period at WestMARC shows that only 62 (29%) fell within this recommended guidance. Those with a higher loading over the drive wheel 12 (6%) might be considered at risk of tipping. The largest group of users 138 (65%) had a loading of less than 60% and therefore could be considered to be at risk of loss of traction or catastrophic castor failure.

Loading data on powered wheelchairs involved in a tipping or traction related incident was further analysed and did not appear to support the hypothesis of a safe loading percentage.

**Conclusion**

The hypothesis that people using special seating are likely to have more unstable wheelchairs is not proven. Contrary to the goals of the traditional static ramp test the attendant manual wheelchairs were likely to have a slightly more stable configuration. There is a significant spread in the RBTA of occupied wheelchairs and the value seems to be affected more by the type of equipment used rather than any anticipated clinical need.

Manufacturer’s guidance on configuring the centre of gravity of powered wheelchairs is typically absent or inadequate. Comparing clinical data with manufacturer’s recommendations demonstrates a significant gap between perceived and actual practice. Reported incidents that appear to relate to rearward tipping, castor failure or driving error might be associated with poor centre of gravity configuration. The metric used by some companies to define a safe configuration, percentage weight over rear wheel, does not adequately address dynamic issues. Many low cost models of powered wheelchairs do not allow sufficient adjustment of centre of gravity to allow compliance with manufacturers own guidance.

**References**

**Aim.**
The aim of the abstract is to answer the following question:

In the context of rear wheel stability how do “we” the manufacturer (Otto Bock Healthcare), set seat positions on wheeled mobility base products for individuals with complex seating, mobility, social, environmental and geographic needs at the time of manufacture?

**Objective.**
As part of the presentation we will define the “Demands” and “Constraints” placed upon the manufacturer Otto Bock Healthcare, to be able to make decisions about the fixation of the seats to the wheeled mobility base products using examples of the B400 power wheelchair with a 45 degree seat tilt option and the Discovery wheelbase with 35 degrees of manual seat tilt.

**Demands (Bio)**
These will be centred around the “person” that requires seating within a range of positioning options, such as Custom Contoured Seating and entry level using a basic foam seat surface with a tension adjustable backrest.

This will include a reflection of the physical anatomic needs presented during an assessment, for example:

- Size of the person
- Their type of restricted mobility needs
- Social interaction requirements
- The geography /environmental needs
- Requirements of special controls and/or assistive technology

**Constraints (Mechanical)**
This area will question the actions of how and why we physically fit and secure the seat to the wheeled mobility base products in a particular setting.

The person’s specification and requirements will be taken into account along with the restrictions of mechanical options available on the wheeled mobility base products when considering rear wheel stability and will take into consideration the following aspects:

**CSI**
- Chassis (the base unit), physical size and weight
- Seating, size and weight
- Interface, the physical points of fitting with rear wheel stability considerations
Isn’t the wheelchair meant to move?
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One of the primary aims for a wheelchair is mobility, but sometimes too much emphasis is placed on its foe, namely stability. This presentation will explore the relationship between mobility and stability, and how placement of the combined centre of mass of the wheelchair system and occupant over the wheels is so crucial to the facilitation of mobility.

Providers of wheelchairs are duty bound to ensure issued equipment is fit for purpose. However, the implications of making a wheelchair stable are not always fully considered, perhaps because they are not always adequately understood. The concern is that the wheelchair will tip over if it is not sufficiently stable, which could cause great harm to the occupant, and so emphasis is (quite rightly) placed on taking the necessary measures to avoid this happening. The truth, however, is that ANY wheelchair, no matter how stable, will tip over given the wrong set of circumstances, and so a judgement must be made by the supplier/prescriber as to what is acceptable for the individual in their circumstances – herein lies the challenge.

There are a variety of stability testing techniques available ranging from the historical 12/16 degree ramp, adjustable angle ramps, and computerised force plate systems. All of these approaches focus on the angle at which a wheelchair will tip and from this a judgement is made as to whether this is acceptable. Adjustments are made to the wheelchair chassis in order to improve stability where necessary, but seldom is thought given to exploring the option of REDUCING stability to improve maneuverability.

Challenges exist for clinicians, technicians and manufacturers alike if mobility is to be considered as important as stability. Case study examples will be used in the presentation to explore these issues further.

Bibliography

- Cooper R (2007) *An Introduction to Rehabilitation Engineering* Taylor & Francis