The Design and Evaluation of a Novel System for Predicting Wheelchair and Occupant Stability

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Backgound

Wheelchair stability is affected by user characteristics and abilities, environmental features and conditions, and wheelchair modification and accessories (Male and Massie 1991). Effective tools and methods are needed to provide quantitative evaluation and prediction of the behaviour of the user-wheelchair system in a variety of static and dynamic situations. Such information is very important to guide efficient prescription through management of associated risks and adjustment of chairs to user needs (Kirby et al. 1994).

The most common stability test system in use within the National Health Service in the UK has been a static ramp. Some systems had mechanisms to raise and lower ramp. These systems have manual handling and inadvertent tipping risks associated with them for the tester and wheelchair user. Tipping the wheelchair and it's user for these tests, to angles of, or approaching instability forwards, rearwards and sideways, can often be an uncomfortable sensation for the user (MHRA 2004). These systems have their origins with a, (now withdrawn) national pass/fail test criteria in the UK where wheelchairs were tested for instability at either 12 or 16 degrees.

A few systems are used that have scales to weigh the wheelchair under each wheel and calculate the centre of gravity and the angles of stability (Wawrzinek and Boenick 1987). Typically weighing systems from the motor sport industry have been used with a frame work and bridging pieces to make a platform for easy ingress/egress. They require a means to weigh the wheel in a tilted position, to vary the position of the centre of gravity, for its calculations. The manual handling and inadvertent tipping risks during the testing are significantly reduced, if not eliminated, as well as any distress to the user. The calculation of the centre of gravity and stability can be performed on a computer, along with patient record storage and what-if calculations for variations in, for instance, wheel position. However, such a system has additional parts as above, adds weight and complexity to its use, often making it less portable and requiring more training or familiarity of use than a static ramp. Furthermore, to calculate the centre of gravity, 6 linear dimensions need to be measured on the wheelchair and entered into the computer, adding to the apparent complexity which some testers find daunting. Whilst far more data and analysis is possible through weighing methods, the 12/16 degree pass/fail criteria is still often applied in clinical practise.

In order to resolve these user and technical issues a user-centred approach to the design and evaluation of a new load cell based wheelchair stability assessment system (WheelSense) is being adopted. Research has been undertaken to elicit the needs of both the direct users of the system as well as the broader market, and this has been channelled into the design and evolution of the product. The development was led by a user-centred design process (Moody et al. 2012).

Eliciting the Views of Users

The initial design and development of WheelSense was guided by several research activities with potential end users and beneficiaries of a new system. This included both user and market research.

Online survey

An online survey was completed by 98 participants working in wheelchair provision, ranging from therapists to manufacturers to understand user needs and market requirements. Survey responses highlighted a number of limitations with current stability assessment procedures and systems. Though a ramp test gives the wheelchair occupant a real-life experience of severe angles of tilt, the test was

considered to be distressing for the patient and manually challenging for the clinician. Load cell tests, were seen as beneficial but overly technical, time consuming and intimidating.

Survey respondents were asked to gauge the desirability of 17 potential functions of a new wheelchair stability assessment system. Many features were rated as highly desirable, the most of which was the ability to keep records of stability assessment for clinical use. Also desirable was a system that was portable, user friendly and able to determine the precise angle at which a chair will become unstable.

Prescriber interviews

Ten follow-up interviews were conducted with clinicians from 2 NHS Trusts in the UK which aimed to provide more detailed feedback on what users would like to see from a new system. Interviews confirmed the findings from the survey; participants wanted a portable and easy-to-use system, which would support record keeping by allowing them to have an electronically stored copy of the stability data or by giving them a copy of the results to aid patient and carer education.

The requirements elicited through the market and user research were used to direct the design of WheelSense.

The Design of WheelSense

The resulting design concept is shown in Figure 1 below:

Figure 1. The WheelSense system in use *(note caster trailing arm position)*

Hardware

The design concept was to have a system with as few parts as possible that would "present itself", eliminating detailed instructions and training, whilst providing a system that minimised the risks associated with testing. The test itself should also be minimised in terms of its effort and complexity.

The weighing method is the most appropriate starting point as the manual handling tasks are eliminated. To eliminate the raiser blocks, or steps, one of the weight measurements can be conducted with the only the front castors on platform. These design principles eliminate the need for any modularity or hardware adjusts in preparation or when performing a test.

For portability, keeping the design as a single unit eliminates issues of connecting pieces together, both for physical integrity and electronic connection. The four quadrant hinge design allows the platform to be reduced to manageable dimensions (see Figure 2).

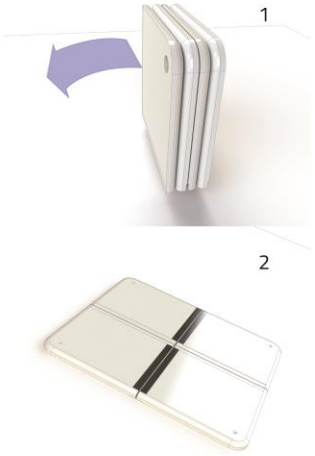

Figure 2. The folding platform

A further significant advantage of this design approach is that platform can be designed to sense the wheels, and determine some dimensional information. This reduces the number of linear measurements that the tester has to take, from 6 measurements to 2, these being the wheel diameters.

Software

The concepts behind the software are that:

- The GUI (graphical user interface) should minimise the number of steps required for a test.
- The software should be able to offer different levels of functionality appropriate for different levels of competency of tester.
- The software should be platform-agnostic giving hardware device choice.
- The GUI should be intuitive rather than requiring training and familiarisation.
- The GUI should guide the tester through the test process.

To achieve these objectives the GUI runs in an HTML 5 web browser (eg Chrome). A windows 8 tablet is being used for the trails. This approach means the system to be developed for cloud storage and testing to be able to carried out from any HTML 5 web browser, eg smartphones, tablets etc.

Test Protocol

A basic test will give angles of stability with no attempt to interpret the clinical meaning. For assisted interpretation of the results it is not possible to give absolute guarantees of safety or performance and the 12/16 degree pass/fail test is no longer recognised, and has significant flaws.

To support clinical reasoning with test results from WheelSense a system is being developed to compare test data with other reference points. The more reference points used then more confidence can be given to the testers clinical reasoning and increase the “Confidence of Reasoning”.

Reference points being developed include:

- Manufacturers stated maximum slope usage
- Manufacturers stated ISO 7176 static stability results (manual wheelchairs)
- Slope data from the users environment
- Users abilities and goals in propelling/operating the wheelchair
- Recognised optimum configurations from research (eg weight distribution over front/rear wheels)

The Evaluation of WheelSense - Early Findings

Currently, the system is under evaluation within 3 UK NHS Trusts. Following training, a range of practitioners are using the new system over a 3 month period. To date 17 NHS employees (Wheelchair Prescribers, Rehabilitation Engineers and Occupation Therapists) have been recruited to the study beginning with a training session in each location. The system was well received, taking approximately one hour to train all attendees. Each measurement took a few seconds per person once they had practiced, and the participants felt that this would be easily integrated into a clinical session.

The training workshops included a feedback session for participants to suggest design improvements. Many of the suggestions focused on the GUI, and included: more annotation on the printed output to support non-technical staff; options to resize text and improve on-screen keyboard use; use of icons to aid navigation; the ability to enter client/chair details at a separate time to the assessment to save time in clinic; a section to write general assessment notes. The hardware itself was considered easy to use but participants wanted to see future versions incorporating six-wheeled chairs.

Concern was expressed that the ramped sides of the system were a little steep leading to manual handling issues particularly for heavier patients and the suggestion was made that the ramp be made gentler, however it was acknowledged that this would have an impact on the footprint of the system.

Next Steps

The evaluation is ongoing and will involve collecting feedback on the use of the system in a clinical setting until April 2014. The evaluation process will include:

- Observations of the WheelSense system in use during clinical practise
- Completion of reflective logs by participants (clinical staff) using the system
- Interviews with clinical staff who have used the system as well as patients, and carers who have been present during use of the system
- A patient survey on the prescription experience using the system

The findings will be used to evaluate the effectiveness of the system and guide future development and research in the area. The project team are currently reviewing options to get the product to market, including licensing the technology. Wheel-Sense is showcased on booth 105, if you would like further information including commercial opportunities, please visit the booth

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