

Ambulatory Monitoring for Chronic Disease Rehabilitation

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Abstract

We recently conducted an observational trial of ambulatory devices designed to record movement of elderly patients for the purposes of falls assessment and improving stroke rehabilitation services. Upon review of the project at its completion, it is timely to consider factors affecting wider implementation of this technology to chronic disease patients. A consultative workshop was held with a broad range of aged care providers, including physiotherapists, geriatricians and rehabilitation specialists. This paper reports on the outcome of these consultations, specifically how ambulatory monitoring technology can assist in meeting current unmet needs in chronic disease management, and enhancing the functional capacity of an ageing population.

Ambulatory Monitoring and Chronic Disease

Recent advances in sensor and microprocessor technology have resulted in the production of lightweight patient-worn devices to monitor physiological parameters, such as movement or ECG. These devices are becoming smaller, more sensitive and are able to last from hours to days on a single battery charge. Many devices store data to an internal card or transmit data wirelessly, thus eliminating the need for tethered cabling and allowing a patient to ambulate or roam about. Devices recently trialled by the E-Health Research Centre ranged from 'matchbox' to 'mobile phone' in size, and included sensors for movement (accelerometers, gyroscopes, magnetometers) and 2-lead electrocardiograph electrodes. Data extracted from the devices included:

- acceleration signals, used to visualise patient movement patterns during the day;
- the angle of the patient's upper torso with the vertical plane;
- a daily activity profile for the patient.

By review and analysis of these measures, a more in-depth understanding can be gained by patient carers of the potential risks for each patient, and how to best tailor care plans for each individual patient.

The EHRC are currently investigating how data obtained from monitoring devices increases support for chronic disease rehabilitation programs. Chronic disease patients include those with type 2 diabetes mellitus, cardiovascular disease (coronary heart disease, heart failure and stroke), chronic respiratory disease (chronic obstructive pulmonary disease and asthma), renal disease and depression (as a co-morbidity of these chronic diseases). Many older people suffering from multiple chronic diseases, have relatively high levels of disability.¹ Their needs include support and aids to enhance their independence and mobility, and to stay in their own homes where possible.

This work supports a vision of Promoting Healthy Ageing in Australia¹ by providing additional years of healthy and productive life expectancy. We wish to assist older persons to maintain functional capacity over their life. Figure 1 illustrates that functional capacity increases in childhood and peaks in early adulthood, eventually followed by a decline. The rate of decline is determined partly by genetics and individual biology, but is strongly influenced by factors related to adult lifestyle (such as smoking, alcohol consumption, diet and levels of physical activity) and by the environment in which people live¹. Changes in the social and built environment can raise or lower the disability threshold. A supportive environment can enable people to remain independent even when they have substantial losses of functional capacities. This paper proposes that ambulatory monitoring can provide that supportive environment, and address several unmet needs in chronic disease rehabilitation.

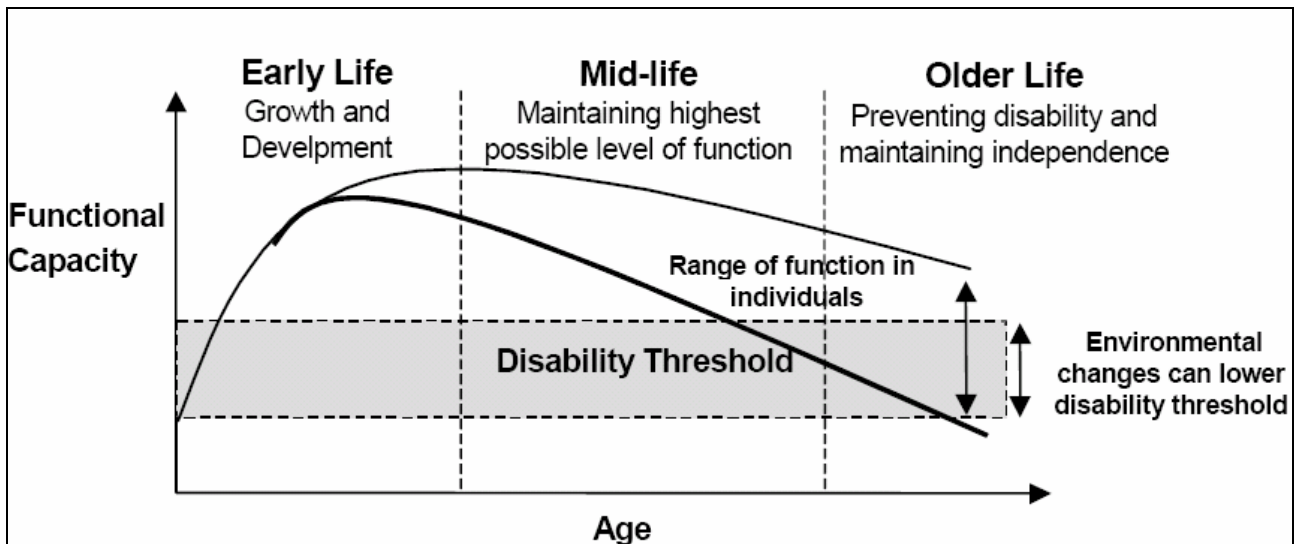


Figure 1 - Maintaining functional capacity over the lifecourse; Source [1]

Unmet Needs in Chronic Disease Rehabilitation

The needs of chronic disease patients reported in this paper were identified through a consultation process involving several one-on-one interviews and a stakeholder workshop. Consultations were made with those affected and intimately acquainted with the issues of hospital and community based chronic disease rehabilitation services. By considering the views of these stakeholders (comprising clinicians involved with the previous work, nurses and specialists affected by the proposed research and others who have an interest), we can be assured of continuous improvement of the quality of research.

There are several unmet needs that can be addressed with ambulatory monitoring technology.

1) Quantifying chronic disease rehabilitation progress

Mobility is a large component of chronic disease rehabilitation programs. Mobility needs of patients include assistance to get out of bed, walking with assistance, walking independently, and undertaking the daily living activities required from their home environment (eg. walking 50 meters plus ascending 3 stairs). Current rehabilitation assessment of patients is predominantly of qualitative and subjective in nature. Some measures relate to function (eg. swallowing, ability to shower), and others relate to mobility and balance. Widely used indices of rehabilitation include the Functional Independence Measure Score (FIMS), the Berg Balance and the Timed Up and Go (TUG), and many of these and similar indices have been found to have high sensitivity for predicting falls risk in patients^{2,3,4}. However, due to their nature, these tests are performed periodically. An assessment tool that provides more frequent or even continuous assessment of mobility would enable rehabilitation progress to be more closely monitored, allowing a therapist to potentially adjust or modify exercise programs based on the additional information. Such a tool would provide rehabilitation activity information to tailor individual needs to a care plan for ongoing care management in chronic disease patients.

Sometimes chronic disease patients spend too long in hospital, while others are discharged prematurely, leading to readmission within short timeframes. The consultations revealed that these problems are often attributed to the lack of robust functional mobility assessment prior to discharge or delays in the readiness of facilities to which patients are transferred. Both physicians and

physiotherapists have expressed that robust assessment for discharge readiness of patients could be achieved through a more quantitative combination of scores such as TUG, FIMS and Barthel indices (depending on the institution choice of indices). Assessment of discharge readiness could also be supported by an accelerometer-based tool, providing frequent mobility information, and quantifying progress of rehabilitation. Analysis of a patient's daily activity profile will not only provide an overall assessment of the patient's rehabilitation progress but determine the degree or time of day of their lack of mobility for better management. Measures of daily activity profile could also contribute to patient's care plan in the way they are managed by a carer following their discharge from hospital. The tool would also be useful in providing nurses in low level care with information to determine the type of specialised care that each individual patient may need.

Ongoing management of chronic diseases can also be enhanced by the monitoring of vital signs. In many cases, patients are managed for two or more medical conditions requiring multiple medications. Real-time monitoring of vital signs such as blood pressure, ECG and heartrate, is useful for care of patients both within hospitals and in external environments (nursing homes, homes, etc.). For example, one geriatrician advised that monitoring of vital signs would have an impact on the care of 25-50% of the patients under geriatric care. Further examples from the literature on the benefits of monitoring for improved chronic disease management are presented in Table 1.

Table 1 – Studies of chronic disease management via monitoring technologies

Ref.	Intervention	Sample Size	Results
5	Twice-daily patient self-measurement of weight, blood pressure, heart rate, and rhythm with automated devices linked to a cardiology center vs primary care by physician	426	Mean duration of admissions was reduced by 6 days (95% confidence interval 1 to 11)
6	Heart failure patients monitoring weight, blood pressure, heart rate and oxygen saturation level transmitted to secure internet site vs home nursing visit	216	Quality of life was significantly improved: fewer heart failure readmissions (13 vs 24), shorter lengths of stay (50 vs 105 days), hospitalisation charges per group:
7	Weekly interactive, computer controlled telephone monitoring vs routine medical care	267	A significant improvement in medication adherence in the non-adherent patients in the experimental group (p = .03).
8	Home cardiac rehab program with simultaneous ECG & voice transmission to hospital vs hospital exercise program	20	Significant improvement within group of physiological measures (maximal oxygen consumption, pressure rate product, systolic blood pressure, heart rate)
9	Self monitored blood glucose results weekly to clinic via modem vs routine clinic visit	38	Significant improvement within group in HbA1c (random blood glucose) in the experimental group (p=0.05)
10	Blood pressure telemetry system in home for hypertension in pregnancy vs routine hospital care	67	Interventions are feasible with no detrimental effects
11	Portable ECG monitor transmitting single-lead ECG trace for heart failure patients	74	Patients had average of 0.2 hospitalisations each compared with pre-study values of 1.8
12	Telemonitoring for blood pressure, heart rate, arterial oxygen saturation and weight	60	Significant reduction in admissions, length of stay and hospital charges (p<0.001) compared with pre-study values.

Anticipated Benefit 1 - Adoption of monitoring of patient mobility (via accelerometer devices) may enable shorter lengths of stay within hospital, reduced readmissions to hospital, and improve clinical information allowing more comprehensive care.

2) Verifying work practices

One of the greatest needs expressed by rehabilitation physiotherapists is input into verifying treatment methods in relation to time exposure. None of the existing tests/instruments (eg. the “Timed-Up-and-Go” test) provide any input into how much physical time, or how much contact of staff is needed to achieve a result. What is the staff vs expenditure needed to achieve the result? How much time input is needed? Should one-on-one individual therapy or a group scenario be provided ie. can group therapy achieve the same result? There is a need to assess time exposure for example 10 people vs 1 person in 1 hour. When staff invest time with their patients, is it useful? Should they provide less, more, or what type?

Anticipated Benefit 2 - Review of patient activity and movement patterns (via accelerometer devices) will assist staff to verify work practices and determine the duration and type of therapy required.

3) Improving hospital discharge services

Communication of health information for patients transitioning between acute and aged care is often disjointed. It is proposed that community or home-based monitoring programs based on periodic assessment by carers of their patient’s activity levels, gait smoothness and vital signs, can lead to an improved continuum of care. Periodic assessment from home or community environments could also reduce avoidable patient visits to public and private hospitals, GPs, private practice specialists, and outpatient physiotherapy sessions, and reduce travel costs for patients.

Anticipated Benefit 3 – Improved continuum of care and reduced direct health costs.

4) Increasing physical activity levels

Physical inactivity causes the greatest burden of disease for women and the second greatest burden of disease for men in Australia¹³. Figure 2 shows this burden and the relative risks associated with physical inactivity.

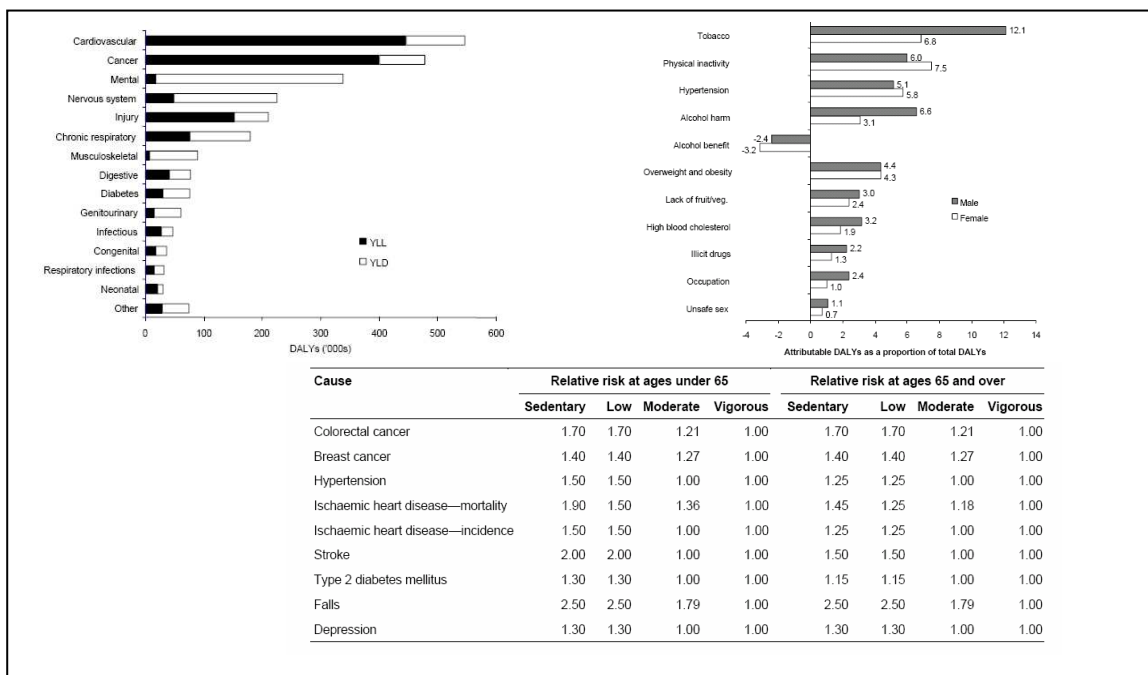


Figure 2: Top Left - Burden of disease (DALYs) for major disease groups;
 Top Right - Proportion of total burden attributed to selected risk factors;
 Bottom: Relative risks for diseases and injuries associated with physical inactivity; Source [13]

Physical activity is a risk factor which can influence outcomes in all six of the National Health Priority Areas: cardiovascular health, cancer control, injury prevention and control, mental health, diabetes mellitus and asthma. Physical activity provides protection against heart disease, stroke, hypertension, some cancers, type 2 diabetes, and can improve mental health. Finding ways to increase physical activity is the most cost effective and sustainable way to tackle health problems¹⁴.

Anticipated Benefit 4 – Increased physical activity by fitting chronic disease patients (and even the health aged population) with activity monitors and instructing them to increase step counts (measured by devices). Patients could display data within the home to see a visual on the changes in gait pattern that have arisen as a result of increased physical activity levels.

Conclusion

This paper has reported on consultations identifying current needs of chronic disease patients that can be addressed with ambulatory monitoring technology. Several anticipated benefits were identified along with examples from the literature of where monitoring technologies have delivered quantifiable benefits to chronic disease management. From review of this material, it can be seen that there is potential for delivering quantifiable health impacts through monitoring technologies. We now intend to undertake further research trials in this area which has relevance within hospitals, community care environments and homes as follows:

- hospital rehabilitation wards: quantifiable indicators (gait, vital signs, activity profiles) to manage and improve patient care;
- community dwelling/nursing homes: key indicators to address specialised care services on a needed basis;
- homes: patient self-management with appealing visual markers to achieve goals they have set with the GPs in their activity and medication program.

References

- ¹ Prime Minister's Science, Engineering And Innovation Council (PMSEIC), Promoting Healthy Ageing in Australia, 2003
- ² Bogle Thorbahn LD, Newton RA. Use of the Berg Balance Test to predict falls in elderly persons, *Phys Ther.* 1996 Jun;76(6):576-83
- ³ Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. *Phys Ther.* 2000 Sep;80(9):896-903
- ⁴ VanSwearingen JM, Paschal KA, Bonino P, Chen TW. Assessing recurrent fall risk of community-dwelling, frail older veterans using specific tests of mobility and the physical performance test of function. *J Gerontol A Biol Sci Med Sci.* 1998 Nov;53(6):M457-64.
- ⁵ Cleland JG et al, Noninvasive home telemonitoring for patients with heart failure at high risk of recurrent admission and death: the Trans-European Network-Home-Care Management System (TEN-HMS) study. *J Am Coll Cardiol.* 2005 May 17;45(10):1654-64.
- ⁶ Benatar D et al, Outcomes of chronic heart failure. *Arch Intern Med.* 2003 Feb 10;163(3):347-52.
- ⁷ Friedman R et al. A telecommunications system for monitoring and counselling patients with hypertension. Impact on medication adherence and blood pressure control. *American Journal of Hypertension* 1996;9 (4 Part 1):285-292
- ⁸ Sparks K et al. Alternatives for cardiac rehabilitation patients unable to return to a hospital based program. *Heart and Lung* 1993;22(4):298-303.
- ⁹ Ahring K et al. Telephone modem access improves diabetes control in those with insulin-requiring diabetes. *Diabetes Care* 1992;15(8):971-975.
- ¹⁰ Cartwright W et al, Objective measurement of anxiety in hypertensive pregnant women managed in hospital and in the community. *British Journal of Obstetrics and Gynaecology* 1992;99:182- 185.
- ¹¹ Scalvini S, et al, A pilot study of nurse-led, home-based telecardiology for patients with chronic heart failure. *Journal Telemedicine and Telecare.* 2004;10(2):113-7
- ¹² Bondmass M, et al, The Effect of Physiologic Home Monitoring and Telemanagement on Chronic Heart Failure Outcomes. *The Internet Journal of Advanced Nursing Practice* 2000; Volume 3,Number 2:
- ¹³ Mathers C, Vos T, Stevenson C 1999. The burden of disease and injury in Australia. AIHW cat. no. PHE 17, AIHW
- ¹⁴ Physical Activity Facts: A Summary of Information About Physical Activity for Physical Activity Stakeholders, The Southern Public Health Unit Network, Queensland Health, May 2001