Utilisation of Telemedicine to Assess Energy Expenditure and Stability in Older People with Chronic Kidney Disease

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Abstract

Chronic Kidney Disease (CKD) and falls are common in older people. Whilst aggressive blood pressure (BP) control is the main treatment, its effects are unknown. We have been evaluating a new technology capable of energy and stability monitoring in a patient's home environment.

5 participants wore a portable monitor during modification of BP therapy. This small device, worn on the waist, contains two accelerometers allowing measurement of the force and direction of movement.

No significant problems were reported. Data were collected on 89% of days. Energy expenditure appears lower during BP therapy reintroduction, than after withdrawal. 710 stability events were recorded.

This well-tolerated system can provide high resolution data on both energy and stability. Although not significant, the reduction in energy expenditure may relate to changes in overall well being. Further work will evaluate the relevance of the large number of events seen.

1. Introduction

Chronic Kidney Disease is common, affecting approximately 5% of the UK population. The marked increase in prevalence seen with increasing age results in around 25% of individuals over 70 years old displaying biochemical evidence of CKD stage 3 and 4. Although ~50% of this group have stable disease, CKD is associated with a wide ranging set of clinical consequences. CKD is an increasingly well recognised independent cardiovascular (CV) risk factor, with documented evidence of increased vascular calcification [1, 2], abnormalities of adipokine profiles [3], endothelial dysfunction [4] and increasing blood pressure dysregulation [5]. CKD also predisposes to skeletal changes and increased fracture potential [6].

Crucially, whilst aggressive blood pressure control forms the mainstay of CKD treatment, its CV and functional consequences are unknown, particularly in the more vulnerable older age group. The older patient is both likely to benefit from such an approach (in terms of CKD progression and CV risk), but also to be at risk from worsening the already well recognised CV dysregulation that is characteristic of the older person [7]. This potentially leads to an increased propensity for falls. Falls are a major public health issue in this patient group. The annual UK NHS financial cost of hip fractures alone, associated with falls, approaches £2 billion.

We are currently undertaking a study to investigate the effects in the elderly of optimal antihypertensive medication titration to recommended targets of BP control. We hypothesise that pursuit of such a strategy in the older patient with CKD may result in an exacerbation of blood pressure dysregulation and increase the propensity to fall.

Objective assessment of stability, falls and energy expenditure in a home setting is challenging. Overall energy expenditure as an integrated measure of physical capability and psychological volition appears an excellent potential objective measure of quality of life. As part of this study we have been evaluating a new technology capable of providing high resolution, convenient assessment in a patient's home environment.

2. Methods

5 patients from our initial recruitment cohort were included in a sub-study to investigate the practicality and validity of community stability and energy monitoring using an ambulatory device.

Potential participants were identified from nephrology outpatients. Exclusion criteria included diabetes mellitus, atrial fibrillation, uncontrolled hypertension and severe heart failure. After recruitment, antihypertensive therapy was cautiously withdrawn, and after full washout (4 weeks) participants then underwent an integrated cardiovascular and functional assessment, which included a Timed Up and Go Test (TUGT). Antihypertensive therapy was then reintroduced, and titrated to target 130/80mmHg. Once stable (4 weeks at target BP without change in therapy), assessment was repeated. Participants were given a monitor at recruitment; this was then worn throughout antihypertensive washout and reintroduction. All participants provided written informed consent and the study was approved by the Trent Multi-centre Research Ethics Committee.

The PreventaFall Monitor (TriAx - Telemedcare Ltd, Lincoln, UK) is a small pager-like device, worn on the waist, that contains two accelerometers allowing measurement of orientation, force and direction of movement. This monitor unit communicates using Bluetooth with a basestation (MiiLink portal – Telemedcare Ltd) installed in the patient's home. The basestation buffers data from the monitor and transmits it daily, either via an in-built analogue modem or Ethernet connection to a home broadband hub, to a central server for further analysis and storage. The monitor contains sufficient memory to allow it to be worn outside the home, automatically emptying its buffer when it returns within range of the basestation. The monitor is worn throughout the day, and charged every night. Installation of the basestation only involves connection of power and the necessary communication cable. Written instructions and telephone advice are provided to support successful installation, no user configuration is required.

The monitor contains a 30 second buffer, and constantly analyses the accelerometer data. If the measured acceleration exceeds a preset threshold at any time, the previous 30 and subsequent 60 seconds recording are stored. Recording may also be triggered manually using a button on the front of the monitor. Energy data is always calculated and stored every 60 seconds.

The system used multiple analysis techniques. These include a heuristic movement classifier to basically classify standing, lying, sitting, walking and the appropriate transitions (including stand-lie as a potential marker of a fall) [8]. Whilst this proved accurate in controlled laboratory conditions, further refinement using Gaussian mixture models has improved the accuracy of classification in the home environment [9]. A significant feature of this system is that most processing is performed in real-time onboard the monitor [10].

Energy data is analysed as daily cumulative expenditure. This is currently provided from the device as SMA (normalised signal magnitude area), which is thus a velocity (m/s) [12]. Whilst velocity may be converted to energy by the following formula: Energy (J) = 0.5 x Mass (kg) x Velocity (m/s) squared, this is not currently implemented as body weight is not included in the onboard measurements. Event data is currently returned with event date and time, and markers denoting if the participant remained lying after 60 seconds or if the recording was triggered manually.

All data were tested for normality. Group data are presented as mean ± SD unless otherwise stated. Analysis was performed using SPSS v12.0.1 (SPSS Inc, Chicago, IL). Categorical data was compared using Chi-square test, continuous data using unpaired or paired Students t-test or Mann-Whitney U or Wilcoxon test as appropriate.

3. Results

All 5 patients completed the study. Their demographic data are presented below (Table 1). All patients reported no significant problems with the system and found it minimally intrusive to their usual lifestyle.

Table 1. Baseline demographic data for the cohort. (off – at the assessment after antihypertensive withdrawal; optimal – at the assessment after full titration of antihypertensive therapy).

ID	Age (yrs)	Gender	CKD Stage	Weight (kg)	TUG test (secs)	
					off	optimal
1	78	M	3	63	8	8
2	71	M	3	70	7	6
3	84	F	3	71	9	8
4	80	M	4	77	9	9
5	75	F	4	62	8	8

All patients succeeded in installing the portal within their home. Data were successfully collected for 263 of 296 days (89%). Missing data were due to system errors (20 days) and patient concordance (13 days), frequently due to patients not wishing to take the device on holiday.

3.1. Events

710 TriAx events relating to stability were recorded. 119 events were triggered manually. 554 events were triggered by the monitor but the participant was not horizontal at end of 60 seconds. 37 events were monitor triggered and the participant was horizontal at the end of 60 seconds.

There was marked variability between participants in both rate and type of event recorded. There was no significant difference in event rate with AHT washout and reintroduction (Figure 1), due in part to intra-participant variability (Figure 2).

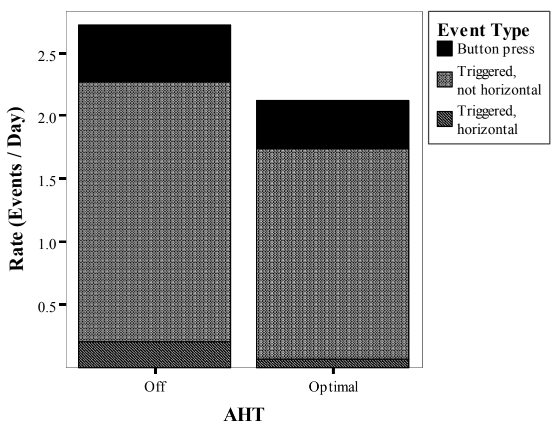

Figure 1. Event rate by AHT therapy.

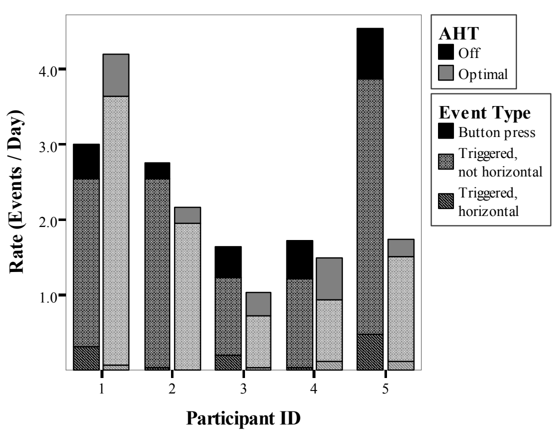

Figure 2. Event rate by AHT therapy and participant.

3.2. Energy

Average energy expenditure was variable between participants, and does not appear to be related to body weight. There was no significant difference by gender. Average energy expenditure was not significantly lower during antihypertensive reintroduction than after withdrawal of previous antihypertensive medication (405±79 c.f. 446±77M/s; p=0.079).

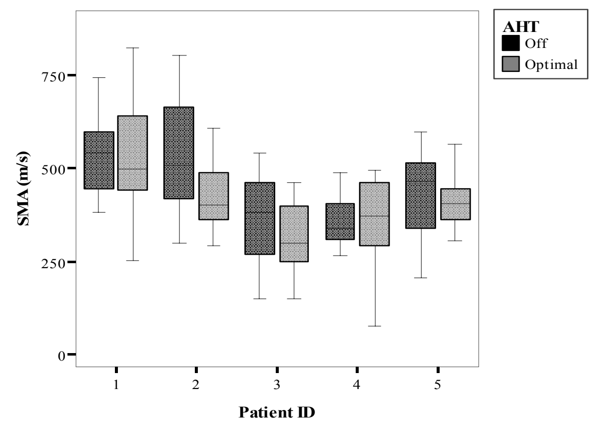

Figure 3. Variability in average energy expenditure.

There was no correlation between TUG test performance and either energy expenditure or event rate.

4. Discussion and conclusions

Domiciliary monitoring presents a number of challenges. Telemedicine needs to be minimally intrusive, reliable and supportable in an environment remote from central support and control. In this study we have demonstrated acceptable reliability and good patient concordance. Our participants were unselected from our recruitment cohort; whilst some possessed basic computer knowledge, none had broadband internet and none would regard themselves as particularly proficient in home electronics. However, all participants were able to connect and successfully use this system with minimal central input. In a study using a previous version of the system, Mathie et al recruited 6 healthy people, all aged over 80 years, for a period of 13 weeks [11]. Similar levels of concordance (88%) without significant problems were demonstrated, even though a daily directed routine was required. The low incidence of system error is encouraging, especially considering that this is research equipment still under development. Furthermore, the device used in this study is an improvement on that documented previously, primarily due to extended inbuilt memory that permits wear outside the house.

A significant factor in patient acceptability is the number and position of devices. Whilst many studies have utilised multiple accelerometers, the use of a single device with central placement will be less obtrusive and thus more suited to long-term use.

Metabolic energy expenditure is linearly related to triaxially assessed SMA [12, 13]. Whilst this correlates well, it excludes static exercise and upper limb energy expenditure [10], load carriage, or changes in surface or terrain [13]. Further limitations may include day-to-day variability in wearing times and acceleration due to external forces. Despite these issues, SMA has been shown to correlate with self-reported health status [11]. Although the change in energy expenditure did not reach statistical significance in this small initial cohort, the observed reduction in average energy expenditure with the reintroduction of antihypertensive therapy may therefore relate to changes in patients' overall well being. The large number of recorded events indicates the high sensitivity of this system, however further work is required to qualify their significance.

Future research and development focuses on the use of Directed Routines, performed whilst wearing the monitor, to further quantify falls risk. Recent work has demonstrated that the extraction of specific features from these assessments (primarily components of the TUGT) correlates with falls risk calculated from more intensive evaluation by Physiological Profile Assessment and Abbreviated Mental Test [14]. It is planned to further train and refine the falls/stability analysis systems using monitored periods that include TUGT and falls diaries. It is also hoped to be able to quantify both gait and sway, as have been examined with other triaxial systems, and thus move falls detection forward into falls prediction.

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References

[1] Sigrist M, Bungay P, Taal MW, McIntyre CW. Vascular calcification and cardiovascular function in chronic kidney disease. Nephrol Dial Transplant. 2006;21(3):707-14.

[2] McIntyre CW, Taal MW. Imaging and assessment of vascular calcification in chronic kidney disease patients. Current Opinions in Nephrology and Hypertension. 2004;13:637-40.

[3] Mallamaci F, Tripepi G, Zoccali C. Leptin in end stage renal disease (ESRD): a link between fat mass, bone and the cardiovascular system. J Nephrol. 2005 Jul-Aug;18(4):464-8.

[4] Schmidt RJ, Baylis C. Total nitric oxide production is low in patients with chronic renal disease. Kidney Int. 2000 Sep;58(3):1261-6.

[5] Chesterton LJ, Sigrist M, Bennett T, McIntyre CW. Reduced baroreflex sensitivity is associated with increased vascular calcification and arterial stiffness. Nephrol Dialysis Transplant. 2005;20(6):1140-7.

[6] Coburn JW, Elangovan L. Prevention of metabolic bone disease in the pre-end-stage renal disease setting. J Am Soc Nephrol. 1998;9(12 Suppl):S71-7.

[7] Youde J, Panerai RB, Gillies C, Potter JF. Reproducibility of circulatory changes to head-up tilt in healthy elderly subjects. Age Ageing. 2003 Jul;32(4):375-81.

[8] Mathie MJ, Celler BG, Lovell NH, Coster AC. Classification of basic daily movements using a triaxial accelerometer. Med Biol Eng Comput. 2004 Sep;42(5):679-87.

[9] Allen FR, Ambikairajah E, Lovell NH, Celler BG. Classification of a known sequence of motions and postures from accelerometry data using adapted Gaussian mixture models. Physiol Meas. 2006 Oct;27(10):935-51.

[10] Karantonis DM, Narayanan MR, Mathie M, Lovell NH, Celler BG. Implementation of a real-time human movement classifier using a triaxial accelerometer for ambulatory monitoring. IEEE Trans Inf Technol Biomed. 2006 Jan;10(1):156-67.

[11] Mathie MJ, Coster AC, Lovell NH, Celler BG, Lord SR, Tiedemann A. A pilot study of long-term monitoring of human movements in the home using accelerometry. J Telemed Telecare. 2004;10(3):144-51.

[12] Bouten CV, Koekkoek KT, Verduin M, Kodde R, Janssen JD. A triaxial accelerometer and portable data processing unit for the assessment of daily physical activity. IEEE Trans Biomed Eng. 1997 Mar;44(3):136-47.

[13] Mathie MJ, Coster AC, Lovell NH, Celler BG. Accelerometry: providing an integrated, practical method for long-term, ambulatory monitoring of human movement. Physiol Meas. 2004 Apr;25(2):R1-20.

[14] Narayanan MR, Scalzi ME, Redmond SJ, Lord SR, Celler BG, Lovell NH. A Wearable Triaxial Accelerometry System for Longitudinal Assessment of Falls Risk. EMBS 2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society; Vancouver.

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