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Validation of the NANA (Novel Assessment of Nutrition and Ageing) touch screen system for use at home by older adults

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ABSTRACT

Prospective measurement of nutrition, cognition, and physical activity in later life would facilitate early detection of detrimental change and early intervention but is hard to achieve in community settings. Technology can simplify the task and facilitate daily data collection. The Novel Assessment of Nutrition and Ageing (NANA) toolkit was developed to provide a holistic picture of an individual's function including diet, cognition and activity levels. This study aimed to validate the NANA toolkit for data collection in the community. Forty participants aged 65 years and over trialled the NANA toolkit in their homes for three 7-day periods at four-week intervals. Data collected using the NANA toolkit were compared with standard measures of diet (four-day food diary), cognitive ability (processing speed) and physical activity (self-report). Bland–Altman analysis of dietary intake (energy, carbohydrates, protein fat) found a good relationship with the food diary and cognitive processing speed and physical activity (hours) were significantly correlated with their standard counterparts. The NANA toolkit enables daily reporting of data that would otherwise be collected sporadically while reducing demands on participants; older adults can complete the daily reporting at home without a researcher being present; and it enables prospective investigation of several domains at once.

1. Introduction

Nutrition, cognition, and physical activity all contribute to health and wellbeing in later life but all are vulnerable to conditions of ageing. These domains also interact such that poor nutrition is linked to both cognitive impairment (Wells and Dumbrell, 2006) and depression (Phillips, 2012), and reduced physical activity is associated with depression (Strawbridge et al., 2002), cognitive impairment (Laurin et al., 2001) and poor nutrition (Drewnowski and Evans, 2001). Collectively these factors may increase the risk of physical frailty (Fried et al., 2004) and sarcopenia (Vandewoude et al., 2012), which in turn increase the risk of disease burden (Patel et al., 2013) and mortality (Arango-Lopera et al., 2013) in older people.

Early detection of change in any of these domains would facilitate early intervention and potentially prevent serious deterioration or hospitalisation. However, the progressive and dynamic nature of ageing and the varying rate of change in cognitive and physical function make it challenging to collect prospective information from older adults, particularly from those living independently in the community. Simple, easy-to-use measures that capture accurate data from individuals in their natural environment would facilitate this. However, existing measures of diet and cognition in particular, only provide snapshots of the situation, for example a one-off cognitive assessment in a memory clinic or research laboratory. This makes it difficult to identify the presence or rate of decline, or to look for co-occurring changes between domains.

Additionally, many currently available methods of assessment (for example, written food diaries, or psychometric cognitive assessments) rely upon pen and paper, and are time consuming for participants who may find them burdensome to complete. Existing tools have also not been designed for the individual to use at home without a researcher being present for at least part of the process, or for data collection over an extended time period. There is also a large human resource cost attached to interviewing participants and scoring the measures.

Recently the possibility of using interactive technology for data collection has been recognised with the advent of 'momentary' measures

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that prompt participants to record aspects of their current experience, such as mood or social exchanges, at different times of the day (Cain et al., 2009). Similarly the potential of computer-based dietary assessment methods (Illner et al., 2012) are starting to be explored, although not specifically for older adults. These developments highlight the potential for using interactive technology to collect data from a range of domains within a community setting. Multidimensional assessment of nutrition along with cognition and physical activity would enable effective targeting of interventions (Balducci and Beghe, 2000) and early detection of change in functioning. The Novel Assessment of Nutrition and Ageing (NANA) project has developed and evaluated a touch screen computer-based, comprehensive daily assessment toolkit for older adults to use in their own homes to collect detailed information across domains including dietary intake, cognitive function, and physical activity.

A key aim of NANA was to provide a user-friendly interface that makes it easy for older people to enter data. Touch screens are particularly useful for people with no prior computer experience (Wandke et al., 2012) as they can be used without a mouse or keyboard and require little training. To develop the integrated NANA toolkit we used an iterative design approach (Nielsen, 1993), refining the system over multiple iterations. Also, the individual components of nutrition, cognition, and physical activity were developed and tested separately before combining them for validation in the home. This development process also included the reliability of measuring grip strength and exhaustion, which are two of the five indicators of physical frailty (Fried et al., 2001), in people's own homes without a researcher being present. These 'development', 'test' and 'refine' stages of the NANA project are discussed more fully elsewhere (Astell et al., in press). In this study we assessed the validity of the diet, cognition and physical activity measures within the NANA system.

The ability of the NANA system to accurately collect dietary intake information from older adults was validated against a four day estimated food diary. The validity of the NANA cognitive measures was examined using correlation coefficients with the Symbol Digit Modalities Test (SDMT (Smith, 1982)), an existing measure of cognitive processing speed that is considered a marker of cognitive ageing (Deary et al., 2010) and is predictive of numerous health outcomes (Lara et al., 2013). The NANA physical activity measure was compared with the Community Healthy Activities Model Program for Seniors (CHAMPS (Stewart et al., 2001)), a validated self-report measure of physical activity developed for older adults.

The design of the study fulfilled two purposes. The first objective was to validate the diet, cognition and physical activity elements of the NANA toolkit and the second objective of the study was to determine whether older adults were amenable to data collection over several non-consecutive weeks, as may occur in a longitudinal study design. The data collected during the second recording period was used for the purposes of validation. For the purposes of dietary assessment the reference method (food diary) was at a different time period to the test method (NANA), which is the typical approach used to ensure that the reference method does not interfere with the test method (Margetts and Nelson, 1997).

2. Method

2.1. Study overview

Within a 14-week protocol, participants used the NANA system for three separate one-week periods over 12 consecutive weeks with a three-week resting period between each period of use (Fig. 1). For every day of each 7-day NANA recording period, participants used the system to record their dietary intake and were scheduled to complete two brief cognitive tests. At the start and end of each 7-day recording period they were also presented with questions about their physical activity and exhaustion over the past seven days. In week 1 the participants completed a baseline assessment of current gold standard measures in each domain. These were repeated in Week 11 to identify any changes in the sample over the study period and to provide the comparison data for that collected with the NANA toolkit.

In week 8 participants attended a clinical research facility for collection of biomarkers of nutrient intake (these data are reported and analysed in Timon, et al., *submitted*).

2.2. Participants

Forty older adults (16 men) aged between 65 and 89 years (mean age 72.39 years) who were living independently in the community were recruited to take part in this study. Participants were recruited from two different locations in the UK to extend the representativeness of the sample. Twenty were recruited from Sheffield, a large UK city with a population of approximately 550,000, and 20 from St. Andrews, a small UK town with a population of approximately 11,000. Socioeconomic data were not collected from the participants. However, average income in St. Andrews (N.E. Fife £23,200) was above the UK average (£21,326) while Sheffield was below (£20,310; (http://www.theguardian.com/news/datablog/2011/nov/24/wages-britain-ashe-mapped#data)) in 2011 when the study took place. Exclusion criteria were: suffering from a serious illness, unable to understand/communicate effectively, unable to provide informed consent or anticipating a deviation from their habitual diet during the study period. Participants were recruited between April and June 2011 and the study commenced in July 2011.

2.3. Materials

2.3.1. NANA toolkit

The NANA toolkit comprised a touch screen computer, webcam, (Fig. 2) and hand dynamometer (not shown or reported here). The NANA software, which includes elements for measuring dietary intake, cognition, and physical activity, was loaded onto a 15.6″ touchscreen (Asus Eeetop, model ET1610PT) computer'. A Microsoft® LifeCam Cinema™ Webcam with microphone was mounted on the top of the computer in the centre, directed downwards in order to capture food and drink images.

2.3.1.1. NANA dietary assessment. The NANA dietary data entry comprised a hierarchical food tree structure in which participants selected the food item they were about to consume through progressive levels of the food tree allowing a specific food or drink item to be selected. Fig. 2 shows the 12 high-level food groups. Once all food items had been entered, participants were prompted to take a photograph of the food and drink they were about to consume. At the end of the meal they were prompted to photograph any leftovers they had. Items not found in the food tree, forgotten at the time of meal entry, or consumed outside of the home were entered later. However, in these cases instead of photographing the items the participant was asked to verbally describe the food and drink consumed, which was audio-recorded by the NANA system.

The nutritionist used food/drink descriptions, food photographs and voice recordings to enter the dietary intake data into WinDiets nutritional analysis software (Windiets nutritional software). Food portion size assessment was based upon the pre-consumption images and any photographs of leftover meal/drinks. For instances of food items consumed outside of the home where portion size information was not available, small, medium and large portion sizes (MAFF, 1988) were assigned based on the participants' normal consumption amount.

2.3.1.2. NANA cognitive assessments. The cognitive assessment comprised two brief tasks (the white square task and the shopping list task) that were developed for the NANA system. Both tasks were designed to be measures of cognitive processing speed but at different levels of complexity. Cognitive processing speed is a sensitive measure of cognitive

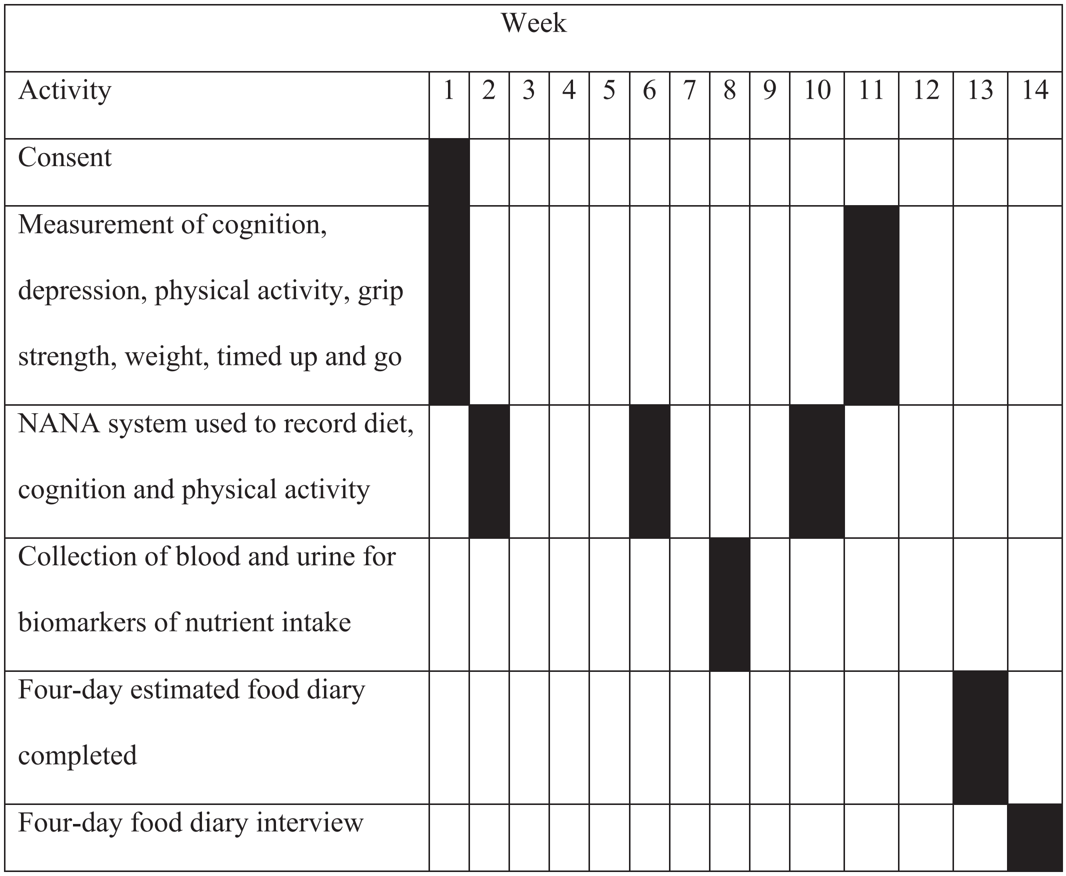

Fig. 1. The study design of the "NANA system" integrated toolkit validation.

ageing (Deary et al., 2010) and the tasks developed for NANA were based on existing gold standard measures used in the assessment of cognitive function. The white square task was a simple measure of processing speed requiring participants to touch a white square as quickly as possible once it appeared on one of four green rectangles on the screen. The shopping list task provided a more complex measure of processing speed as participants were required to 'report what is on the shopping list as quickly as you can'. The 'shopping list' comprised four items 'apples', 'carrots', 'lemons' or 'onions', that were each paired with one of the digits 2, 3, 4, and 5 (e.g. 4 apples, 2 lemons, etc). A total of 10 trials were presented in each session for each task. Performance on both tasks was judged according to the mean response time for correct responses. Participants were not given any feedback regarding the accuracy of their responses during or after the task. Performance on these tasks was compared with performance on the SDMT (Smith, 1982), a validated pen and paper measure of processing speed (see Section 2.3.2 below).

Fig. 2. NANA system showing nutrition data entry.

2.3.1.3. NANA physical activity assessment. The NANA physical activity measure comprised three questions about the number of hours ('none', 'less than 1 hour', '1 to 3 hours', '3 to 5 hours', '5 to 7 hours', 'more than 7 hours') in the past week spent on the following activities: (i) "HOUSEWORK, DIY, or GARDENING"; (ii) WALKING outside the home and (iii) OTHER physical activity The participants were asked to select the response that best reflected the time they estimated they had spent doing each of these activities or chose not to answer by selecting "No answer". The format of the questions was in keeping with the intention to reduce burden on the participants and followed that of the self-report exhaustion questions from the CES-D (Orme et al., 1986) that are incorporated into the NANA system (after (Fried et al. (2001)).

2.3.1.4. Other NANA assessments. The NANA toolkit also included measures of self-reported mood, appetite, exhaustion, plus a device and instructions for measuring grip strength that are not reported here (please contact the authors for further details).

2.3.2. Traditional measures

2.3.2.1. Dietary assessment

2.3.2.1.1. Four-day estimated food diary. A four-day estimated food diary (Bingham, 1987) was used as the reference method against which the relative validity of the dietary intake estimated using the NANA systems was assessed. Participants were given a paper food diary, and asked to record in it all food, drinks and supplements consumed over a 4-day period (including one weekend day). Participants were also provided with a food portion size booklet containing photographs from the Ministry of Agriculture Food and Fisheries food atlas (Nelson et al., 1997). Participants were instructed to use the food portion size booklet to aid in their recording of food portion sizes. Within one week of completion of the food diary participants were visited at home by a researcher and interviewed about their diet diaries. Any anomalies or missing information was gathered by the researcher with the aid of the MAFF photographic atlas of food portion size (Nelson et al., 1997). Data from the food diary was analysed for macronutrient and micronutrient content using Windiets (see above).

2.3.2.2. Cognitive assessments. All participants completed a short battery of cognitive tests in weeks 1 and 11 of the study to provide assessment of their current cognitive function. This included the Mini-Mental State Examination (MMSE; (Folstein et al., 1975)) a brief measure of global cognitive function scored out of 30; the National Adult Reading Test (NART; (Nelson, 1982)), which produces a measure of verbal IQ. The Symbol Digit Modalities Test (SDMT: (Smith, 1982)), a measure of processing speed was used as the reference measure for the NANA cognitive data. The SDMT is scored as the total correct responses recorded over a 90-second period.

2.3.2.3. Physical activity assessments. Participants were asked to complete the Community Healthy Activities Model Program for Seniors (CHAMPS, (Stewart et al., 2001)), a validated self-report measure that is commonly used as an outcome measure of physical activity (e.g. (King et al., 2008)). The CHAMPS was designed as a research tool to measure weekly frequency and duration of physical activity undertaken by older adults and consists of a 41-item questionnaire. Questions are of the following three-part format: “In the past four weeks in a typical week did you…walk fast or briskly for exercise?”; “if YES, How many times?” “How many TOTAL hours a week did you do it?”. This yields the total hours of activity per week, from which estimates of caloric expenditure can be calculated by considering the activity reported and the frequency and duration of the activity.

2.3.2.4. Other assessments. A selection of additional measures was carried out in at baseline (week 1) to characterise this sample of older adults and repeated in week 11 to identify any changes in the sample that might occur during the study. These comprised measures of weight, depression, which could affect motivation, grip strength, gait and general mobility.

2.3.2.4.1. Weight. Participants were weighed at home using Tanita™ Inner Scan Body Composition Monitor (BC-543) scales on two occasions (baseline and week 11). Weight (SECA medical class 3 scales and a SECA stadiometer) and height measurements from the clinic visit (week 8) were used to calculate Body Mass Index (BMI).

2.3.2.4.2. Depression. The Geriatric Depression Scale short (GDS-short; (Yesavage et al., 1983) is a 15-item self-report assessment designed specifically to identify depression in older adults.

2.3.2.4.3. Grip strength. Isometric grip strength was measured using a Jamar™ Plus Digital Hand Dynamometer. Participants were asked to squeeze the dynamometer as tightly as possible 3 times. Participants were instructed to stop if they felt any discomfort and were allowed a 60 second rest between each squeeze. Maximum grip strength of the three grips in kg was reported, as recommended (Desrosiers et al., 1995).

2.3.2.4.4. Gait video recorded 3-metre walk (home). Walking speed and step time were recorded during the study as indicators of gait function using a traditional video-recorded walk (Dickens and Smith, 2006). Participants were video-recorded walking in their homes over 3 m at baseline and week 11. Each recording was analysed to derive the individual step-times for each walk. The mean step-time and standard deviation were then used to produce the step-time coefficient of variance (CV) for each participant.

2.3.2.4.5. Timed up and Go (TUG) (Podsiadlo and Richardson, 1991) in the home. The TUG is a measure of an individual's mobility. Participants are asked to stand up from sitting in an armchair, walk 3 m, turn around and walk back to the chair and sit down. The time to complete the whole task is recorded. Twelve seconds is suggested as a practical cut-off value to indicate normal versus below normal TUG test performance (Bischoff et al., 2003).

2.3.2.4.6. Demographic information. A demographic questionnaire was compiled to collect background information from the participants. This included current medical conditions, number of prescribed medications food supplements, smoking history, self-reported difficulties with activities of daily living and familiarity with a range of current technologies.

2.4. Procedure

2.4.1. Nutritional assessment procedure

The NANA systems were installed in participants' homes by the researchers. The majority of the participants chose to locate the NANA system in the kitchen while a few preferred the dining area. Participants were given structured individual training in the use of the system from one of the researchers, and were provided with a NANA reference manual and a help-line telephone number. Participants were instructed to use the NANA system to record all food and drink items consumed over 3×7 day periods at intervals of 4 weeks over 12 consecutive weeks. At the end of each of the three recording periods the system was uninstalled from the participant's home and the data analysed.

2.4.2. Cognitive assessment procedure

The cognitive assessments were each scheduled to be administered by the system once a day, alongside additional measures of mood and appetite (not reported here). When a cognitive assessment was due, an image of a silhouette head with cogwheels in it appeared on the screen, and the next time the participant interacted with the system, they were prompted with the message “There are readings or exercises overdue. Do you want to do them now?” If a participant did not complete a cognitive assessment before the next one was due, both would be presented the following day (and the date and time of completion recorded in the system).

2.4.3. Physical activity assessment procedure

The physical activity questions were scheduled on day 1 and day 7 of each week of using the NANA system to allow participants to report on their activity over the past week. These activities were prompted by the message “There are readings or exercises overdue. Do you want to do them now?”, accompanied by a symbol of a running figure.

2.5. Data input and analysis

2.5.1. Nutrition

For this validation study there were three separate 7-day periods of diet recording using the NANA system. It was decided that the second week of dietary data recording should be used for the analysis for two reasons: 1) this period was closest to the collection of the blood and 24 hour urine specimens and hence would be most reflective of the markers of nutrient intake (Bischoff et al., 2003) and 2) users would be more familiar with recording their diet using the NANA system than the first recording period. Four days from the second week of

Table 1
Demographic data collected from the participants in the NANA validation study.

Caucasian	40 (100%)
Age (years), mean (range)	71.87 (65–89)
Female/male	24/16
Body Mass Index, mean (range)	26.9 (16.7–39.6)
Medical history:	
Participants with ≥1 medical condition	32 (80%)
Participants taking ≥1 prescribed medicine	33 (82.5%)
Supplement use: ≥1	19 (47.5%)
Smoking status:	
Current smoker	2 (5%)
Ex-smoker	8 (20%)
Never smoked	30 (75%)
Factors affecting everyday living	
Participants who reported:	
– Having arthritis in the hands	9
– Hearing problems	9 (22.5%)
– Difficulty reading newsprint	2 (5%)
– Difficulty preparing food	0
– Difficulty shopping for food	8 (20%)
Technology usage	
Participants who reported prior use of:	
– A mobile phone	38 (95%)
– A digital camera	32 (80%)
– A microwave	33 (82.5%)
– Self-service supermarket check-outs	22 (55%)
– A computer	36 (90%)
Participants who reported:	
– Home internet access	36 (90%)
– Being internet users	32 (80%)

NANA dietary data collection (3 weekdays and 1 weekend day) were used for dietary assessment. Food intake descriptions and photographs from each participant were entered and analysed using Windiets nutritional software (Windiets nutritional software). The Windiets nutritional software was also used to analyse the four-day food diary.

2.5.2. Cognition

Although each participant was scheduled to complete seven iterations of each test (one each over the seven days), some participants completed more or fewer than this due to procedural errors in the scheduling of the tasks or technical errors. The total number of complete datasets (i.e. containing data for both the shopping list task and the white square task) entered into the analysis ranged from 1 to 9 per participant, with a mean of 6.68 (SD = 1.31) and a total of 267 (74%) across all participants. The mean response times (and SD) for correct responses on the two NANA cognitive tasks during the second week of using NANA (same as nutrition data) were calculated for each participant.

2.5.3. Physical activity

The utility of the NANA physical activity questions was assessed by comparing the total number of hours per week reported by the participants with the amount of total hours of activity estimated on the CHAMPS (Stewart et al., 2001).

2.6. Statistical analysis

Bland–Altman analysis (Bland and Altman, 1986) was used to assess the relationship between the NANA method and the 4-day estimated food diary for the reporting of macronutrient intake. Paired student t-tests were used to further explore the relationship between the two methodologies. Statistical analysis was performed using SPSS (Version 21, 2012, IBM Corp. Armonk, NY).

In order to assess concurrent validity of the cognitive and physical activity, Pearson's product moment correlation coefficients were calculated between the mean response times on each of the two NANA cognitive tasks with the number of correct responses made on the SDMT task, which was performed in the second week of pen-and paper data collection.

3. Results

All participants were British Caucasians with their average BMI putting them in the overweight category (above 25), which is similar to that reported for this age group in the UK National Diet and Nutrition Survey (Bates et al., 2012); Table 1). The majority of participants had one or more concurrent medical conditions, were taking medications and had never smoked. Other demographic information and descriptive data on their current technology use are contained in Table 1.

The MMSE scores at baseline confirmed that all participants were healthy and performing within the normal range for their age at entry to the study (Table 2). Additionally, their NART IQ was in the normal range and their scores on the GDS suggested that they were not depressed at baseline. The mean gait speed was within normal limits and the mean TUG time (for general mobility) was under the cut-off limit, suggesting that they were performing within the normal range. Baseline grip strength was similar to that reported in other studies with this population (Desrosiers et al., 1995).

The NANA validation comprised two stages. First the data from the baseline traditional pen and paper measures were compared with the data from the second administration of these tests (Table 2) to look for any changes in the sample during the study. Diagnostic tests showed the data from the majority of the variables were normally distributed but that the TUG test data were not. Therefore, paired samples t-tests were carried out on the normally distributed data and the Wilcoxon Signed Ranks Test was carried out on the TUG test data. The results of the comparisons revealed that there were no significant differences between the variables (MMSE, GDS, weight, grip strength, gait and TUG) at baseline and the second data collection (week 11) indicating that there were no changes in the samples over time. This confirmed the suitability of using the second set of data for comparison with the NANA data.

The second stage of the validation involved extracting the data from the second week of using the NANA system and comparing these with the second week of data collected using the traditional measures for each domain. Table 3 shows the means and standard deviations for each measure. The results for each domain are presented below.

3.1. Nutrition

Bland–Altman analysis was used to explore the differences between energy and macronutrient intake derived from the NANA system and the four-day food diary. Fig. 3 shows the Bland–Altman plot for total daily energy intake as reported by the traditional food diary record and using the NANA system. The mean difference for energy between NANA and the diary was −250 kJ/day with lower and upper limits of agreement of (mean difference of ±2SD) of −1711 to 1212 kJ/day to. Analysis was also performed for protein, fat and carbohydrate (plots not shown). The mean difference (limits of agreement) for protein was −3.36 g/day (−24.18 to 17.46 g/day), for fat 1 g/day (−21.66 to 23.66 g/day) and for carbohydrate −7.4 g/day (−73.01 to 58.27 g/day).

Table 2
Group means (SD) on traditional measures at start and end of NANA validation study (n = 40 unless otherwise indicated) to examine consistency in the sample over the study period.

Measure	Baseline data collection mean	Second data collection mean
MMSE/30	28.63 (1.64)	28.93 (1.49)
NART FS IQ	117.88 (5.71)	n/a
GDS	1.62 (1.91)	2.21 (2.44)
Weight kg	79.80 (19.03)	80.06 (18.91)
Grip strength Jamar – mean maximum grip KG (range) (n = 38)	27.48 (11.06)	28.16 (11.52)
Gait speed (m/s) (n = 39)	1.12 (0.32)	1.08 (0.26)
Gait step-time variability (ms) (n = 39)	0.055 (0.03)	0.067 (0.03)
TUG	10.64 (3.05)	10.42 (2.57)

Table 3
Mean (SD) of the traditional (pen and paper) and NANA measures at T2.

Measure	Traditional (mean, SD)	NANA (mean, SD)
Nutrition	Estimated food diary	NANA dietary entry
Nutrition – energy (KJ/d)	7348 (1502.9)	7098 (1381.8)
Nutrition – carbohydrates (g/d)	192 (55.6)	185 (51.8)
Nutrition – protein (g/d)	79 (17.5)	76 (16.0)
Nutrition – fat (g/d)	70 (18.2)	71 (17.0)
Cognitive function	SDMT	NANA processing speed 1 & 2
Processing speed 1	40.15 (12.45)	1.03 (0.23) s
Processing speed 2	(correct responses)	2.64 (0.61) s
Physical activity (self report)	CHAMPS	NANA questions
Weekly hours of reported activity	15.4 (12.05)	9.2 (4.17)

Key: pen and paper cognition 1 & 2 = SDMT substitution (correct); NANA processing speed 1 = white square task; NANA processing speed 2 = shopping list task (mean RT of correct responses, in seconds).

Paired t-tests were used to compare the mean values obtained by both methods and to establish whether there was a significant difference for any of the nutrients measured by the NANA system and the food diary. The two methods were not significantly different for estimated intake of carbohydrate (g) $t = -1.348$, $p = .186$; protein (g) $t = -1.935$, $p = 0.061$ and fat (g) $t = 0.530$, $p = 0.600$, however there was a small, but significant difference for the estimated Energy (KJ) $t = -2.049$, $p = .048$, with the NANA estimate being lower than the food diary. Despite the small difference in energy intake taken together these results suggest that NANA is a suitable alternative to estimated food diaries in older adults.

3.2. Cognition

Performance on both of the NANA measures of processing speed were both highly correlated with participants' performance on the traditional processing speed measure (SDMT; White Square $R = -0.65$, $p < .001$; and Shopping List $R = -0.86$, $p < .001$ respectively), indicating a high level of concurrent validity. Performance on the two NANA tasks were also highly correlated with one another ($R = 0.83$, $p < .001$).

3.3. Physical activity

The hours of physical activity self-reported by participants using the CHAMPS questionnaire were much higher than those from the NANA system (Tables 1 and 2) although there was a significant correlation ($R = 0.343$, $p < 0.05$) between the two measures.

4. Discussion

The NANA toolkit was developed to facilitate collection of holistic data on a range of health-related behaviours and indicators from community-dwelling older adults. The results of this study show that the toolkit provides a valid means of assessing dietary intake and cognitive function over a 7-day period. Regarding capturing physical activity data, although correlated, our experience suggests that further work is needed on the most appropriate method.

All methods of self-reported dietary assessment are prone to measurement error for a whole host of reasons including daily variation in dietary intake, inaccurate estimation of portion size, and bias in the data as a result of recall error and over and underestimating of certain foods (Margetts and Nelson, 1997). However the use of technology provides an opportunity to create more objective and accurate measures of dietary assessment (Adamson and Baranowski, 2014; Thompson et al., 2010). In the absence of a true measure of habitual dietary intake we can, at best, only compare the relative validity of one method against another. The reference method for this study was the 4-day estimated food diary, which was chosen because of its popularity as a dietary assessment method in the UK.

Estimates of dietary energy and macronutrient intake obtained using the NANA method of dietary assessment were in close agreement with estimates obtained from the traditional food diary method. A significant difference ($p < 0.048$) was observed for estimated energy intake, however the difference in energy intake between the two methods was modest at just 249 kJ/day (around 60 kCals, or approximately 3% of total energy intake). There are several possible explanations for this apparent discrepancy. The first, most obvious reason is that the two methods were applied at different time points, several weeks apart and the lower energy intake using the NANA method may reflect a genuine lower energy intake at that time. Alternatively participants may have failed to record every food item consumed using NANA, or else over-estimated their true dietary intake using the food diary. This final explanation is a strong possibility since the food diary method relies on the participant to estimate their portion size whereas a trained nutritionist assesses portion size from photographs using the NANA method. One solution is to use age appropriate portion sizes (Food Standards Agency). Given the challenges and inaccuracies of dietary assessment, the small difference in energy intake found here is tolerable and the good agreement between the two methods indicates that the NANA method of food recording is a valid method of dietary assessment, and is a potential alternative to the food diary in older adults.

Performance on each of the two NANA cognitive tests was highly correlated with the Symbol Digit Modalities Test (SDMT) (Smith, 1982), although the shopping list task was stronger, indicating that they both provide valid measures of cognitive processing speed. Cognitive processing speed is a functional marker of ageing (Deary et al., 2010) that is correlated with other domains of cognitive ability (Tucker-Drob and Salthouse, 2011) and is predictive of health, morbidity, and everyday function (Lara et al., 2013). The two NANA cognitive tests are therefore likely to provide meaningful information about current and future functional status.

The amount of hours participants reported in various types of physical activity was lower in response to the NANA self-report questions than on the CHAMPS questionnaire. This may simply be because we used fewer questions in NANA, or because the CHAMPS overestimated energy expenditure, possibly by encouraging over-reporting of activity or overestimation of the amount of time spent on various activities (Hekler et al., 2012). These findings suggest that individuals' subjective

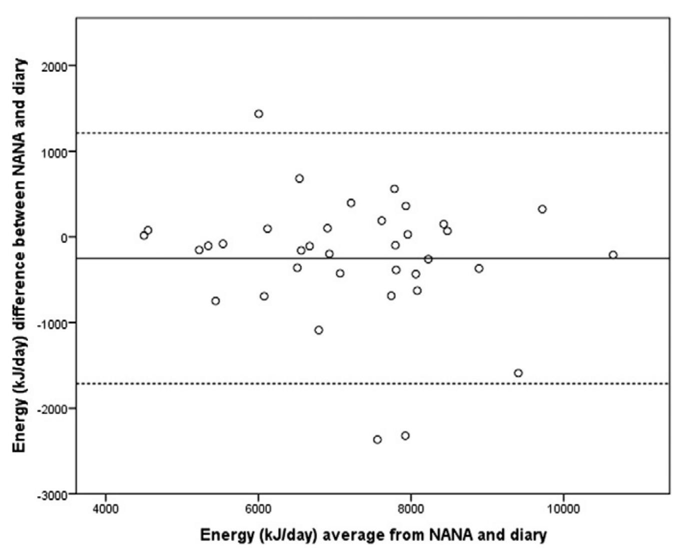

Fig. 3. Bland–Altman plot (NANA-food diary) of the difference between energy intake recorded by the NANA method with that recorded by the 4-day food diary against the mean energy intake for the 2 methods. Mean difference [solid line] and upper and lower limits of agreement (mean difference ± 2SD) [dashed lines] for energy: −250 kJ/day, −1711/1212 kJ/day.

self-reports provide a useful insight into their own perception of how healthy or fit they are, even if it is inaccurate against objective measures. This is important for developing behaviour change interventions and targeting information appropriately to individuals. However, for future studies we are looking at extending the objective measurement through incorporation of data from accelerometers into NANA.

The computer-based NANA system utilises an innovative touch-screen software interface to: (1) facilitate capture of detailed diet and nutritional information, (2) provide unobtrusive assessment of cognitive function, mood and appetite, (3) capture physical activity data and grip strength and (4) generate data to enable exploration of the relationships amongst the data streams. This multidimensional toolkit takes advantage of the benefits offered by technology to ease the burden on participants during data collection, hence enabling the collection of detailed data for an extended period of time.

A unique element of the NANA toolkit is its capacity to provide an individualised profile of performance in several domains that could be used to identify changes in performance relative to how the individual usually performs. This would be an advance over comparison with age-related norms and may be useful for early detection of change in both research and clinical settings. For example, an individual's cognitive speed may slow over a few days relative to their usual performance, which may be related to accompanying changes in dietary intake, mood or amount of reported physical activity. These changes may indicate an acute situation such as a chest or urinary tract infection (UTI) or the early signs of a more significant cognitive decline, or perhaps the onset of a mood disorder.

The NANA profiling ability could also be used to support the delivery of interventions by providing on-going monitoring of the individuals' performance in any combination of the domains. For example, participant compliance to dietary intervention trials could be accurately assessed using the NANA toolkit and participants failing to meet intervention targets could be offered additional support. We are keen to further explore the potential of the NANA data for both detecting early signs of change and to support interventions. We are also keen to explore the further development of additional functionality, particularly related to the detection of frailty that has not been possible in this study.

Factors that may limit the generalizability of the study include the relatively small sample size of 40 who were from one ethnic group and who showed an interest in technology, although were not necessarily early adopters of technology. Another potential limitation is the comparison of data from different time points. This is the traditional method in dietary assessment to ensure that the reference method does not interfere with the test method (Margetts and Nelson, 1997). As a consequence all of the data were collected at these time points, as this was when the participants had the NANA system in their homes. However, this is less critical for the cognitive data as the reference measures are typically only carried out on single occasions and the first stage of the data analysis confirmed that there were no significant differences between the data collected at baseline and the second time point using the traditional measures.

The participants were drawn from two socioeconomically diverse communities in an attempt to gain a broad sample of older adults. They were a healthy, if overweight sample as evidenced by their cognitive scores, grip strength, gait and lack of depression. The majority were computer users and reported few limitations in their everyday activities. While attempts were made to recruit participants from different living situations, including extra care and social housing, the extent to which the results can be extrapolated beyond this sample will require further investigation. Additionally we excluded residents of care-home facilities, people suffering from a serious illness, which could include cognitive impairment or who were not able to understand/communicate effectively and more work needs to be done to explore the utility of NANA with these populations. Strengths of the study include the broad range of ages of the older adult participants who were recruited from two demographically different areas.

The NANA toolkit development has been informed by the need to make it acceptable and accessible for older people to have in their own homes. Its focus on holistic multidimensional assessment in one integrated modular system makes it an ideal tool for investigating the complex relationship amongst the multiple factors that contribute to good nutritional status, cognition, mood and physical activity in older adults.

Assurances

The project received a favourable ethical opinion from the Fife and Forth Valley Research Ethics Committee (08/50501/104). All participants gave written informed consent.

Roles

All authors were involved in designing the NANA toolkit and the validation study. Additionally, AA led on writing the MS; FH analysed the grip strength data; LB designed the cognition and mood tasks and cleaned and analysed the cognition and mood data; CT recruited participants/conducted the data collection and also analysed the nutrition data; LM recruited participants/conducted the data collection and analysed the gait data; TS programmed the software; TA cleaned and prepared the physical activity data; HK cleaned and prepared the grip strength data; EW supervised the nutritional analysis and analysed the physical activity data.

Conflict of interest

The authors declare that they have no conflicts of interest.

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