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# Leg extensor power, cognition, and functional performance in independent and marginally dependent older adults

JOHN K. PETRELLA<sup>1</sup>, L. STEPHEN MILLER<sup>2</sup>, M. ELAINE CRESS<sup>3</sup>

<sup>1</sup>Department of Physiology and Biophysics, Muscle Research Laboratory University of Alabama-Birmingham, VAMC/GRECC 11-G, 700 19th Street South, Birmingham, AL 35233, USA

<sup>2</sup>Department of Psychology, Gerontology Center, Neuropsychology and Memory Assessment Laboratory, Psychology Building, University of Georgia, Athens, GA, USA

<sup>3</sup>Department of Exercise Science, Gerontology Center, Aging and Physical Performance Laboratory, University of Georgia, Athens, GA, USA

All work was completed at the Aging and Physical Performance Laboratory, University of Georgia, USA

Address correspondence to: J. K. Petrella. Fax: (+1) 205 558 4749. Email: jpetrella@physiology.uab.edu

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## Abstract

**Background:** physical and cognitive function must be integrated and optimised in performance of daily activities. Age-related loss of physical function can result in poor performance of necessary daily activities and possibly lead to increased dependency and a change of living status.

**Objectives:** (1) to evaluate average differences in physiological, cognitive, and functional performance of older adults from two different levels of independence, (2) to examine contributions of leg power, cognition, and functional performance to level of independence.

**Design:** cross-sectional study of self-reported 'independent' *versus* 'marginally dependent' older adults.

**Subjects:** 35 older adults ( $77.2 \pm 6$  years) were placed into independent ( $n = 18$ ) or marginally dependent ( $n = 17$ ) groups based upon the Medical Outcomes Study SF36 physical function scores (independent: SF36PF  $\geq 85$ , marginally dependent: SF36PF  $< 85$ ) and living status.

**Methods:** assessment of physical function includes the dependent variable, SF36PF. Assessment of physical, cognitive, and functional performance include the independent variables of leg extensor power, reaction time, processing speed, memory, attention, and functional performance. Functional performance is assessed by the Continuous Scale Physical Functional Performance Test.

**Results:** independent older adults have greater performance on leg power, reaction time, processing speed, memory, and functional performance than marginally dependent older adults. Functional performance is an independent predictor of level of independence. Leg power and cognition were separate small but significant predictors of independence.

**Conclusions:** independent older adults have greater physiological, cognitive and functional performance than marginally dependent older adults. Individuals with greater functional performance tend to remain independent.

**Keywords:** older adults, muscle power, cognition, physical function

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## Introduction

Maintaining independent function is a primary goal of health care for older adults [1]. Physical function is the integration of physiological and cognitive capacities to optimise physical performance in daily function [2]. Older adults perceive quality of life to be more influenced by their level of functioning than by disease conditions and symptomology [3]. When physical function begins to decline, limitations in

mobility, including difficulty walking or climbing stairs, typically occur and can predict the onset of physical declines [4, 5] resulting in loss of independence.

Muscle strength and power are important contributors to mobility and function in older adults [6, 7]. Recent research has studied the influence of lower limb peak power on independence in older adults [8]. Muscular power, the product of strength and speed of activation, is functionally relevant to physiological capacity since power rather than

strength alone is often used in mobility [8, 9]. Leg extensor power (LEP) is needed for many activities of daily living [10] such as walking, climbing stairs, and rising from a seated position [8]. Leg power has been shown to decline at greater annual rates than strength suggesting the importance of the speed component in determining muscle power [6, 11]. Loss of the speed component of muscular power is of practical significance as age-related slowing and weakening of muscle is significantly associated with falls [10]. Maintaining leg power throughout life may reduce fall risk and associated fractures [10].

Another possible contributor to reduced function and slower mobility performance is the domain of cognition [12, 13]. Declines in cognitive performance including reaction time (RT), processing speed (PS), memory (MEM), and attention (ATT) have been well documented [14–16]. The extent to which cognitive declines impact the ability to plan, initiate and carry out daily functional tasks is not fully understood. Previous studies have shown independent contributions of poor performance in physical and cognitive domains for risk of functional dependence across a wide range of ability in older adults [17]. However, the independent contribution of cognition to functional disability in non-demented older adults has been debated [18].

The purposes of this study are two-fold. First, to evaluate average differences in physiological, cognitive, and functional performance of older adults with different levels of independence. Second, to examine contributions of leg power, cognition, and functional performance to level of independence. We hypothesize independent older adults to have greater leg power, cognition and functional performance than marginally dependent older adults. We also hypothesize leg power, cognition and functional performance to be significant contributors to level of independence of older adults.

## **Methods**

### **Subjects**

Individuals were recruited from a pool of previous participants or respondents to informational meetings and flyers. Respondents were interviewed by telephone to determine eligibility. Responses were verified and medical clearance received prior to participation. Exclusion criteria included poorly controlled or unstable cardiovascular disease, diabetes or thyroid disease, obesity, recent unhealed bone fracture, severe hypertension, arthritis or anatomic deformity (amputation), severe osteopenia, classic anterior compression factors, terminal illness, chronic vestibular disease, disorders with highly variable course (e.g. multiple sclerosis), or inability to speak English or follow directions. Participants signed an informed consent approved by the University of Georgia Institutional Review Board – Human Subjects Committee before participation.

Eligible participants were classified into two groups based on self-report limitations in function or living status. The Medical Outcomes Study physical function (SF36PF) scale [19] was used as a dichotomous variable to classify participants into either an independent (IND) group (SF36PF  $\geq 85$ ) or

marginally dependent (MDEP) group (SF36PF  $< 85$ ). Secondly, any participants living in facilities providing daily assistance were classified MDEP.

Perceived and performance-based functional performance are at most moderately related [20, 21]. Individuals living in an environment where daily tasks are routinely performed for them may not recognise mild declines in physical function particularly in the absence of the need to perform those tasks on a regular basis. We employed a strategy that combined self-rated function and living status to classify individuals as IND or MDEP. To be classified as IND, a participant met both criteria of SF36PF  $\geq 85$  and independent living status.

All testing was performed at the University of Georgia Aging and Physical Performance Laboratory. Subjects were randomly assigned to the order of two batteries of testing administered on separate days approximately 1 week apart. One battery of tests included the Continuous Scale Physical Functional Performance Test (Cs-PFP total) and LEP. The second battery included computerised cognitive testing assessing RT, PS, MEM and ATT.

### **Self-perceived physical function**

The SF36 is a valid measure of health status that contains eight domains [19], however for this study only the physical function domain (SF36PF) was assessed. The scale range is 0–100 with higher scores reflecting higher self-perceived function. SF36PF consists of ten questions assessing health-related limitations in a variety of physical activities, ranging from strenuous to basic [22]. The 10 questions include the following activities: vigorous and moderate activities, lifting/carrying groceries, climbing several flights of stairs, climbing one flight of stairs, bending/kneeling/stooping, walking more than a mile, walking several blocks, walking one block, and bathing/dressing [19]. A SF36PF score  $< 85$  is associated with a transition to disability [23, 24]. To obtain a score  $< 85$ , a participant had to report being ‘limited a little’ on at least three of the ten questions [23]. Scores of 85 or greater on SF36PF are associated with older adults without chronic conditions and associated disability [25, 26].

### **Muscular power**

The Nottingham leg power rig (University of Nottingham, Nottingham, UK) was used to assess LEP according to methods and calculations published elsewhere [27]. The leg power equipment consists of a rig with an adjustable backless chair facing pedals connected through a chain to a flywheel. The participant placed one foot on a pedal and pressed it forward and down as hard and as fast as possible. The force of the pedal moved a flywheel through a chain and gear system while an optoswitch detected flywheel speed [27]. Peak power for each leg was detected, calculated, and recorded in watts by a microcomputer. Peak power was the highest power recording achieved prior to a plateau in output over two trials (minimum of five trials). Rest periods of 30 seconds were given between trials to prevent fatigue. To minimise differences in body mass, LEP was expressed as average peak power of the right and left leg relative to body weight (W/kg).

**Cognitive function**

The Cognitive Stability Index [28] is an innovative, web-based series of ten reproducible neurocognitive subtests sensitive to changes in central nervous system functioning [29]. The CSI is a valid and reliable measure of cognitive performance with criterion-related validity and concurrent validity to traditional face-to-face tests of cognition including the Wechsler Adult Intelligence Scale-III, Stroop Test, Wechsler Memory Scale-III, Trail Making Test A and B, and the Wechsler Abbreviated Scale of Intelligence [30]. The ten sub-tests of the CSI measured four empirically derived cognitive factors of RT, PS, MEM, and ATT. Normative data on these four factors has been compiled for adults aged 18–90 across sex, race and educational background [29]. The tasks and metrics used to quantify cognitive performance are listed in Table 1.

**Physical functional performance**

The Cs-PFP is a valid, performance-based measure of function specifically designed to discriminate across a broad range of physical function for older adults [2, 31]. The Cs-PFP was used to quantify functional performance in 16 common tasks important for living independently. These tasks are performed serially under standard conditions designed to mimic activities of daily life required for independence [2, 31]. Functional performance is quantified using weight carried, time to task completion, or distance travelled (Table 2). Scores are scaled 0–100 by utilising the following formula based upon lower and upper extremes of performance by previously tested older adults [31]:

$$\text{Cs-PFP score} = (\text{observed score} - \text{lower limit}) / (\text{upper limit} - \text{lower limit}) \times 100.$$

Higher scores indicate higher functional performance. Participants were asked to perform tasks safely and comfortably but as quickly as possible and with maximal effort. Task performance yields five domain scores including upper and lower body strength, upper body flexibility, balance and

coordination, endurance, and a summary score (Cs-PFP total) [2]. Domain scores can assist in determining the nature of self-reported declines in physical function [31] while the total score is an indicator of physical function. All testing followed the published protocol for the Cs-PFP. Performance data were scored using the Cs-PFP web-based program at <http://www.coe.uga.edu/cs-pfp>.

**Statistical analysis**

All analyses were conducted using SPSS 10.0 (Chicago, IL). The dependent variable is group membership (IND versus MDEP) as determined by SF36PF and living status. Independent variables include LEP, cognition (RT, PS, ATT, MEM), and functional performance (Cs-PFP total). One-way ANOVA was used to detect mean differences between groups for all independent variables. The study was powered to detect significant differences between groups in LEP and Cs-PFP requiring twelve and eighteen individuals respectively.

Time as a variable may present skewed data violating the assumption of normality. For Cs-PFP data, this violation is corrected by dividing time (sec) into one [32]. All variables met the assumption of normality except for SF36PF and PS. PS was positively skewed and exhibited positive kurtosis. To meet the assumption of normality, PS was transformed for use during statistical analysis by dividing time (sec) into one. Means and standard deviations (SD) for PS and RT are reported in seconds or milliseconds. A ceiling effect exists for SF36PF which was negatively skewed and exhibited positive kurtosis. Many participants reported no limitations in physical function resulting in the highest possible score of 100. The primary function of this variable was to determine group membership of each participant.

Univariate correlation (Pearson's *r*) was used to determine the associations between the independent variables of LEP, cognition (RT, PS, ATT, MEM), and functional performance (Cs-PFP total). A stepwise-forward binary logistic regression

**Table 1.** Cognitive stability index: list of performance tasks and metrics

Task	Measurement
Attention/working memory	
Number recall	No. correct, no. errors
Number sequencing	No. correct, no. errors
Spatial memory/learning	
Object memory recall	No. correct over four trials
Delayed object memory recall	% retained
Pictorial incidental learning number 2	Time, no. errors, no. omissions
Reaction time	
Number recognition response	Time, no. correct, no. omissions
Opposite number recognition response	Time, no. correct, no. omissions
Pictorial incidental learning number 1	Time, no. correct, no. omissions
Pictorial incidental learning number 2	Time, no. correct, no. omissions
Processing speed	
Symbol scanning	Time, no. correct
Pictorial animal decoding	No. correct, no. errors

**Table 2.** Continuous scale physical function performance test measurements

Low effort tests:	Measurement
1. Kitchen pot carry	Time, weight
2. Milk jug pour	Time, weight
3. Put on jacket	Time
4. Shoe strap	Time
5. Scarves pickup	Time
6. Height reach	Distance
Medium effort tests:	
7. Floor sweep	Time
8. Laundry loading/unloading (4.1 kg)	Time
9. Bed making	Time
10. Vacuuming	Time
11. Up off the floor (simulated bath tub exit)	Time
12. Open fire door	Time
Hard effort tests:	
13. Luggage carry on to bus (up steps)	Time, weight
14. Grocery carry/walk (46.5 m)	Time, weight
15. Stair climbing (1 flight)	Time
16. 6-minute walk	Distance

based upon the Wald statistic was used to determine the variance in independence level explained by LEP, cognition and functional performance. Similar to previously published procedures, three separate binary logistic regressions were constructed to predict independence level for each variable domain: physiological (LEP), cognitive (RT, PS, MEM, and ATT), and functional (Cs-PFP total) [8]. The level of significance was set at  $P < 0.05$ .

**Results**

**Subjects characteristics**

Results are expressed as mean  $\pm$  SD unless otherwise noted. Of 55 eligible respondents, eight individuals did not receive medical clearance. Twelve individuals, after receiving medical clearance, decided not to participate due to scheduling problems, personal reasons or lack of transportation. The sample included 35 participants composed of men ( $n = 11$ ) and women ( $n = 24$ ) ranging in age from 65 to 94 years (mean age  $77.2 \pm 6$  years). As shown in Table 3, groups were similar in selected physical characteristics where as by design, SF36PF was significantly different. The sample was 95% Caucasian with a high-school or college degree, and primarily classified as middle to high socioeconomic status (88%).

Eighteen participants were classified as IND using criteria of scoring 85 or higher on SF36PF and living independently. These individuals all lived as community dwellers in detached single family dwellings. Seventeen participants were classified as MDEP for scoring  $<85$  on SF36PF ( $n = 9$ ) or for living in facilities that provided personal assistance ( $n = 8$ ). Of the eight individuals living with assistance, five scored  $<85$  on SF36PF. The three individuals scoring  $>85$  had MDEP placement

confirmed during data analysis as all fell on or below the Cs-PFP threshold predictive of independence.

**Performance measures**

IND was significantly different from MDEP on LEP and Cs-PFP total score as shown in Table 4. One individual in the MDEP group declined to participate in leg power testing for fear of injury. Means and SD for cognitive indices are also reported in Table 4. With the exception of ATT, groups demonstrated significantly different cognitive performance. We were unable to collect complete CSI data on a small number of participants due to technical difficulties during testing. The number of participants who completed each measure is presented in Table 4.

Linear associations among the variables of LEP, RT, PS, MEM, ATT and Cs-PFP total are shown in Table 5. Based upon binary logistic regression, Cs-PFP total was selected as the best model to predict independence ( $P = 0.006$ ). The model had a  $-2$  Log likelihood of 35.249 and explained 29.3% of the variance in group membership. Cs-PFP total correctly predicted independence in 67.7% of the participants. In the physiological model, LEP significantly contributed to independence ( $P = 0.002$ ) with a  $-2$  Log likelihood of 37.801, explained 31.7% of the variance, and correctly predicted independence in 67.6% of the participants. In the cognitive model, RT and MEM significantly contributed to independence ( $P = 0.003$ ) with a  $-2$  Log likelihood of 28.459, explained 44.3% of the variance in independence, and correctly predicted independence in 79.3% of participants. In the functional model, Cs-PFP total significantly contributed to independence ( $P = 0.005$ ) with a  $-2$  Log likelihood of 40.584, explained 27% of the variance, and correctly predicted independence in 65.7% of participants.

**Table 3.** Subject characteristics and physical function of independent and marginally dependent older adults

Characteristic	Independent			Marginally dependent			F (1, 34)	P value
	n	M	SD	n	M	SD		
Age (years)	18	76.8	5.8	17	77.6	6.3	0.137	0.714
Female (%)	18	66.7		17	70.6		0.059	0.810
Weight (kg)	18	68.1	12.3	17	73.5	14.8	1.378	0.249
Height (cm)	18	165.0	11.1	17	164.6	16.8	0.009	0.925
SF36PF	18	94.2	5.6	17	71.8	20.0	20.805	0.001

$n$  = group size; M = mean; SD = standard deviation;  $P$  = group differences; SF36PF = SF36 physical function domain.

**Table 4.** Differences of independent and marginally dependent older adults in leg power, cognition, and functional performance

Variable	Independent			Marginally dependent			F value	df	P value
	n	M	SD	n	M	SD			
Leg extensor power (w/kg)	18	2.0	0.8	16	1.3	0.4	9.423	1, 33	0.004
Cognitive stability index									
Reaction Time (ms)	17	756.0	89.1	16	834.0	117.3	4.630	1, 32	0.039
Processing speed(s)	17	5.0	2.5	17	7.4	5.8	4.340	1, 33	0.045
Attention	17	11.6	4.3	15	9.4	4.1	2.169	1, 31	0.151
Memory	17	7.7	1.1	16	6.6	1.4	5.788	1, 32	0.022
Cs-PFP total	18	60.3	14.7	17	48.0	10.3	8.132	1, 34	0.007

$n$  = group size; M = mean; SD = standard deviation;  $P$  = group difference; Cs-PFP total = Continuous Scale Physical Functional Performance Test summary score.

**Table 5.** Correlations (Pearson’s r) between measures of leg power, cognition, and functional performance

Variable	LEP (watts/kg)	Cognitive stability index				Cs-PFP total
		RT (ms)	PS (s)	ATT	MEM	
LEP (W/kg)	1.00					
Cognitive stability index						
RT (ms)	-0.259	1.00				
PS (s)	0.408 <sup>a</sup>	-0.691 <sup>b</sup>	1.00			
ATT	0.236	-0.181	0.330	1.00		
MEM	0.152	-0.395 <sup>a</sup>	0.620 <sup>a</sup>	0.087	1.00	
Physical function						
Cs-PFP Total	0.658 <sup>b</sup>	-0.405 <sup>b</sup>	-0.687 <sup>b</sup>	0.210	0.267	1.00

LEP=leg extensor power; RT=reaction time; PS=processing speed; ATT=attention; MEM=memory; Cs-PFP=Continuous Scale Physical Functional Performance Test summary score. ATT and MEM are composite scores and do not have units.

<sup>a</sup>*p*<0.05.

<sup>b</sup>*p*<0.01.

## Discussion

This study is one of a few to examine differences of physiological, cognitive, and functional performance in independent and marginally dependent older adults and the contribution of each domain in predicting independence. The main findings of this study were (i) independent older adults had significantly greater leg power, reaction time, processing speed, memory, and functional performance than marginally dependent older adults; (ii) functional performance was an independent predictor of independence of older adults; (iii) leg power, reaction time, and memory were small but significant contributors to prediction of independence of older adults.

Leg power is needed to perform tasks of mobility and locomotion [9]. Older adults with leg power <2.0W/kg exhibit reduced function particularly in stair climbing [8]. In our study, MDEP had peak leg power below this threshold and exhibited reduced performance in mobility tasks of the Cs-PFP including stair climb and 6-minute walk. IND exhibited greater performance on speed-based cognitive indices (RT, PS) than MDEP. Declines in cognitive performance may be due to changes in processing speed and the ability to use short-term memory while information is being processed [15]. Significant differences in processing speed and memory suggests that independent older adults have greater ability to encode, store, retrieve, and recall information. Groups did not differ on attention indexes possibly due to the novelty of the computer and thus all were focused on the task. Our findings show IND exhibited fewer declines in cognitive performance than MDEP.

IND had significantly greater functional performance than MDEP who expressed limitations or required daily assistance. Functional performance of IND suggests adequate physical capacity necessary for independent living. A score of 57 on Cs-PFP is predictive of independence and thresholds in peak oxygen consumption and knee extensor strength needed to maintain independence [33]. Our sample supports this functional performance threshold of 57 with IND per-

forming above the threshold while MDEP was below the threshold. MDEP closely resembles the pre-clinical disability classification [34]. Individuals with pre-clinical disability are characterised by early functional limitations or impairments that might not be evident clinically [1, 34]. Our findings support the pre-clinical disability concept with physiologic, cognitive and functional declines evident for MDEP. Individuals reporting performance limitations or requiring daily assistance are in a transition to disability and exhibit significantly reduced leg power, cognition and functional performance.

The only independent predictor of independence level was functional performance. Functional performance using the Cs-PFP has no known ceiling effect [31] and was the strongest predictor of independence level in older adults. Separate predictions for each domain showed small but significant contributions to independence by leg power and cognition. Significant contributions of leg power have been found for single-item functional tasks such as chair rising, stair climbing, and walking [9]. Our findings step beyond single item tasks and show a significant contribution of leg power to physical function. In this study, two cognitive factors that predicted independence were reaction time and memory previously shown to predict frailty [15]. This study found performance-based cognition to also predict independence level of older adults.

We did not find independent contributions of functional performance and cognition as previously published [17]. Our results support findings that suggest cognitive and functional decline influence the development of one another [35]. We found no independent effects of cognition and functional performance associated with independence. Significant relationships existed between the variables of leg power, cognition and functional performance which may have attenuated the independent effects of cognition in predicting independence.

We did not measure participants for prior mental status. It was assumed individuals who could keep appointments were of sufficient mental status to participate. No participant scheduled for testing missed a session. Twelve individuals were cleared by physicians for participation but dropped before being scheduled. Selection bias may be operating such that only individuals with sufficient cognitive and physical capabilities to participate did so. Demographic issues also limit the study as the sample was predominantly well educated, Caucasian, and middle to high socioeconomic status.

## Conclusions

Results of this study provide insight into the nature of physical, cognitive, and functional characteristics of older adults with different levels of independence. We conclude that leg power, cognition, and functional performance are significant contributors to independence in older adults. Individuals who have greater leg power, shorter reaction time, faster processing speed, better memory or greater functional performance tend to have higher physical function and remain independent. Independence is clearly multi-factorial but we

found the strongest predictor to be functional performance. Since older adults determine quality of life more so by level of independence than by disease-state and resulting symptoms [3], interventions could be developed that target the improvement of physical function in order to assist older adults in maintaining quality of life and remaining independent. Further studies are needed to investigate the independent contributions of physical, cognitive, and functional capacities in relation to physical function and independence. This study needs to be replicated with larger numbers of individuals including minorities and people with low literacy and low socioeconomic status.

### Key points

- Independent older adults exhibit greater leg power than marginally dependent older adults.
- Independent older adults exhibit greater performance on cognitive measures of reaction time, processing speed, and memory.
- Functional performance is a significant predictor of independence in older adults.
- Leg power and cognition are small but significant predictors of independence in older adults.

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### Conflicts of interest

The authors on this paper, John K. Petrella, L. Stephen Miller and M. Elaine Cress, have no conflicts of interest in sources of funding or provenance of laboratory or biochemical equipment.

The data presented in this paper have been published as an abstract [36].

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## A randomised controlled trial of senior Lay Health Mentoring in older people with ischaemic heart disease: The Braveheart Project

ANDREW J. COULL<sup>1</sup>, VALERIE H. TAYLOR<sup>2</sup>, ROB ELTON<sup>3</sup>, PETER S. MURDOCH<sup>4</sup>, ALLISTER D. HARGREAVES<sup>4</sup>

<sup>1</sup>Stroke Prevention Research Unit, Department of Clinical Neurology, Radcliffe Infirmary, Oxford, UK

<sup>2</sup>Dalkeith Medical Practice, Dalkeith, Midlothian, UK

<sup>3</sup>Department of Public Health Sciences, University of Edinburgh, Edinburgh, UK

<sup>4</sup>Falkirk and District Royal Infirmary, Majors Loan, Falkirk FK1 5QE, UK

Address correspondence to: P. Murdoch, Department of Geriatric Medicine, Falkirk Royal Infirmary, Majors Loan, Falkirk FK1 5QE, UK. Fax: (+44) 1324 616149. Email: peter.murdoch@fvah.scot.nhs.uk

### Abstract

**Objective:** to examine the effects and feasibility of educating and empowering older people with ischaemic heart disease using trained senior lay health mentors.

**Design:** randomised controlled trial with blinded evaluation.

**Setting:** Falkirk and District Royal Infirmary.

**Participants:** inpatients and outpatients aged 60 or over attending secondary care with a diagnosis of angina or acute myocardial infarction. Three-hundred and nineteen entered and 289 completed exit assessments. The intervention group took part in mentoring groups for 1 year, meeting monthly for 2 hours, each led by two trained lay health mentors in addition to standard care.