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ORIGINAL ARTICLE

# Approaches in methodology for population-based longitudinal study on neuroprotective model for healthy longevity (TUA) among Malaysian Older Adults

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**Abstract** A number of longitudinal studies on aging have been designed to determine the predictors of healthy longevity, including the neuroprotective factors, however, relatively few studies included a wide range of factors and highlighted the challenges faced during data collection. Thus, the longitudinal study on neuroprotective model for healthy longevity (LRGS TUA) has been designed to prospectively investigate the magnitude of cognitive decline and its risk factors through a comprehensive multidimensional assessment comprising of biophysical health, auditory and visual function, nutrition and dietary pattern and psychosocial aspects. At baseline, subjects were interviewed for their status on sociodemographic, health, neuropsychological test, psychosocial and dietary intake. Subjects were also measured for anthropometric and physical function and fitness. Biospecimens including blood, buccal swap, hair and toenail were collected, processed and stored. A subsample was assessed for sensory function, i.e., vision and auditory. During follow-up, at 18 and 36 months, most of the measurements, along with morbidity and mortality outcomes will be collected. The description of mild cognitive impairment, successful aging and usual aging process is presented here. A total 2322 respondents were recruited in the data analysis at baseline. Most of the respondents were categorized as experiencing usual aging (73 %), followed by successful aging (11 %) and mild cognitive impairment (16 %). The LRGS TUA study is the most comprehensive longitudinal study on aging in Malaysia, and will contribute to the understanding of the aging process and factors associated with healthy aging and mental well-being of a multiethnic population in Malaysia.

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## Introduction

Morbidities associated with cognitive decline are the major economic and social burden to a population, with a linear increase in developed countries, but an exponential increase in low income countries. Over the past decade, epidemiological studies have shown that physical health, lifestyle, dietary pattern and social interaction have been recognized to be associated with cognitive decline leading to dementia [1]. Other lifestyle factors than can modify the risk of dementia and Alzheimer's disease (AD) continuing to be unrevealed through epidemiological research, however, most of the data were from the developed countries [2]. Searching for prudent dietary pattern and the 'brain' food is still ongoing, with berries, nuts, fish, Mediterranean diet have been identified as neuroprotective in the Western diet [3–7]. The very few studies conducted in Asian countries revealed that tea [8, 9], curry consumption [10], hypercholesterolemia, obesity and physical inactivity [11] were the factors associated with cognition. In addition to specific nutrients, fatty acids and dietary pattern, foods with large amounts of aluminum-containing additives or aluminum from drinking water may affect the risk of developing AD [12]. Nevertheless, more data are needed to support the possible role of these metals in cognitive impairment associated diseases.

Although physical activity has been recognized to improve cognition, the specific prescription for exercise and fitness to prevent cognitive decline is still being investigated. Furthermore, the main intrinsic requirements for optimum physical performance which includes mobility, agility and balance [13], has not been well studied in a large prospective cohort study. It has been proposed that age-related reductions in the quality of neural information flowing through peripheral and central sensory systems involving the auditory function and vision acuity contribute to age-related cognitive decline [14]. Understanding sensory impairment such as hearing and visual in elderly is important because the concomitant cognitive decline worsens the degree of disability in this age group. The deterioration of hearing function in the elderly differs from that in younger population, in that it affects not only the peripheral, but also the central auditory processing mechanisms, resulting in marked difficulties to perceive rapid speech and speech in background noise [15, 16]. Although the rate of auditory and visual declines in elderly has been studied, a comprehensive study which reports on how different functions and parts of auditory and visual pathways deteriorate with age in the same cohort is lacking. In Malaysia for example, The National Eye Survey was carried out in 1996 [17], while the National Survey of Ear and Hearing Disorders was conducted in 2005. As cognitive impairment may progress in severity despite pharmacological and non-pharmacological interventions, an estimation of the cost-effectiveness for different care models is required. Clinical and societal costs of cognitive impairment, taking into consideration losses in opportunity costs and other cost of care had been reported [18, 19]. However, despite the evidence of demographic transition, the impact of rapid population aging on the nation's labor force, health care and social protection systems remain under rated and poorly understood [20, 21]. Data are much needed for policy and legislative reforms to address the issues and challenges that arise from a changing population age structure.

In rapidly developed countries such as Malaysia, more efforts should be conducted in trying to predict and prevent the undesirable cognitive decline and impairment in the aging population, leading to the irreversible diseases such as dementia and Alzheimer's diseases (AD). There is evidence to suggest that the prevalence of cognitive impairment among the Malaysian elderly is higher than other populations [11]. Recognizing the importance of identification of specific risk factors of cognitive impairment for a population in formulating a cost effective and culturally suitable prevention strategies, this study aimed to determine the predictors of cognitive decline of an aging population in Malaysia, from a wide range of biophysical health, lifestyle, psychosocial, sensory and dietary assessment through a prospective study aiming to develop a neuroprotective model for healthy longevity among Malaysian elderly.

## Methodology

### Study design

The LRGS TUA is a prospective study on aging focusing on a wide range of neuroprotective factors among a population-based sample of Malaysian elderly from four states in Malaysia that have the highest numbers of older adults aged 60 years and above, namely Johor, Perak, Selangor and Kelantan. The baseline study was conducted from May 2012 till February 2013, followed by an 18 and 36 months follow-up. Patient information sheet was given to subjects and written consent was obtained from them. Verbal consent was done for those who were illiterate and unable to sign the consent form. Verbal consent procedure was done by the researcher to the respondent and a literate witness

(family members or close friend of respondents). It included explanation of the objectives of the research, what will be done during data collection and the benefits of participating in the current study. This was followed by asking respondents if they were willing to participate in the study. If they were interested to join, their names will be written on the consent form by the researcher and will be signed by the literate witness. The thumbprint of the respondent will also be included. This study was approved by the Medical Research and Ethics Committee of Universiti Kebangsaan Malaysia.

### Sampling frame and sample size

The sampling frame for this survey was updated in 2010 prior to the National Population and Housing Census 2010. Based on the frame, Malaysia was divided into Census Circles (CC) which is a geographically continuous areas with identified boundaries. There were 10,822 CCs in Malaysia in the year 2010. Each Census Circle contains about 7 Enumeration Blocks (EBs), which in turn each EB contains about 80–120 Living Quarters (LQs). However, for this survey, the frame only included CCs with elderly populations making up at least 10 % from total number of population in the CC. The sampling frame was provided by Department of Statistics Malaysia.

### Sample size

The sample size was calculated using an appropriate formula for a study estimating population prevalence, and it was determined based on the expected prevalence of diseases or health-related problems in the population, margin of error and confidence interval. The sample size was determined on the basis of the ability to estimate the prevalence of the health conditions specified in this study, with adequate or acceptable precision. The sample size was then inflated to consider for the estimated design effect and non-response. The sample size was then adjusted according to the need of the analysis, giving the final sample size of 2800.

### Sampling design

The sampling for this study was done with the assistance from the Department of Statistics, Malaysia. The sampling involved three stages; the primary sampling unit (PSU) was the region, the secondary sampling unit (SSU) was census circle (CCs) and the tertiary sampling unit (TSU) was the living quarter (LQ). The first stage sampling involved selection of one state from each region. The second stage sampling was the random selection of 35 CC from each selected state and within selected CC, 20 LQ were randomly selected (third stage sampling). All eligible individuals in the selected LQ were included in the survey.

### Preparation of field area

Research team members who acted as scout visited the selected LQs based on the EB maps provided by the Department of Statistics about a week prior to the predetermined date of data collection. They also informed the members of LQs and the Residential Community information related to the survey. After screening the respondents according to the inclusion and exclusion criteria, the researcher asked the respondent's permission to conduct the study and also explained to the respondent the purpose of the study, study procedures, risks of the study, as well as the freedom of the subject to withdraw from the study. Research team member further invited the eligible respondents to come for data collection session. Inclusion criteria were individuals aged 60 years and above with no documented major psychiatric illness or mental disorders. This study also included subjects who are either normal and with mild or moderate cognitive impairment. Those subjects with MMSE score of 14 and below were excluded because this indicated moderately severe or severe cognitive impairment. Respondents were asked to fast overnight prior to the day of data collection and not to cut their finger and toe nails about a week before the date. Data collection was carried out at the nearest community hall on pre-determined dates.

During the data collection activity, respondents who have agreed to participate in this study, were screened using Geriatric Depression Scale (GDS) to ensure that the subjects do not suffer from depression because it will indirectly affect the overall cognitive function of the subject. The GDS used in this screening process had undergone back to back translation and validated in earlier study [22]. Eligible respondents were registered and socio-demographic characteristics were recorded.

### Study instrument and data collection technique

Subjects were interviewed face to face using a standardized questionnaire and measured for a number of parameters, as summarized in Table 1. The questionnaire consisted of information on socio-demography, neuropsychological and psychosocial functions, lifestyle and dietary intake. Biophysical measures which included anthropometry, blood pressure, physical fitness and functional status were measured. Biospecimens measures including blood, buccal swap, hair and toe nails were collected. Since the measurements were rather comprehensive and lengthy, respondents were allowed to rest in between and refreshments and monetary incentives were provided. Respondents in this study were categorized into three aging groups as shown in Table 2. MMSE cut-off's were chosen based on local findings by Ibrahim et al. [23] who proposed

**Table 1** Summary of parameters used in this study

| | Parameters |
|---|---|
| Socio-demography, health, lifestyle | Gender, race, ethnicity, education level, marital status, living arrangement, employment status, total income, household income, current income satisfaction, economic hardship, medical history, history of fall, alcohol intake, smoking status, lifestyle activities |
| Psychosocial and functional status | Depression, perceived stress scale, loneliness, religiosity, quality of life, sexual relationship, disability, social support, basic activities of daily living, instrumental activities of daily living |
| Body composition | Weight, height, arm span, mid-upper arm circumference, waist circumference, hip circumference, calf circumference, fat mass, muscle mass |
| Dietary intake | Diet history questionnaire, Omega 3 food frequency |
| Cognitive function status | Modified mini mental state examination (M-MMSE), Montreal Cognitive Assessment (MoCA), Digit Span Test, Digit Symbol Test, Rey Auditory Verbal Learning Test (RAVLT), Visual Reproduction Test (VR-I and VR II) |
| Physical fitness | 2-min Step Test, Grip Strength Test, Chair Stand Test, Chair Sit-and-Reach Test, Back Scratch Test, Timed Up-and-Go Test |
| Vision | Modified Index of Visual Functioning (VF-14) questionnaire (Malay version), Visual Acuity, Determination of refractive error, Binocular functions, contrast sensitivity function and Ophthalmoscopy |
| Hearing | Otoscopic examination, Pure-Tone Auditory, Dichotic Digit Task (DDT), Pitch Pattern Sequence Test (PPST), Gap-In-Noise (GIN) |

**Table 2** Definition of aging groups

| Successful aging [25, 26] | Usual aging | Mild cognitive impairment [11, 27] |
|---|---|---|
| 1. Free from diabetes, hypertension, cancer, heart diseases, chronic lung diseases, and stroke | 1. Subjects with average performance in most of the cognitive test administered (scores above MCI but below SA) | 1. Subjective memory complaint by subjects or caregivers |
| 2. No functional limitations as indicated by full score in both ADL and IADL | 2. No dementia | 2. Objective memory impairment [poor performance in one or more cognitive tests (Digit span and RAVLT) with score of at least 1.5 SD below the mean average] |
| 3. Normal global function as indicated by MMSE score $\geq$22 | 3. No or very minimal functional limitations | 3. No dementia |
| 4. No depression by having a score of $\leq$4 in the GDS-15 item | | 4. No limitations in basic activities of daily living (ADL) |
| 5. Good quality of life | | 5. No or very minimal difficulties in instrumental activities of daily living by having a score of $\leq$1.5 SD from mean norm |
| 6. Good self-perceived health | | 6. Preserved global function by having MMSE score of $\geq$19 |

*MMSE* Mini mental state examination, *GDS* Geriatric Depression Scale, *RAVLT* Rey Auditory Verbal Learning Test, *ADL* activities of daily living, *IADL* instrumental activities of daily living

MMSE-7 cut-off $\geq$22 and MMSE-S cut-off $\geq$19 for normal global function among Malaysians. The greater cut-off point for SA was due to the higher education level of SA as compared to UA and MCI. MMSE had great education bias, and thus a lower cut-off was chosen for those with MCI in consideration to their lower education level. There was no specific MMSE cut-off point for UA. In addition, UA was mainly characterized by having average performance in most of the cognitive test administered (Digit Span, Digit Symbol, MoCA, RAVLT, Visual Reproduction). Average performance indicated scores above MCI, but below that of SA. Older adults in the group of UA were free from dementia. This study excluded all subjects with severe cognitive impairment which was characterized by MMSE score below 15 according to Malaysia Clinical Practice Guidelines of Dementia (CPG) [24].

### *Assessment of cognitive status*

Evaluation of cognitive status was conducted using Malay version of Mini Mental Examination State (M-MMSE), Malay version of Montreal Cognitive Assessment (MoCA-BM), Rey Auditory Verbal Learning Test (RAVLT), Digit Span Test, and Digit Symbol Test.

*Malay Version Mini Mental State Examination (M-MMSE)* MMSE was a cognitive assessment tool that has been used widely for evaluation of global function. MMSE

focused on orientation, memory, registration, calculation, attention, language. M-MMSE which had been validated by Razali et al. [28] was used in this study. M-MMSE had a Cronbach's alpha of 0.76 with sensitivity and specificity of 97.5 and 60.6 %, respectively.

*Malay version of Montreal Cognitive Assessment (MoCA-BM)* MoCA, was similar to MMSE and was an instrument for assessing attention, concentration, executive function, memory, language, visuo-constructional skill, calculation and orientation. For this study, researcher used the MoCA-BM which had been validated in Malaysia [28]. MoCA-BM had an alpha Cronbach's of 0.80.

*Rey Auditory Verbal Learning Test (RAVLT)* RAVLT was an instrument used to detect short-term verbal memory, working memory, verbal learning and declarative memory. Internal reliability for this instrument was high with Cronbach's alpha of 0.90 and sensitivity and specificity of 73.8 and 90.0 %, respectively [29, 30]. RAVLT consisted of two sections namely list A and list B with 15 words, respectively. Respondents were required to recall the 15 words after the researcher has completed reading it to them. List A will be repeated for five times and scores will be given based on the correctly recalled words. This was followed by repeating List B only once and finally respondents were asked to recall words from List A without any hints (Trial 6) [31]. Trial 5 represented Best Learning, list B was for interference and trial 6 was for immediate recall. This instrument was conducted within 10–15 min for each subject. Scoring was based on numbers of correctly recalled words. The total of words which was the raw score then will be converted to the *T* score and will be analyzed.

*Digit span* Digit span was a test from Wechsler Adult Intelligence Scale (WAIS) [32]. This instrument focused on memory, attention and concentration. Subjects were required to repeat the numbers both in forward and backward order. Total score was the number of correctly recalled trial. Raw score will be converted to scale score.

*Digit symbol* Digit symbol, a subset of WAIS was used to evaluate information processing, visual-motor speed, coordination and visual memory. It was one of the most sensitive instruments to detect neuropsychological dysfunction [31]. The total score of this instrument ranged from 1 to 133 and will be changed to scale score for analysis purpose.

*Evaluation of social activity*

Evaluation of social activity was done using Instrumental Activity Daily Living (IADL) and Lifestyle Activity Questionnaire.

*Instrumental Activity Daily Living* Physical functioning was screened using Lawton Instrumental Activities of Daily Living Scale (IADL). IADL was an appropriate assessment to assess independent living skills. It was developed by Lawton and Brody in 1969 [33]. IADL questionnaire used in this study was translated into Malay and contained seven items related to ability to use phone, shopping, doing housework, managing finance, traveling, food preparation and taking own medications.

*Activity Lifestyle Questionnaire* The original Activity Lifestyle Questionnaire (ALQ), which was a validated self-reported questionnaire, contained 70 items related to physical, mental and social lifestyle activities. It was used in the Victoria Longitudinal Study [34]. For the purpose of this study, this questionnaire had been adapted into 26 items, to make it more compatible for Malaysian population. Physical domain consisted of six items while mental and social domains contained ten items, respectively. Face validity approach had been used for adaptation of ALQ. This questionnaire was using five-point Likert scale and higher score indicated active participation in lifestyle activities. Pilot testing of the adapted version of questionnaire was done to determine its reliability and the Cronbach's alpha was 0.66 [35].

*Assessment of Dietary Intake*

Assessment of Dietary intake was done using Dietary Habits Questionnaire (DHQ) and omega-3 fatty acid food frequency questionnaire.

*Dietary Habits Questionnaire* Subjects were interviewed individually to obtain their usual food and drinks intake within a week. Diet History Questionnaire that has been validated for older adults [36] was used during interview. Amount of food intake was measured using food album and household measurements such as cups, glasses, tea spoons, table spoons and bowls of various sizes to obtain a precise food intake of subjects. Easy, simple and understandable language had been used to obtain the most reliable information from subject.

*Omega-3 Fatty Acid Food Frequency Questionnaire* A validated questionnaire on polyunsaturated fatty acid (PUFA) [37] was used to determine the intake of Omega-3 fatty acid among the survey respondents.

*Socioeconomic and psychosocial status*

*Socioeconomic* Socio-economic status included current and past job sector, current and past income, total household income, household facilities, insurance ownership, type of house and current home ownership, income adequacy, economic hardship, debt and loan was obtained. Economic burden focused on morbidity or health status for past 2 weeks, outpatient care for past 6 months, inpatient care for past 1 year, caregiver expenditure and overall health expenditure.

*Psychosocial* Among the psychosocial aspect being assessed was satisfaction with social support using Lubben Social Network Scale (scores ranged from 0 to 30) and Medical Outcome Social Support Survey. Medical Outcome Social Support Survey required subjects to choose an answer from the four point Likert scale namely 0 (none of the time), 1 (some of the time), 2 (most of the time), and 3 (all the time) [38]. Higher score indicated better social support. Meanwhile, for Lubben Social Network Scale, risk of social isolation was predicted with score of less than 12 [39].

Quality of life, life event (death of spouse, children, parents, family members, divorce, birth of child, retirement, children marriage), Neuroticism Subscale of Eysenck Personality Disorder (EPQ) (higher score indicated neurotic disorders) [40] were also determined. Loneliness was assessed using 'three-item loneliness scale' and each item had three response categories each, namely hardly ever, some of the time, and often [41]. Other tools used included; four-item Perceived Stress Scale (PSS-4) with responses scored on 0 (never) to 4 (very often) point scale [42], Flourishing Scale, an eight-item questionnaire with seven-point Likert scale (1—strongly agree, 2—agree, 3—slightly agree, 4—neither agree nor disagree, 5—slightly disagree, 6—disagree, 7—strongly disagree) [43], Religiosity Intrinsic-Extrinsic Scale, with five-point Likert scale and had two major domains, namely intrinsic and extrinsic [44], Satisfaction with Life Scale (SWLS) with score of 20 represented the neutral point on the scale, scores between 21 and 25 (slightly satisfied), 15 and 19 (slightly dissatisfied with life), 26–30 (satisfied), and 5–9 (extremely dissatisfied with life) [45].

*Disability and health* Sleep pattern and sexual relationship were measured using close-ended questionnaires. WHO Disability Assessment Schedule (WHODAS) was a tool to measure disability [46], Activities of Daily Living (ADL) emphasized on questions related to personal care such as bathing, dressing, toileting, transferring, and continence [47]. In a subsample, caregiver (those who care for older adults when they are sick) information was also obtained.

*Biospecimens*

Fingernails and toenails samples were taken from each subject. Nails were clipped from all fingers and toes with a stainless steel cutter and stored in a labeled plastic zip bag at room temperature. Hair samples were plucked from different part of the subject head with a stainless steel tweezers and stored in a separate labeled plastic zip bag. Both samples were kept at room temperature. A total of 30 ml fasting venous blood were collected using heparinised tube, one EDTA tube and one serum separating tube (SST) by a phlebotomist. One tube of the heparinised sample was kept at −4 °C in portable freezer during sampling for not more than 4 days before transferred to the laboratory and stored at −80 °C. The remaining bloods from the heparinised and SST tube were centrifuged at 3500 rpm for 5 min at 25 ± 2 °C for obtaining plasma and serum, respectively. The plasma and serum were aliquoted in several 1.5 ml eppendorf tubes and kept at −20 °C, before transferred to the freezer at −80 °C at the central laboratory. A total of 10 ml urine were also collected from each respondent and centrifuged at 3000 rpm for 10 min and aliquot in several 1.5 ml eppendorf tubes and kept for not more than 4 days at −4 °C, then transferred to −80 °C. The temperature of the freezers was monitored regularly.

Buccal cells were also collected, from the inside cavity of the mouth of the participants. The oral cavity was rinsed twice thoroughly with 100 ml mineral water to remove excess debris. For each participant, a 10 ml buccal cell buffer was prepared using a 30 ml centrifuge tube. A small-headed unused toothbrush was rotated gently and firmly ten times against the inside of the cheek wall in a circular motion starting from the middle and gradually increasing in circumference to produce an outward spiral effect. The head of toothbrush was then placed into the buffer containing tube and rotated repeatedly to dislodge and release into the cells into the buffer. The cell suspension was stored in a buffer at 4 °C prior to laboratory analysis [48].

*Anthropometric and body composition measurements*

Body weight, body height, arm span, body mass index, waist circumference, hip circumference, mid-upper arm circumference (MUAC) and calf circumference were measured twice by researcher. All measurement used were validated and suitable for older adults [49].

*Height and weight* Leicester Height Measure (CMS Weighing Equipment, UK) was used to measure height. Participants were required to stand upright without shoes, hips and shoulders in a straight line, head and eyes is straight on the Frankfurt plane. Readings of height were taken to the nearest 0.1 cm [49]. For participants who were unable to stand straight or had kyphosis, arm span measurement was used [50]. Arm span was measured with participants leaning against the wall with two hands opened

at shoulder height. Measurement of arm span was taken from the right middle finger to left middle finger using Lufkin tape to the nearest 0.1 cm [51]. Reading taken from arm span was used to estimate the height of participants using predictive equation [50]. Tanita HD319 (Tanita Corporation of America, IL, USA) weighing scale was used to measure weight. Participants were required to stand upright with feet balanced, head and eyes straight on the Frankfurt plane without wearing shoes. Readings of weight were taken to the nearest 0.1 kg [52].

*Waist (WC) and hip circumferences (HC)* Participants were required to stand straight with arm at side. Waist circumference was measured at a level midway between the lower rib margin and iliac crest with Lufkin tape all around the body in horizontal position [53]. Readings of waist circumference were taken to the nearest 0.1 cm. Hip circumference was measured at the maximal circumference over the buttocks [53]. Readings of hip circumference were taken to the nearest 0.1 cm.

*Mid-upper arm circumference (MUAC)* Respondents were required to stand upright with arms bent at the elbow position at 90° with the upper arms and palms facing upwards. Distance between acromion and olecranon bones was marked. Mid-upper arm circumference was measured at the marked area. Measuring tape touched on the skin of the arm and does not compress the soft tissues on the arm [54]. Measurements were taken to the nearest 0.1 cm.

*Calf circumference (CC)* Calf circumference was measured using Lufkin tape at sitting position. Measurement was at the most prominent part using Lufkin tape [55]. Measurements were taken to the nearest 0.1 cm.

*Fat mass and muscle mass* Body compositions (percentage body fat mass and skeletal muscles mass) were measured using Bio-electrical Impedance Analysis Inbody S10 (Biospace, Seoul, Korea). Prior to the measurement, respondents were asked to fast for 12 h. Participants were asked to lie in a symmetrical condition with the back of the body in relax condition. Legs and arms were placed straight and not crossed or bent. In their respective position, two electrodes were placed on the hands (in the middle fingers and thumbs of the right and left hand) and two electrodes were placed on the leg (one electrode was placed on the right ankle and another electrode was placed on the left ankle) of the respondents.

*Assessment of physical fitness*

Physical fitness was measured using Senior Fitness Test (SFT) [56]. SFT measures the principal physical factors associated with functional ability, and ascertain whether an older adult may be at risk for loss of functional ability. In this study, six items were used to measure the fitness of respondents:

*30-Second Chair Stand Test* A 30-Second Chair Stand Test was used to assess lower body strength. Participants were asked to sit on a chair with arms folded across chest. The numbers of full stands that can be completed in 30 s were taken. Measurements were repeated twice and the higher score was analyzed.

*Grip Strength Test* Grip strength was measured using hand dynamometer (Jamar Plus + Hand Dynamometer, SI instruments Pty Ltd, SA, Australia) on dominant hand to assess upper body strength. The maximum grip reading (kg) was taken twice and recorded. The higher score was used in analysis.

*Chair Sit-and-Reach Test* Chair Sit-and-Reach test was used to assess lower body flexibility. Respondents were required to extend the legs and hands reaching toward toes from a sitting position at front of chair, the distance (cm) between extended fingers and tip of top is taken. Measurement was repeated twice and the value taken to the nearest 0.1 cm.

*Back Scratch Test* Back Scratch test was used to assess upper body (shoulder) flexibility. Participants were required to put one hand reaching over the shoulder and one hand up the middle of the back. The distance (cm) between extended middle fingers was taken. Measurement was repeated twice and the value was taken to the nearest to 0.1 cm.

*2-Minute Step Test* A 2-Minute Step test was used to assess aerobic endurance. The number of right knee reaches a point midway between the patella (kneecap) and iliac crest (top hip bone) within 2 min was taken.

*Timed Up-and-Go Test* Timed Up-and-Go test was used to assess agility or dynamic balance. The numbers of seconds required getting up from a seated position, walk three meters, turn, and return to seated position were taken. Measurements were repeated twice and the values were taken to the nearest 0.1 s.

*Assessment of vision and hearing*

Sensory function as assessed using vision and hearing was measured on a subsample of respondents, i.e., Selangor and Johor.

*Malay Version Visual Functioning Index (VF-14)* VF-14 was developed to measure functional impairment due to cataract [57]. In this study, a modified Malay version of VF-14 that was translated and validated in the Singapore Malay Eye Study (SiMES) was used Rosman et al. [58]. Eleven visual functioning covering activities involving vision, i.e., navigating stairs, reading road signs, recognizing friends, watching television, reading newspaper, reading small print, cooking, filling out form, playing chess or cards, and driving at night and during daytime were asked in a face-to-face interview.

*Visual acuity* A logMARchart (Precision Vision USA) was used to measure unaided vision and visual acuity with participant's own glasses. This is followed by best corrected visual acuity after objective and subjective refraction was carried out to determine refractive error. The chart used logarithmic principle as described in Bailey and Lovie [59]. If letters/numbers on the LogMAR chart could not be read at 4 m, the participant will be moved 2 or 1 m consecutively and finally visual acuity will be assessed as counting fingers, hand movements, perception of light, or no perception of light. A value of 0.02 is assigned to each letter of LogMAR chart and each line has a value of 0.1 log. Unaided and aided near visual acuity test was determined using the Log MAR near vision chart (Lighthouse International, USA) at 25 cm testing distance.

*Determination of refractive error* Refractive error was determined objectively using Righton Retinomax K-plus followed by subjective refraction performed by trained and certified optometrists. The final correction obtained was used when performing stereopsis and contrast sensitivity tests.

*Binocular functions* Cover test was done to determine misalignment of the two eyes. Qualitative measurements, i.e., type of phoria or tropia (strabismus) were determined. This is followed by measurement of stereo acuity using Frisbystereotest that has been shown to be precise and reliable in measuring stereopsis [60]. If participants were not able to response to the test at a distance of 50 cm, it is reduced to 40 or 30 cm consecutively. Participant's lowest disparity was measured in second of arc.

*Contrast sensitivity function (CSF)* CSF test was done using Pelli-Robson contrast sensitivity chart (Clement Clark International, UK). The chart consists of letters of constant size; three letters made up each group of letters of decreasing contrast in 0.15 log sensitivity steps. Participants view the chart at 1 m testing distance and contrast threshold is reached when two out of three letters at the lowest contrast were incorrectly identified [61].

*Ophthalmoscopy* Ophthalmoscopy was performed to determine any media opacities particularly opacity in crystalline lens. View of fundus was not attempt because of small pupil size in elderly.

*Peripheral and central hearing assessment* Assessment of the peripheral and central auditory function was carried out on the subjects. Puretone audiogram was performed to assess hearing acuity. Central auditory assessment was conducted on subjects with the pure-tone hearing thresholds not more than 40 dB HL at test frequencies of 500 through 4000 HZ.

Pure-tone audiometry (PTA) was conducted in a sound treated mobile booth, using standard TDH-39 earphones and a Madsen OB822 audiometer (Madsen Electronics Itera 2) which was calibrated regularly during the study period to International Organization if Standards (ISO) 389. Testing was performed by an audiologist who also examined the ears using otoscopic examination and tympanometry for wax occlusion and middle ear disorders. If present, the subject was referred to the nearest government hospital for treatment. Audiometric thresholds for air conduction (AC) for right and left ears were measured for frequencies of 500, 1000, 4000, and 8000 Hz. Bone conduction (BC) was evaluated whenever AC thresholds were greater than 20 dB HL for frequencies of 500, 1000, 2000 and 4000 Hz.

*Dichotic Digit Test (DDT)* DDT was conducted using the Malay Double Dichotic Test Mukari et al. [62], which was recorded in a compact disk (CD). Pairs of different digits were presented simultaneously to each of the two ears at 60 dB HL. Stimuli were routed from a CD player SONY X202ES through a calibrated audiometer and were delivered to the subject's ears through a headphone. The DDT was conducted using free recall test condition, in which the subject was instructed to repeat all the four digits that they heard in no specific order. The subject practiced using five digit pairs in the practice list to familiarize them with the test concept. Subsequently, the test was carried out using 20 stimulus items; each item consists of four different digits. A correct response was allocated to each digit that was repeated correctly. The possible total correct score was 40 for each ear. The right ear score (RES) and the left ear score were calculated as percent correct.

*Pitch Pattern Sequence Test (PPST)* The PPST was performed using the CD version of PPST material, produced by AUDiTEC (St. Louis, MO, USA). Forty series of triads of pure tones with two different frequencies, which occur sequentially, were presented binaurally through a CD player, which was routed to a pure-tone audiometer. Frequencies of the pure-tone stimuli were 880 Hz (low

frequency) and 1430 Hz (high frequency). Stimuli were presented diotically through TDH headphones at 60 dB HL. In each series, triad tones of 200 ms were presented with a 10 ms rise–fall time and separated by 150 ms gaps. The triads were separated by 10 s gaps.

Subjects were tested twice using two different response modes, which were humming and verbal labeling responses. In the humming response mode, subjects were asked to respond by imitating the frequency pattern heard. In the verbal labeling response mode participants were required to state the pitch pattern of tones heard. For example, if the presented tones were 880–880–1430 Hz, then participants should verbally indicate low–low–high as the correct sequence response. A response was considered correct if the pitch pattern was repeated according to the sequence presented. The sequence of response pattern was counter balanced across subjects to reduce biases due to learning effect. The test was preceded by four to five practice trials to make sure participants understood the tasks. For each of the response modes, PPST was scored based on the percent of stimulus patterns correctly hummed/verbally labeled.

*Gap-in-Noise Test (GIN)* The GIN test was administered and scored according to the set criteria Musiek et al. [63]. The GIN contains a series of 36 different 6 s white noise segments. Each of the white noise segments contain between 0 and 3 gaps of silence. The duration of the silence gaps is either 2, 3, 4, 5, 6, 8, 10, 12, 15 or 20 ms. The GIN contains 60 gaps and the order of the gap durations is randomized. A 5 s gap of silence separates each 6 s noise segment. The test was conducted in each ear. A practice list was provided at the beginning of the test to ensure that the subject understood the task.

In GIN test, the subject was asked to listen to the silence gap that may or may not occur within each noise burst. The subject had to press a response button as soon as a gap was detected. GIN threshold was defined by the shortest silence gap that was correctly detected by the subject at least four out of six times.

## Quality control

Trained research assistants and enumerators were employed for the study, with regular monitoring and retraining conducted. Quality control was done during field data collection to ensure data collected was of high-quality. Upon completion of each day of data collection, questionnaires and measurements were checked by senior research assistants. At the central level, all forms were rechecked for the validity of the answers. Some of the incomplete socio-demographic and health data were verified again with respondents through phone interview.

## Feedback of baseline results

The results from the biophysical measurements, fasting blood glucose, fasting serum lipid and body weight status were compiled into a one-page summary report and posted to each respondent within 1 month of recruitment. The report also contained basic explanation on what the normal values were. Those with abnormal results were advised to see their doctor for further investigation and treatment.

## Follow-up

Respondents will be followed up at 18 and 36 months with the same questionnaires after some minor modifications, including addition of questions on hospitalization, morbidity and mortality. The study planned to add on Dementia Rating Scale and repeating the biospecimens procedure at 36 months.

## Data entry

The questionnaire was printed using an OMR system, thus, data entry was done using a scanner. All answers that were captured during the scanning process were verified by a verifier before they were exported to the database. With respect to dietary history questionnaire, the food intake data were entered into the database using Nutritionist Pro software. The output from Nutritionist Pro was then exported into the Excel database.

## Data analysis

Data analysis was done by exporting the raw data (in CSV form or Excel) into other statistical tools such as SPSS. The data were then checked and cleaned. The analysis was done according to the terms, operational definitions, and dummy tables prepared by research group. The sample weight was calculated, starting with the calculation of the base or design weight, and the weight was then adjusted for the non-responses. In general, the weight of a sampled unit is the reciprocal of its probability of selection into the sample. The final weight used in the analysis was the post-stratification weight based on the information from the 2010 census in Malaysia. Taking into consideration the sampling design, which was a complex sampling design, the analysis was done accordingly. Prevalence estimates for all the outcomes were also performed. All the analysis processes were done by a data management team.

## Results

Total number of respondents for the survey was 2322, giving a response rate of 87.8 %. The non-response was the highest in Johor (24.2 %), especially in the rural areas (29.8 %). Similar trend was noted for Selangor of which non-response was higher in rural area as compared to urban. In contrast, a better response was observed for rural areas as compared to the urban in Perak and Kelantan (Table 3).

As shown in Table 4, baseline characteristics of respondents were comparable with the statistic of the Malaysian Population Census. Most of the respondents were women, younger age (60–69 years), Malays and married.

In the present study, initially a total of 2342 subjects were recruited. However, a total of 349 subjects who did not meet the inclusion criteria or who had MMSE score below 15 ($\leq$14) were excluded to avoid dilution effect. As shown in Fig. 1, most of subjects were categorized as experiencing usual aging (73 %), followed by successful aging (11 %) and mild cognitive impairment (16 %).

The mean age of respondents was 68.5 $\pm$ 5.9 years old, with those within the MCI category were the oldest (66.8 $\pm$ 5.5 years old), followed by UA (68.6 $\pm$ 5.9 years old) and SA (69.4 $\pm$ 6.0 years old) ($p < 0.05$) (Table 5). Successful agers were mostly Malays (59.6 %), men (56.0 %), had higher education level (7.79 $\pm$ 4.13 years), living with others (93.6 %), had lower rate of illiteracy (1.4 %), mostly working (27 %), had higher total monthly (RM 1400.63 $\pm$ 1434.87) and household (RM 1998.36 $\pm$ 2481.36) income, satisfied with current financial situation (50.7 %) and had never experienced economic hardship (93.1 %) as compared to those in the category of UA and MCI (Table 5). Post-hoc analysis had proven that those in SA group were younger, had higher education level and had greater monthly and household income ($p < 0.05$) (Table 6).

## Discussion

The LRGS TUA study, to our knowledge, is among the very few longitudinal study investigating the predictors of cognitive decline and successful aging, from a wide range of psychosocial, biophysical, health, lifestyle and dietary assessment in a single study, especially among a multiethnic Asian older adults. Several studies have highlighted the importance of optimum biophysical health, lifestyle and prudent dietary pattern and also some psychosocial domain with cognition and successful aging [2], however, most of the studies are conducted among Western populations and did not highlight the magnitude of the associations in a single study. Thus, this study tested these observations longitudinally among multiethnic Asian older adults in a single study. The results could have particular importance given the exponential rise in the number of older adults in developing countries, of which most of the aged population would come from the region [64].

This study has its strength in sampling as it involved the representative respondents from four regions in peninsular Malaysia which has been selected using appropriate

**Table 3** Number of response and non-response according to state and urban and rural localities

| State | Total eligible subjects invited | Number participated | Number of non-response | Percentage of non-response |
|---|---|---|---|---|
| Johor | | | | |
| Urban | 263 | 231 | 32 | 12.2 |
| Rural | 304 | 251 | 53 | 17.4 |
| Total | 567 | 482 | 85 | 15.0 |
| Perak | | | | |
| Urban | 396 | 320 | 79 | 19.9 |
| Rural | 264 | 223 | 42 | 15.9 |
| Total | 706 | 543 | 121 | 17.1 |
| Kelantan | | | | |
| Urban | 160 | 127 | 33 | 20.6 |
| Rural | 680 | 596 | 88 | 12.9 |
| Total | 840 | 723 | 121 | 14.4 |
| Selangor | | | | |
| Urban | 570 | 468 | 104 | 22.2 |
| Rural | 136 | 106 | 30 | 28.3 |
| Total | 706 | 574 | 134 | 19.0 |
| Grand total | 2819 | 2322 | 461 | 16.4 |

**Table 4** Baseline characteristics of respondents in the study as compared to the Malaysian Population Census 2010 [presented as *n* (%)]

| Parameters | LRGS TUA ($n = 2322$) | Malaysian Population Census 2010 [58] |
|---|---|---|
| Gender | | |
| Men | 1114 (48.0) | 1,067,892 (48.9) |
| Women | 1208 (52.0) | 1,114,912 (51.1) |
| Age groups (years) | | |
| 60–69 | 1330 (57.3) | 1,322,591 (60.6) |
| 70 and above | 992 (42.7) | 860,213 (39.4) |
| Ethnic group | | |
| Malays | 1447 (62.3) | 1,242,865 (57.0) |
| Chinese | 750 (32.3) | 777,622 (35.6) |
| Indian and others | 125 (5.4) | 162,317 (7.4) |
| Educational level | | |
| No formal education | 492 (21.2) | NA |
| Primary education | 1338 (57.6) | |
| Secondary education | 444 (19.1) | |
| Tertiary education | 48 (2.1) | |
| Marital status | | |
| Single | 41 (1.8) | 115,314 (5.1) |
| Married | 1585 (68.2) | 1,539,889 (68.4) |
| Widow | 655 (28.2) | 577,302 (25.7) |
| Divorcee | 41 (1.8) | 18,711 (0.8) |
| Urban | 1146 (49.4) | 755,833 (34.6) |
| Rural | 1176 (50.6) | 1,426,971 (65.4) |

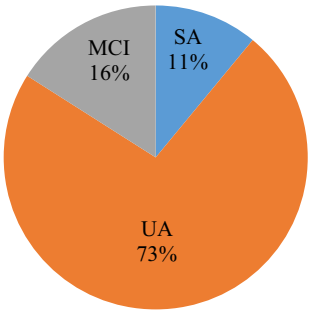


**Fig. 1** Prevalence of successful aging, usual aging and mild cognitive impairment

sampling method and standardized data collection activities. Thus, the socio-demographic profiles of the respondents, i.e., gender, ethnicity, age groups and marital status are comparable with the characteristic of Malaysian elderly according to the national census in the year 2010 [65]. In calculating the sample size for this study, few factors have been considered (i.e., estimated prevalence, margin of error, design effect and estimated response rate). The margin of error for the survey has been set at 5 %. Naing et al. [66] stated that it was appropriate to have a precision of 5 % if the prevalence of the disease was between 10 and 90 %. However, when the prevalence was below 10 % or more than 90 %, the precision of 5 % was no longer appropriate and it needed to be adjusted accordingly. The design effect for this study is estimated based on the previous nationwide studies. Design effect is the ratio of the variance of an estimate based on the complex survey design relative to the corresponding variance of the same sample size, if a simple random sampling is used. Design effects in a survey data are caused by three features of the sample design and estimation process: stratification of the survey population prior to selection; clustering or grouping of elements in the process of sample selection; and differential weighting of sample units in estimation and analysis. For a well-designed study, the design effects generally range from 1 to 3.

The response rate of this study is 88 % indicating good response rate, which is similar with responses of another local longitudinal study conducted among elderly [67]. The relatively good response rate could be due to several factors including good collaborations and supports from relevant agencies and department such as the Department of Statistics Malaysia (DOSM) and local authorities. Enumeration block (EB) maps for data collection activities and information on Malaysian population are provided by DOSM. Support on the sampling by the DOSM reduced sampling errors in the survey. This study has adopted an appropriate methodology for a population survey. All the necessary steps has been taken, starting from planning of the survey, determination of the sample size, sampling design, development and validation of the questionnaires, data collection techniques, quality assurance measures, and data processing (including data entry, data cleaning and analysis) to ensure retrieval of valid and quality data [68].

This study has adopted a household visit to scout for possible respondents, with assistance from community leaders and residential committee. During this visit, eligible respondents have been identified and invited to the prescheduled data collection session at the respective community centers. In addition, the data collection schedule also has taken into account festive seasons and celebrations specific to the religion and ethnic groups involved in the study. Further, subjects are provided with monetary incentive following their participation. Specific investigations including anthropometric status and health screening parameters from the blood including body weight status, fasting blood glucose and fasting serum lipid and also blood pressure are posted to subjects and appropriate referral letter to nearby health centers is also provided, whenever necessary. The study has also recruited fieldworkers who are well verse with specific ethnic languages and local dialect. Nevertheless, a higher number of non respondents are noted in Johor, especially rural areas.

**Table 5** Baseline characteristic of subjects [presented as *n* (%) or mean ± SD]

| Parameters | SA ($n = 218$) | UA ($n = 1460$) | MCI ($n = 315$) | Total ($n = 1993$) | $p$ value[a] |
|---|---|---|---|---|---|
| Age (years) | 66.8 ± 5.5 | 68.6 ± 5.9 | 69.4 ± 6.0 | 68.5 ± 5.9 | 0.001 |
| Ethnicity | | | | | |
| Malay | 130 (59.6) | 972 (66.6) | 165 (52.4) | 1267 (63.6) | 0.001 |
| Chinese | 78 (35.8) | 411 (28.2) | 137 (43.5) | 626 (4.1) | |
| Indians and others | 10 (4.6) | 77 (5.2) | 13 (4.1) | 100 (32.3) | |
| Gender | | | | | |
| Men | 122 (56.0) | 702 (48.1) | 178 (56.5) | 1002 (50.3) | 0.005[b] |
| Women | 96 (44.0) | 758 (51.9) | 137 (43.5) | 991 (49.7) | |
| Localities | | | | | |
| Urban | 137 (62.8) | 717 (49.1) | 155 (49.2) | 1009 (50.6) | 0.001 |
| Rural | 81 (37.2) | 743 (50.9) | 160 (50.8) | 984 (49.4) | |
| Education level (years) | 7.79 ± 4.13 | 5.40 ± 3.94 | 4.62 ± 3.18 | 5.54 ± 3.94 | 0.001 |
| Education level | | | | | |
| Primary (≤6 years) | 100 (45.8) | 867 (59.4) | 224 (71.1) | 1191 (59.8) | 0.001 |
| Secondary (6–13 years) | 92 (42.2) | 294 (20.1) | 40 (12.7) | 426 (21.3) | |
| Tertiary (>13 years) | 13 (6.0) | 33 (2.3) | 0 (0.0) | 46 (2.3) | |
| No formal schooling | 13 (6.0) | 266 (18.2) | 51 (16.2) | 330 (16.6) | |
| Marital status | | | | | |
| Married | 48 (22.0) | 438 (30.0) | 77 (24.4) | 563 (28.2) | 0.013[b] |
| Single/divorced/widow | 170 (78.0) | 1022 (70.0) | 238 (75.6) | 1430 (71.8) | |
| Living | | | | | |
| Arrangement | | | | | |
| With others | 204 (93.6) | 1313 (89.9) | 280 (89.9) | 1797 (90.2) | 0.171 |
| Alone | 14 (6.4) | 147 (10.1) | 35 (11.1) | 196 (9.8) | |
| Employment status | | | | | |
| Still working | 58 (27.0) | 343 (23.7) | 71 (22.8) | 472 (23.9) | 0.506 |
| Not working/retired | 157 (73.0) | 1107 (76.3) | 240 (77.2) | 1504 (76.1) | |
| Total monthly income (MYR) | 1400.6 ± 1434.9 | 929.8 ± 1684.7 | 790.1 ± 746.0 | 959.3 ± 1553.7 | 0.001 |
| Total household income (MYR) | 1998.36 ± 2481.36 | 1348.46 ± 2361.79 | 1117.87 ± 1323.56 | 1383.49 ± 2255.18 | 0.001 |

[a] One-way ANOVA for continuous variable (income, age, education level only) and cross-tabulation for categorical variable was used

[b] Significant at $p < 0.05$

It is noted that during the period of data collection in Johor there has been a bad haze that may cause difficulties for respondents to participate. It should also be noted that the period of data collection in Johor is also coincide with unavoidable national election period, that might result in low response in certain areas.

The findings of this current study has revealed that the prevalence of successful aging, usual aging and mild cognitive impairment are 11, 73 and 16 %, respectively. The prevalence of MCI of 16 % among subjects in this study is lower than the previous study conducted among low to middle income elderly population in a suburban area of Malaysia (21.1 %) [11] and also a nationwide survey in Korea (27.6 %) [69] but higher than another study in Italy (7.7 %) [70]. It should be noted that all of these studies using a similar criterion for MCI, however, discrepancies in the prevalence could be due to dissimilarity of sociodemographic profile and geographical area that influence the environment and lifestyles. For example, the study by Lee et al. [11] has involved a smaller convenience sample from low socioeconomic status and the study by Lee et al. [69] among Korean elderly which consisted of an older cohort with mean age of 71.9 ± 5.7 years old as compared to the mean age of the present study which is 68.5 ± 5.7 years old.

The prevalence of successful aging (SA) of 11.0 % observed in this study is slightly lower as compared to the previous nationwide survey conducted in the year 2002–2006 [24], of 13.8 %. Nevertheless, the prevalence of successful aging obtained from the current study is also comparable with developed country such as US. The prevalence of successful aging from the US longitudinal

**Table 6** Post hoc analysis using Bonferroni

| Variables | Neurocognitive status (*I*) | Neurocognitive status (*J*) | Difference (*I*–*J*) | *p* value |
|---|---|---|---|---|
| Age | SA | UA | −1.77 | <0.001 |
| | | MCI | −2.67 | <0.001 |
| | UA | SA | 1.77 | <0.001 |
| | | MCI | −0.90s | 0.044 |
| | MCI | SA | 2.67 | <0.001 |
| | | UA | 0.90 | 0.044 |
| Education level | SA | UA | 2.39 | <0.001 |
| | | MCI | 3.18 | <0.001 |
| | UA | SA | −2.39 | <0.001 |
| | | MCI | 0.79 | 0.003 |
| | MCI | SA | −3.18 | <0.001 |
| | | UA | −0.79 | 0.003 |
| Monthly income | SA | UA | 470.87 | <0.001 |
| | | MCI | 610.50 | <0.001 |
| | UA | SA | −470.87 | <0.001 |
| | | MCI | 139.63 | 0.455 |
| | MCI | SA | −610.50 | <0.001 |
| | | UA | −139.63 | 0.455 |
| Household income | SA | UA | 649.91 | <0.001 |
| | | MCI | 880.50 | <0.001 |
| | UA | SA | −649.91 | <0.001 |
| | | MCI | 230.59 | 0.300 |
| | MCI | SA | −880.50 | <0.001 |

study, known as The Health and Retirement Study (HRS), is 11.9 % in 1998, 11.9 % in 2000, 11.0 % in 2000 and 10.9 % in 2004 [71]. However, certain studies reported a rather high prevalence of successful aging such as 62.0 % in Brazil [72] and 46.2 % in China [73]. This may be attributed to the variation in tools administered to classify successful aging and difference in MMSE cut-off point to indicate normal cognition. For example, Li et al. [73] has used MMSE score of 25 and above for those with more than 5 years of schooling and 20 for those less than 6 years of schooling. Current study has defined normal cognition from MMSE as 19 and above based on previous local study done among community dwelling elderly [11]. Besides that, majority of the subjects (59.8 %) in the current study have similar findings primary education level (less than 6 years of formal schooling).

In addition to reporting the prevalence of MCI and SA, this study has further classified 73 % of the subjects as experiencing usual aging. These subjects are not classified as SA neither MCI, but represents the majority of the aging population at higher risk of suffering of chronic diseases as proposed earlier [23]. It should be noted that in this study those with low MMSE score, i.e., less than 14 has been excluded from the UA criteria. Although our study has similar findings with earlier study [23], we were very interested to investigate the cognitive status of the older adults that Rowe and Khan failed to highlight. Thus, in this study, we proposed that individuals experiencing usual aging have average intellectual capacity supported by average performance in the neuropsychological test administered (having mean score above those in the group of MCI but below that of SA). Elderly who are eligible in the usual aging criteria should be free of dementia (either self reported by subjects or their caregivers), have no disability (full score in ADL) and have higher risk of suffering from eight major chronic diseases (hypertension, hyperlipidemia, osteoarthritis, cancer, lung diseases, diabetes, cataract/glaucoma and stroke). Moreover, this study has also found that MCI subjects have the of monthly and household income as compared to UA and SA ($p < 0.05$ for all parameters). These findings are expected as cognitively impaired older adults have been reported to be older, less educated and socioeconomically deprived [74–76].

One of the limitations of the study is that the samples did not include all states in Malaysia, i.e., 14 states. However, the findings of this large-scale community study are able to represent the prevalence of MCI, SA and UA from the four states in Malaysia; which are almost similar to the characteristic of nationwide aging population in the country in terms of gender, ethnic and urban and rural

distribution [77]. The strengths of the study are due to the comprehensiveness of the measurements and the random sampling approach of the samples of a multiethnic Asian population, with a good response rate. Further, measurements of sensory function are only conducted in a subsample due to difficulties to provide the mobile booth in all areas.

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**Compliance with ethical standards**

**Conflict of interest** The authors report no conflict of interest related to the work.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and /or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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