Aging Clinical and Experimental Research (2023) 35:3157–3165
https://doi.org/10.1007/s40520-023-02612-7

ORIGINAL ARTICLE

An examination of the validity of neuropsychological and physical testing batteries in Latin-American adults aged over 55 years

Rebeca Hernández-Gamboa[1,2] · Mónica Salazar-Villanea[3] · Ricardo Alvarado-Barrantes[4] · David K. Johnson[5] · Yamileth Chacón-Araya[1,6] · José Moncada-Jiménez[1,6]

Received: 30 November 2022 / Accepted: 30 October 2023 / Published online: 21 November 2023

Abstract

Background Valid and reliable measurements are necessary to understand and monitor age-related changes.

Aims To describe the factor structure and provide validity evidence of a neuropsychological and a physical testing batteries using factor analysis.

Methods We performed a secondary analysis of data from the Epidemiology and Development of Alzheimer's Disease (EDAD) project. Community-dwelling adults aged 55 to 85 years underwent comprehensive physical and neuropsychological assessments. An exploratory factor analysis was performed on both assessment batteries. The models were later confirmed with a random subsample using confirmatory factor analysis.

Results Data from 238 adults (163 females and 75 males) was included. The neuropsychological model revealed a four-factor structure formed by "Executive Functioning", "Verbal Memory", "Logical Memory", and "Labeling And Reading" (Extraction Sums of Squared Loadings [ESSL] = 56.41% explained variance; Standardized Root Mean Square Residual [SRMSR] = 0.06; Comparative Fit Index [CFI] = 0.98). The physical model was formed by a two-factor structure including "Health-related Fitness and "Functional Fitness" (ESSL = 50.54% explained variance; SRMSR = 0.07; CFI = 0.93).

Discussion To our knowledge, this is the first study to analyze the structure of comprehensive testing batteries for the Latin-American older adults. Our analysis contributes to the understanding of theoretical constructs that are evaluated in the EDAD project.

Conclusion Our findings provide validity evidence for simplified and reduced testing batteries, which imply shorter testing times and fewer resources.

Keywords Aging · Cognition · Physical fitness · Assessments · Validity

Introduction

Health assessments in older adults are relevant and complex tasks, given the drastic increase in global aging, and great diversity of their capacities [1, 2]. Aging is specially related to changes in physical [3–5] and cognitive domains [6, 7].

Physical fitness [8], is considered a multi-component construct [9]. The American College of Sports Medicine (ACSM) classifies physical fitness into health-related and skill-related components [10]. This classification emulates the distinction between *physical function* and *physical fitness*. Physical function has been described as the ability to carry out activities of daily living, while physical fitness includes measurable outcomes related to health and mortality [11].

Life cycle effects of protective factors, risk factors, and compensatory scaffolding processes combine in various

✉ Rebeca Hernández-Gamboa
rebecahg@student.ubc.ca

1 School of Physical Education and Sports, University of Costa Rica, San José, Costa Rica

2 Rehabilitation Sciences, The University of British Columbia, Vancouver, BC, Canada

3 Psychological Research Institute (IIP), University of Costa Rica, San José, Costa Rica

4 School of Statistics, University of Costa Rica, San José, Costa Rica

5 Department of Neurology, University of California at Davis, Davis, CA, USA

6 Human Movement Sciences Research Center (CIMOHU), University of Costa Rica, San José, Costa Rica

levels of cognitive function [12], such as learning, memory, language, perception, attention, and executive functions [13, 14]. A wide range of neuropsychological tests has been used to measure cognitive function. Some tests may evaluate multiple cognitive functions at a time or capture only one aspect of a given function; thus, a comprehensive cognitive assessment often employs a battery of several tests [15, 16].

The worldwide increase in older adult population imposes a need for strategies to face the demands of aged individuals and prevent or delay negative changes that may occur in healthy or pathological aging. These changes include a decrease in muscle mass [3], muscle strength and aerobic capacity [4], changes in mobility, balance [5], memory, processing speed [6], inhibition, and working memory [17].

Improving measurements and data collection of older adults' characteristics is necessary to understand and monitor healthy aging and changes associated with aging [2]. Valid and reliable measurements are essential to achieve this goal, yet few neuropsychological assessment batteries have been validated in Spanish for the Latin American population. As for physical testing batteries, to our knowledge, there are no validated assessment protocols for the older adult population in Latin America.

The Epidemiology and Development of Alzheimer's Disease (EDAD) project sought to study social and environmental factors that contribute to healthy aging and the development of Alzheimer's disease in Costa Rica (registration R21-TW009665). A subsample of healthy older adults from EDAD was assessed to compare physical and cognitive aging between participants from Costa Rica and Kansas, US. In the study, older adult volunteers completed comprehensive physical and neuropsychological assessments. The testing batteries comprised multiple cognitive tests previously validated in Spanish [18–21]. Notably, many studies of cognitive aging have created global cognition scores by averaging the z-scores of the tests that make up an assessment. However, this approach has been questioned because it leads to the loss of important information [22]. Contrarily, factor analysis is a more sophisticated and robust approach that allows the representation of multiple aspects of a concept with one score and provides evidence of validity and reliability for tests [23]. Therefore, the present study aimed to use factor analysis to describe the factor structure of the neuropsychological and physical testing batteries used in the EDAD project.

Methods

Design and participants

We performed a secondary analysis of data from a cross-sectional subsample from EDAD. Community-dwelling adults aged 55 to 85 years were recruited from the greater metropolitan area in Costa Rica. Individuals were excluded if they presented: (a) possible cognitive impairment as defined by a Mini Mental State Examination (MMSE) score < 24), (b) major psychiatric disorders as defined by Diagnostic and Statistical Manual of Mental Disorders IV (DSM-IV), (c) stroke history, (d) clinically significant infections in the past 30 days, (e) drug or alcohol abuse in the past two years, or (f) medical contraindication for physical testing. All participants provided written consent, and the University of Costa Rica's Scientific Ethics Committee previously approved the study protocol.

Procedures

Participants underwent physical and neuropsychological assessments in two separate sessions. Individuals attended the first session in fasted state. A physician performed an interview and general health assessment to grant permission for participation. After this, an exercise scientist and the physician recorded anthropometric measures (i.e., body height in cm and body weight in kg) and performed the Senior Fitness Test (SFT). The SFT is a comprehensive functional fitness test battery to evaluate older adults' ability to perform activities of daily living safely and independently [24]. It is comprised of (a) 30-s chair stand, (b) 30-s arm curl, (c) 2-min step test, (d) Chair sit-and-reach, (e) Back scratch, (f) Timed up-and-go, and (g) 6-min walking test (6MWT). Then, handgrip strength was recorded using a handheld dynamometer (Jamar, Patterson Medical, Nottinghamshire, UK). Participants performed three attempts; the highest score was considered the maximum grip strength. Finally, a graded exercise test assessed peak oxygen consumption (VO_2peak) with a modified Bruce protocol on a Jaeger CPX metabolic cart (CareFusion Corporation, San Diego, CA). Participants ingested a small breakfast following the physical tests.

Individuals attended the neuropsychological testing session approximately one week after the first session. A psychologist or a trained advanced psychology student applied the following neuropsychological tests: (a) MMSE [25], (b) Logical Memory [26], (c) Category fluency [27], (d) Trail Making Test [28], (e) Digit Symbol Substitution Test [13], (f) Boston Naming Test [29], (g) Block Design [26], (h) Stroop Test [30], (i) Free and Cued Selective Reminding Test [31], (j) Crossing Off [32], (k) Letter Number Sequencing [26], (l) Digit Span Test [26], (m) Hidden Patterns [33], and (n) Identical Pictures [33]. After the neuropsychological evaluation, an exercise scientist carried out the remaining physical measure; a body composition assessment using a dual-energy X-ray absorptiometer (DXA) General Electric™, model Lunar

Prodigy Advance (GE Medical Systems Lunar, Madison, WI), with the enCORE 2011 software version 13,60,033.

Statistical analysis

Analyses were performed using the IBM-SPSS Statistics version 23 and IBM-SPSS AMOS version 24 (Armonk, NY, USA). Statistical significance was set at $p \leq 0.05$. Descriptive statistics included continuous variables' mean and standard deviation (M ± SD). In addition, two primary analyses were computed: a) exploratory factor analysis (EFA) and b) confirmatory factor analysis (CFA).

EFA is used to analyze patterns in complex and multidimensional relationships. It allows summarizing an extensive data set into a smaller number of factors that represent latent variables or constructs [23]. We performed an EFA for the physical and cognitive testing batteries. Before the factor extraction, we estimated the Kaiser–Meyer–Olkin measure (KMO) to verify adequate sampling and performed Bartlett's test of sphericity [23]. For both analyses, we used oblique rotation, given that factors cannot be assumed to be uncorrelated [23].

After extracting the factor structure with the exploratory analysis, we confirmed this structure with a random subset of the data (i.e., CFA). To examine convergent validity, we analyzed the Composite Reliability, Average Variance Extracted, and factor loadings. Values of CR > 0.70 and AVE > 0.50 were set as cut offs of adequate convergent validity, as well as factor loadings above 0.50 with an average of ≥ 0.70. We interpreted discriminant validity as a low correlation between factors (< 0.70). Adequate model fit was determined according to the Maximum Shared Variance (MSV < AVE), Comparative Fit Index (CFI) (> 0.90), Root Mean Square Error of Approximation (RMSEA < 0.05), and Standardized Root Mean Square Residual (SRMR < 0.09) [34–36].

We eliminated some indicator variables (i.e., test scores) from the original testing batteries. Importantly, the elimination of indicators was done to ensure practical significance, not just to meet mathematical criteria. A factorial load of 0.5 means that 25% of the variance in the factor is explained [23]. For this reason, we removed indicators with factor loadings < 0.5.

Results

Volunteers were 238 adults (163 females and 75 males). The participant's age was 69.22 ± 5.13 yr., body mass 68.09 ± 12.36 kg, body height 157.85 ± 9.40 cm, VO_2 peak 22.24 ± 5.13 ml·kg^{-1}·min^{-1}, body fat mass 38.64 ± 8.92%, and MMSE score of 28.88 ± 1.51 pts.

The statistical assumptions for EFA and CFA were studied. The KMO measure verified adequate sampling for the physical (0.79) and neuropsychological (0.83) testing batteries. Bartlett's sphericity test indicated a proper correlation structure for factor analysis for the physical ($\chi^2 = 683.88$, $df = 28$, $p \leq 0.001$) and neuropsychological ($\chi^2 = 1337.71$, $df = 91$, $p \leq 0.001$) testing batteries.

Physical assessments

EFA

The maximum likelihood estimation method created a two-factor solution that explains 50.54% of the variance. Table 1 presents the pattern loading matrix for eigenvalues ≥ 0.3. Twelve measures were included in the analysis. Four measures were removed from the model (height, weight, Chair sit-and-reach, and Back scratch) to obtain adequate discriminant validity. Both factors had low internal consistency, evidenced by Cronbach's α for Functional Fitness ($\alpha = 0.26$) and for Health-related Fitness ($\alpha = 0.32$).

CFA

The two-factor model was confirmed using data from a random subsample (Fig. 1).

The model has adequate fit, as determined by SRMR (0.07) and CFI (0.93) measures. Both factors evidence adequate convergent validity, as they both present factor loadings ≥ 0.50 in all indicator variables and average loadings ≥ 0.70. The convergent validity measure AVE is 0.50 for Functional Fitness and 0.49 for Health-related Fitness, approaching the cut-off criteria of 0.50 [36]. However, some authors consider the AVE a very strict measure of convergent validity [34, 35]. The CR measures are 0.79 and 0.80 for Health-related Fitness and Functional Fitness respectively, suggesting good construct reliability. Although both factors are significantly related ($r = 0.62$, $p < 0.001$), the model reaches suggested thresholds [23] (Table 2).

Neuropsychological tests

EFA

The maximum likelihood extraction method created a four-factor solution that explains 56.41% of the variance. The pattern matrix is presented in Table 1.

Notably, out of the 25 items that were included in the analysis, 11 (44%) were removed from the model to obtain proper discriminant validity. All four resulting factors present adequate internal consistency, evidenced by Cronbach's α (Executive Functioning = 0.75, Verbal Memory = 0.78, Logical Memory = 0.88 and Naming and Reading = 0.75).

Table 1 Pattern loading matrix for the physical and the neuropsychological tests models

Indicator		Factor		
Physical tests		Functional fitness		Health-related fitness
30-s Chair stand		0.77		
30-s Arm curl		0.74		
2-min steps		0.65		
Timed up and go test		0.57		
Grip strength				0.77
6 min walking test				0.73
Fat free mass				0.72
VO_2 peak				0.60
Neuropsychological tests	Executive functioning	Verbal memory	Logical memory	Naming and reading
Hidden patterns	0.82			
Identical pictures	0.53			
Stroop 3	0.50			
Trail making test A	0.49			
Trail making test B	0.54			
Block design	0.89			
Digit symbol substitution	0.73			
SRT free 1		0.63		
SRT free 2		0.75		
SRT free 3		0.84		
Delayed logical memory			0.84	
Logical memory			0.95	
Stroop 2				0.82
Stroop 1				0.78

As was done for the physical testing battery, the four-factor model for the neuropsychological testing battery was confirmed using data from a random subsample (Fig. 2). The model fit is excellent (SRMR = 0.06, CFI = 0.98).

All four factors present factor loadings > 0.50 in all their indicator variables and average > 0.70, which provides evidence for acceptable convergent validity [23]. The AVE and CR also indicate proper convergent validity (Table 2). The square root of AVE is greater than inter-construct correlations suggesting proper discriminant validity.

Discussion

This study aimed to describe the factor structure of the neuropsychological and physical testing batteries used in the EDAD project and provide evidence of validity for their use in Latin American older adults. The neuropsychological battery was comprised of four factors (i.e., Executive Functioning, Verbal Memory, Logical Memory, and Labeling And Reading), and the physical model was formed by two factors (i.e., Health-related Fitness and Functional Fitness).

Four indicators (33%) were removed in the physical model out of the 12 original indicator variables. This may reduce the evaluation time of research protocols, yet it excludes the assessment of flexibility, a domain considered relevant for the physical health of older persons [37]. The other two removed indicators were anthropometric characteristics, usually recorded for research or health assessments; thus, we do not recommend their elimination for other purposes.

Varela et al. [38] reviewed some of the most relevant physical testing batteries for the older population and classified them according to their purpose (i.e., health-related or related to activities of daily living). For example, the 6MWT, grip strength, chair-stand, and arm curl were found in batteries classified in both categories. This reflects how different tests have been conceptualized in diverse ways. Therefore, our analysis contributes to the understanding of theoretical constructs that are evaluated in the EDAD

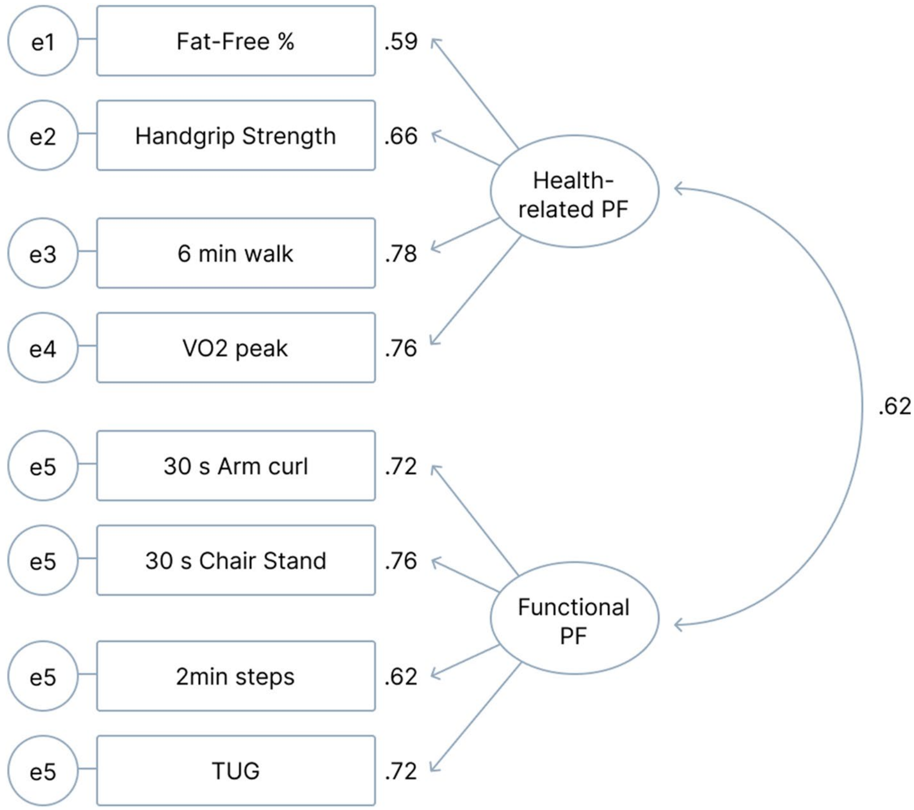


Fig. 1 Two-factor model for the physical assessment battery

Table 2 Validity measures for the physical and the neuropsychological tests models

Physical tests	CR	AVE	MSV	Health-related fitness	Functional fitness		
Health-related fitness	0.79	0.49	0.38	**0.71**			
Functional fitness	0.80	0.50	0.38	0.62*	**0.70**		
Neuropsychological tests				Executive functioning	Verbal memory	Logical memory	Naming and reading
Executive functioning	0.86	0.51	0.19	**0.71**			
Verbal memory	0.77	0.53	0.27	0.41*	**0.73**		
Logical memory	0.89	0.81	0.27	0.34*	0.52*	**0.90**	
Naming and reading	0.76	0.62	0.19	0.43*	0.21	0.08	**0.79**

coefficients are presented in bold

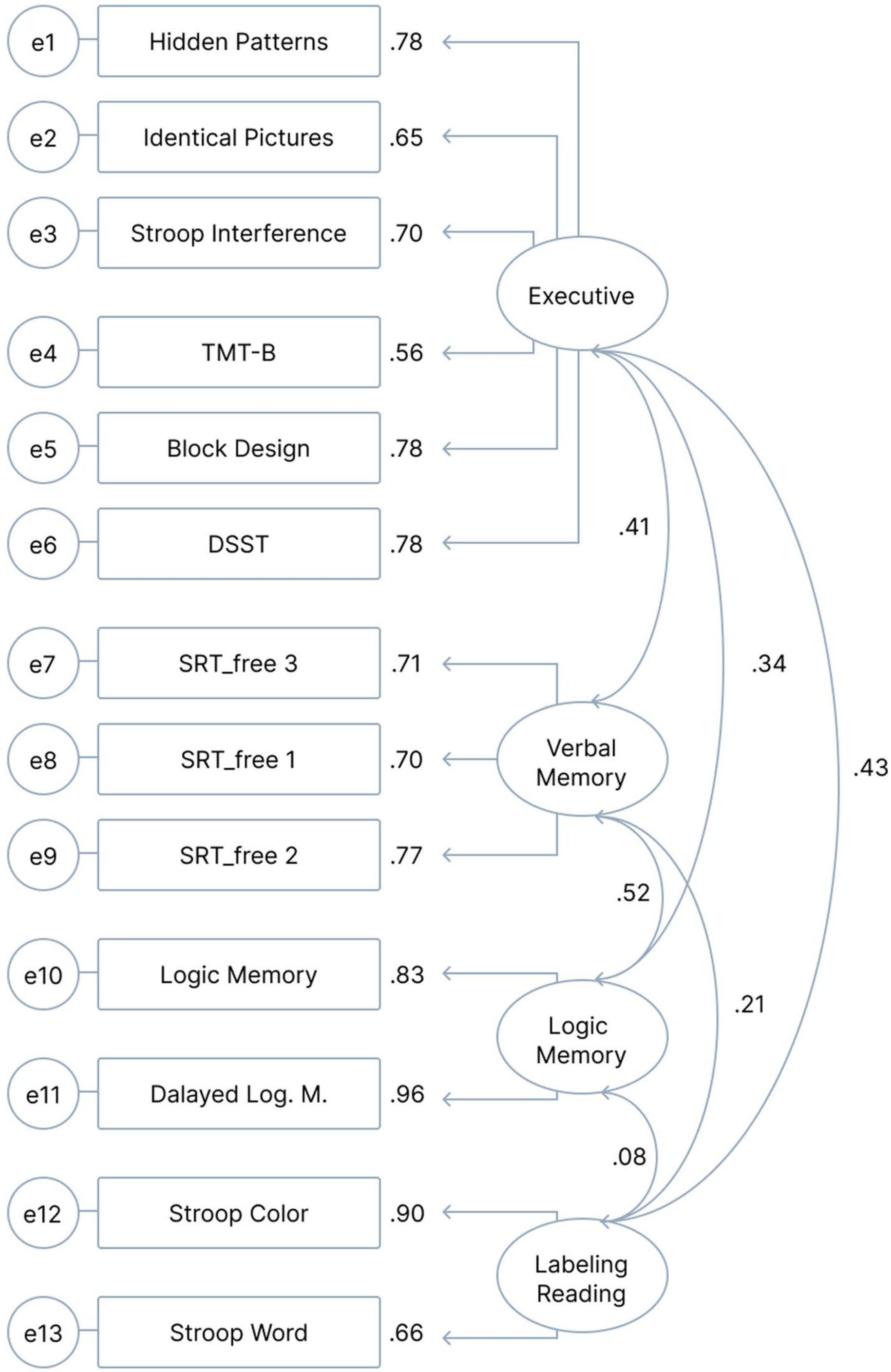
Note: CR: adequate construct reliability (> 0.70); AVE: inadequate average variance extracted (< 0.50); MSV: adequate maximum shared variance (< AVE); Adequate square root of the AVE (> correlations)

*significant correlations at $p < 0.001$

project. Nevertheless, the nomenclature must be confirmed with a more extensive data set.

The "Health-related Fitness" factor is formed by three basic physical parameters, muscle strength, aerobic capacity, and body composition. Muscle strength was assessed with the grip strength test, a test widely used to predict mortality in older adults [39–42]. The 6MWT, an assessment of cardiovascular aerobic capacity, is related to death risk [24]. Although the original testing battery included a graded test to measure maximal oxygen uptake (VO_2 max) directly, the sample from this study did not reach a respiratory exchange ratio > 1.10; a ratio needed to consider that an individual's maximal VO_2 has been achieved. Thus, we instead recorded the VO_2 peak. This may explain why the

Fig. 2 Four-factor model for the neuropsychological assessment battery. Factors: Executive functioning (indicators: Hidden patterns, Hand, Verbal memory, Logical memory and Labeling and Reading).



6MWT was associated with "Health-related Fitness", and the graded test, a gold standard for cardiorespiratory fitness, was not. Finally, body composition is often expressed in two compartments, fat mass and fat-free mass. Fat-free mass, the final component of this factor, is of particular interest for the health of older adults, as aging is related to the loss of muscle mass and function (i.e., sarcopenia).

The second physical factor was labeled "Functional Fitness" and is composed of four test from the SFT, a testing battery specifically designed to assess older adults' abilities to perform activities of daily living independently [24]. This factor includes the evaluation of capacities such as upper body strength (Arm curl and Chair stand), agility, and dynamic balance (Timed-Up-and-Go and 2-min step test) [11, 24]. Although the 2-min step test is provided as an alternative for the 6MWT, a detailed analysis of both procedures evidences that the step test requires better mobility and balance, as the individual must lift their leg in a way that is not habitual, like walking. Therefore, we suggest that the 2-min step test evaluates the ability to perform more complex movements, not just aerobic capacity. For this reason, it is related to other indicators that form the “Functional Fitness” factor.

The neuropsychological model was comprised of four factors and 13 indicator variables. Twelve indicators were removed for practical reasons, making for a shorter assessment protocol. The first neuropsychological factor was named “Executive Functioning” and is formed by six tests (i.e., Block design, Hidden Patterns, Digit Symbol Substitution Test, Identical Pictures, Stroop Test, and Trail Making Test B). Notably, not all these tests were initially designed to evaluate executive functions. However, as we analyzed the tests’ characteristics and demands, we found that all indicator variables presented visual stimuli tasks related to cognitive control, planning, and self-monitoring tasks, which implies strategy generation and complex perceptual and motor resolution.

“Verbal Memory” was the second neuropsychological factor. It comprises three scores from the Selective Reminding Test, a test where individuals are asked to recall 16 images they had observed. Participants performed six trials, three free (not cued) and three cued attempts to recall. Unlike the unidimensional structure reported before [31], where all six trials form one factor, only the scores for the three free recalls conform the “Verbal Memory” factor in our findings. This may be due to the healthy cognitive status of our participants, whose scores may have been affected by a ceiling effect [22] in the cued portion of the test. Meanwhile, free recall assesses the individual’s learning curve with an effective memory encoding strategy.

The remaining two factors, “Logical Memory” and “Naming and Reading” only have two indicator variables. Caution is warranted when interpreting factors with less than three indicator variables [23]. Thus, we discuss the factors; yet this limitation should warn their use for future analyses. The “Logical Memory” factor comprises two scores from the same test (Immediate Logical Memory and Delayed Logical Memory). This test assesses recall memory similarly to daily memory demands [22]. Two scores form the "Naming and Reading" factor from the Stroop Test (Color Naming and Word Reading). These two scores may simply be associated with the same factor because of the identical format of the test and not because of a common underlying construct. Based on our analysis, we warn readers against the interpretation of these two-factor scores.

Strengths and limitations

Research with neuropsychological and physical testing implies the need to develop, standardize, and evaluate testing procedures. Having reliable and valid assessment instruments is fundamental to studying aging-related changes.

Following the thresholds recommended by Hair et al. [23], we found evidence of adequate convergent and discriminant validity for both the physical and neuropsychological testing batteries. Evidence of consistency (e.g., test, re-test) and predictive validity is necessary to ensure that these measures are helpful and trustworthy in research and clinical settings.

In neuropsychology, it is uncommon to find instruments that measure only one cognitive function; consequently, different interpretations can be found in the literature about each instrument. This was evidenced in the fact that some indicators loaded on two factors at a time. However, with factor analysis, we were able to identify the cognitive functions being evaluated by observing how scores were related and covaried, allowing for interpretation based on theory and real observations (i.e., scores).

A strength of using factors as indicators of latent variables instead of simple test scores is that the variable (i.e., factor) is represented by integrating common variance and better estimating the construct, which minimizes measurement error [23]. The findings of this study contribute to future research in the field by providing simplified and reduced testing batteries, which implies shorter testing time and fewer resources. These findings also reinforce the notion that a comprehensive and valid evaluation does not need to be extensive or expensive; it is possible to evaluate physical and cognitive capacities in older adults using low-cost procedures.

Notably, the older adults who participated in the present study represent a selective population of Latin-American older persons. The participants were mainly healthy, physically active, and independent. Therefore, caution is warranted when generalizing these results. Another limitation of our study is that education (i.e., years of formal schooling) and socioeconomic variables were not considered. There is evidence that individuals with higher education and socioeconomic levels perform better in neuropsychological tests [43].

In conclusion, this is the first study to analyze the structure of comprehensive testing batteries for the Latin-American older adult population to the best of our knowledge. Practitioners will save time and resources by using simplified and reduced physical and neuropsychological testing batteries. Future studies should focus on replicating these analyses with older adults with distinct cognitive and physical statuses, and from rural and urban settings to allow generalizability.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40520-023-02612-7.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by RH-G, JM-J and MS-V. The first draft of the manuscript was written by RH-G and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding No funding was received to assist with the preparation of this manuscript.

Data availability Data will be provided upon reasonable request to the lead author.

Declarations

Conflict of interest The authors report no competing interests.

Statement of human and animal rights This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University of Costa Rica (08/01/2016).

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

References

1. Belsky DW et al (2015) Quantification of biological aging in young adults. Proc Natl Acad Sci 112:E4104–E4110
2. Organization, W.H., Decade of healthy ageing: baseline report. 2020.
3. Landers-Ramos RQ, Prior SJ (2018) The microvasculature and skeletal muscle health in aging. Exerc Sport Sci Rev 46:172–179
4. Ramnath U et al (2018) The relationship between functional status, physical fitness and cognitive performance in physically active older adults: a pilot study. PLoS ONE 13:e0194918
5. Demnitz N et al (2016) A systematic review and meta-analysis of cross-sectional studies examining the relationship between mobility and cognition in healthy older adults. Gait Posture 50:164–174
6. Chu CH et al (2015) Exercise and fitness modulate cognitive function in older adults. Psychol Aging 30:842–848
7. Dupuy O et al (2018) Higher cardiovascular fitness level is associated to better cognitive dual-task performance in Master Athletes: Mediation by cardiac autonomic control. Brain Cogn 125:127–134
8. Corbin, CB, Le Masurier GC (2014) Fitness for life.: Human Kinetics
9. McMorris T (2016) Exercise-cognition interaction: Neuroscience perspectives. 2015: Academic Press
10. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 2018, Philadelphia, PA: Wolters Kluwer
11. Åhlund K et al (2017) Effects of comprehensive geriatric assessment on physical fitness in an acute medical setting for frail elderly patients. Clin Interv Aging 12:1929–1939
12. Reuter-Lorenz PA, Park DC (2014) How does it STAC up? Revisiting the scaffolding theory of aging and cognition. Neuropsychol Rev 24:355–370
13. Lezak MD et al (2004) Neuropsychological assessment. Oxford University Press, USA
14. Sachdev PS et al (2014) Classifying neurocognitive disorders: the DSM-5 approach. Nat Rev Neurol 10:634–642
15. Hugo J, Ganguli M (2014) Dementia and cognitive impairment: epidemiology, diagnosis, and treatment. Clin Geriatr Med 30:421–442
16. Stokin GB et al (2015) Mild neurocognitive disorder: an old wine in a new bottle. Harv Rev Psychiatry 23:368–376
17. Voss MW et al (2010) Functional connectivity: a source of variance in the association between cardiorespiratory fitness and cognition? Neuropsychologia 48:1394–1406
18. Duggan EC et al (2019) Contributing towards a cultural neuropsychology assessment decision-making framework: comparison of WAIS-IV norms from Colombia, Chile, Mexico, Spain, United States, and Canada. Arch Clin Neuropsychol 34:657–681
19. Arango-Lasprilla JC et al (2017) Trail making test: normative data for the Latin American Spanish-speaking pediatric population. NeuroRehabilitation 41:627–637
20. Rivera D et al (2015) Stroop Color-Word interference test: normative data for the Latin American Spanish speaking adult population. NeuroRehabilitation 37:591–624
21. Smith-Castro V (2014) Compendio de Instrumentos de Medición IIP-2014
22. Lezak MD Neuropsychological assessment. 5th ed. 2012, New York;Oxford;: Oxford University Press
23. Hair J et al (2014) Pearson new international edition. Multivariate data analysis, Seventh Edition. Pearson Education Limited Harlow, Essex
24. Rikli RE, Jones CJ (2013) Senior fitness test manual. Human kinetics
25. Folstein MF, Folstein SE, McHugh PR (1975) “Mini-mental state”. a practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 12:189–198
26. Wechsler D (1997) Wechsler adult intelligence scale-III. Psychological Corporation, San Antonio
27. Wechsler D, WAIS-R : manual : Wechsler adult intelligence scale--revised. 1981, New York, NY: Harcourt Brace Jovanovich [for] Psychological Corp
28. Spreen O, Strauss E (1998) A compendium of neurological tests, 2nd edn. Oxford University Press Inc., New York
29. Kaplan EH, Weintraub S (2001) Boston naming test
30. Stroop JR (1992) Studies of interference in serial verbal reactions. J Exp Psychol Gen 121:15–23
31. Grober E et al (1997) Free and cued selective reminding and selective reminding in the elderly. J Clin Exp Neuropsychol 19:643–654
32. Ferreira S et al (2010) Comparative norms of RAPID neuropsychological battery tests for subjects aged between 50 and 89 years. Revue neurologique 166:606–614
33. Johnson W et al (2004) Just one g: consistent results from three test batteries. Intelligence 32:95–107
34. Henseler J, Ringle CM, Sarstedt M (2015) A new criterion for assessing discriminant validity in variance-based structural equation modeling. J Acad Mark Sci 43:115–135
35. Malhotra NK, Dash S (2010) An applied orientation. Market Res. 2
36. Hu LT, Bentler PM (1999) Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Model Multidiscip J 6:1–55
37. Lee PG, Jackson EA, Richardson CR (2017) Exercise prescriptions in older adults. Am Fam Physician 95:425–432
38. Varela S, Ayán C, Cancela JM (2008) Batteries assessing health related fitness in the elderly: a brief review. Eur Rev Aging Phys Act 5:97–105
39. Arvandi M et al (2016) Gender differences in the association between grip strength and mortality in older adults: results from

the KORA-age study. BMC Geriatr. https://doi.org/10.1186/s12877-016-0381-4
40. Guadalupe-Grau A et al (2015) Association of regional muscle strength with mortality and hospitalisation in older people. Age Ageing 44:790–795
41. Loprinzi PD (2016) Lower extremity muscular strength, sedentary behavior, and mortality. Age. https://doi.org/10.1007/s11357-016-9899-9
42. Strand BH et al (2016) The association of grip strength from midlife onwards with all-cause and cause-specific mortality over 17 years of follow-up in the Tromsø Study. J Epidemiol Commun Health 70:1214–1221
43. Harada CN, Natelson Love MC (2013) Triebel, normal cognitive aging. Clin Geriatr Med 29:737–752