Research Article

Lifestyle Behavioral Factors and Integrative Successful Aging Among Puerto Ricans Living in the Mainland United States

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Received: April 4, 2020; Editorial Decision Date: August 24, 2020

Decision Editor: Anne B. Newman, MD, MPH, FGSA

Abstract

Background: Few studies have assessed multidimensional models for predicting successful aging that incorporate both physical and cognitive-psychosocial elements among minority populations. This study aimed to establish a comprehensive lifestyle behavioral factors (cLBF) score and an integrative successful aging (ISA) score and explore their associations among older Puerto Rican adults.

Methods: Data were assessed from 889 adults (45–75 years) participating in the longitudinal (baseline and 2-year follow-up) Boston Puerto Rican Health Study. Higher cLBF score (range 0–10) indicates healthier behaviors (nonsmoking, lack of sedentarism, physical activity, high diet quality, and adequate sleep). The physical domain score of ISA included 8 components (functional impairment, hypertension, diabetes, cancer, cardiovascular disease, respiratory disease, arthritis, osteoporosis) and ranged 0–11. The cognitive-psychosocial domain of ISA included 5 components (cognitive impairment, depressive symptoms, social support, perceived stress, and self-rated health) and ranged 0–10. The sum of both domains comprised the ISA score, ranging 0–21. Higher scores of ISA and its domains indicate more successful aging.

Results: At 2 years, the mean $\pm$ SD of cLBF score was 4.9 ± 1.8 , and ISA was 10.1 ± 3.3 . In multivariable-adjusted models, cLBF score was significantly and positively associated with 2-year change in overall ISA (β [95% CI]: 0.15 [0.07, 0.24] points), in physical domain (0.09 [0.04, 0.13] points), and in cognitive-psychosocial domain (0.08 [0.02, 0.14] points).

Conclusions: Maintaining healthier lifestyle behaviors may contribute to successful aging through both physical and cognitive-psychosocial domains. The results support using a multidimensional definition of successful aging in Puerto Ricans and evaluating it in other populations.

Keywords: Lifestyle behaviors, Minority populations, Successful aging

Global average life expectancy increased by more than 5 years between 2000 and 2016 (1), calling for a need to further understand what it means to age successfully. For more than 4 decades, several definitions and predictors of successful aging have been posited, yet there is no uniform operational definition (2). Definitions of successful aging that include multiple physical and psychological dimensions of the aging process are widely accepted, with the following dimensions as commonly included elements in the definitions of successful aging; life satisfaction, longevity, freedom from

disability, mastery/growth (self-direction, complexity of viewpoints, and openness to accept others' experiences), active engagement with life, high independent functioning, and positive adaptation (satisfaction with changes in quality of life) (2–5).

Although there has been much debate and variation in the multidimensional definition of successful aging, Rowe and Kahn proposed a prevailing biomedical theory with 3 facets; avoidance of disease and disability, high cognitive and physical function, and active engagement with life (6). Avoidance of risk factors of disease and

disability later in life is based on scientific evidence that intrinsic factors and genetics alone are not the major determinants of risk in advancing age, but rather extrinsic environmental factors such as lifestyle health behaviors (7). Rowe and Kahn argue that even modest reductions in cognitive or physical function may impede older adults from fully participating in daily life activities which, in turn, may affect successful aging (7). Lastly, active engagement with life that encompasses social ties, emotional and instrumental support, and productive activities, both paid and unpaid, has relevant positive health effects (7).

However, this biomedical theory fails to recognize that advancing age without disease may not be realistic for most individuals (8). In contrast to the previous theory, psychosocial approaches have defined successful aging by strongly emphasizing life satisfaction, social participation, social functioning, and psychological resources (8). However, few investigators have attempted to create new interdisciplinary models that incorporate more psychosocial elements (8) that can further define successful aging in a holistic and valid way.

Lifestyle behavioral factors, including physical activity, sedentarism, smoking, sleeping, and dietary patterns, have been found to be associated with components commonly inherent in successful aging definitions (9–13). Therefore, these lifestyle behavioral risk factors should be taken into consideration as potential modifiable factors. To account for the potential synergistic effects of multiple lifestyle behaviors on disease outcomes, we previously developed a healthy lifestyle score, which was associated with healthier cardiometabolic profile and neuroendocrine markers among mainland Puerto Rican adults (14). Nevertheless, research has not yet explored the association of comprehensive lifestyle behavioral factors (cLBF) as a predictor of successful aging. Puerto Ricans are the second largest Hispanic/Latino population living in the U.S. mainland, with unique, often worse, health outcomes and lifestyle behaviors than other racial/ethnic groups (15,16). Various studies have been conducted on the Puerto Rican population in relation to factors associated with successful aging. Poor performance-based physical function has been significantly associated with prevalent health conditions and was highly correlated with self-reported disabilities in middle-aged Puerto Ricans (17). Puerto Rican adults were more likely to report poorer health status, multiple chronic conditions, lower neurocognitive function, and serious psychological stress than other Hispanic adults (18,19). Nonetheless, they exhibit strong social ties and familial support (20), factors that may mitigate negative health effects during aging. Thus, the 3 areas proposed by Rowe and Kahn for successful aging (ie, avoid disease and disability, high cognitive and physical function, and active engagement with life) would bring important benefits to older Puerto Rican adults residing in the U.S. mainland.

Thus, the aims of this study were to develop a integrative successful aging (ISA) score encompassing physical and cognitive-psychosocial domains, and to determine if a cLBF score is associated with 2-year change in ISA, as well as its physical and cognitive-psychosocial domain scores, among Puerto Rican adults aged 45–75 years at baseline, living in Massachusetts. We hypothesized that healthier cLBF score would be independently associated with the ISA score, and more strongly than individual risk factors. Secondly, we hypothesized that the cLBF score would be associated with higher successful aging, for both the physical and the cognitive-psychosocial domains, with higher effect size for the combined ISA. Having tools available to identify ethnic health disparities in an aging population may help address the underlying factors for these disparities, especially as the

Hispanic population in the United States is projected to reach 111 million by 2060 (21).

Method

Participants

The Boston Puerto Rican Health Study (BPRHS) is an ongoing longitudinal cohort of Puerto Ricans, aged 45–75 years, living in the Greater Boston area, that began recruiting and collecting social, biological, and demographic information for baseline in 2004 through 2009, has 2-year and 5-year follow-up time points, and in 2017 began its 8-year follow-up. The baseline cycle included 1500 participants and retained 1258 participants at 2 years. A subset of 974 participants from the 2-year data collection cycle participated in the ancillary Boston Puerto Rican Osteoporosis Study that collected data on sleep behavior. The main reasons for not participating in the ancillary Osteoporosis Study were no interest, problems with scheduling, loss to follow-up, relocation, and death (22). Individuals who decline participation in the ancillary study were more likely to be older; men were more likely to have lower body mass index (BMI) and lower waist circumference; and women were more likely to have higher energy-adjusted intakes of alcohol (22). All other sociodemographic and dietary variables were not significantly different (22). The current analysis utilized data from 950 participants who completed both baseline and 2-year visits, and the ancillary sleep quality and quantity questionnaires. Questionnaires were available in English and Spanish and facilitated by bilingual personnel, with the majority of the questionnaires (86%) administered in Spanish. Study design, recruitment, and data collection are described elsewhere (23). Written consent was obtained from all participants, and the study was approved by the Institutional Review Board at Tufts University and Northeastern University.

Assessment of Lifestyle Behaviors

Physical activity was assessed using a modified Paffenbarger questionnaire of the Harvard Alumni Activity Survey and calculating the sum of hours spent on typical activities multiplied by weighing factors that parallel the rate of oxygen consumption associated with each activity (24,25). Higher scores indicate higher levels of physical activity: sedentary activity (score < 30), light-to moderate physical activity ($30 \leq \text{score} < 40$), and moderate or vigorous activity (score ≥ 40) (14). Sedentary behavior was assessed through self-reported hours spent watching television (26,27). In a comprehensive questionnaire, participants were asked about the type and frequency of use of tobacco products. Diet was collected via a semiquantitative food frequency questionnaire (FFQ) developed and validated within this population (23,28). Food groups and nutrient intakes were analyzed using the Nutrition Data System for Research software (Nutrition Coordinating Center, Minneapolis, Minnesota). Participants reporting implausible energy intakes (≤ 600 or ≥ 4800 kcal), or with ≥ 10 FFQ questions left blank, were excluded from analysis ($n = 67$). The Alternate Healthy Eating Index-2010 (AHEI-2010) was calculated as a score that incorporates 11 foods and nutrients that have had consistent evidence of relation to lower risk of chronic diseases (14,29). Each component (vegetables, fruits, nuts and legumes, whole grains, trans fats, long-chain (n-3) fats, polyunsaturated fats, sugar-sweetened beverages and fruit juice, red or processed meat, sodium, and alcohol) was given a score from 0 (worst) to 10 (best). The sum of these scores was used as the total

AHEI-2010 score, which ranged between 0 (nonadherence) and 110 (perfect adherence). Sleep quality and quantity were assessed via sleeping pattern questions that indicated total hours usually spent sleeping over a 24-h period and level of tiredness during the day, snoring, and restful sleep (30).

Definition of cLBF

Following previous research and validation of a healthy lifestyle score and its association with cardiometabolic and neuroendocrine risk factors (14), we adapted the cLBF by including the 5 following individual lifestyle behavioral factors (iLBF): (i) physical activity, (ii) sedentarism, using hours of television watching per day as a proxy (31), (iii) smoking, (iv) sleep quantity and quality, and (v) diet quality as measured with the AHEI-2010. All attributes were measured at baseline and at 2 years, with the exception of sleep, which was only measured at 2 years. Sleep score was assumed to remain stable within this time frame, as mean scores for other lifestyle behaviors were similar at baseline and at 2 years (14).

Five iLBF were scored with a range of 0 (worst) to 2 points (best); the sum of the iLBF components was used as the cLBF, which ranged from 0 (worst) to 10 (best), with higher scores reflecting better lifestyle behaviors (Table 1). Equal point distribution was given to all 5 components.

Physical Assessments

A modified Katz Activities of Daily Living (ADL) (32) captured adequacy of performing several physical tasks; its items have been effectively used in a previous cohort of older Puerto Rican adults (33). Systolic and diastolic blood pressures were measured in duplicate at 3 time points at the interview and the average of the second and third readings was used (23). A 12-hour fasting blood sample was obtained by a trained phlebotomist for analysis of serum glucose. Participants were asked to self-report whether a doctor had ever told them that they had any of the following conditions: hypertension, diabetes, cancer (excluding skin), heart disease or stroke (other than heart attack), respiratory disease, arthritis, and osteoporosis (23). Participants were also asked to show their current medication bottles to gather detailed information on prescription and over-the-counter medication use (23).

Cognitive and Psychosocial Assessments

Self-rated health status was assessed and was used as a global measure of health status (34). Cognitive function was assessed using the mini-mental state examination (MMSE) for general function for Spanish-speaking populations (35).

Social support and social network were measured using the Norbeck Social Support Questionnaire (36). Questions assessed the size of the individual's social network and level of support both emotional and tangible. The Social and Community Support and Assistance Questionnaire was used to measure social activities related to family life and social activities within the community (37). Social support and network score had 4 subcomponents of 5 points each: (i) size of social network, (ii) average emotional support from social network, (iii) average assistance from social network (tangible support), and (iv) number of social activities (38). Depressive symptomatology was assessed using the 20-item Center for Epidemiological Studies-Depression (CES-D) scale (37–39), with higher scores indicative of higher depressive symptoms. The Spanish version of the 14-item Perceived Stress Scale (PSS) was used to assess the participants' perceptions of viewing

Table 1. Components and Scoring of a Comprehensive Lifestyle Behavioral Factors Score

Components*	Score	Percentage at Baseline†	Percentage at 2 Years‡
Physical activity score‡			
Sedentary (score < 30)	0	43.5%	43.5%
Light (30 ≤ score < 40)	1	51.4%	51.2%
Moderate–vigorous (score ≥ 40)	2	5.1%	4.8%
Sedentary behavior			
≥10 hours TV/d	0	6.4%	6.6%
>2 to <10 hours TV/d	1	72.3%	75.2%
≤2 hours TV/d	2	20.7%	17.5%
Smoking			
Current	0	23.3%	20.7%
Former	1	30.5%	33.4%
Never	2	46.0%	45.4%
Sleep score§			
≤7	0	34.3%	34.3%
>7 to ≤12.5	1	32.2%	32.2%
>12.5	2	33.5%	33.5%
AHEI-2010¶			
≤50.9	0	30.4%	32.5%
>50.9 to ≤57.5	1	30.3%	32.8%
>57.5	2	30.2%	32.6%

Notes: AHEI-2010 = Alternate Healthy Eating Index-2010; TV = television.

*Maximal points for each individual component was 2 points (range: 0–2); maximal points for the comprehensive lifestyle behavioral factors (cLBF) score was 10 (range: 0–10). A higher cLBF score represents better behavioral lifestyle.

†*n* = 950; missing baseline values ranged between 0% and 9.1% and missing 2-year values ranged between 0% and 4.1%.

‡Assessed using a modified Paffenbarger questionnaire of the Harvard Alumni Activity Survey and calculated as the sum of hours spent on typical activities multiplied by weighing factors for each activity. Higher scores indicate higher levels of physical activity.

§Assessed as a score incorporating quantity of sleep (over a 24-h period) and quality of sleep (level of tiredness during the day, snoring, and restful sleep). Sleep score at baseline and 2 years assumed to be the same as data were collected only at the 2-year time point.

¶Calculated as a sum score of 11 foods and nutrients; the score ranges between 0 (nonadherence) and 110 (perfect adherence).

their lives as stressful (40), higher scores were indicative of higher perceived stress.

Definition of ISA Score and Its Domains

The ISA consists of 2 major domains, the physical domain and the cognitive-psychosocial domain. Assigned points differed by individual component (either 0–1 or 0–2) for the physical domain, but equal point distribution was given for each component in the cognitive-psychosocial domain (0–2). The points differed in the physical domain because 3 components (Activities of Daily Living, hypertension, and diabetes) had 3 levels of severity. The physical domain score included 8 individual components, including medical conditions due to their potential role in successful aging, that were added to a total range from 0 (worst) to 11 (best) (Table 2). The cognitive-psychosocial domain included 5 individual components that were added to range from 0 (worst) to 10 (best) (Table 3). The sum of both domains comprised the ISA score from 0 (worst) to 21 (best). A higher ISA score reflected a more successful aging process. All components were measured at baseline and 2 years.

Table 2. Components and Scoring of the Physical Domain of the Integrative Successful Aging Score

Components of Physical Domain*	Score	Percentage at Baseline [†]	Percentage at 2 Years [‡]
Functional status—Activities of Daily Living score [‡]			
Considerable functional impairment (=0)	0	24.1%	24.2%
Some functional impairment (≥1 to ≤5)	1	46.3%	45.4%
No impairment (≥ 6)	2	29.5%	29.9%
Hypertension (mmHg)			
Hypertension (≥140/90)	0	40.4%	40.4%
Pre-hypertension (120–139/81–89), or normal (<120/80) with medication	1	43.5%	48.0%
Normal (<120/80 with no medication)	2	14.0%	11.3%
Diabetes (mg/dL)			
Diabetes (blood glucose ≥ 126)	0	24.5%	22.3%
Pre-diabetes (100–125), or normal (<100) with medication	1	35.2%	38.1%
Normal (<100 with no medication)	2	39.8%	39.1%
No cancer (excluding skin cancer) [§]	1	95.3%	93.3%
No heart disease/stroke (other than heart attack) [§]	1	84.8%	81.8%
No respiratory disease [§]	1	60.5%	53.6%
No arthritis [§]	1	48.1%	37.9%
No osteoporosis (hip fracture) [§]	1	88.0%	83.4%

Notes: *Higher physical domain score represents better physical health status; maximal points were 11 points (range: 0–11).

[†]*n* = 950; missing values at baseline ranged between 0% and 9.1%; missing values at 2 years ranged between 0% and 4.1%.

[‡]Assessed with a modified Katz Activities of Daily Living for adequacy of performing several physical tasks.

[§]An affirmative self-reported response to the medically diagnosed condition was scored as 0.

Covariates

The sociodemographic questionnaire asked for sex, age, educational attainment, and total household income. Psychological acculturation was assessed using a 10-item scale regarding cultural preferences and identity (41). Health insurance coverage was self-reported. Body mass index was calculated by dividing weight (kg) by height (m²).

Statistical Analysis

Of the 1500 participants from the baseline visit, 950 participants had sufficient data (≥75% complete) to calculate cLBF and ISA scores. Main analyses were conducted for participants with complete data for both scores as well as all covariates that were used in the models (*n* = 889).

We determined differences in baseline characteristics by high versus low ISA (cutoff at the median), using *t* test for continuous variables, chi-square test for categorical variables, and Wilcoxon Rank Sum test for the non-normally distributed variable for total household income. The most appropriate covariance structure for the linear mixed model with repeated measures was selected (compound symmetry) using the smallest AIC value. Potential confounders included in the models were based on the literature regarding successful aging (42–44). Body mass index was considered a potential mediator of healthy lifestyle factors and successful aging (45).

For primary analysis, we used linear mixed models with repeated measures over time to assess the association between cLBF as a continuous exposure and 2-year ISA and its domains as continuous outcomes, adjusting for potential confounders. Model 1 included baseline cLBF score, age, sex, education, psychological acculturation, total household income, health insurance, and energy intake; Model 2 included Model 1 + time between measurements and corresponding baseline aging score.

As secondary analysis, we used linear mixed models with repeated measures over time to assess the association between each iLBF as a categorical exposure and scores for ISA and its domains as continuous outcomes, adjusting for the same covariates as well

as all other iLBF. To complement the secondary analysis, we conducted the same analyses comparing within iLBF and each aging score outcome.

We conducted 4 sensitivity analyses: (i) adjusting for BMI as a potential mediator of the association between cLBF and ISA and its domains; (ii) excluding time between measurements and baseline aging score to determine whether these variables had a significant effect; (iii) excluding the sleep score from the cLBF in the main analysis model, as it was the only variable assumed to remain stable from baseline to the 2-year follow-up; (iv) removing cancer from the physical domain and ISA score, to determine whether cancer was a significant component in successful aging, as a cancer diagnosis may motivate adults toward healthier lifestyle changes that could affect survivorship and quality of life (46–48).

Statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC). Continuous variables are reported as mean ± *SD* except for total household income which is presented as median (interquartile range), and categorical variables are reported as number (percentage). A significance level of *p* < .05 was used for all analyses.

Results

Participants

Of the 950 participants with complete data at baseline, 71.4% were female and had a mean age of 56.6 ± 7.4 years (Table 4). Most had health insurance, preferred speaking in Spanish, had elevated BMI, and 47.6% had attained less than 12th grade or GED education. Participants engaged in light–moderate physical activity, watched ~5 hours of television per day, only 23% were current smokers, had a moderate sleep, and AHEI-2010 score. Similar results were observed at 2-year follow-up, although participants were slightly older, had higher median income, higher preference for Spanish, higher sedentary score, lower prevalence of smoking, lower diet quality, and lower ISA and its domains. The mean cLBF score at baseline and 2 years was statistically similar (4.9 ± 1.8 vs 4.9 ± 1.8; *p* = .33). However,

Table 3. Components and Scoring of the Cognitive-Psychosocial Domain of the Integrative Successful Aging Score

Cognitive-Psychosocial Domain*	Score	Percentage at Baseline [†]	Percentage at 2 Years [‡]
Mini-mental state examination score			
Severe cognitive impairment (<18)	0	6.2%	4.7%
Mild cognitive impairment (≥18 to <24)	1	45.3%	43.6%
No impairment (≥24)	2	48.5%	47.5%
Depressive symptomatology score [§]			
Clinical depression (≥16)	0	61.3%	54.5%
Using antidepressant medication without clinical depression (<16)	1	7.4%	9.5%
No clinical depression (<16) and no medication	2	30.7%	35.5%
Social support and network score (0–20) [§]			
Tertile 1 (<8)	0	32.3%	33.8%
Tertile 2 (8–13)	1	38.2%	37.2%
Tertile 3 (>13)	2	29.6%	29.1%
Perceived stress score			
Tertile 3 (>28)	0	32.8%	33.1%
Tertile 2 (20–28)	1	34.0%	34.7%
Tertile 1 (<20)	2	32.8%	31.8%
Self-rated health			
Fair or poor	0	69.4%	65.8%
Good	1	19.3%	20.5%
Very good or excellent	2	11.2%	13.1%

Notes: *Higher cognitive-psychosocial score represents better cognitive-psychosocial health; maximal points were 10 points (range: 0–10).

[†]n = 950; missing values at baseline ranged between 0% and 9.1%; missing values at 2 years ranged between 0% and 4.1%.

[‡]Assessed using the 20-item Center for Epidemiological Studies-Depression (CES-D) scale; higher scores indicative of higher depressive symptoms.

[§]Measured using the Norbeck Social Support Questionnaire assessing the size of the individual's social network and level of support both emotional and tangible, and the Social and Community Support and Assistance Questionnaire to measure social activities related to family life and social activities within the community.

^{||}Assessed with a 14-item scale on perceptions of lives as stressful; higher scores indicative of higher perceived stress.

significantly higher scores (all $p < .0001$) were observed at baseline than at 2 years for ISA (11.2 ± 3.6 vs 10.1 ± 3.3), physical domain (6.7 ± 2.0 vs 6.4 ± 2.0), and cognitive-psychosocial domain (4.5 ± 2.4 vs 3.7 ± 2.1). See Table 4 for overall 2-year follow-up status.

Participants with high ISA had significantly lower BMI, higher total household income, higher educational attainment, and were less likely to be female and to have health insurance, compared to those with low ISA. Individuals with high, versus low, ISA also had significantly higher physical and cognitive-psychosocial domains score, and higher scores for all the iLBF, except for smoking.

Main Analyses

The cLBF score was significantly associated with 2-year change in ISA, physical domain, and cognitive-psychosocial domain scores for both models (Table 5). For every 1-point increase in cLBF score, ISA score was 0.15 points higher (95% CI: 0.07, 0.24; $p = .0002$) in a 2-year period, after adjusting for all covariates, including time between measurements and corresponding baseline ISA or its domains score. For every 1-point increase in cLBF score, physical domain score was 0.09 points higher (95% CI: 0.04, 0.13; $p = .0002$), and cognitive-psychosocial domain score was 0.08 points higher (95% CI: 0.02, 0.14; $p = .011$) over 2 years. These associations were similar to models excluding time between measurements and baseline aging score.

Secondary Analyses

Between and within comparisons of iLBF showed that only light physical activity and never smoking were associated with significantly higher ISA score in a 2-year period (Supplementary Table 1). Within comparisons, physical activity was also associated with higher score of the physical and cognitive-psychosocial domains, but

never smoking was only associated with the cognitive-psychosocial score. Additional significant associations were observed for lower sedentary behavior and higher sleep score with higher cognitive-psychosocial domain score.

Sensitivity Analyses

After adjusting for BMI, effect estimates for main analysis with cLBF as well as iLBF were slightly attenuated but remained significant (data not shown). When excluding sleep score from the cLBF, associations remained significant with ISA and physical domain scores, but not with the cognitive-psychosocial domain score (Supplementary Table 2). Similar results were obtained when excluding sleep and adjusting for BMI (data not shown). Effect estimates and significance remained identical when excluding cancer from the physical domain and ISA scores (Supplementary Table 3). Participants with and without cancer did not differ by iLBF, cLBF, or ISA and its domains, or baseline characteristics, except for age (60.1 years with cancer vs 56.4 years without; data not shown).

Discussion

We had the opportunity to analyze data from the largest ongoing study on older adult Puerto Ricans residing in the U.S. mainland to date to address a gap in the published literature on factors associated with predicting successful aging. Puerto Ricans are seldom distinguished in the research conducted for overall Hispanics/Latinos, which are predominantly of Mexican heritage, yet do experience a significantly higher burden of chronic disease than other Hispanic/Latino ethnic backgrounds. Addressing the health challenges of this unique population may help inform public health intervention strategies targeting specific lifestyle behaviors.

Table 4. Characteristics of Participants in the Boston Puerto Rican Health Study by Integrative Successful Aging Score

	Overall at Baseline*	Overall at 2-Year Follow-up	<i>p</i> Value†	High ISA at Baseline‡	Low ISA at Baseline‡	<i>p</i> Value§
Age (y)	56.6 ± 7.4	58.7 ± 7.5	<.0001	55.8 ± 7.4	57.5 ± 7.3	.0004
BMI (kg/m ²)	32.3 ± 6.6	32.3 ± 6.6	.48	30.8 ± 6.0	34.2 ± 7.2	<.0001
Female (%)	71.4%	71.4%	N/A	63.8%	80.8%	<.0001
Total household income (\$/y)	11 800 (8600–20 200)	12 900 (10 000–21 400)	.01	14 300 (9000–25 000)	10 000 (8400–15 600)	<.0001
Educational attainment (%)			N/A			<.0001
Less than 8th grade	47.6%	47.6%		35.1%	63.2%	
9th–12th grade or GED	37.3%	37.3%		45.9%	26.6%	
Some college or higher	15.1%	15.1%		19.0%	10.2%	
Psychological acculturation score (10–45)	18.3 ± 6.7	17.9 ± 7.1	.14	18.9 ± 6.9	17.6 ± 6.4	.004
Health insurance (%)	95.3%	76.8%**	<.001	92.8%	98.3%	<.0001
Language of administration (%)						.02
English	4.2%	4.1%	1.0	5.3%	2.9%	
Spanish	86.3%	92.9%	<.001	83.5%	89.8%	
Both, English and Spanish	9.5%	3.0%	<.001	11.2%	7.4%	
Comprehensive lifestyle behavioral risk factor score (0–10)	4.9 ± 1.8	4.9 ± 1.8	.33	5.2 ± 1.8	4.4 ± 1.7	<.0001
Individual lifestyle behavioral factors						
Physical activity score (0–63)	31.8 ± 4.8	31.8 ± 4.7	.96	32.7 ± 5.3	30.6 ± 3.8	<.0001
Sedentary behavior (hours/d watching TV)	4.8 ± 2.7	5.1 ± 2.8	.003	4.6 ± 2.6	5.1 ± 2.8	.004
Current smoker (%)	23.3%	20.7%	.03	22.5%	24.2%	.38
Sleep score (0–20) [¶]	10.0 ± 5.2	10.0 ± 5.2	N/A	10.9 ± 5.3	8.8 ± 4.9	<.0001
AHEI-2010 score (0–84) [#]	54.2 ± 9.0	52.6 ± 7.4	<.0001	55.3 ± 9.1	52.8 ± 8.7	<.0001
Integrative successful aging score (0–21)	11.2 ± 3.6	10.1 ± 3.3	<.0001	13.7 ± 2.3	8.0 ± 1.7	<.0001
Physical domain score (0–11)	6.7 ± 2.0	6.4 ± 2.0	<.0001	7.8 ± 1.6	5.3 ± 1.6	<.0001
Cognitive-psycho-social domain score (0–10)	4.5 ± 2.4	3.7 ± 2.1	<.0001	5.9 ± 2.0	2.7 ± 1.3	<.0001

Notes: AHEI-2010 = Alternate Healthy Eating Index-2010; BMI = body mass index; GED = general education diploma; ISA = integrative successful aging; TV = television.

*Shown as mean ± SD (median [interquartile range] for total household income) for continuous or percent for categorical variables. *n* = 864–950.

†Differences between baseline versus 2 years tested with paired *t* test or Wilcoxon signed-rank test for continuous or McNemar's test for categorical variables.

‡Defined as less than the baseline median ISA score of 11 (low ISA) versus greater than or equal to the baseline median (high ISA).

§Differences by high ISA versus low ISA tested with *t* test or Wilcoxon Rank Sum for continuous or chi-square for categorical variables.

^{||}Assessed using a modified Paffenbarger questionnaire of the Harvard Alumni Activity Survey and calculated as the sum of hours spent on typical activities multiplied by weighing factors for each activity. Higher scores indicate higher levels of physical activity.

[¶]Assessed as a score incorporating quantity of sleep (over a 24-h period) and quality of sleep (level of tiredness during the day, snoring, and restful sleep). Sleep score at baseline and 2 years assumed to be the same as data were collected only at the 2-year time point.

[#]Calculated as a sum score of 11 foods and nutrients; the score ranges between 0 (nonadherence) and 110 (perfect adherence).

**Question at 2-year follow-up asked if participants still had the same health insurance plan as baseline.

We found that a healthier cLBF score was significantly associated with positive 2-year change in ISA, as well as its 2 comprising domains: physical and cognitive-psycho-social function, in Puerto Rican middle-aged adults living in the mainland United States. These associations were observed after adjusting for sociodemographic characteristics, energy intake, time between measurements, and baseline corresponding aging score. The magnitude of change in the physical domain score and the cognitive-psycho-social domain score were similar for every 1-unit increase in the cLBF score, suggesting that both domains contribute equally to aging in response to lifestyle behaviors. Including both the physical and cognitive-psycho-social domains in the ISA score nearly doubled the effect size for every 1-unit increase in cLBF score. This suggests an additive effect of the domains and supporting the value of including both cognitive and psycho-social factors as part of a successful aging definition, and not just absence of disease and disability.

We found that the overall cLBF score was more strongly associated with ISA than individual behaviors alone, suggesting that although individual behaviors play a role, synergistic behaviors have a larger effect on successful aging. We also noted that the effect size of individual lifestyle factors varied in their association with ISA score and its domains. For example, light physical activity or never smoking alone was positively and significantly associated with ISA, while only light physical activity was associated with physical domain. Meanwhile, higher cognitive-psycho-social scores were observed for higher quality of sleep. These findings suggest that these 3 iLBF (physical activity, never smoking, and higher quality of sleep) may play a predominant role on successful aging. Furthermore, healthy sleep seemed to be relevant for the cognitive-psycho-social domain. In sensitivity analyses, we found that the positive change in cognitive-psycho-social domain score was no longer significant when sleep score was excluded, suggesting that healthy sleep habits were an essential component for cognitive-psycho-social health.

Table 5. Association Between a Comprehensive Lifestyle Behavioral Factors Score and 2-Year Change in Aging Scores

	Model 1				Model 2			
	Effect Estimate	SE	95% CI	p Value	Effect Estimate	SE	95% CI	p Value
Integrative successful aging score (0–21)	0.17	0.06	0.06, 0.29	.003	0.15	0.04	0.07, 0.24	.0002
Physical domain score (0–11)	0.09	0.03	0.03, 0.15	.003	0.09	0.02	0.04, 0.13	.0002
Cognitive-psychosocial domain score (0–10)	0.10	0.05	0.01, 0.19	.025	0.08	0.03	0.02, 0.14	.011

Notes: Model 1 adjusts for baseline comprehensive lifestyle behavioral factors score, age, sex, education, psychological acculturation, total household income, health insurance, and energy intake; $n = 889$. Model 2 adjusts Model 1 + time between measurements, corresponding baseline score; $n = 889$.

Multidisciplinary research suggests that sleep is associated with increased cognitive functioning and may protect against aging-related cognitive decline (49). Of note, increases in ISA scores for either the cLBF or iLBF were not mediated by BMI, suggesting that the recognized beneficial effects of healthy lifestyles may directly affect successful aging.

Previous studies have focused on the odds of successful aging and healthy behaviors, rather than quantifying healthy behaviors and successful aging using scores. Researchers using 20-year data from the Nord-Trondlag Health Study (HUNT) found that their split concepts of successful aging (absence of disease, high cognitive and physical functioning, and active engagement with life) and their unified concept (meeting all individual components of successful aging) were differentially associated with lifestyle factors (smoking, alcohol consumption, physical activity, obesity, and social support) (50). Overall, they found that not smoking and moderate/high physical activity were the only 2 factors positively related to both their unified and their split concepts of successful aging. The authors also found higher odds of successful aging for individuals with 2 or more positive lifestyle factors at baseline, as well as with increasing number of positive lifestyle factors. Another study also found that engaging in 4 healthy behaviors (never smoking, moderate alcohol consumption, moderate/vigorous physical activity, and daily intake of fruits and vegetables) was associated with 3.3 greater odds of successful aging; a linear association was also noted with 1.3 odds of successful aging per healthy behavior in a 10-year period (51). In addition, the authors found that individual behaviors were moderately associated with successful aging, but that the combination of healthy behaviors had a larger effect (51). Our results agree with the existing literature.

Our study has various strengths. We defined a cLBF score that included modifiable behaviors that individuals could improve over time to potentially influence their aging process. We also created an ISA score that included both physical and cognitive-psychosocial components with several data that were collected through validated instruments and laboratory measurements. Furthermore, we explored the relationship between lifestyle behaviors and successful aging in an underrepresented minority population that has poor lifestyle behaviors and multiple chronic diseases (52), and a shifting population age structure toward older strata.

However, our study has some limitations. First, the time between baseline and follow-up was relatively short, thus not allowing pronounced aging to occur. Second, there were no data on sleep at baseline and thus the sleep score was assumed to remain the same at both time points; we have previously shown that other lifestyle behaviors remain similar over time in this population. We also acknowledge the self-reported nature of the lifestyle behaviors, albeit

we used validated questionnaires, and some of the chronic disease diagnoses. Additionally, although the scores were based on existing literature, they were created subjectively, as there is no unanimous definition for comprehensive behaviors or successful aging. We recognize that simplifying the sum of scores for the aging score, placing fairly equal weights on each component may not be accurate; however, this simplified definition was created purposefully so that it could be applied by other researchers and potentially adapted as a fast screener in clinical or research settings. Lastly, the results may not be generalizable to other racial/ethnic groups or populations. Future research is needed to explore the relationship between the cLBF and the ISA scores with data from longer follow-ups from this and other populations. Also, the potential integration of biomarkers of aging, such as markers of allostatic load, may help define pathways of the aging process in future research (53–55).

In conclusion, a cLBF score was associated with higher 2-year change in ISA score, including both physical and cognitive-psychosocial domains, supporting the notion that successful aging should incorporate both. Overall, the comprehensive score was more strongly associated with all aging scores than individual lifestyle behaviors. Previous studies and our findings suggest that an increasing number of healthy individual lifestyle behaviors influences successful aging, but that never smoking and physical activity may play a larger than average role. Additionally, healthy sleep may positively influence cognitive-psychosocial health during aging. When addressing successful aging in older Puerto Rican adults, health promotion campaigns and health providers should emphasize increasing physical activity, quitting or never smoking, and improving sleep quality and quantity, while maintaining a healthy diet. We expect our research to encourage further work that would lead to an improved ISA definition that could be used across populations.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

Funding

This study is supported by the National Institutes of Health (K01-HL120951 to J.M.; and P50-HL105185, P01-AG023394, R01-AG055948 to K.L.T.); and a McLennan Dean's Challenge Grant Program Award (to J.M.).

Conflict of Interest

None declared.

Author Contributions

M.A.L.-B. researched the literature, contributed to analytic strategy, conducted statistical analyses, and wrote the manuscript. H.J.O. supervised analytical plan, conducted statistical analyses, and contributed to the manuscript writing and careful revision. R.C.W. contributed to data analysis and careful revision of the manuscript. M.S.-P., X.G., L.M.F., and K.L.T. contributed to study design and critically revised and edited the manuscript. J.M. developed the study concept and analytic strategy, supervised data analyses, and contributed to manuscript writing and careful revision. All authors contributed meaningful intellectual content to the manuscript and read and approved the final version.

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