Archives of Gerontology and Geriatrics 87 (2020) 103966

Contents lists available at ScienceDirect

Archives of Gerontology and Geriatrics

journal homepage: www.elsevier.com/locate/archger

Estimating quality of life with biomarkers among older Korean adults: A machine-learning approach

Sung-Ha Lee[a], Incheol Choi[a,b], Woo-Young Ahn[b], Enyoung Shin[c], Sung-Il Cho[d], Sunyoung Kim[e], Bumjo Oh[c,*]

[a] *Center for Happiness Studies, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Republic of Korea*
[b] *Department of Psychology, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Republic of Korea*
[c] *Department of Family Medicine, SMG- SNU Boramae Medical Center 20, Boramae-ro 5-gil, Dongjak-gu, Seoul 07061, Republic of Korea*
[d] *School of Public Health and Institute of Health and Environment, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Republic of Korea*
[e] *Department of Family Medicine, Kyung Hee University Medical Center, 23, Kyungheedae-ro, Dongdaemun-gu, Seoul 02447, Republic of Korea*

ARTICLE INFO

Keywords:
HRQoL
SF-36
Elastic net
Handgrip strength
Elderly
Penalized regression

ABSTRACT

Background: While health-related quality of life (HRQoL) has clinical value, its determinants, particularly objective health-related measurements, have not been fully explored. This study seeks to identify the biological indicators that relate to HRQoL among a group of older Korean adults using a machine-learning approach.
Methods: We used physical and mental scores from the 36-item Short Form Health Survey (SF-36) to measure HRQoL among older Korean adults who participated in the Korean Longitudinal Study of Aging (KLoSA) biomarker pilot study (N = 385). The variables for the multivariate penalized regression analysis included demographic factors, medical measurements, physical performance, and health-related behaviors.
Results: The multivariate profiles identified several significant biomarkers that relate to quality of life. Among the 20 variables, handgrip strength was the most powerful indicator in both men and women for the SF-36 physical scores, followed by walking speed. Age and total sleep duration exclusively were significantly associated with the SF-36 physical scores only in women, whereas body mass index, blood pressure, and sit-to-stand times were unique elements in men.
Conclusions: The present study suggests significant physical indicators that explain quality of life in elderly populations, using a data-driven approach. Based on these findings, maintaining a good level of physical performance is considered a key element of successful aging.

1. Introduction

Due to increasing life expectancy and decreasing fertility rates, the proportion of the elderly population has increased substantially in South Korea, accounting for 14.2 % of the total population in 2017 (Korean population census, 2017). Substantial increases in elderly populations worldwide over the past century have led to increasing interest in how to age well. “Aging well” is a broad-ranging concept, but its main components include minimizing physical and mental deterioration (Bowling & Dieppe, 2005; Crowther, Parker, Achenbaum, Larimore, & Koenig, 2002). Since the concept of successful aging is closely associated with aging-related physical deficits, such as frailty, the onset of disability, and all-cause mortality (Collins, Goldman, & Rodríguez, 2008; Kojima, Iliffe, Jivraj, & Walters, 2016; Lahoud et al., 2017; Lyyra, Törmäkangas, Read, Rantanen, & Berg, 2006), maintaining and even improving one’s quality of life represents a key strategy for aging well.

Previous studies have identified a wide range of factors associated with quality of life (QoL) among aged adults. For instance, demographic factors, including gender, age, and marital status, contribute to one’s quality of life (Gallicchio, Hoffman, & Helzlsouer, 2007; Tajvar, Arab, & Montazeri, 2008). Social and environmental factors, including socioeconomic status (defined by income, education, and occupation), social support, social contact, and financial security, are likewise significant

---

Abbreviations: QOL, quality of life; HRQoL, health-related quality of life; SF-36, 36-item short form health survey; KLoSA, Korean longitudinal study of aging; BMI, body mass index; FVC, forced vital capacity; FEV, forced expiratory volume in one second; TG, triglyceride; SBP, systolic blood pressure; DBP, diastolic blood pressure; WHR, waist-to-hip ratio

[*] Corresponding author.

E-mail addresses: lsh80@snu.ac.kr (S.-H. Lee), ichoi@snu.ac.kr (I. Choi), wahn55@snu.ac.kr (W.-Y. Ahn), enole@naver.com (E. Shin), scho@snu.ac.kr (S.-I. Cho), ggutsun@naver.com (S. Kim), bo39@snu.ac.kr (B. Oh).

https://doi.org/10.1016/j.archger.2019.103966
Received 4 July 2019; Received in revised form 14 October 2019; Accepted 16 October 2019

(Netuveli & Blane, 2008; Netuveli, Wiggins, Hildon, Montgomery, & Blane, 2006; Tajvar et al., 2008). Furthermore, health conditions, such as independent functioning in daily life and the number of chronic diseases, are significant factors contributing to the quality of life of elderly populations (Jing, Willis, & Feng, 2016; Oh et al., 2014). HRQoL, a domain of QoL, also includes a multidimensional approach that considers the physical as well as mental components related to health (DuMontier, Gorr, Silliman, Stuck, & Moser, 2018). HRQoL is increasingly used in healthcare research to assess how individuals' well-being may be affected over time by a disease, disability, or disorder. Surprisingly, however, although HRQoL has clinical value, its determinants, particularly objective health-related measurements, have been understudied. Moreover, empirical evidence of the extent to which biomedical measurements determine the degree of HRQoL is limited for the elderly Korean population.

Therefore, the present study was designed to identify precise variables associated with HRQoL among the elderly Korean population. The study particularly seeks to estimate HRQoL with biological and medical measurements using a data-driven approach. We applied a machine-learning approach, which is promising for selecting generalizable markers of individual differences and clinical outcomes to identify multivariate profiles of biological indicators that estimate HRQoL. Among the various machine-learning algorithms, we used an algorithm called the elastic net (Zou & Hastie, 2005), a penalization regression method in which the sum of the absolute values of the coefficients is constrained. The elastic net allows for automatic variable selection among many variables, leading to a parsimonious predictive model. Because of the grouping effect of the elastic net, highly correlated variables are selected or removed together, which addresses the collinearity issue. In previous studies, the elastic net successfully identified parsimonious models that were optimized to make predictions in new samples by successfully predicting the risk factors for depression (Kim et al., 2015) and genetic risks factors for human diseases, such as coronary disease, hypertension, and diabetes (Abraham, Kowalczyk, Zobel, & Inouye, 2013; Waldmann, Mészáros, Gredler, Fuerst, & Sölkner, 2013).

Here, we attempted to duplicate that success and identify the most powerful factors for estimating the quality of life among older Korean adults. We used nationally representative samples from the Korean Longitudinal Study of Aging (KLoSA) and biomedical indicators related to the respondents' health conditions to achieve that goal.

2. Materials and methods

2.1. Study population and data collection

We extracted the variables from the KLoSA national public database, a longitudinal survey of Korean adults over age 45, and its Biomarker Pilot study. While the main survey has been administered every two years since 2006, the KLoSA Biomarker Pilot Study was embedded in the second wave of KLoSA to develop biomarkers of aging for the elderly Korean population. Details about the study design, eligibility criteria, and information about the Ethics Committee are described elsewhere (Choi, Son, Cho, Park, & Cho, 2012; Oh et al., 2014). Among all the participants, we included individuals who did not have missing values for the selected variables described in the "Measurements" section below. As a result, 385 patients were eligible for the analysis. The Institutional Review Board of the SMG-SNU Boramae Medical Center (IRB No. 30-2018-93) approved of all the analytical procedures.

2.2. Measurements

2.2.1. Health-related quality of life

Health-related quality of life (HRQoL) is measured using the 36-item Short Form Health Survey (SF-36). SF-36 is commonly used to measure HRQoL in terms of physical and mental health constructs (McHorney, Ware, & Raczek, 1993; Patel, Donegan, & Albert, 2007). The 36 questions are based on a general psychological well-being inventory, questions on various physical and role-specific functions, as well as a health perception questionnaire, aggregated into two summary constructs – physical and mental health components. We used the summary of physical and mental components of SF-36 for the analysis.

2.2.2. Demographic measures

Demographic measures include gender, age, and level of education: less than elementary education (less than six years), middle school education (6–9 years), high school education (10–12 years), and more than college (13 years or more).

2.2.3. Medical measurements

- Anthropometric measurements: Body mass index (BMI), which is defined as weight (kg)/height^2 (m^2), and waist-to-hip ratio, calculated from waist and hip circumferences, were measured.
- Blood pressure and resting heart rate: Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were averaged after three measurements of both the left and right arms using a standard sphygmomanometer after a five-minute stabilization period. Resting heart rate was measured by counting the heartbeats in one minute.
- Pulmonary function was assessed by determining the forced expiratory volume in one second (FEV1) and forced vital capacity (FVC), as described elsewhere (Choi et al., 2012).
- Blood chemistry tests (laboratory test) included assessments of creatinine, total cholesterol, and triglyceride (TG) levels.
- Number of teeth: the number of residual teeth was counted.
- Number of chronic diseases (hypertension, diabetes, cancer, pulmonary disease, liver disease, coronary heart disease, cardiovascular disease, mental disease, and arthritis) was provided by the participants.

2.2.4. Physical performance test

- Walking speed was measured by asking each participant to walk at his or her normal walking speed for four meters from a static start in three trials. The average speeds were used in the analysis.
- The sit-to-stand times assess the time taken when participants repeat standing up and sitting down as quickly as possible five times in succession, keeping their arms folded across the chest. Timing began at the first stand up and finished at the end of the fifth repetition.
- Handgrip strength was measured with a Jamar Hand Dynamometer (Tanita, NO6103, Japan). Participants were asked to use the instrument in a sitting position, with the elbow flexed at 90 degrees on both sides. The test was repeated three times, and the highest maximum value was used.

2.2.5. Health-related behaviors

The variables for sleep duration (hours/day), current alcohol consumption (Yes/No), and tobacco smoking status (Yes/No) were collected to estimate health-related behavior. The variables for alcohol consumption and tobacco smoking status were coded as binary variables (Yes = 1; No = 0).

2.3. Statistical analysis

2.3.1. Correlations among the indicators

We calculated the pairwise correlation coefficients between each indicator using the 'cor' function implemented in R to examine the correlations among the indicators. Pearson's correlation coefficients and p-values were obtained and used to construct a correlation plot.

2.3.2. Machine-Learning Models

We employed the elastic net to identify multivariate patterns of the SF-36 score (physical vs. mental component score)(Zou & Hastie, 2005). The elastic net is a penalization regression (supervised learning) method that compromises the Least Absolute Shrinkage and Selection Operator (LASSO) penalty (L1) and the Ridge penalty (L2)(Zou & Hastie, 2005). For the weight of the L1 and L2 penalties, we used an alpha value of 0.5 (LASSO if alpha = 0; Ridge if alpha = 1). Notably, the results reported in the paper were unaffected when we varied the alpha value. For model fitting, we used a machine-learning protocol reported in previous studies (Ahn & Vassileva, 2016; Ahn et al., 2014). For a brief description of the analytical procedure, we used fivefold cross validation and divided the dataset into a training set (67 %) and a test set (33 %), which was iterated 1000 times to identify robust correlation scores across different divisions of training/test sets. We used the easyml R package, a user-friendly wrapper of various machine-learning packages, including the glmnet r package, to apply the elastic net to our dataset (Friedman, Hastie, & Tibshirani, 2010). Demographic measures were considered as confounding factors to be controlled for to examine the effect of the bioindicators on HRQoL.

3. Results

3.1. General characteristics of participants

The participants in this study were 42.3 % male and 57.7 % female, which is representative of the ratio of elderly men to women in Korea (42 % and 58 %; Korean Statistical Information Service, 2015). Table 1 shows the demographic and medical characteristics of the participants stratified by gender. No gender differences in age were observed; the mean ages of male (n = 163) and female (n = 222) participants were 63.1 and 63.3 years, respectively. However, the women had a significantly lower level of education than the men, with more than half the women having completed less than six years of school. Moreover, the women reported significantly lower mental and physical SF-36 scores. Significant gender differences in pulmonary function (FEV and FVC), waist-to-hip ratio, BMI, number of chronic diseases, health-related behaviors, and physical performance were also observed.

3.2. Correlations between the indicators

Fig. 1 depicts the pairwise correlation coefficients between the 20 available indicators from the dataset for the men (A) and women (B). Among both male and female participants, pulmonary functions (FEV and FVC), handgrip strength, number of teeth, and level of education formed a distinct block with a positive correlation. Moreover, in both groups, age was negatively correlated with physical performance, such as walking speed and stand-up test scores; older participants took longer to complete the physical tests. Other medical measurements were also correlated, but showed different patterns in the male and female groups. For example, creatinine levels correlated with the number of chronic diseases and BMI in men, whereas this parameter correlated with physical performance and age in women. Moreover, the correlation between TG and cholesterol levels was not as clear in women as in men.

3.2.1. Elastic net results estimating SF-36 physical and mental scores

3.2.1.1. SF-36 physical scores. Fig. 2 shows the multivariate profiles estimating the degree of health-related quality of life, as captured by the SF-36 physical score in men (blue) and women (red). Among all available bioindicators, handgrip strength was the most powerful indicator of the SF-36 physical score in both men and women. The number of chronic diseases and walking speed were also significant biological indicators for both groups, indicating that a slower walking

Table 1

Description of the parameters (predictors and SF-36 physical and mental scores) recorded for the participants. n (%) or mean (sd).

Parameters	Men	(n = 163)	Women	(n = 222)	
	mean (or N)	s.d. (or %)	mean (or N)	s.d. (or %)	*p* value
Demographic factors					
Age (yr)	63.1	10.06	63.29	9.9	0.85
Education					< .001***
less than elementary	53	32.50%	134	60.36%	
middle school graduation	29	17.80%	32	14.41%	
high school graduation	56	34.40%	46	20.72%	
above college	15	15.30%	10	4.50%	
Laboratory measurements					
BMI (kg/m^2)	24.25	2.79	25.08	3.38	< .01**
Waist hip ratio	0.92	0.06	0.89	0.06	< .001***
Number of teeth	26.25	4.04	26.91	2.93	0.08
Resting heart beat	69.67	9.94	69.74	10.03	0.94
SBP (mmHg)	133	17.82	130.97	18.61	0.28
DBP (mmHg)	84.04	10.14	83.01	10.59	0.33
Total cholesterol (mg/dl)	180.54	34.12	193.65	35.08	< .001***
Creatinine (mg/dl)	0.92	0.23	0.68	0.16	< .001***
Triglyceride (mg/dl)	183.01	155.22	155.13	94.17	< .05*
FEV$_1$	2.38	0.64	1.8	0.49	< .001***
FVC	3.25	0.7	2.36	0.63	< .001***
Number of chronic diseases	0.73	0.86	1.07	1.07	< .001***
Physical performance					
Hand grip strength (kg)	32.02	6.93	19.94	4.90	< .001***
Walking speed (sec)	4.06	1.03	4.67	2.25	< .01**
Sit to stand time (sec)	10.72	3.73	12.09	4.62	< .01**
Health-related behaviors					
Sleep duration (hour)	6.85	1.24	6.48	1.40	< .01**
Tobacco smoking	52	31.90%	1	0.01%	< .001***
Alcohol use	106	65.00%	46	20.72%	< .001***
SF-36 physical score	73.46	21.81	63.81	22.89	< .001***
SF-36 mental scores	73.44	20.49	67.96	19.39	< .01***

P values were calculated using two-sample t-tests or chi squared tests (for categorical variables).

BMI = body mass index, FVC = forced vital capacity, FEV$_1$ = forced expiratory volume in one second, TG = triglyceride, SBP = systolic blood pressure, DBP = diastolic blood pressure, WHR = waist to hip ratio.

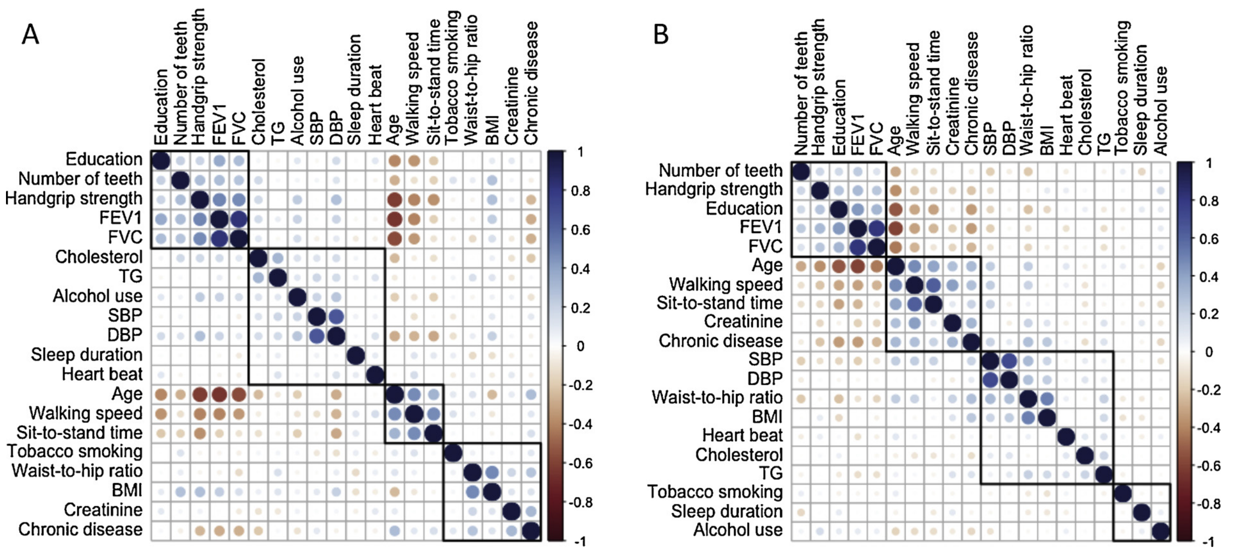

Fig. 1. Correlogram visualizing the pairwise correlation between the parameters in men (A) and women (B). Positive correlations (Pearson coefficient is above 0) are displayed in blue, whereas negative correlations (Pearson coefficient is below 0) are in red. The spaces were left blank if the coefficient is not significant ($p < .05$). The rectangles were drawn according to hierarchal cluster grouping.

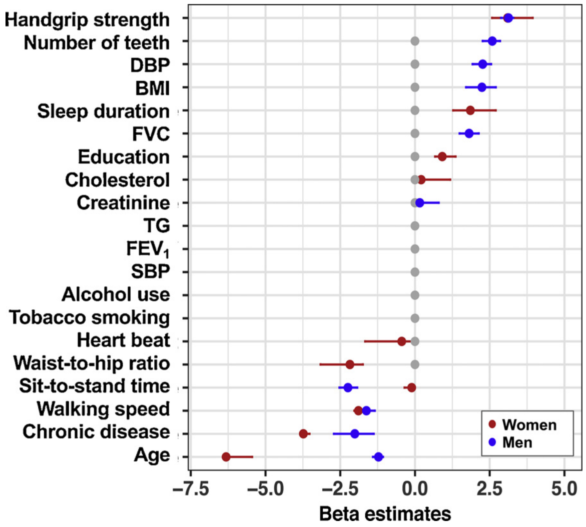

Fig. 2. Multivariate patterns of demographic and biological measurements that predict the SF-36 physical scores of men (blue) and women (red). BMI = body mass index, FVC = forced vital capacity, FEV_1 = forced expiratory volume in one second, TG = triglyceride, SBP = systolic blood pressure, DBP = diastolic blood pressure, WHR = waist-to-hip ratio. Error bars indicate 95 % confidence intervals.

speed and greater number of chronic diseases are associated with lower SF-36 physical scores. Along with physical performance, age was also a common indicator for both groups, but the effect size (beta estimate) was much larger in women than in men. Several other measurements were associated with one group or the other. The number of teeth, pulmonary function (FVC), and blood pressure (DBP) were notable indicators only for men, while sleep duration, education, and waist-to-hip ratio exclusively estimated SF-36 physical scores only for the women. TG levels, FEV, and alcohol use/smoking were not significantly associated with the HRQoL of both groups.

Fig. 3 shows the model performance measured by the correlation coefficients and their mean values in men (A and B) and women (C and D). When we assessed the correlation scores using a randomly selected training set and a test set with 1000 iterations, the mean correlation score was 0.64 for the training set and 0.5 for the test set for men, whereas it was 0.67 and 0.59, respectively, for women. The selected indicators in this study estimated approximately 25%–36% of the variances in SF-36 physical scores.

3.2.1.2. Handgrip strength and SF physical scores. Since handgrip strength was the most powerful and significant indicator of the SF-36 physical score, we closely examined the relationship between handgrip strength and SF-36 physical scores in the participants. The range of handgrip strength was narrower in women than in men: 4.5 kg–40 kg and 14 kg–55.75 kg, respectively. The linear regression model used to estimate the score revealed a steeper slope for the women's scores than the men's scores; beta coefficient = 1. 71 ($p < .0001$) for women and 1. 47 ($p < .0001$) for men (Fig. 4).

3.2.1.3. SF-36 mental scores. Similar to the SF-36 physical scores, handgrip strength, number of chronic diseases, and walking speed were significant biological indicators of the mental component of SF-36 for both men and women (supplemental Fig. 1). Sleep duration and age were significant only for women, whereas BMI, blood pressure, and pulmonary function were unique indicators for men. Although several biological indicators were significant, the correlation scores were much lower than those for the physical scores (supplemental Fig. 2), 0.36 and 0.47 for men and women, respectively. In other words, only 12–22% of the variance in mental scores on SF-36 was explained by the selected indicators.

4. Discussion

This study investigated the significant biomedical indicators related to HRQoL among older Korean adults using a penalized regression model. Among all available bioindicators, handgrip strength most powerfully estimated the SF-36 physical scores of the participants; higher muscular function was associated with a better perceived QoL in both men and women. Other physical assessments, including walking speed, were also significant indicators in the elderly population. Moreover, age and the number of chronic diseases were also critical indicators of QoL, suggesting that deteriorating physical condition during aging is one of the main factors that reduces HRQoL in the elderly. Compared to the physical health component, the SF-36 mental scores were not estimated well by biological indicators, showing lower correlation scores. However, handgrip strength was still a significant indicator of the mental health summary score.

Based on our results, handgrip strength successfully estimates the

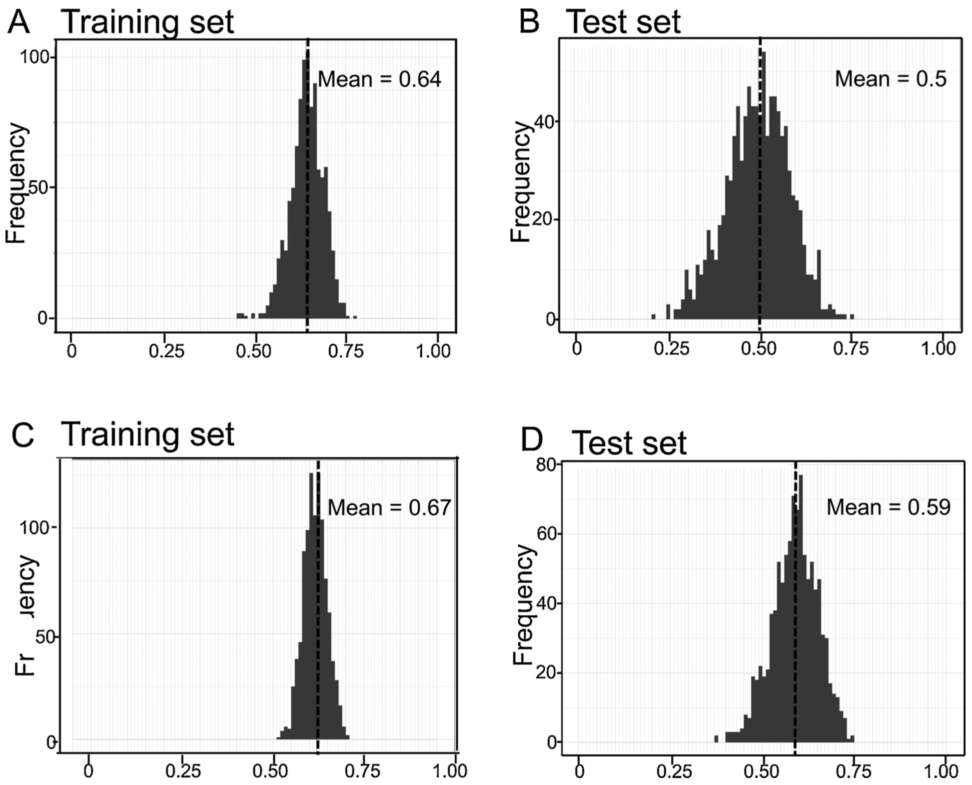

Fig. 3. Measures of correlation scores with SF-36 physical components for the training set (A and C) and test dataset (B and D) in men (A and B) and women (C and D).

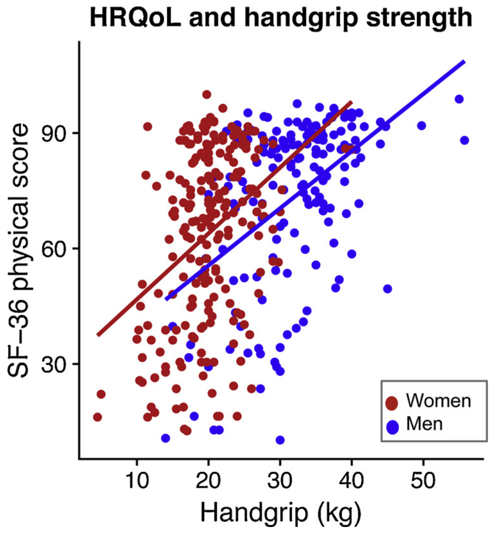

Fig. 4. Relationship between handgrip strength and SF-36 physical scores.

personal assessment of HRQoL. Handgrip strength, a simple and fast clinical measurement, has emerged as a proxy assessment of overall muscular strength. In fact, handgrip strength is emerging as a successful indicator for QoL; increasing evidence has recently linked low handgrip strength to poor quality of life among elderly Koreans (Kang, Lim, & Park, 2018) and Europeans (Musalek & Kirchengast, 2017). Handgrip strength has also recently been linked to cardiac function and structure (Beyer et al., 2018), pulmonary function (Da, Yoo, Cho, & Lee, 2018), and nutrition status (Flood, Chung, Parker, Kearns, & O'Sullivan, 2014), as well as functional independence in the elderly population (Gopinath, Kifley, Liew, & Mitchell, 2017). In addition to being a diagnostic tool for frailty and sarcopenia (loss of muscle) in aging populations, we recommend handgrip strength as a diagnostic tool to assess normal and deteriorating aging based on our results.

The clinical significance of our analytical methods depends on the ability to select biomarkers. Our model using the elastic net model, with the 20 available demographic and bioindicators, explained approximately 25 % and 36 % of the variance in SF-36 physical scores for men and women, respectively. Thus, the objective biomedical indicators explain approximately 30 % of the overall assessment of one's physical condition. One option for increasing prediction power is to use an expanded list of laboratory panels, including inflammation markers and other aging-related factors, such as cognitive decline. Future studies employing tailored physiological and mental factors as predictors will be able to develop a more precise model for predicting QoL in the elderly.

As mentioned above, one of the limitations of the current study is the lack of assessment of inflammation markers, such as interleukin (IL) -6 and C-reactive protein (CRP), both of which are direct indicators of physical and mental health (Chirinos, Murdock, LeRoy, & Fagundes, 2017; Yang et al., 2016). Additionally, this study was based on a cross-sectional survey with a limited number of participants, which does not generate inferences regarding causality. Follow-up longitudinal research is necessary to investigate the attributed contributions of changes in these predictors to quality of life. Despite these limitations, our study is important in that it successfully proves the essential role of physical performance in maintaining higher quality of life among elderly people. Our findings not only demonstrate the link between physical performance state and the subjective evaluation of the quality of life, but also provide evidence supporting that adequate helping inventions among older adults sustaining biological physical performance would result in enhanced quality of life.

In conclusion, using novel analytical methods, the findings of the present study suggest handgrip strength is a powerful indicator of HRQoL in elderly populations. However, this finding should be interpreted with caution because the correlational nature of the present study prevents us from determining the causal relation between handgrip strength and HRQoL in the elderly population. Nonetheless, individuals should monitor their physical condition to maintain a positive evaluation or perception of their quality of life. Furthermore, strategies that preserve physical performance, including handgrip strength, are likely to maintain a good quality of life for a longer period; thus, physical performance is a key component of aging well.

Ethical approval and consent to participate

This project was reviewed and approved by Institutional Review Board of the SMG-SNU Boramae Medical Center.

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Funding statement

This study was supported by grants from SMG-SNU Boramae Medical Center (BRM 03-2018-24) and Center for Happiness Studies via the Center for Social Sciences at Seoul National University.

Author's contributions

Study conception and design: Lee. Statistical analysis: Lee and Ahn. Drafting of the manuscript: Lee, Shin and Oh. Critical revision of the manuscript: all authors. Study supervision: Choi and Oh. All authors have read and approved the final manuscript.

Authors' information

Not applicable

Declaration of Competing Interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Acknowledgements

Not applicable

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.archger.2019.103966.

References

Abraham, G., Kowalczyk, A., Zobel, J., & Inouye, M. (2013). Performance and robustness of penalized and unpenalized methods for genetic prediction of complex human disease. *Genetic Epidemiology, 37*(2), 184–195. https://doi.org/10.1002/gepi.21698.

Ahn, W. Y., & Vassileva, J. (2016). Machine-learning identifies substance-specific behavioral markers for opiate and stimulant dependence. *Drug and Alcohol Dependence, 161*, 247–257. https://doi.org/10.1016/j.drugalcdep.2016.02.008.

Ahn, W.-Y., Kishida, K. T., Gu, X., Lohrenz, T., Harvey, A., Alford, J. R., et al. (2014). Nonpolitical images evoke neural predictors of political ideology. *Current Biology: CB, 24*(22), 2693–2699. https://doi.org/10.1016/j.cub.2014.09.050.

Beyer, S. E., Sanghvi, M. M., Aung, N., Hosking, A., Cooper, J. A., Paiva, J. M., et al. (2018). Prospective association between handgrip strength and cardiac structure and function in UK adults. *PloS One, 13*(3), e0193124. https://doi.org/10.1371/journal.pone.0193124.

Bowling, A., & Dieppe, P. (2005). What is successful ageing and who should define it? *BMJ, 331*(7531), 1548–1551. https://doi.org/10.1136/bmj.331.7531.1548.

Chirinos, D. A., Murdock, K. W., LeRoy, A. S., & Fagundes, C. (2017). Depressive symptom profiles, cardio-metabolic risk and inflammation: Results from the MIDUS study. *Psychoneuroendocrinology, 82*, 17–25. https://doi.org/10.1016/j.psyneuen.2017.04.011.

Choi, H.-C., Son, K. Y., Cho, B., Park, S. M., & Cho, S.-I. (2012). An implication of the short physical performance battery (SPPB) as a predictor of abnormal pulmonary function in aging people. *Archives of Gerontology and Geriatrics, 54*(3), 448–452. https://doi.org/10.1016/j.archger.2011.03.010.

Collins, A. L., Goldman, N., & Rodríguez, G. (2008). Is positive well-being protective of mobility limitations among older adults? *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 63*(6), P321–7.

Crowther, M. R., Parker, M. W., Achenbaum, W. A., Larimore, W. L., & Koenig, H. G. (2002). Rowe and Kahn's model of successful aging revisited: Positive spirituality—The forgotten factor. *The Gerontologist, 42*(5), 613–620.

Da, H. S., Yoo, J. W., Cho, M. R., & Lee, Y. J. (2018). Relationship between handgrip strength and pulmonary function in apparently healthy older women. *Journal of the American Geriatrics Society, 24*, 623. https://doi.org/10.1111/jgs.15410.

DuMontier, C., Gorr, K. M. C., Silliman, R. A., Stuck, A. E., & Moser, A. (2018). Health-related quality of life in a predictive model for mortality in older breast Cancer survivors. *Journal of the American Geriatrics Society, 66*(6), 1115–1122. https://doi.org/10.1111/jgs.15340.

Flood, A., Chung, A., Parker, H., Kearns, V., & O'Sullivan, T. A. (2014). The use of hand grip strength as a predictor of nutrition status in hospital patients. *Clinical Nutrition (Edinburgh, Scotland), 33*(1), 106–114. https://doi.org/10.1016/j.clnu.2013.03.003.

Friedman, J., Hastie, T., & Tibshirani, R. (2010). Regularization paths for generalized linear models via coordinate descent. *Journal of Statistical Software, 33*(1), 1–22. https://doi.org/10.1109/TPAMI.2005.127.

Gallicchio, L., Hoffman, S. C., & Helzlsouer, K. J. (2007). The relationship between gender, social support, and health-related quality of life in a community-based study in Washington County, Maryland. *Quality of Life Research, 16*(5), 777–786. https://doi.org/10.1007/s11136-006-9162-4.

Gopinath, B., Kifley, A., Liew, G., & Mitchell, P. (2017). Handgrip strength and its association with functional independence, depressive symptoms and quality of life in older adults. *Maturitas, 106*, 92–94. https://doi.org/10.1016/j.maturitas.2017.09.009.

Jing, W., Willis, R., & Feng, Z. (2016). Factors influencing quality of life of elderly people with dementia and care implications: A systematic review. *Archives of Gerontology and Geriatrics, 66*, 23–41. https://doi.org/10.1016/j.archger.2016.04.009.

Kang, S. Y., Lim, J., & Park, H. S. (2018). Relationship between low handgrip strength and quality of life in Korean men and women. *Quality of Life Research, 27*(10), 2571–2580. https://doi.org/10.1007/s11136-018-1920-6.

Kim, G. R., Netuveli, G., Blane, D., Peasey, A., Malyutina, S., Simonova, G., et al. (2015). Psychometric properties and confirmatory factor analysis of the CASP-19, a measure of quality of life in early old age: The HAPIEE study. *Aging & Mental Health, 19*(7), 595–609. https://doi.org/10.1080/13607863.2014.938605.

Kojima, G., Iliffe, S., Jivraj, S., & Walters, K. (2016). Association between frailty and quality of life among community-dwelling older people: A systematic review and meta-analysis. *Journal of Epidemiology and Community Health, 70*(7), 716–721. https://doi.org/10.1136/jech-2015-206717.

Lahoud, R., Chongthammakun, V., Wu, Y., Hawwa, N., Brennan, D. M., & Cho, L. (2017). Comparing SF-36® scores versus biomarkers to predict mortality in primary cardiac prevention patients. *European Journal of Internal Medicine, 46*, 47–55. https://doi.org/10.1016/j.ejim.2017.05.026.

Lyyra, T.-M., Törmäkangas, T. M., Read, S., Rantanen, T., & Berg, S. (2006). Satisfaction with present life predicts survival in octogenarians. *The Journals of Gerontology Series B, Psychological Sciences and Social Sciences, 61*(6), P319–26.

McHorney, C. A., Ware, J. E., & Raczek, A. E. (1993). The MOS 36-Item Short-Form Health Survey (SF-36): II. Psychometric and clinical tests of validity in measuring physical and mental health constructs. *Medical Care, 31*(3), 247–263. https://doi.org/10.2307/3765819.

Musalek, C., & Kirchengast, S. (2017). Grip strength as an Indicator of health-related quality of life in old age-A pilot study. *International Journal of Environmental Research and Public Health, 14*(12), 1447. https://doi.org/10.3390/ijerph14121447.

Netuveli, G., & Blane, D. (2008). Quality of life in older ages. *British Medical Bulletin, 85*(1), 113–126. https://doi.org/10.1093/bmb/ldn003.

Netuveli, G., Wiggins, R. D., Hildon, Z., Montgomery, S. M., & Blane, D. (2006). Quality of life at older ages: Evidence from the English longitudinal study of aging (wave 1). *Journal of Epidemiology and Community Health, 60*(4), 357–363. https://doi.org/10.1136/jech.2005.040071.

Oh, B., Cho, B., Choi, H.-C., Son, K. Y., Park, S. M., Chun, S., et al. (2014). The influence of lower-extremity function in elderly individuals' quality of life (QOL): An analysis of the correlation between SPPB and EQ-5D. *Archives of Gerontology and Geriatrics, 58*(2), 278–282. https://doi.org/10.1016/j.archger.2013.10.008.

Patel, A. A., Donegan, D., & Albert, T. (2007). The 36-item short form. *Journal of the American Academy of Orthopedic Surgeon*.

Tajvar, M., Arab, M., & Montazeri, A. (2008). Determinants of health-related quality of life in elderly in Tehran, Iran. *BMC Public Health, 8*(1), 323. https://doi.org/10.1186/1471-2458-8-323.

Waldmann, P., Mészáros, G., Gredler, B., Fuerst, C., & Sölkner, J. (2013). Evaluation of the lasso and the elastic net in genome-wide association studies. *Frontiers in Genetics, 4*, 270. https://doi.org/10.3389/fgene.2013.00270.

Yang, Y. C., Boen, C., Gerken, K., Li, T., Schorpp, K., & Harris, K. M. (2016). Social relationships and physiological determinants of longevity across the human life span. *Pnas, 113*(3), 578–583. https://doi.org/10.1073/pnas.1511085112.

Zou, H., & Hastie, T. (2005). Regularization and variable selection via the elastic net. *Journal of the Royal Statistical Society*. https://doi.org/10.1111/j.1467-9868.2005.00503.x@10.1111/(ISSN)1467-9868.TOP_SERIES_B_RESEARCH.