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Important correlates of purpose in life identified through a machine learning approach

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Abstract

Objective: A wealth of evidence has linked purpose in life (PiL) to better mental and physical health and healthy aging. Here, we aimed to determine important correlates of PiL using a machine learning approach.

Methods: Participants were recruited from retirement communities by the Rush Memory and Aging Project and assessed for childhood experience, adulthood sociodemographic factors (e.g., education, income, marital status), lifestyle and health behavior (e.g., cognitively stimulating activities, exercise, social activities, social network size), psychological factors (e.g., depression, loneliness, perceived discrimination, perceived social support), personality traits (e.g., PiL, harm avoidance), and medical conditions. Elastic Net was implemented to identify important correlates of PiL.

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Author Contributions

Zhen Mei performed the analysis and wrote the first draft. Adriana Lori helped with the analysis. David Bennett leads the MAP study and provided the data. Thomas Wingo and Aliza Wingo conceptualized the project, supervised the analysis, and critically revised the manuscript. All authors reviewed and edited the manuscript.

Data availability

Study data may be requested at https://www.radc.rush.edu.

Conflict of Interest

The authors report no conflicts in this article.

Results: A total of 1839 participants were included in our analysis. Among the 23 variables provided to Elastic Net, 10 were identified as important correlates of PiL. In order of decreasing effect size, factors associated with lower PiL were loneliness, harm avoidance, older age and depressive symptoms, while those associated with greater PiL were perceived social support, more social activities, more years of education, higher income, intact late-life cognitive performance, and more middle-age cognitive activities.

Conclusions: Our findings identify potentially important modifiable factors as targets for intervention strategies to enhance PiL.

Keywords

Purpose in life; machine learning; healthy aging; loneliness; harm avoidance

Objective

Purpose in life (PiL) is a trait-like tendency to derive meaning from life experiences and to possess a sense of direction and intentionality in life (1). PiL has been shown to be an important building block for psychological resilience and eudaimonic well-being (2, 3), as well as a protective factor for mental and physical health and for healthy aging. For instance, greater PiL predicts lower incidence of sleep disturbances (4), better physical functioning (5), lower risk for depression (6), lower incidence for stroke (7), lower risk for cardiovascular disease (8), and greater longevity (9). Additional studies have shown that higher level of PiL is associated with slower decline of cognitive performance in advanced age (1, 10), less perceived cognitive decline in mid-life (11), and reduced risk for mild cognitive impairment and Alzheimer's disease (12).

PiL is a complex construct that is influenced by demographic characteristics, physical and mental health status, health-promoting behaviors, and psychosocial factors. With few exceptions, PiL declines with age (13, 14) and men tend to possess higher PiL in older age than women (12, 15). More years of education, higher income, being married, and being a member of a minority race/ethnicity predict greater PiL (9, 16, 17). Regular exercise and low alcohol use are correlated with higher PiL (3, 18), while smoking and having depression have been associated with lower PiL (19, 20). Social engagement is an important factor fostering PiL in older age. Specifically, PiL is negatively correlated with perception of loneliness (21) and positively correlated with perceived social support and more social activities(22, 23). In addition to social engagement, PiL is affected by childhood experience. Childhood maltreatment, including childhood abuse or childhood neglect, is negatively correlated with PiL after controlling for other factors (24).

PiL is also potentially modifiable. For instance, intensive meditation training program has been shown to promote PiL (25). Moreover, a recent meta-analysis revealed significant improvement on meaning and purpose with psychosocial interventions (26).

Since greater PiL is associated with several key positive health outcomes, understanding important predictors for PiL is illuminating, particularly for efforts in improving PiL. But most of factors known to be associated with PiL have been examined either in isolation or by

adjusting for a limited number of other potentially predictive factors, it is unclear which factors remains reliably and independently associated with PiL when considering all factors together simultaneously. To fill this knowledge gap, we considered many factors that might influence PiL and identified a number of important factors for PiL using a machine learning approach. To that end, the current study advances our understanding of the important contributors to PiL, potentially informing intervention work, and shedding light on how healthy aging occurs.

Methods

2.1 Participants

Participants were recruited by the Rush Memory and Aging project (MAP), an ongoing longitudinal study of common chronic conditions of aging that has been approved by an Institutional Review Board of Rush University Medical Center (27). MAP started in 1997 and recruits older adults without known dementia from retirement communities and subsidized senior housing facilities throughout Chicago and northeastern Illinois. All participants signed an informed consent and a repository consent to allow their study data to be repurposed.

Our study only included participants who did not have a diagnosis of dementia at the baseline evaluation. The clinical diagnosis of dementia was based on a three-stage process (27) including computer scoring of cognitive tests, clinical judgment by a neuropsychologist, and final diagnostic classification by a clinician. A total of 1839 participants were included in our study and their baseline data were analyzed.

2.2 Demographics

Demographic information included age, sex, race, years of education, income and marital status. We dichotomized marital status as married or other (never married, separated, or widowed).

2.3 Psychological factors

2.3.1 Depressive symptoms—Current depressive symptoms were assessed with the 10-item version of the Center for Epidemiologic Studies Depression Scale (28). Participants were asked whether they had experienced each of the ten symptoms in the past week. The test included 3 items of negative affect (e.g., I felt sad), 2 items of positive affect (e.g., I was happy), 3 items of somatic symptoms (e.g., my sleep was restless) and 2 items of interpersonal problems (e.g., people were unfriendly). Items for positive affect were reverse coded so the score was the sum of depressive symptoms reported. In our analyses, participants were categorized as no symptoms (CESD=0), mild symptoms (CESD=1–3), and clinically relevant depression (CESD≥4) as previously described (29).

2.3.2 Loneliness—Loneliness was assessed with 5 items from a modified version of the De Jong-Gierveld Loneliness Scale (30), which included: “I experience a general sense of emptiness”, “I miss having people around”, “I feel like I don’t have enough friends”, “I often feel abandoned”, and “I miss having a really good friend”. Participants were asked to

rate agreement with each item on a 5-point scale ranging from strongly disagree (1) to strongly agree (5). We took the average of the item scores to represent each participant's loneliness, with higher values indicating higher sense of loneliness.

2.3.4 Perceived social support and perceived discrimination—Perceived social support was assessed with the subscale from the Multidimensional Scale of Perceived Social Support (31). Participants were asked to rate their level of agreement with each of the four items on a 5-point scale ranging from strongly disagree (1) to strongly agree (5). The total score was the average of the item scores, with higher values indicating greater perceived social support.

Perceived discrimination was assessed by asking participants to rate how often they experienced nine instances of discrimination in common everyday situations (e.g., You are treated with less courtesy than other people), with often or sometimes (1) and rarely or never (0) (32). The score was the sum of the item scores, with higher scores indicating more discrimination. This scale has been found to have high internal consistency (33).

2.4 Personality traits

2.4.1 Purpose in life—Purpose in life (PiL) was assessed with a modified measure from Ryff's and Keyes's scales of Psychological Well-Being (34). The measure has ten questions and has been evaluated psychometrically (35, 36). Participants were asked to rate their level of agreement with each item (Supplementary table 1) on a 5-point scale, with 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree. Ratings for items that were negatively worded were reverse-coded so that higher scores indicate higher sense of purpose for all items. The Cronbach's coefficient alpha of this scale was 0.73 (37). We took the average of the ratings for these ten items to represent each participant's PiL, with higher scores denoting higher level of PiL.

2.4.2 Harm avoidance—Harm avoidance was assessed using the 35-item scale derived from Cloninger's Temperament and Character Inventory (38). The scale consists of four subscales: anticipatory worry (e.g., Things often go wrong for me unless I am very careful); fear of uncertainty (e.g., I usually feel tense and worried when I have to do something new and unfamiliar); shyness (e.g., When I have to meet a group of strangers, I am more shy than most people); fatigability (e.g., I have less energy and get tired more quickly than most people). Participants were asked to respond with either true/mostly true or false/mostly false to each item. The score was the sum of positive responses across all 35 items, with higher scores denoting greater harm avoidance.

2.5 Childhood adversity

Childhood adverse experience was assessed by items adapted from the Childhood Trauma Questionnaire (39) and other established scales (40, 41), with a focus on emotional and physical adverse experience during the first 18 years of age. We collected 5 facets of childhood adversity: emotional neglect, financial need, parental intimidation, parental violence, and family problems and separation. Emotional neglect was assessed with 6 items related to the extent to which participants' emotional needs were met by their family during

childhood (e.g., Was there someone in your family who helped you feel important or special). Financial need was assessed with 2 items (i.e., Was there not enough to eat; Did you have to wear dirty clothes) from birth to 18 years of age on a 5-point rating scale. Parental intimidation and parental violence were assessed by rating the frequency of emotional and physical abuse with 4 items (e.g., How often did an adult say mean or hurtful things to you) and 2 items (e.g., Were you punished with a belt, board, cord, or some other hard object) respectively. The score of family problems and separation defined as the number of positive responses to 8 items related to family turmoil (e.g., Did a household member attempt suicide; Did your parents ever separate or divorce). For each scale, higher scores indicate more adverse childhood experience (42, 43).

2.6 Lifestyle and health behaviors

We characterized lifestyle using social network size and social activity. Social network size was expressed as the number of children, family, and friends with whom the participant interacted at least once per month (44). Social activity was scored by asking participants to rate how often they would participate in social activities involving social interaction (e.g., go on day trips, do unpaid community/volunteer work) on the following five-point scale: 1=once a year or less, 2=several times a year, 3=several times a month, 4=several times a week, and 5=every day/almost every day (45).

We collected self-reported assessments of physical activity, lifetime daily alcohol intake, smoking status, and cognitively stimulating activity in childhood, young adult age, middle age and late life. Physical activity was assessed using questions adapted from the 1985 National Health Interview Survey (46). Participants reported the hours per week that they spent in any of the 5 activities (i.e., walking for exercise, yard work, calisthenics, biking, and water exercise) during the past two weeks. Alcohol intake was reported as the number of alcoholic drinks consumed per day during the period the participants drank the most. We transformed the counts into a dichotomous variable with values of light/moderate (females:≤1 drink per day, males: ≤2–3 drinks per day) and high (females:>1 drink per day, males: >2–3drinks per day) based on guidelines from National Institute on Alcohol Abuse and Alcoholism (NIAAA) (47). Smoking status was treated as a binary variable with never versus ever smoked cigarettes. Cognitively stimulating activity (e.g., reading, writing, visiting museums, playing board games, etc.) was assessed in childhood (ages 6 and 12), young adult age (age 18), middle age (age 40) and current age on the following five-point scale: 1=once a year, 2=several times a year, 3=several times a month, 4=several times a week, and 5=every day/almost every day (48).

2.7 Medical conditions and medications

We collected self-reported history of 7 chronic illnesses including stroke, cancer, diabetes mellitus, heart disease, hypertension, thyroid disease, and head injury and defined the medical conditions score as the number of conditions present in each participant. We similarly defined the medications score as the number of prescription and over-the-counter medications for anxiety, depression, mania, and psychosis taken by each participant.

2.8 Statistical analyses

We examined correlations between PiL and 28 baseline characteristics using Spearman correlation. The following 6 variables were dichotomously scored: sex (0=female, 1=male), race (0=other, 1=white), marital status (0=other, 1=married), cognitive status (0=MCI, 1=NCI), smoking status (0=never smoked, 1=ever smoked), and alcohol use (0=light/moderate level, 1=high level). Income and depressive symptoms were treated as ordinal variables and all other characteristics were treated as continuous variables. Only variables correlated with PiL at p-value < 0.1 (see supplementary table 2) were included in the subsequent elastic net modeling to focus the elastic net analysis on the most potentially informative variables.

Elastic Net was used to select the most important subset of correlates for PiL and to estimate their magnitude of effects. Elastic Net is a machine learning algorithm that combines Lasso and Ridge regression. It modifies the commonly used ordinary least squares (OLS) approach by adding a penalty term to prevent overfitting or underfitting (49). While many principles of regression still apply in Elastic Net, it is developed to overcome the limitation of the OLS approach regarding prediction accuracy as well as to perform automatic variable (or feature) selection by shrinking the uninformative coefficients towards zero (49). We first generated a complete dataset by removing participants with missing values as Elastic Net requires complete data on all considered variables. Potential selection bias was evaluated and found to be non-significant (Supplementary table 3). Then, we randomly split the dataset into training and testing sets with a ratio of 2:1. There are two tuning parameters (α and λ) in the elastic net, among which parameter α controls the elastic net penalty and bridges the gap between lasso (α=1) and ridge (α=0), while parameter λ controls the overall strength of the penalty applied to the regression. So we first set a sequence of α ranging from 0 to 1 with an interval of 0.1. Then for each α, we fitted the model and performed 10-fold cross-validation to find the optimal value of parameter λ on the training set. We then compared the performance of those models by computing the mean-squared error (MSE) on the testing set. The best model was the one with the lowest MSE. In the best model, the variables with non-zero coefficient estimates were declared to be the important correlates for PiL. We standardized all the variables so that all the coefficient estimates were comparable after Elastic Net. Elastic net regression (Gaussian family) was performed with the 'glmnet' package (50) in R version 3.6.1.

Results

3.1 Characteristics of the participants

A total of 1839 participants were included in the analysis, of whom 75% were female, 93% were Caucasian, and 39% were married. Mean age was 79 (SD=7.7) and average education was 15 years (SD=3.3). Most (74%) participants were cognitively normal when PiL was assessed, and their PiL score ranged from 2 to 5 with a mean of 3.7 (SD=0.46). Most participants reported cognitive activities of several times a month in childhood, young adulthood, middle age, and late life, respectively. They participated in social activities several times a month on average and interacted with an average of 7 (SD=5.9) relatives and friends at least once a month (Table1).

3.2 Pairwise correlation between purpose in life and other baseline characteristics

Spearman correlation was used to examine bivariate associations between PiL and 28 baseline characteristics. We found that higher PiL was correlated with being male, more years of education, being married, higher income, having no cognitive impairment, more physical activity, more cognitive activity in childhood, young adulthood, middle age, and later life, more childhood witnessing of parental violence, more social activity, larger social network size, and greater perceived social support (Figure 1). The following factors were found to be correlated with lower PiL: older age, more medical conditions, more medications taken, more childhood emotional neglect, more childhood perception of financial need, greater perception of loneliness, greater perception of discrimination, more depressive symptoms, and higher level of harm avoidance (Figure 1). Notably, race, a history of prior smoking, alcohol intake, childhood parental intimidation, and childhood family problems were not significantly correlated with PiL (Figure 1).

3.3 Important correlates of purpose in life

We used Elastic Net to identify important correlates for PiL and estimate their magnitude of effects. We included 23 variables correlated with PiL at $p < 0.1$ (Supplementary table 2) to focus elastic net analysis on the most informative variables. Among the 23 variables, 10 were identified as important correlates of PiL. In decreasing order of effect size, PiL was negatively associated with loneliness, harm avoidance, older age, and depressive symptoms and positively associated with perceived social support, more social activities, more years of education, higher income, absence of cognitive impairment, and more cognitively stimulating activities in middle age (Table 2).

Discussion

In the present study, we built on previous studies in disentangling the construct of PiL and we expanded further by investigating important correlates of PiL using a machine learning approach. Among the 23 variables that were correlated with PiL, Elastic Net modeling identified 10 important correlates for PiL.

Loneliness was the strongest correlate of PiL among the variables considered in our analysis. An possible explanation is that lonely individuals may have maladaptive affective styles that reduce their sense of PiL. For instance, lonely individuals tend to pay more attention to negative stimuli (51) and are more sensitive to painful facial expressions (52). By contrast, individuals with higher PiL recover more rapidly from an acute negative emotional provocation (53) and are slower to evaluate negative information (54), which suggest that greater PiL promotes a more optimal affective style by promoting reappraisal of negative stimuli as less threatening and less salient. Another possibility for this association is that one out of five items in the loneliness scale (i.e. “I experience a general sense of emptiness”) may reflect a lack of PiL (Supplementary table 1).

A finding that we believe to be novel is that PiL was associated with harm avoidance (HA), an anxiety- related personality trait that has been shown to be predictive of increased risk for depression, mild cognitive impairment, and Alzheimer’s dementia in older adults (55–57).

Greater HA was associated with decreased activity in the ventromedial prefrontal cortex (vmPFC) (58). Conversely, increased vmPFC activity was reported in individuals with greater PiL (54). Hence, HA may be directly related to the neural bases involved in PiL and future study is needed to investigate the biology underlying the association between HA and PiL.

Our findings also revealed that greater perceived social support and more social activities associated with higher PiL. The significant correlations between PiL and social support as well as with social activities have been documented in other studies as well (7, 22, 23). This may indicate that while aging might involve a decrease in a sense of having goals and life purpose, many age-related losses may be compensated for by quality social relationships and frequent social interaction. Interventions that assist older adults in building supportive social connections and becoming integrated in their social environment may serve as important resources that provide PiL.

Furthermore, we found that more cognitively stimulating activities in middle age were associated with higher PiL. Cognitively stimulating activities have been shown to be positively correlated with PiL and psychological well-being through cognitive enhancement (22, 59). Our analysis extended those work and showed that middle-age cognitive activity had stronger effects on PiL than those of late-life (current) cognitive activity. There is evidence that midlife cognitive activity is the strongest predictor of late-life cognitive reserve (60). By this account, midlife cognitive activity may enhance late-life PiL by developing and maintaining cognitive reserve.

It is no surprise that depressive symptoms were found to be negatively associated with PiL. From a clinical perspective, depressed mood states invoke broad reductions in motivated action (61), thereby reducing individual’s intentionality and PiL. In addition, it is worth noting that early-life experiences (i.e. childhood adversity, childhood cognitive activity, and young adult age cognitive activity) did not significantly contribute to late-life PiL. This may indicate that older adults tend to derive their purpose mainly from contemporaneous situations.

Our findings have some limitations. First, the cross-sectional design of our study limits our ability to determine causality between PiL and these correlates. Hence, we cannot imply any causal relationship between these important correlates and PiL. Second, our study was based on a predominantly female and Caucasian cohort, which potentially limits the generalizability of our findings. Third, many of the participants did not have complete data on all 23 considered variables and were excluded from the Elastic Net analysis. However, we found no difference in the distribution of the variables identified to be important correlates of PiL between the included participants and all participants (Supplementary table 3). Future work should investigate correlates of PiL in ethnically diverse cohorts, such as the Health and Retirement Study, which has more ethnically diverse participants and assessment of a rich array of childhood and adulthood psychosocial factors needed for this study. Furthermore, performing a meta-analysis using data from multiple cohorts could refine our understanding of the correlates of PiL for different age ranges and ethnicities.

Our study has several strengths. To our knowledge, this is the first study to determine important correlates for PiL using a machine learning approach that simultaneously performs continuous shrinkage and feature selection. Furthermore, participants with dementia were excluded from our analyses based on a uniform clinical evaluation, which reduces the potential recall bias and strengthens the reliability of all the self-reported scales. In addition, we studied a relatively large group of community-based participants with comprehensive assessments, which enhances the generalizability of our findings.

Our findings suggest that advanced age is associated with decreasing PiL, highlighting that intervention programs aimed at improving PiL in older adults might be beneficial for healthy aging. Current purpose-oriented interventions implement supportive-expressive, cognitive-behavioral, or educational techniques to provide the context for reflection, exploration, and acceptance to help participants gain purpose or meaning in life (62). One of the intervention strategies, life crafting, has emerged as an effective way to enhance PiL. In life crafting, participants undergo a series of writing exercises with the goal of formulating goals for important areas of life, making plans, and putting these into actions in a manner consistent with their values and interests (63). Digital forms of therapy are emerging and should be considered for future interventional studies to enhance PiL in older adults (64).

Conclusion

To conclude, our findings identify a number of important and potentially modifiable correlates for PiL. We note that interventions have been developed to reduce loneliness (65), level of harm avoidance (66), and depressive symptoms. Future studies should test whether improving these important correlates would increase PiL (67).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights:

1. Since purpose in life (PiL) is associated with better mental and physical health, we aimed to determine important correlates of PiL using a machine learning approach.
2. We identified 10 important correlates for PiL. In order of decreasing effect size, factors associated with lower PiL were loneliness, harm avoidance, older age, and depressive symptoms, while those associated with greater PiL were social support, social activities, more years of education, higher income, normal cognition, and middle-age cognitive activities.
3. Our findings identified important modifiable factors as potential targets for intervention strategies to enhance PiL.

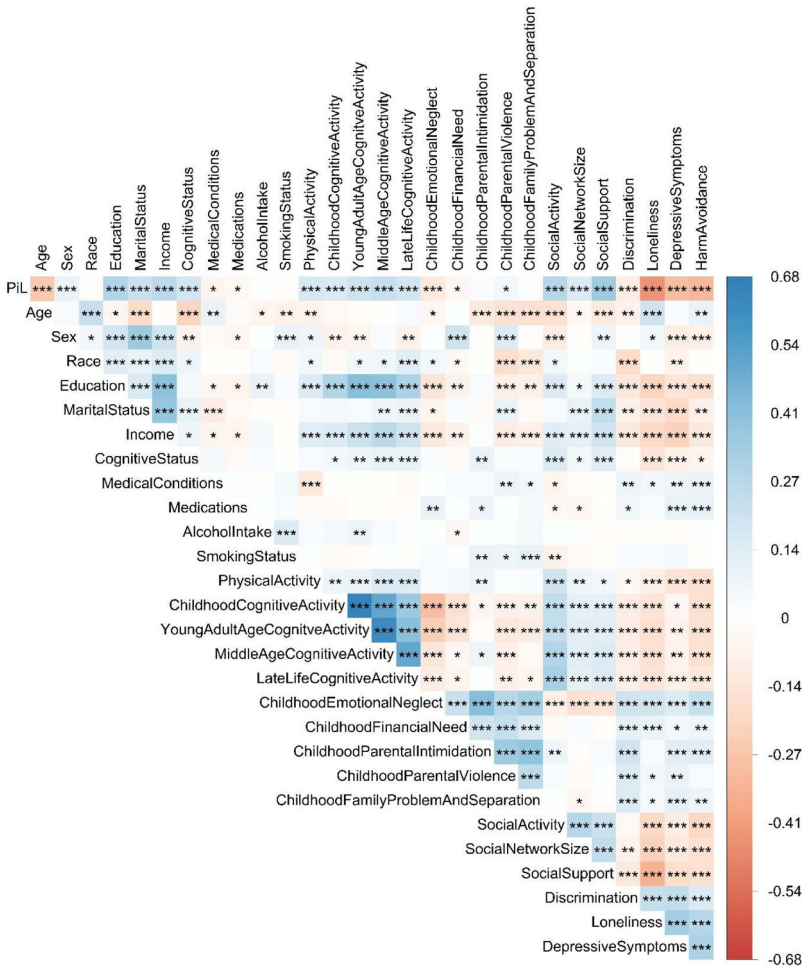

Figure 1. The correlation heatmap between purpose in life and other baseline characteristics.

Spearman correlation was used to examine pairwise correlations. The following 6 variables were dichotomously scored: sex, race(other, white), marital status(other, married), cognitive status(MCI, NCI), smoking status(never smoked, ever smoked), and alcohol use(light/moderate level, high level). Income and depressive symptoms were treated as ordinal variables and other factors were treated as continuous variables. The color bar indicates the correlation coefficient. Spearman correlation: *p < .1, **p < .01, p < .001, Spearman r and sample size are in supplementary table 2.

Table 1

Characteristics of the participants (N=1839*).

Variable	Mean(SD), Median, Range
Age	79.6(7.7), 80.4, [53.4–100.4]
Sex (N, %)	
Female	1381(75.1%)
Male	458(24.9%)
Race(N,%)	
White	1704(92.7%)
Other	135(7.3%)
Education(years)	14.9(3.3), 15, [0–30]
Marital status (N,%)	
Married	717 (39%)
Other status	1121 (61%)
Income (N,%)	
$24999 or less	487(28%)
$25000 to $34999	304(17.5%)
$35000 to $74999	589(33.9%)
$75000 or more	359(20.6%)
Cognitive status (N,%)	
NCI	1358(73.8%)
MCI	481(26.2%)
Number of medical conditions	1.4(1.1), 1, [0–6]
Number of medications taken	0.1(0.3), 0, [0–3]
Alcohol intake (N, %)	
Light/moderate level (females:≤1 , males: ≤2–3)	1560 (93%)
High level (females:>1, males: >2–3)	118 (7%)
Smoking status (N,%)	
Never smoked	958 (57%)
Ever smoked	721 (43%)
Physical activity	3.4(3.7), 2.5, [0–35]
Childhood cognitive activity	3(0.7), 3.1, [1–4.7]
Middle age cognitive activity	3.3(0.6), 3.3, [1–4.8]
Young adult age cognitive activity	3.1(0.7), 3.1, [1–4.7]
Late life cognitive activity	3.2(0.7), 3.1, [1–4.7]
Childhood adversity-Emotional neglect	4(4.2), 3, [0–18]
Childhood adversity-Financial need	0.8(1.3), 0, [0–8]
Childhood adversity-Parental intimidation	2.8(2.6), 2, [0–15]
Childhood adversity-Parental violence	0.8(1.2), 0, [0–7]
Childhood adversity-Family problem and separation	1(1.2), 1, [0–6.7]
Social activity	2.7(0.6), 2.7, [1–4.3]
Social network size	7 (5.9), 5, [0–66]

Variable	Mean(SD), Median, Range
Loneliness	2.2(0.6), 2.2,[1–4.6]
Perceived discrimination	0.8(1.4), 0, [0–9]
Perceived social support	4.4(0.7), 4.2, [1–5]
Depressive symptoms (N,%)	
None (CESD=0)	959 (52.2%)
Mild (CESD=1–3)	681 (37%)
Clinically relevant (CESD≥4)	199 (10.8%)
Harm avoidance	10(6.5), 9, [0–34]
Purpose in life	3.7(0.46), 3.7, [2–5]

*Sample size varied due to different missingness of different variables.

Table 2

Robust correlates for late-life purpose in life selected by Elastic Net (N=1404, α=0.7). Less robust factors had their coefficients shrunk to zero as denoted by "-".

Variable	Standardized Coefficient
1 Loneliness	−0.1065
2 Harm avoidance	−0.0622
3 Age	−0.0506
4 Perceived social support	0.0370
5 Depressive symptoms	−0.0309
6 Late life social activity	0.0226
7 Education	0.0150
8 Income	0.0149
9 Cognitive status	0.0118
10 Middle age cognitive activity	0.0097
11 Marital status	-
12 Sex	-
13 Medical conditions	-
14 Medications	-
15 Social network size	-
16 Perceived discrimination	-
17 Physical activity	-
18 Late life cognitive activity	-
19 Young adult age cognitive activity	-
20 Childhood cognitive activity	-
21 Childhood adversity-Emotional neglect	-
22 Childhood adversity-Financial need	-
23 Childhood adversity-Parental violence	-