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Association between subjective well-being and exceptional longevity in a longevity town in China: a population-based study

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Abstract To examine the associations of cognitive and emotional facets (measured by life satisfaction [LS], positive affect [PA], negative affect [NA], and affect balance [AB]) of subjective well-being (SWB) with exceptional longevity (EL), we conducted a population-based study with 463 EL individuals (95+, EL group) recruited from a longevity town of Rugao, China (N=755, with a response rate of 71.6 %), and 926 elderly individuals (60–69, elderly/control group). The population-based controls were sampled from the resident registry according to the gender ratio of the EL group. We found that the EL group had significantly higher levels of LS (30.74 vs. 28.93), PA (3.91 vs. 3.67), and AB (7.89 vs. 7.40) and a lower level of NA (1.02 vs. 1.27) than the elderly group. Multivariate logistic regression analysis revealed that higher levels of LS, PA, AB, and NA were significantly associated with EL, with odds ratios (ORs) of 1.98 (95 % CI, 1.36–2.89), 2.35 (95 % CI, 1.59–3.48), 2.56 (95 % CI, 1.75–3.75), and 0.50 (95 % CI, 0.33–0.74), respectively. Stratification analysis showed that the associations were significant in the healthy subsample, with the following ORs: LS= 2.31, PA=2.53, AB=3.05, and NA=0.39. In conclusion, SWB, with high cognitive and emotional facets, was associated with EL in the healthy Rugao population. The findings imply that interventions that aim to improve elderly individuals' SWB may promote their quality of life and, ultimately, EL.

Keywords Exceptional longevity · Subjective well-being · Life satisfaction · Positive affect · Negative affect · Affect balance

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Introduction

Longevity has become a public health issue due to increases in life expectancy over the past several decades. In spite of the ongoing progress in improving the health of older adults, only an extremely small proportion of individuals in a population can survive to an advanced old age. Therefore, exceptional longevity (EL, 95+) individuals have been suggested to represent a highly select group. EL implies exceptional survival with intact health or function and has been considered to be a rare but important phenotype (Newman and Murabito 2013). EL is an ideal model to address factors that are related to life span and age-related diseases and, therefore, targeted prevention and health promotion. In the past few decades, an increasing number of studies have attempted to identify environmental and genetic factors related to EL and estimate their contributions.

For instance, research has found that approximately 25–32 % of the variance in longevity is explained by genetic factors and that several polymorphisms are associated with EL (Christensen et al. 2006; Hjelmborg et al. 2006). Although the related factors and mechanisms of EL remain largely unknown, these studies have provided insight for further research opportunities. Among the suggested factors of EL, psychosocial well-being, an important determinant in maintaining a high quality of life, has received limited attention. Using a model of aging focusing on psychosocial aspects (including happiness), Cho et al. compared octogenarians and centenarians and found that a higher percentage of octogenarians displayed successful aging (Cho et al. 2012). This study provided direction for the exploration of the psychosocial factors that are related to EL. However, our understanding of the associations between multiple psychosocial factors and EL as well as the strength of these associations remains limited.

Subjective well-being (SWB), a new psychosocial factor, was proposed by Diener (2000) as "people's cognitive and affective evaluations of their lives." To date, SWB has been widely examined and generally regarded as an important indicator of mental health. According to the conceptualization, SWB consists of cognitive and emotional facets (Diener 2000). More specifically, the cognitive facets include two components, life satisfaction (LS, global judgments of life) and satisfaction with important domains. These components are proposed to stably reflect individuals' evaluations of life circumstances over time. The emotional facets include two components, positive affect (PA) and negative affect (NA). They are assumed to be much more reactive to daily uplifts and hassles (Chow et al. 2005; Larsen and Prizmic 2008). Affect balance (AB) is considered to be a balance between PA and NA and a valid measure of a sense of well-being (Schuur and Kruijtbosch 1995). Whereas PA and NA are distinct orthogonal dimensions (Bradburn 1969; Baker et al. 1992), AB represents a comprehensive understanding of emotional facets. In sum, these components constitute an important and effective index system in evaluating the relationship between SWB and health outcomes or EL.

In recent years, SWB has been linked to mortality or survival (Sadler et al. 2011; Wiest et al. 2011; Xu and Roberts 2010). For instance, the Alameda County Study found that SWB and its various positive components, including domain life satisfaction (DLS), global life satisfaction (GLS), and PA, predicted lowered risk of mortality over 28 years (1965–1993) (Xu and Roberts 2010). In addition, in the population-based Longitudinal Study of Aging Danish Twins (LSADT), SWB was found associated with increased survival time independent of familial factors of genes and shared environment (Sadler et al. 2011). Such literature is accumulating (Chida and Steptoe 2008; Howell et al. 2007; Iwasa et al. 2006; Levy et al. 2002; Li 2005; Pressman and Cohen 2005).

However, less is known regarding the association of SWB with EL, partially due to limited sources of data on EL individuals. In the relevant studies, longevity has been indicated by risk of mortality or survival time (Iwasa et al. 2006; Sadler et al. 2011; Wiest et al. 2011; Xu and Roberts 2010), as mortality is considered to be the ultimate result of survival or health. However, few of the subjects who were defined in these mortality or survival studies survived to an advanced old age (e.g., 95+). Therefore, an examination of EL, rather than the surrogate endpoint mortality or survival time, is particularly needed. In addition, most of previous studies on mortality or survival have used only a single item or a few items of established standardized scales to define components of SWB, such as LS (Li 2005; Sadler et al. 2011) and PA (Levy et al. 2002; Xu and Roberts 2010), or even SWB itself (Li 2005). Furthermore, most of these studies have excluded NA and AB (Iwasa et al. 2006). According to the broader conceptualization of SWB (Diener 2000), NA is an important construct that functions as a relatively independent dimension of emotional well-being (Larsen and Prizmic 2008). As previously mentioned, AB reflects an emotional state rather than one facet. Hence, we argue that all components of the index system are imperative for a full understanding of the relationship between SWB and EL.

In summary, existing studies have focused on establishing the relationship between SWB and mortality/survival. However, despite the simple measurement of SWB, little is known about the effects of SWB components on EL. Consequently, we performed a well-established population-based association study in a longevity town of Rugao, China. The strengths of the current study included the ascertainment of a reasonably large sample size of EL individuals; and randomly recruited population-based controls who shared homogenous environmental exposure with EL individuals. These study design features allowed us to examine the associations of cognitive (LS) and emotional facets (PA, NA, and AB) of SWB with EL.

Methods

Design and study population

The data from the Rugao longevity cohort were collected between December 24, 2007 and February 29, 2008 in Rugao, Jiangsu Province, China. It is a well-designed population-based case–control study that has been described in detail elsewhere (Cai et al. 2009). The aim of the cohort study is to examine possible genetic and environmental factors that influence EL. Notably, Rugao has been termed as a "longevity town" in China since ancient times. The strong survival advantage of the EL subjects at Rugao (less than 1/10,000 Rugao people survive to 100 years, while the average life span in Rugao is 75.58 years) is crucial to our study approach (Cai et al. 2009).

The current study subjects were sampled from the Rugao longevity cohort. According to a strict four-step verification process, the number of persons aged 95+ years was 705 (149 males and 556 females), including 102 centenarians (18 males and 84 females), in Rugao. Of these individuals, 463 were recruited into the Rugao longevity cohort, with a response rate of 71.6 % (Cai et al. 2009). Of these subjects, 446 (EL group; 346 female, 77.6 %; mean ± SD age, 97.4±2.08 years; range, 95–107 years) responded to all covariates and no less than two thirds of the items of the LS, PA, or NA subscale and, thus, were included in the current study.

It is pivotal to ensure a representative sample of the general population as a control in population-based studies. With the support of the local government and local inhabitants, we obtained the current control group from the original population. In short, twofold control subjects who were aged 60–69 years were systematically randomly recruited from the resident registry at the local government offices of Rugao according to the gender ratio of the EL group. Of these individuals, nine were excluded due to missing covariates data, resulting in a final population-based control of 917 subjects (elderly group; 712 females, 77.6 %; mean ± SD age, 64.8±2.93 years; range, 60–69 years).

Procedures

All subjects were contacted at home and examined by physicians who were previously trained to administer a structured questionnaire. The questionnaire includes demographic characteristics, histories of chronic disease (tuberculosis, chronic obstructive pulmonary disease, stroke, coronary heart disease, and malignant tumor), daily activity histories, mental health appraisals, etc. All interviews were tape-recorded, and 5 % of the recorded interviews were evaluated for interviewing quality. Approximately 3–5 % of the subjects were re-contacted by phone to evaluate the interviewers' work. Written informed consent was obtained from each participant or a member of his/her immediate family. The Human Ethnics Committee of Fudan University School of Life Sciences approved the research (Cai et al. 2009).

Measures

Subjective well-being (SWB) and covariates assessments

We used cognitive and emotional facets to operationalize SWB by means of the following two scales: the Life Satisfaction Index A (LSIA) and Bradburn's Affect Balance Scale (ABS). More specifically, the cognitive facets were measured by the LS component, and the emotional facets were measured by the PA, NA, and AB components. All covariates in the current models were collected from the questionnaire. Demographic variables (gender, education levels, marital status), physical health status (histories of chronic diseases, the Katz Index of ADLs), and perceived overall health status (fair, good, excellent) were previously shown to be associated with longevity and psychological factors such as SWB and depression (Engstrom et al. 1999; González Gutiérrez et al. 2005; Xu and Roberts 2010).

The Life Satisfaction Index A (LSIA)

The LSIA scale, developed by Neugarten et al. (1961), includes 12 positively and 8 negatively loaded items with the response alternatives of "Agree" "?" or "Disagree". For positively worded items, "Agree" and "Disagree" responses are scored as 2 and 0 points, respectively. For negatively worded items, "Agree" and "Disagree" responses are scored as 0 and 2 points, respectively. For all items, "?" responses are scored as 1 point. Total scores are obtained by summing all points for the 20 items. The scores range from 0 to 40, with higher scores indicating higher LS. The LSIA scale has been widely used and shown to be a reliable scale (Bienenfeld et al. 1997). An average reliability of 0.79

was found by Wallace and Wheeler (2002), and the reliability was unrelated to sample characteristics such as sample size, age, and sex. In the present study, Cronbach's alpha for the LSIA was 0.792, indicating an adequate internal consistency. The LSIA correlated 0.39 with clinical ratings using Life Satisfaction Ratings (LSR), which includes the following attitudes: zest (as opposed to apathy), resolution and fortitude, congruence among desired and achieved goals, a positive self-concept, and mood tone (Schiaffino 2003).

Bradburn's Affect Balance Scale (ABS)

The Bradburn's Affect Balance Scale (Bradburn 1969) is based on the definition of "happiness" as a preponderance of PA over NA. It consists of five positive items and five negative items. All items are formulated as questions about the subject's feelings during the last few weeks, and answers are provided using a dichotomous "yes" or "no" scale. Positive and negative questions are summed separately, with a score of 1 for a "yes" response and a score of 0 for a "no" response. Thus, the score on each subscale (PA and NA) ranges from 0 to 5. In addition, a general AB score is computed as PA minus NA plus a constant of 5 (in order to avoid negative values), resulting in a range from 0 to 10. ABS has satisfactory strong reliability. With a sample of 200 over a 3-day period, Bradburn reported the test-retest reliability of PA, NA, and AB to be 0.83, 0.81, and 0.76, respectively. The internal consistency reliabilities of PA range from 0.55 to 0.73 and those of NA range from 0.61 to 0.73 (Schiaffino 2003). In the current study, Cronbach's alpha was 0.595 for PA and 0.692 for NA. The ABS instrument also has convergent validity. Bradburn (1969) showed that PA correlated with single-item indicators of happiness from 0.34 to 0.38 and with corresponding NA values from −0.33 to −0.38 (Schiaffino 2003). PA and NA are distinct orthogonal dimensions, as has been widely replicated (Baker et al. 1992). Factor analyses have indicated that PA relates more to situational factors and NA relates more to dispositional factors (Baker et al. 1992).

The Katz Index of Activities of Daily Living (ADL)

The ADL scale, which was modified from the original scale used by Lawton and Brody (1969), comprises one instrumental and one physical dimension and has been widely used to assess the functional status of older adults in research. Specifically, the Katz Index of ADLs was used to represent the physical health status of the current study sample. The Katz Index is based on the six daily tasks of bathing, dressing, indoor transferring, going to the toilet and cleaning oneself afterwards, eating, and continence (Katz et al. 1963). Each task has the following three response alternatives: strongly dependent, somewhat dependent, and strongly independent, with a score of 1, 2, and 3 points, respectively. Based on the total summed scores, a nominal variable with two categories, ADL independent (total score ≤9) and ADL dependent (total score >9), is constructed.

Missing data treatment

In the current study, subjects who missed any of the covariates and subjects who answered less than two thirds of the items of a SWB component (LS, PA, or NA) were excluded from the analysis. The missing value of each item of SWB was imputed with the subject's mean component value. The AB score was calculated by subtracting the NA score from the PA score and then adding a constant of 5, as previously mentioned. A similar strategy for missing data was used by Xu and Roberts (2010).

Statistical analyses

To compare the covariates of the EL and elderly groups, Student's *t* test was used for continuous variables and the Pearson chi-square test was employed for dichotomous variables. In the empirical analysis, LS was partitioned into two categories (higher group and lower group) using the median of 31 as a cutoff point. Similarly, the following variables were dichotomized according to their median values: PA (median = 4), NA (median = 1), and AB (median = 8). To estimate the relative probability of EL as a function of SWB between the EL and elderly groups after adjusting for the covariates, odds ratios (ORs) and 95 % confidence intervals (CI) were derived from multivariate logistic regression models in SPSS, version 19.0 (SPSS Inc., Chicago, IL, USA). In the current study, four models were performed. Crude ORs were calculated in model 1. Model 2 added demographic variables, e.g., gender, education levels, and marital status, to model 1. Physical health status, including histories of chronic diseases and the Katz Index of ADLs, was

added in model 3, and model 4 added perceived overall health status. Furthermore, in order to estimate the effects of a one standard deviation (SD) increase in the SWB components on EL probability, LS, PA, NA, and AB were standardized (Z score, with a mean of 0 and SD of 1) and then entered into the multivariable models. The ORs of these SWB components for EL were obtained in the same manner as described above.

Stratification analyses for gender, education levels, and physical health status were performed, as many studies have reported that these variables account for effects of SWB on other health outcomes. For physical health status, subjects were classified as healthy if they had no chronic disease and were ADL independent and as nonhealthy otherwise (Krijthe et al. 2011; Xu and Roberts 2010). LS, PA, NA, and AB were analyzed as dichotomous and continuous (Z scores) variables, and the ORs were calculated.

Results

As expected, LS was positively correlated with PA (correlation coefficient = 0.433) and AB (correlation coefficient = 0.525), and PA was negatively correlated with NA (correlation coefficient = −0.353). AB was correlated with the other three components (correlation coefficient [LS, PA, and NA] = 0.525, 0.741, and −0.715, respectively). As the descriptive statistics in Table 1 show, the EL group had significantly higher levels of LS (30.74 vs. 28.93, $p<0.001$), PA (3.91 vs. 3.67, $p<0.001$), and AB (7.89 vs. 7.40, $p<0.001$) and a lower level of NA (1.02 vs. 1.27, $p<0.001$) than the elderly group.

Associations between SWB components and EL

ORs for EL in relation to the components of SWB for the full sample are presented in Table 2. In the

Table 1 SWB and sociodemographic characteristics of the study population

	EL group (95+, n=446)	Elderly group (60–69, n=917)	p value
SWB (mean ± SD)			
LS	30.74±4.93	28.93±6.64	<0.001
PA	3.91±1.17	3.67±1.33	<0.001
NA	1.02±1.23	1.27±1.42	<0.001
AB	7.89±1.80	7.40±2.13	<0.001
Covariates			
Demographics			
Gender (female, n [%])	346 [77.6]	712 [77.6]	N.S.
Education levels (illiterate, n [%])	365 [81.8]	499 [54.4]	<0.001
Marital status (currently married, n [%])	22 [4.9]	740 [80.7]	<0.001
Physical health status			
History of chronic diseases (none, n [%])[a]	372 [83.4]	759 [82.8]	N.S.
ADL (independent, n [%])[b]	320 [71.7]	898 [97.9]	<0.001
Psychological health status			
Perceived overall health status (n [%])			
Excellent	87 [19.5]	185 [20.2]	
Good	249 [55.8]	465 [50.7]	
Poor	110 [24.7]	267 [29.1]	
p value for trend			N.S.

The range of scores was as follows: LS, 8–40; PA, 0–5; NA, 0–5; AB, 0–10

SWB subject well-being, *LS* life satisfaction, *PA* positive affect, *NA* negative affect, *AB* affect balance, *N.S.* nonsignificant

[a] None: subjects had no history of several types of chronic diseases (tuberculosis, chronic obstructive pulmonary disease, stroke, coronary heart disease, and malignant tumor)

[b] ADL independent (total score of six daily tasks ≤9), ADL dependent (total score of six daily tasks >9)

Table 2 Odds ratios of multivariate logistic analysis between components of SWB and EL in the full sample

SWB	Model 1[a]			Model 2[b]			Model 3[c]			Model 4[d]		
	OR	95 % CI		OR	95 % CI		OR	95 % CI		OR	95 % CI	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
LS	1.57***	1.25	1.98	1.68**	1.20	2.37	2.22***	1.54	3.19	1.98***	1.36	2.89
PA	1.54**	1.21	1.97	1.99***	1.39	2.85	2.52***	1.71	3.71	2.35***	1.59	3.48
NA	0.70**	0.54	0.90	0.56**	0.39	0.81	0.47***	0.31	0.69	0.50**	0.33	0.74
AB	1.72***	1.35	2.18	2.33***	1.64	3.31	2.79***	1.92	4.05	2.56***	1.75	3.75

SWB subject well-being, *LS* life satisfaction, *PA* positive affect, *NA* negative affect, *AB* affect balance, *OR* odds ratio, *CI* confidence interval
**$p<0.01$; ***$p<0.001$

[a] Model 1: unadjusted

[b] Model 2: add demographic variables (gender, education levels, marital status)

[c] Model 3: add physical health status (histories of chronic diseases, the Katz Index of ADLs) to model 2

[d] Model 4: add perceived overall health status to model 3

unadjusted model, significant associations between EL and LS (model 1, OR=1.57, 95 % CI=1.25–1.98, $p<0.001$), PA (model 1, OR=1.54, 95 % CI=1.21–1.97, $p<0.01$), NA (model 1, OR=0.70, 95 % CI=0.54–0.90, $p<0.01$), and AB (model 1, OR=1.72, 95 % CI=1.35–2.18, $p<0.001$) were observed. Compared with the individuals who reported a lower LS score, the individuals who reported higher LS, PA, AB, and NA had a 1.57-, 1.54-, and 1.72-fold increased probability of EL and a 0.30-fold decreased probability of EL, respectively. The significant associations remained when the demographic variables (gender, education levels, marital status) were included. After physical health status was controlled in model 3, stronger associations were observed (LS, OR=2.22, 95 % CI=1.54–3.19, $p<0.001$; PA, OR=2.52, 95 % CI=1.71–3.71, $p<0.001$; NA, OR=0.47, 95 % CI=0.31–0.69, $p<0.001$; AB, OR=2.79, 95 % CI=1.92–4.05, $p<0.001$). In the final model, which included perceived overall health status, the significant associations between LS, PA, NA, AB, and EL remained, although they were slightly weaker than those in model 3.

Stratification analysis

Potential confounders may influence the associations between the components of SWB and EL; therefore, we performed a stratification analysis. We found that the elevated EL probability with higher LS, PA, and AB and decreased EL probability with higher NA were more pronounced in the healthy subsample (EL group, N=266; elderly group, N=749), with the following ORs: LS=2.12 (95 % CI=1.58–2.85, $p<0.001$), PA=2.08 (95 % CI=1.51–2.88, $p<0.001$), AB=2.22 (95 % CI=1.63–3.02, $p<0.001$), and NA=0.52 (95 % CI=0.37–0.73) (see Table 3). However, these associations were nonsignificant in the nonhealthy subsample ($p>0.05$). The significant associations in the healthy subsample remained after gender, education levels, marital status (model 2), and perceived overall health status (model 3) were included (see Table 3). After standardizing (Z score) all components of SWB, we found that with 1 SD increase in the components (LS, PA, AB, NA), the EL probability increased by 37, 22, and 30 % and decreased by 18 %, respectively, for the full sample (data not shown).

Discussion

To our knowledge, the current study is the first population-based association study to comprehensively explore the associations between the cognitive and emotional facets of SWB and EL in a longevity town. We found that higher LS, PA, and AB and lower NA were significantly associated with EL. In addition, the associations were especially salient among healthy subjects, indicating that physical health status is a mediator of the relationship. The current findings suggest that SWB,

Table 3 Odds ratios of multivariate logistic analysis between components of SWB and EL in healthy and nonhealthy subsamples

	Model 1[a]			Model 2[b]			Model 3[c]		
	OR	95 % CI		OR	95 % CI		OR	95 % CI	
SWB		Lower	Upper		Lower	Upper		Lower	Upper
LS									
Healthy[d]	2.12***	1.58	2.85	2.51***	1.65	3.83	2.31***	1.50	3.55
Nonhealthy	1.29	0.84	1.97	1.13	0.57	2.21	0.87	0.41	1.83
PA									
Healthy[d]	2.08***	1.51	2.88	2.67***	1.70	4.18	2.53***	1.61	3.98
Nonhealthy	1.18	0.77	1.81	1.73	0.87	3.45	1.40	0.67	2.91
NA									
Healthy[d]	0.52***	0.37	0.73	0.36***	0.23	0.58	0.39***	0.25	0.63
Nonhealthy	0.95	0.61	1.48	1.20	0.58	2.46	1.37	0.64	2.96
AB									
Healthy[d]	2.22***	1.63	3.02	3.27***	2.12	5.05	3.05***	1.96	4.74
Nonhealthy	1.30	0.85	1.99	1.43	0.73	2.82	1.14	0.55	2.34

SWB subject well-being, *LS* life satisfaction, *PA* positive affect, *NA* negative affect, *AB* affect balance, *OR* odds ratio, *CI* confidence interval

***$p<0.001$

[a] Model 1: unadjusted

[b] Model 2: add demographic variables (gender, education levels, marital status)

[c] Model 3: add perceived overall health status to model 2

[d] The number of healthy individuals in the EL group is 266 and that in the elderly group is 749

with high cognitive and emotional facets, plays an important role in the healthy Rugao population.

Psychosocial factors have been linked to EL for inextricably influencing functioning, health, and quality of life among older adults (Lawton 1983). However, our understanding of the relationship between psychosocial indicators of well-being and EL remains limited due to few sources of data on EL individuals and objective measurements of psychosocial exposures. The conceptualization of SWB provides an effective index system (LS, PA, NA, and AB) to examine the associations of psychosocial factors with EL. Generally, LS is proposed to reflect one's cognitive assessments of the extent to which one's life matches one's expectations (Okun and Stock 1987; Schimmack and Oishi 2005). In the current study, we found that LS (cognitive facets of SWB) had a favorable effect on exceptional survival, and the associations remained significant after controlling for potential confounders, such as gender, education levels, marital status, etc. Similarly, emotional facets of SWB (higher PA and lower NA) were also associated with EL. This study is the first to establish this striking relationship in a famous longevity town. SWB and its components have been widely studied and associated with a lower risk of mortality or prolonged survival time (Chida and Steptoe 2008; Collins et al. 2009; Howell et al. 2007; Lyyra et al. 2006; Maier and Smith 1999; Pressman and Cohen 2005; Sadler et al. 2011; Wiest et al. 2011; Xu and Roberts 2010). From a survival point of view, the present findings corroborate those of the previous studies on mortality. EL implies considerable long-term survival time. To some extent, the findings can be considered as an effective compensation of causal inference, although whether EL individuals maintain cognitive and emotional facets of SWB across their life span remains uncertain (Charles et al. 2001; Stacey and Gatz 1991; Stone et al. 2010).

As one of the few studies with measures of both PA and NA, the current study obtained an index of AB on the basis of the ABS scale, which was extensively validated to measure one's emotional state, with good psychometrics. We are the first to suggest that AB might play an important role in EL among subjects in a famous longevity town, which is scarcely examined in

epidemiologic investigations. PA was previously associated with a higher risk of mortality than was NA (Ostir et al. 2001). Therefore, at times, NA has been ignored as an exposure. The current study focused on AB as a whole to provide a valid measure of a sense of well-being (Schuur and Kruijtbosch 1995) without regard to the inherent limitation of AB in concept and content (Schiaffino 2003). AB may reflect emotion situations well, likely through the accumulation of other positive, health-producing attributes or experiences (Meeks et al. 2012). AB confers a mental health advantage over time and regulates a balance that appears to be an important aspect of successful adjustment in later life (Meeks et al. 2012). Considering the unfounded positivity ratio (Brown et al. 2013) and lack of direct evidence of the impact of mechanisms of AB on longevity, further research on this aspect is needed. In addition, future studies should examine whether AB is directly pertinent to interventions to promote resilience or help older adults adapt to various life adversities (Meeks et al. 2012).

The present study revealed that cognitive and emotional facets of SWB display compelling relationships with EL. The highly consistent results not only indicate the accuracy of component measurements, but also imply a considerable advantage of EL individuals over the elderly in Rugao. High SWB in EL individuals in Rugao may be attributed to two main factors, the social environment and family care-giving resources. Rugao has been termed as a "longevity town" in China since ancient times. The local government of Rugao has provided a list of preferential care schemes for long-lived individuals. For example, the government delivers a bottle of milk each day, provides an allowance and color television, performs door-to-door physical examinations free of charge, regularly visits the long-lived individuals to extend sincere greetings and sympathies, and celebrates their birthdays. In addition, the local government has devoted a substantial body of financial and material resources to construct entertainment facilities and organizations for EL individuals. This is interesting, as Diener and his colleagues argued that a good society is one offering the most SWB to the greatest number of its citizens (Diener 2012). On the other hand, our prior investigation (Cai et al. 2009) showed that approximately 94 % of the EL subjects in Rugao lived with their offspring of three or four generations, who provided sufficient financial and spiritual support. Filial respect, a traditional virtue, is particularly emphasized in Rugao. It may be that the SWB measures used in the current study reflect the harmonious social environment and high proximity of EL individuals to offspring in Rugao, which substantially promote the high SWB of EL individuals in the famous longevity town of China.

Then, what might be the mechanisms of the association between SWB and EL? A recent review by Diener and Chan (2011) suggested two potential pathways that link SWB and longevity. They argued that the broader conception of SWB emphasizes positive emotions and attitudes over negative feelings. In terms of indirect pathways, the positive feeling affects health and longevity through its relationship with protective psychosocial and behavioral factors such as greater social connectedness, perceived social support, optimism, preference for adaptive coping responses, and a greater probability of performing healthy behaviors (Diener and Chan 2011; Fredrickson et al. 2003; Grant et al. 2009; Lyubomirsky et al. 2005; Waugh and Fredrickson 2006). The broaden-and-build theory proposed by Fredrickson (2003), resting on a strong empirical foundation that was constructed across multiple laboratories (Cohn et al. 2009; Fredrickson and Branigan 2005; Fredrickson et al. 2008), emphasizes that positive emotions broaden an individual's momentary mindset in ways that gradually reshape the individual (Garland et al. 2010). On the other hand, discussion has mainly focused on the direct pathway. Many studies have demonstrated that positive emotions/affect are associated with physiological indicators, especially those involved in cardiovascular health and immune functioning, which help interpret the effects of positive well-being on longevity (Howell et al. 2007; Marsland et al. 2006). For example, Steptoe et al. (2005) found that PA was related to reduced levels of cortisol, a key stress hormone linked to a range of risk factors for metabolic, cardiovascular, and immune diseases. In sum, further research is needed to verify whether the indirect cognitive-behavioral and direct physiological pathways underlie the association between SWB and EL.

In the current study, we employed stratification analysis to examine whether the associations of cognitive and emotional facets of SWB with EL were modified by potential confounders. We focused on physical health status due to its important effect on the relationship between psychosocial factors and health outcomes. We showed consistent associations between the components of SWB and EL in the healthy subsample but no significant associations in the nonhealthy subsample. When

comparing the effect of SWB on EL in the full sample and the healthy subsample, the results indicated that physical health status mediates the effects of SWB on EL in the Rugao population. Previous studies on related health outcomes have paid substantial attention to physical health status. For instance, Xu and Roberts (2010) and their colleagues found a similar pattern that the associations between positive predictors (SWB, PF, GLS, DLS, and PA) and mortality were stronger in the "healthy" group than in the "not healthy" group. Krijthe et al. (2011) demonstrated that the association of PA with survival might be moderated by differences in health status among the oldest old. To a great extent, the current results corroborate prior studies. However, more importantly, the present study is the first to reveal that physical health status is a mediator in the relationship between various components of SWB and EL, although this relationship seems controversial for other health outcomes (Chida and Steptoe 2008).

The present study has several strengths. First, the reasonably large sample size of EL individuals and the population-based approach allowed us to obtain credible findings. It is still a challenge to ascertain EL individuals and match population controls. However, in the current study, all cases were recruited from Rugao City, a famous longevity town of China, with a high response rate. The sample frame of our control group was also obtained from the original population of the case group and was well matched in terms of gender ratio, thus minimizing the population stratification and false positive results. The study population was relatively homogeneous in regard to environmental exposures, minimizing the selection bias for case–control matching (Cai et al. 2009). Second, we used a multiple index system to assess the cognitive and emotional facets of SWB by means of established standardized scales. Despite the current well-designed research protocol, the findings should be interpreted with caution due to the protocol's inherent limitations. First, the current design was not an experimental approach; therefore, no causal inferences can be made. Second, histories of chronic diseases were collected through self-report. However, this method is widely used. In fact, in most epidemiologic investigations, self-report is the only available measurement of chronic disease history. Compared with medical examinations, self-reports might underestimate some conditions (Goldman et al. 2003). The current study adopted the Katz Index of ADLs, which is a relatively objective measure of physical health status. Third, the present findings might not extend to other general populations due to the special culture of Rugao, as described above, and the small/moderate effect sizes (e.g., the Cohen's *d* of LS was 0.30). However, the current study highlights the potential to increase life span through the promotion of SWB among the elderly who live in an environment with protective social support and harmonious social and family relationships. The findings may be instructional and meaningful in formulating health promotion policies and programs for other populations. Finally, future advanced interdisciplinary studies are needed to finely dissect the potential mechanisms of the association between SWB and EL to promote a greater understanding of the relationship.

In conclusion, the present study found that SWB, with high cognitive and emotional facets, was associated with EL in a longevity town in China. In addition, physical health status is more likely to be a mediator of this relationship in the Rugao population. The findings imply that interventions that aim to improve elderly individuals' SWB may also promote their quality of life and, ultimately, EL.

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