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Successful aging among Chinese near-centenarians and centenarians in Hong Kong: a multidimensional and interdisciplinary approach

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Objectives: This study applied a multidimensional model on a continuum to examine successful aging (SA) and investigated whether SA is associated with biomedical and psychosocial−demographic factors among Hong Kong Chinese near-centenarians and centenarians.
Method: A cross-sectional data analysis was performed on a geographically representative sample of 120 near-centenarians and centenarians with an age range of 95−108 years. We developed an integrated and cumulative Successful Aging Index (SAI) based on participants' performance in four dimensions: (1) physical and functional health (PF), (2) psychological well-being and cognition (PC), (3) social engagement and family support (SF), (4) economic resources and financial security (EF). To examine the criterion validity of SAI, we conducted a multiple binary logistic regression with interviewer-rated health. A multiple regression model was ran to investigate the independent biomedical and psychosocial−demographic correlates of SAI.
Results: Results show that only 5.8% of participants attained SA in all four dimensions. PF had the least achievers, whereas the proportion was the highest in PC. SAI was significantly associated with interviewer-rated health and a high level of high-density lipoprotein cholesterol. Living with family or friends, high level of optimism, fewer diseases, and barriers to social activities were independent predictors of SAI score.
Conclusion: In the light of the lack of consensus on the constituents and assessment of SA especially among very old adults, our findings add to the extant literature by underscoring the importance of the multidimensional nature and the utility of an integrated and cumulative-based assessment of SA at the extreme of longevity.

Keywords: centenarians; Hong Kong SAR; successful aging; healthy longevity; well-being

Introduction

In the recent decades, researchers have observed a continuous deceleration of old-age mortality, alongside with the proliferation of centenarians (Vaupel, 2010). According to the United Nations projection (2013), the world's population of oldest-olds (80+) will increase sevenfold, from 120 million in 2013 (14% of the total population), to 392 million in 2050 (19%), and to 830 million in 2100 (28%). Hong Kong is no exception. In 1980−2010, the oldest-old population has expanded approximately at 6.0% per annum (Cheung et al., 2012), and has been projected to grow from about 246,100 in 2010 (3.5% of the total population) to 956,800 in 2041 (11.3%). The number of centenarians has also increased fourfold, from 289 in 1981 to 1890 in 2011 (Census and Statistics Department HKSAR, 2012). The emergence of centenarians has sparked interest not only locally in an urge to study the social and health profile of the oldest-old population (Ho & Woo, 1994), but also internationally in the search of the limit of human longevity (Kannisto, 1988; Robine, Saito, & Jagger, 2003; Thatcher, 2001; Vaupel & Jeune, 1995). To the best of our knowledge, no study on centenarians has, however, been conducted in Hong Kong, a place with one of the most rapidly aging populations and the longest life expectancies.

Centenarians were frequently connoted as the sickest and frailest group in many disciplines from genetics to social sciences (Perls, 2004) in part due to the focus on biomedical research in the study of aging, whereas they may well represent the prototype of successful aging (SA) (Jeste, 2005). Inspecting the health history of centenarians, Hitt, Young-Xu, Silver, and Perls (1999) reported that these healthy survivors tend to embrace a life-long history of successful adjustment to physical aging. Many centenarians have victoriously escaped or delayed life-threatening diseases (Evert, Lawler, Bogan, & Perls, 2003; Jeune, 2002) and postponed the onset of cognitive impairment (Perls, 2004; Poon et al., 2011) and suffered from only a modest decline in functioning (Andersen-Ranberg, Schroll, & Jeune, 2001; Christensen, McGue, Petersen, Jeune, & Vaupel, 2008; Gondo et al., 2006).

In terms of psychosocial well-being, many very old adults make use of various coping strategies and salubrious lifestyles (Baltes, 1997; Du, 2008; Rajpathak et al., 2011), and are selective in their social engagement and avoid conflict (Jopp & Rott, 2006). They also tend to be high in emotional stability and self-security (Buono, Urciuoli, & De Leo, 1998; Martin, 2008; von Faber et al., 2001) and possess a spirit of stoicism (Hutnik, Smith, &

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Koch, 2012) despite the increasing constraints in their daily lives due to physical limitation. The result is often a comparable level of life satisfaction, resilience, optimism, and happiness compared to their younger counterparts (Darviri et al., 2009; Jeste et al., 2013; Scheetz, Martin, & Poon, 2012; Zeng & Vaupel, 2002). Although social support is pivotal to psychological adjustment among very old adults (Bishop, Martin, MacDonald, & Poon, 2010; Tafaro et al., 2002), centenarians tend to report less social support, including social provisions and social resources, compared to their younger counterparts (Randall, Martin, MacDonald, & Poon, 2010).

Asian elders are more likely to regard family support and financial security as important to their idea of SA compared to the elderly of Western cultures (Hung, Kempen, & De Vries, 2010). Family support was found to be important for both happiness and subjective health among Chinese centenarians and oldest-olds (Deng, Hu, Wu, Dong, & Wu, 2010; Wong et al., 2014). These long-lived family members are also often seen as the symbolic anchors of family and cultural traditions (Yang, 2010). For many older people, financial strain is also a major source of chronic worry which may have negatively impacted their life satisfaction and psychological well-being (Chou & Chi, 2002a, 2002b; Chou, Chi, & Chow, 2004). Financial security, indicated by having enough money to pay for daily expenses and having a relatively financially satisfactory household, can provide an extended sense of security for the elderly, especially for confronting increases in socio-medical care costs.

Multidimensional models of successful aging

SA has been subject to numerous definitions (Bowling, 2007; Bowling & Dieppe, 2005; Depp & Jeste, 2006; Glass, 2003; Ji, Ling, & McCarthy, 2014; Phelan & Larson, 2002; Young, Frick, & Phelan, 2009) ever since the seminal term has been proposed by Havighurst (1961), who also vividly coined the notion of 'adding life to the years.' Rowe and Kahn (1987) subsequently recommended that research should devote greater effort in describing the heterogeneous population who has successfully escaped from pathological aging. Baltes and Baltes (1990) highlighted the importance of psychological and behavioral strategies and presented SA as an adaptive process of selection, optimization, and compensation strategies.

Based on Rowe and Kahn's model (1997), SA which was operationally defined as the absence of disease and disability, maintenance of a high degree of physical and cognitive functioning, and meaningful engagement in life, appears to be the privilege of younger elders. Declines in physical health and functional capacity tend to be age-associated, with younger elders having less physical disability and greater functional independence than older elders (Buono et al., 1998; Zeng & Vaupel, 2002). Accordingly, numerous studies have found that age is one of the most robust predictors of SA (Depp & Jeste, 2006; McLaughlin, Connell, Heeringa, Li, & Roberts, 2010; Pruchno, Wilson-Genderson, & Cartwright, 2010), with older elders showing poorer performance in different SA measures than did younger elders.

Some researchers have, however, called for adopting different conceptual models of SA to different age groups (Grundy & Bowling, 1999; Jeste et al., 2013; Nosraty, Sarkeala, Hervonen, & Jylhä, 2012). Models that place more emphasis on intact physical functions and absence of diseases may be less relevant to the oldest-old population as these criteria will often render an excessively small proportion of successful agers (Cho, Martin, & Poon, 2012; McLaughlin et al., 2010; Motta, Bennati, Ferlito, Malaguarnera, & Motta, 2005). Instead, models that take into account of the psychological adjustments to physical declines and positive psychological traits may serve the population better (Jeste et al., 2013), as SA may coexist with diseases and functional limitations especially when an individual's compensatory psychological and social mechanisms are considered (Young et al., 2009). The differences between the objective indicators (e.g., lack in family and friends, activities of daily living (ADLs) limitations) and the subjective measures (e.g., perceived quality of life, happiness) increase the status of these long-lived individuals to resilient survivors (Martin, MacDonald, Margrett, & Poon, 2010). The disparity between objective and subjective measures of SA had already been reported in previous studies with younger populations (Cernin, Lysack, & Lichtenberg, 2011; Pruchno et al., 2010; Strawbridge, Wallhagen, & Cohen, 2002), but sparsely used for the very old adults (except for Cho et al., 2012). Specifically, psychological well-being, family support, and financial security should be considered as the criteria for SA alongside with physical health and intact daily functioning, based on both subjective and objective indicators.

The field tends to agree that SA should be defined by a multidimensional approach (Bowling & Dieppe, 2005; Cosco, Prina, Perales, Stephan, & Brayne, 2013; Depp & Jeste, 2006; Glass, 2003; Vaillant & Mukamal, 2001). The terms, 'multidisciplinary' and 'interdisciplinary,' are often used interchangeably (Ferraro, 2007). The former refers to different areas of academic inquiry where multi-disciplinary boundaries are maintained and the unique contributions of each are highlighted, while the latter grapples with the multi-faceted nature of the aging process where multi-disciplinary boundaries are transcended and the joint contributions of specific disciplines are synthesized (Ferraro & Chan 1997; Wilmoth & Ferraro, 2007). A handful of studies have looked at multidimensional SA among Chinese (Chou & Chi, 2002a; Feng, Son, & Zeng, 2015; Ng, Broekman, Niti, Gwee, & Kua, 2009; Ng et al., 2011). Some of them (Chou & Chi, 2002a; Ng et al., 2009) have studied oldest-old adults. Chou and Chi (2002a) used four dimensions to examine SA among Hong Kong Chinese elders in three different age cohorts: young-old, old-old, and oldest-old. However, the same model was used over the three age groups and those aged 80 and above were arranged as one age group without considering the heterogeneity of oldest-olds and centenarians. Ng et al. (2009) created a composite SA

measure by forming a dichotomous variable based on cognitive and affective status, physical health, social functioning and engagement, and life satisfaction among Chinese elderly aged 65 years and above in Singapore. Both studies highlighted the suitability of a multidimensional definition of SA over more restricted biomedical definitions for Chinese very old elderly.

Multidimensional SA models have also been applied on nonagenarians and centenarians, despite being limited. Nosraty et al. (2012) investigated SA and applied six different models that encompass three components (physical, social, and psychological), and they found that the prevalence of SA changes depending on the criteria used. SA in the physical component was relatively hard to achieve (SA: 5.3%−25.2%), compared to the psychological (20%) and social (75%) components. In particular, the absence of disease was the most demanding criterion for their sample.

Cho et al. (2012) used Rowe and Kahn's successful aging model including the probability of disease, physical or cognitive capacity, and engagement with life and showed that none of their American centenarian participants achieved the stringent criteria of Rowe and Kahn (1997), whereas a second alternative model focused on psychosocial aspects including three different components: subjective health, perceived economic status, and happiness as they proposed. A total of 62.3% of octogenarians and 47.5% of centenarians were categorized as successful agers according to their revised criteria (favorable subjective health and economic status, and high levels of happiness). This study demonstrates the effectiveness of describing SA of centenarians beyond biomedical and functional aspects. However, a model of such has yet to be adopted among the increasing population of Asian centenarians.

The current study

Despite the declines in physical health and functioning, many centenarians maintain a positive outlook on life and a meaningful social life (Darviri et al., 2009; Jeste et al., 2013; Jopp & Rott, 2006; Wong et al., 2014; Yang, 2010; Zeng & Vaupel, 2002). Especially in Asia, elders tend to believe that family support and financial security are indispensable components of SA, in addition to good physical, functional, and psychological health (Hung et al., 2010). This illustrates the need to reconsider whether SA models that heavily emphasize physical health and intact functioning are able to reflect what is important for a 'good life' for very long-lived adults (Freund, Nikitin, & Riediger, 2012). Previous studies have also called for the assessment of SA on a continuum and the clear distinction between predictors and constituent variables of SA (Bowling, 2007; Cosco, Stephan, & Brayne, 2014). Research that tests a multidimensional model of SA on nonagenarians or even centenarians (except for Nosraty et al., 2012) based on subjective and objective measures (see Cho et al., 2012 for exception) remains scarce. In this light, the current study aimed at examining a multidimensional model of SA with a cumulative and integrated base alongside with both subjective and objective indicators and exploring the correlates of SA among near-centenarians and centenarians in Hong Kong.

Methods

Sampling and procedures

The Hong Kong Centenarian Study (HKCS) was piloted in 2010 (Cheung et al., 2012). The entire study included 153 Chinese elders who were born in 1905−1915 and were interviewed between April and September in 2011. A quota sampling method was used according to the proportion of elders aged 85 or above by the 18 Geographical Constituency Areas (GCAs), in order to recruit a geographically representative sample. Eligible elders were recruited based on two social and clinical networks. The details of the sampling and procedures have been published elsewhere (Kwan, Lau, & Cheung, 2015). Out of the 153 participants, 102 participants participated in blood test. All blood test records were accredited and verified by chemical pathologists and a geriatrician. This study was approved by the Human Research Ethics Committee for Non-Clinical Faculties of the University of Hong Kong in January 2011 (Reference Number: EA200111) and by the Ethics Committee of the Department of Health (Reference Number: L/M 48/2011 in DHHQ/5030/5/5) in May 2011.

Measuring successful aging

Based on previous works (Cho et al., 2012; Chou & Chi, 2002a; Ng et al., 2009), we adopted a multi-dimensional model with subjective and objective measures to examine SA among Hong Kong Chinese centenarians. SA will be measured by four dimensions, namely: (1) Physical and functional health (PF), (2) Psychological well-being and cognition (PC), (3) Social engagement and family support (SF), and (4) Economic resources and financial security (EF). Each dimension was indicated by two indicators with equal weight. Subjective indicators including self-rated health, depressive symptoms, perceived household economic status, and sufficiency of income for daily expenses were used. Objective indicators included independence in ADL, cognition, frequency of social activities, and presence of spousal and children confidants. A numeric score on a newly integrated Successful Aging Index (SAI) was introduced to assess participants' cumulative attainment of SA. A score of 1 will be awarded to the participant if they provide a response in one SA indicator that demonstrates physical, psychosocial, or economic well-being (e.g., having favorable subjective health, having a spousal/children confidant, or economically better off). If the participant provides a response to an indicator that demonstrates ill-being in physical, psychosocial, or economic dimensions (e.g. having poor subjective health, not having a spousal/children confidant, relatively poor in the economic status of their household), he/she will receive a zero for the indicator of each. With eight indicators across the four dimensions, SAI ranges

from 0 to 8. A score of 8 reflects all-rounded SA, whereas a score of 0 indicates not attaining SA in any indicator. In addition, to be regarded as attaining SA in a particular dimension (e.g., PF), participants need to fulfill SA in both indicators of that dimension (i.e., good self-rated health and ADL independence).

Physical and functional health (PF)

In the light of the ubiquity of chronic diseases among near-centenarians and centenarians (Andersen-Ranberg et al., 2001; Cho, Martin, Margrett, MacDonald, & Poon, 2011; Gondo et al., 2006), we used subjective health as an indicator of the physical health of participants. Numerous studies have shown that subjective health is a valid reflection of objective physical health and a potent predictor of mortality and morbidity (Idler & Benyamini, 1997; Jylhä, 2009). We assessed participants' perceptions of their overall health by the question 'how do you rate your current health,' using a five-point scale, with 1 = very bad, to 5 = very good. Functional independence was measured by whether participants could handle six ADLs (bathing, dressing, toileting, indoor transfer, continence, and eating; $\alpha = .77$; Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963) without difficulty independently. For instance, for toileting, independence refers to going to the toilet and cleaning oneself afterwards without assistance (may use object for support, e.g. cane, walker, or wheelchair). We totaled the number of tasks which required assistance to derive the overall dependency score. Participants were considered as aging successfully if they had 'good' or 'very good' subjective health and were independent on all six ADLs.

Psychological well-being and cognition (PC)

PC was grouped into one dimension in the light of the high rate of co-occurrence of depression and dementia among very old adults (Fichter, Meller, Schroppel, & Steinkirchner, 1995; Krishnan et al., 2002). The fear of memory loss is integral to the depression experience of centenarians (Scheetz et al., 2012), while depressive symptoms and anxiety are common emotional symptoms of dementia (Roth et al., 2003). Psychological well-being was assessed with a 15-binary-item Geriatric Depression Scale-Short Form (Nyunt, Fones, Niti, & Ng, 2009; Sheikh & Yesavage, 1986) which consists of two dimensions: positive affect and negative affect. Participants were asked to rate the following statements for positive affect. During the past two weeks, (1) Are you basically satisfied with your life? (2) Are you in good spirits most of the time? (3) Do you feel happy most of the time? (4) Do you think it is wonderful to be alive? (5) Do you feel full of energy? For negative affect, the following statements were asked. (1) Have you dropped many of your activities and interests? (2) Do you feel that your life is empty? (3) Do you often get bored? (4) Are you afraid that something bad is going to happen to you? (5) Do you often feel helpless? (6) Do you prefer to stay at home, rather than going out and doing new things? (7) Do you feel you have more problems with memory than most people? (8) Do you feel pretty worthless the way you are now? (9) Do you feel that your situation is hopeless? (10) Do you think that most people are better off than you are? The scale has shown satisfactory reliability in the current sample ($\alpha = .88$). Lower scores indicated better well-being and less depression, while higher scores indicated poorer well-being and a higher level of depression. Cognition was measured by a Chinese version of the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975; Zeng & Vaupel, 2002). Participants were awarded a score of 1 for a correct answer and 0 for an incorrect answer. The maximum score was 30. Participants who attained a GDS score of 5.00 or less (Lim et al., 2000) and an MMSE score of 21 or more (Chiu, Lee, Chung, & Kwong, 1994) were considered aging successfully.

Social engagement and family support (SF)

Social engagement has been understood as an important component for SA (Rowe & Kahn, 1997) and tends to predict lower perceived stress, fewer depressive symptoms, and better life satisfaction (Fuller-Iglesias, 2015). Participants were asked how often they engage in social activities such as church events, family gatherings, and club gatherings. They were considered as socially active if they engaged in social activities once a week or more frequently. For family support, participants were asked whether they have a spouse or child to confide with if they need emotional support, on a binary scale (yes/ no). SA was indicated by weekly social activities and the presence of a spouse or child as confidant.

Economic resources and financial security (EF)

In the light of the importance of financial security for the well-being of Hong Kong elders (Cheng, Chi, Boey, Ko, & Chou, 2002; Chou & Chi 2002b; Chou et al., 2004; Hung et al., 2010), we added the economic resource and financial security dimension into the model. Participants were asked to evaluate how the economic status of their household compares with an average household in Hong Kong. For financial security, participants were asked whether they have enough money to pay for their living expenses (such as their needs in food, medical services, and daily expenses), using a yes/no scale. Participants who attained SA in this dimension were those who regarded their households as better off than the average and had sufficient money to pay for their living expenses.

To provide evidence to support the construct validity of SAI, we examined its association with interviewer-rated health (IRH). It captures similar health information as subjective health (SH) and is strongly predictive of mortality independent of SH. Thus, IRH could be a good supplementary measurement to the well-adopted SH and well-being measures (Feng, Zhu, Zhen, & Gu, 2015). We also explored the correlates of SA among Hong Kong Chinese near-centenarians and centenarians by investigating the associations between SAI and biomedical and psychosocial−demographic factors. We expected SAI to be

positively associated with IRH. Biomarkers, physical health (number of diseases), functional health (handgrip strength), personality (optimism), socio-environmental (barriers to social activities), and demographic (living arrangement, education attainment) correlates of SAI were also investigated. Since SAI is intended to measure successful adaptation to aging, SAI was expected to be positively associated with better physical and functional well-being (fewer diseases, higher handgrip strength) and more salutary psychosocial characteristics (higher optimism, less barriers to social activities, living with family, higher education). In the light of the scarcity of research on the relationship between specific biomarkers and SA among near-centenarians and centenarians, we did not set a priori predictions for specific biomarkers. The current analysis was based on a subset of 120 participants who provided valid responses on all eight indicators of SAI, with 83 participants participated in the blood test.[1]

Interviewer-rated health

Interviewers were asked to rate the health condition of the participants on four ordinal options: *very frail*, *relatively frail*, *relatively healthy*, and *very healthy* (Zeng, 2008). In the current study, for conducting logistic regression with IRH as the outcome variable, participants in the categories of *very frail*, *relatively frail*, and *relatively healthy* were grouped together and were coded as 0 (58.3%), whereas participants in the *very healthy* category were coded as 1 (36.7%).

Biomedical and psychosocial–demographic correlates of Successful Aging Index (SAI)

Biomedical measures

Thirty-three biomarkers, including full blood cell count, kidney and liver functions, C-reactive protein, HbA1c (glycated hemoglobin), cholesterol, triglycerides, and albumin, were assessed with a blood draw. We also counted the number of medically diagnosed diseases reported by the participants. They were asked wether they are currently suffering from any of a list of 30 diseases diagnosed by hospital, including cerebrovascular accident/stroke, congestive heart failure, cornonary heart disease, hypertension, arrhythmia, Alzheimer's disease, pneumonia, urinary tract infection (in the past 30 days), cancer (exlcuding skin cancer) in the past five years and diabetes. The most common diseases were cataract (79.2%) and hypertension (62.5%). Only three participants (2.5%) had suffered from cancer in the past five years, while 23 participants (19.2%) suffered from congestive heart failure or coronary heart disease. Handgrip strength, which is an important predictor of disability, cognitive function, frailty and mortality among old people (Franke, Margrett, Heinz, & Martin, 2012; Jeune et al., 2006), was measured by a handgrip dynamometer (Takei Kiki Kogyo TK-1201) under standard conditions trained by a clinical exercise specialist (ACSM-CES certified). Participants who were not able to understand or carry out the instruction (e.g., some of the bedridden participants) were excluded. The maximum value in kilograms of three trials of both hands was selected for the analysis.

Psychosocial–demographic measures

Optimism was found to predict survival up to 12 years among Danish nonagenarians (Engberg et al., 2013). The personality variable was measured by asking participants the extent to which they can 'look on the bright side of things,' with a five-point scale running from 1 (very much cannot) to 5 (very much can) (Zeng, 2008). For social–environmental variable, participants were asked to express how much they agree that each of the ten barriers were interrupting their social activities. These barriers included mobility and health problems, lack of toilet facilities, lack of company, difficulties with logistics, transportation problems, (the venues being) too noisy, difficulties in allocating time for the activities, financial burdens, lack of attractive activities, and lack of a variety of suitable activities, with response scales ranging from 'agree' to 'strongly agree.' For demographic variables, we examined gender (female = 0; male = 1), age, living arrangement, and education attainment as independent correlates of SA. Living arrangement was represented by three categories: living with family members or friends, living alone, and living in a care facility. Two dummy variables were constructed by making living with family members or friends the reference category. Regarding education attainment, we asked participants the number of years of formal education they have received. Answers were recoded (0 = none, 1 = 1–6 years, 2 = 7 years or more). The data analysis was conducted with SPSS 19 statistical software.

Results

Sample characteristics

Participants were predominantly female (74.2%), with an age range of 95–108 years. Most participants were born in the mainland China (84.2%) and in a rural area (60.8%). The average year of education was 2.88 (SD = 4.25), with half of them having received no schooling at all (50.8%). Most of them were widowed (80.8%). Half of the sample was living with their family members or friends (53.3%). The average number of household members other than the participant was 1.93 (SD = 1.43). 31.7% were living alone, and 15.0% were living in a care facility.

Compared to the 33 participants who were not included in the current analysis because they were unable to provide valid information on indicators of SAI, the 120 participants in the current sample were more likely to be male, $\chi^2(1) = 4.20$, $p = .040$, received some education, $\chi^2(1) = 5.99$, $p = .014$, and possess a higher level of optimism, $t(33) = 2.44$, $p = .020$. They were also more likely to be regarded as healthy by the interviewers, $\chi^2(1) = 6.82$, $p = .009$. The two groups of participants did not differ on age, living arrangement, number of diseases, handgrip strength, and number of social activities barriers.

Successful Aging Index (SAI)

Descriptive statistics of SAI, and correlates are presented in Table 1.

The eight indicators were all significantly and moderately associated with the SAI scale score [*r*s = .25 (financial sufficiency) to .58 (social activities)]. The four SA dimensions were relatively independent from each other. Out of the six associations, only one was statistically significant – PF and EF (see Table 2).

Table 3 shows the proportion of participants counted as aging successfully (i.e., successful agers) in each of the four dimensions. PC had the greatest proportion of successful agers, followed by SF, EF, and PF.

Figure 1 shows the number of participants in all combinations of SA dimensions. Among the 120 participants, only a minority (5.8%) attained SA in all four dimensions. Most participants, however, achieved SA in one to two dimensions [one dimension total: $n = 41$ (34.2%), including PF ($n = 4$, 3.3%), PC ($n = 31$, 25.8%), SF ($n = 2$, 1.7%), and EF ($n = 4$, 3.3%); two dimensions total: $n = 42$ (35.0%), including PF + PC ($n = 7$, 5.8%), PF + EF ($n = 2$, 1.7%), PC + SF ($n = 17$, 14.2%), SF + EF ($n = 4$, 3.3%), PF + SF ($n = 2$, 1.7%), and PC + EF ($n = 10$, 8.3%)]. Among those who have fulfilled three dimensions ($n = 14$, 11.7%), most accomplished by demonstrating SA in PF, PC, and EF ($n = 6$, 5.0%). Sixteen participants (13.3%) did not fulfill any dimension. The mean (*SD*) of SAI was 5.06 (1.56).

Table 1. Descriptive statistics of indicators of SA, SAI, and correlates.

Indicators of SA	*n* (%)
(1) PF dimension	
Good/very good subjective health	48 (40.0)
ADL independence	73 (60.8)
(2) PC dimension	
GDS ≤ 5.00	101 (84.2)
MMSE ≥ 21	97 (80.8)
(3) SF dimension	
Weekly social activities	64 (53.3)
Spouse/child as confidant	75 (62.5)
(4) EF dimension	
Well-off/slightly well-off	43 (35.8)
Income sufficient for affording daily living	106 (88.3)
Correlates of SA	***n* (%)/*M* (*SD*)**
Female gender	89 (74.2)
Age	97.66 (2.26)
Living arrangement	
Living alone	38 (31.7)
Living with family	64 (53.3)
Living in a care facility	18 (15.0)
Education attainment	
No education	61 (50.8)
1–6 years of education	44 (36.7)
More than 6 years of education	15 (12.5)
No. of self-reported diagnosed diseases	2.98 (1.87)
Handgrip strength in kilogram[a]	15.42 (6.03)
Barriers to social activities[b]	2.13 (1.90)
Optimism	4.52 (0.78)
SAI	5.06 (1.56)
Interviewer-rated health	3.27 (0.66)

Notes: $N = 120$, unless otherwise stated. SA = successful aging, PF = physical and functional health, ADL = activities of daily living, PC = psychological well-being and cognition, GDS = Geriatric Depression Scale, MMSE = Mini-Mental State Examination, SF = social engagement and family support, EF = economic resources and financial security, SAI = Successful Aging Index.
[a]Two participants did not provide their handgrip strength data.
[b]One participant did not provide data on social activities barriers.

Table 2. Spearman's ρ correlations among the four SA dimensions ($N = 120$).

	PF	PC	SF
PC	.02		
SF	.07	.10	
EF	.24**	.02	.15

Note: PF = physical and functional health; PC = psychological well-being and cognition; SF = social engagement and family support; EF = economic resources and financial security.
**$p < .01$.

Association with interviewer-rated health

To examine the association between SAI and IRH, we conducted a binary logistic regression with IRH as the criterion variable, SAI as the predictor variable, and controlled for age, gender, and living arrangement. The regression result shows that SAI was significantly associated with IRH after controlling for the effects from demographic variables (OR = 2.40, 95% CI = 1.62–3.56; see Table 4). No demographic variables were significantly associated with IRH.

Association with biomarkers

We first examined the association between SAI and the 33 biomarkers using bivariate correlations.[2] However, none of the associations was significant (*r*s < .14, *p*s > .20). We subsequently re-ran the bivariate correlations by partialing out the effects of age and gender. SAI is positively associated with the levels of high-density lipoprotein cholesterol [sample mean (*SD*) in mg/dL = 1.43 (0.43), $r = .24$, $p = .026$]. Higher SAI was associated with elevated levels of high-density lipoprotein cholesterol.

Association with demographic, physical health, functional health, and psychosocial characteristics

Female participants ($M = 4.80$, $SD = 1.55$) had a significantly lower SAI than male participants ($M = 5.81$, $SD =$

Table 3. Proportion of successful agers in SA dimensions ($N = 120$).

Dimension	Successful agers; *n* (%)
Physical and functional health (PF)	31 (25.8)
Psychological well-being and cognition (PC)	85 (70.8)
Social engagement and family support (SF)	40 (33.3)
Economic resources and financial security (EF)	39 (32.5)

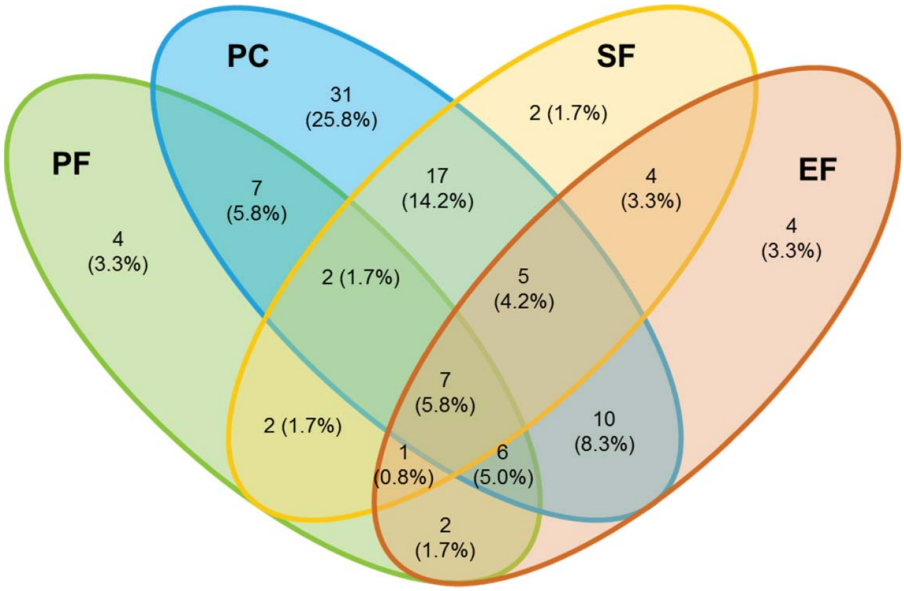

Figure 1. Number of participants fulfilling SA for each combination of the four dimension ($N = 120$). PF = physical and functional health; PC = psychological well-being and cognition; SF = social engagement and family support; EF = economic resources and financial security.

1.38), $t(119) = 3.21$, $p = .002$. Participants living in different arrangements also had significantly different SAI, $F(2,117) = 6.65$, $p = .002$. *Post hoc* comparison with Bonferroni adjustment suggests that participants living with family or friends ($M = 5.50$, $SD = 1.38$) had a significantly higher SAI than participants living in a care facility [$M = 4.22$, $SD = 1.22$, mean difference (SE) = 1.28 (0.40), $p = .005$] or living alone [$M = 4.71$, $SD = 1.77$, mean difference (SE) = 0.79 (0.31), $p = .033$]. SAI of participants living in a care facility and those of participants living alone were not significantly different ($p = .766$). Individuals having a higher level of education attainment also tended to possess a higher SAI score ($\beta = .19$, $t = 2.10$, $p = .038$). Table 5 shows the Pearson's correlations among SAI, its indicator, and age, education, number of diseases, handgrip strength, number of barriers to social activities, and optimism. Higher age, fewer diseases, greater handgrip strength, fewer barriers to social activities, and a higher level of optimism were significantly associated with higher SAI.

We ran a multiple regression model to examine which of the above-mentioned correlates were independent correlates of SAI. Age, gender, living arrangement, education attainment, number of diseases, handgrip strength, barriers to social activities, and optimism were entered simultaneously into a regression model as predictor variables. SAI was entered as the criterion variable. The model explained 33.6% (adjusted $r^2 = .28$) variance of SAI, and was statistically significant, $F(9,108) = 6.06$, $p = .000$. Significant regression coefficients were found for the two living arrangement dummy variables, diagnosed diseases, barriers to social activities, and optimism. Relative to participants who were living with their family members or friends, participants who were living alone or in a care facility tended to have lower SAI. Possessing fewer diseases, experiencing fewer barriers to social activities and having a higher level of optimism were associated with higher SAI (see Table 6).

Discussion

This study examined SA among Hong Kong Chinese near-centenarians and centenarians based on a multidimensional model and a continuum-based measurement. Following an interdisciplinary approach, SAI evaluates SA through multiple dimensions including PF, PC, SF, and EF. Results show that these dimensions were relatively independent from each other, supporting the notion that SA is a multidimensional phenomenon. Aligning with previous findings on centenarians (Cho et al., 2012;

Table 4. Result of the binary logistic regression on interviewer-rated health ($N = 114$).

	Wald	OR (95% CI)	p
Constant	0.67	.00	.413
Gender	0.19	1.23 (0.46−3.41)	.664
Age	0.10	1.03 (0.86−1.24)	.755
Living alone (Ref. = living with family)	1.64	0.52 (0.19−1.41)	.201
Living in a care facility (Ref. = living with family)	0.05	0.85 (0.20−3.57)	.826
SAI	18.77	2.40 (1.62−3.56)	.000
Model summary: χ^2 (5) = 30.74, $p = .000$; −2Log likelihood = 121.32.			

Note: SAI = Successful Aging Index. Interviewer-rated health was not available for six participants.

Table 5. Pearson's correlations between SAI and correlates.

	SAI	SH	ADL	GDS	MMSE	SA	CF	SES	FS	AGE	EDU	DIS	HGS[a]	SB[b]
SH	.48**													
ADL	.44**	.06												
GDS	.43**	.12	−.02											
MMSE	.37**	−.12	.04	.19*										
SA	.58**	.18*	.28**	.19*	.22*									
CF	.39**	.00	.01	.09	.02	.00								
SES	.51**	.31**	.07	.04	−.08	.11	.15							
FS	.25**	−.02	−.08	.06	.22*	−.08	.04	.06						
AGE	.18	.13	.12	.11	−.06	.04	.02	.21*	.01					
EDU	.19*	.06	−.05	−.01	.22*	.01	.17	.21*	.06	.07				
DIS	−.26**	−.20*	−.20*	−.11	.05	−.10	.01	−.25**	−.10	−.24**	.05			
HGS	.34**	.14	.25**	.17	.20*	.18*	.17	.15	−.14	.00	.16	−.04		
SB	−.23*	−.13	−.11	−.21*	−.03	−.25**	.00	−.08	.03	.00	−.05	.00	−.20*	
OP	.29**	.20*	.27**	.29**	.13	.15	.05	.02	−.13	.10	.00	−.12	.28**	−.04

Notes: $N = 120$, unless otherwise stated. SAI = Successful Aging Index; SH = subjective health (0 = mediocre/poor/very poor; 1 = good/very good); ADL = independence in activities of daily living (0 = independent on all six ADLs; 1 = dependent on at least one ADL); GDS = Geriatric Depression Score (0 = score > 5.00; 1 = score ≤ 5.00); MMSE = Mini-Mental State Examination Score (0 = score < 21.00; 1 = score ≥ 21.00); SA = social activities (0 = less frequent than weekly; 1 = weekly or more frequent); CF = presence of spousal/children confidant (0 = absence of confidant; 1 = presence of confidant); SES = economic resources (0 = poorer than average/so-so; 1 = better than average); FS = financial sufficiency (0 = insufficient; 1 = sufficient); EDU = education attainment (0 = no education; 1 = 1−6 years of education; 2 = 7 years or more); DIS = number of diseases; HGS = handgrip strength in kilograms; SB = barriers to social activities; OP = optimism.
[a]Two participants did not provide their handgrip strength data.
[b]One participant did not provide data on social activities barriers.
*$p < .05$; **$p < .01$.

Table 6. Result of the multiple regression with SAI as the criterion variable.

	B	*SE*(*B*)	*β*
Constant	−1.48	5.65	
Gender	.06	.41	.02
Age	.05	.06	.07
Living alone	−.67	.28	−.20*
Living in a care facility	−.83	.38	−.19*
Education attainment	.36	.20	.16
No. of diseases	−.15	.07	−.18*
Handgrip strength[a]	.05	.03	.18
Barriers to social activities[b]	−.14	.07	−.17*
Optimism	.44	.18	.22*
Model summary			
r^2		.35	
Adjusted r^2		.30	
$\triangle F$		6.79**	

Notes: $N = 118$. SAI = Successful Aging Index. List-wise deletion was adopted. Controlling for age and gender, only one biomarker (high-density lipoprotein cholesterol, HDLC) was found to be significantly related to SAI. We also ran the multiple regression model by including HDLC as a predictor variable alongside existing predictor variables (e.g., age, gender, education, etc.). The resultant model was significant $F(10,76) = 4.51$, $p = .000$, $r^2 = .37$, adjusted $r^2 = .29$. However, due to the small sample size for blood test, the sample size for the regression model reduced from 118 to 87. Significant predictors reduced to only no. of diseases ($\beta = -.22$, $p = .030$). In the light of the much reduced sample size, we opted for removing high-density lipoprotein cholesterol from the regression analysis.
[a]Two participants did not provide their handgrip strength data.
[b]One participant did not provide data on social activities barriers.
*$p < .05$; **$p < .01$.

Gondo et al., 2006), our participants found it hardest to fulfill the SA criteria for the PF dimension. The PC dimension, however, was the easiest to fulfill. The results also provide support for the presence of psychological resilience and cognitive reserve among very long-lived adults, which may reflect coping resources against prospective and concurrent physical declines and functional limitation (Darviri et al., 2009; Jopp & Rott, 2006).

Although only a small proportion of participants fulfilled all four dimensions of SA (5.8%), 86.7% participants achieved SA on at least one dimension. This resonates with the call from Cosco et al. (2014) regarding the use of a continuum-based measurement in order to capture intricate but substantial individual differences in fulfilling SA. SAI was also significantly but moderately associated with interviewer-rated health, which provides support to its criterion validity. For biomarkers, SAI was related to greater high-density lipoprotein cholesterol which tends to be related to better cognitive capacity (Atzmon et al., 2002) and lower risks of coronary heart disease (Barbagallo et al., 1998). This pattern of associations provides support to the validity of SAI as an indicator of favorable health. However, we agree with Hausman, Fischer, and Johnson (2012) that biomarkers results must be interpreted with caution, as they can be confounded by factors including genetic characteristics, diseases, and concurrent medications.

SAI was also predicted by variables of different life dimensions. It was robustly associated with demographic (gender, living arrangement, education attainment), physical health (number of diseases), functional health (handgrip strength), personality (optimism), and socio-environmental

(barrier to social activities) variables. The multiple regression model results show that living with family members or friends, possessing fewer diseases, experiencing fewer barriers to social activities, and having a higher level of optimism were independent correlates of SA. This echoes Moreno et al. (2014) results that elderly who have achieved SA tend to possess more psychosocial resources, especially those associated with their living conditions. Our findings underscore the role of bio-psychosocial demographic characteristics in the achievement of SA for Hong Kong Chinese near-centenarians and centenarians, and may be useful to guide health care research, nursing practice, and healthy aging policy. For instance, to facilitate SA among the oldest-old population, elderly centers and medical practitioners in the community may encourage elders and soon-to-be-old individuals to engage in cognitively stimulating activities and regular physical exercises to manage non-communicable diseases (e.g., cardiovascular diseases) and frailty, and preserve cognitive ability. Policies that promote intergenerational support and residence in the proximity may help retain social resources and enhance psychological well-being of elderly, and therefore are imperative to facilitating SA across populations.

This study has several limitations that should be noted. The main limitations include the limited sample size and use of cross-sectional data. Compared to the excluded participants, participants included in the current analysis tended to be more optimistic, better educated, and were judged to be in better health by the interviewers. Future studies are encouraged to replicate the current model in a larger sample with more balanced gender ratio and greater heterogeneity in physical and psychosocial well-being. SA can be conceived as a life-long, dynamic process, involving preparations and choices at different stages of life (e.g., adulthood, middle-aged, and young-old). The cross-sectional nature of the current dataset may have constrained longitudinal investigation on the SA process. Causal inferences may also be tested when longitudinal data are available. Furthermore, a mixed-method approach could be well-adapted to comprehensively capture the meaning, antecedents, and processes of SA in order to validate existing models and measures. The current study assumed all indicators and dimensions carry the same weight toward SA. Qualitative studies which delve into the evaluation process of one's SA could be helpful in clarifying the priorities of different components. The use of qualitative research on lay perceptions (Bowling & Iliffe, 2006; Foster & Walker, 2015; Jopp et al., 2015; Phelan, Anderson, LaCroix, & Larson, 2004; Phelan & Larson, 2002; Strawbridge et al., 2002) of 'successful aging' would help researchers understand SA among individuals who have already attained success in longevity (Martin et al., 2015). With the expansion of the oldest-old and centenarian population, SA models that incorporate aspects including meaning in life, goal achievement, and coping are needed (Flood, 2005). Due to the idiosyncratic nature of life meanings, goals, and coping strategies, qualitative studies may complement extant quantitative findings by illustrating the personal and social context, life events, and life history that contribute to these components of SA. Future research may compare definitions and correlates of SA across different societies and cohorts which could be affected by the unique sociocultural imperatives between different cultures and eras (Hung et al., 2010; Ji et al., 2014; Liang & Luo, 2012; Romo et al., 2013). Based on Hung et al. (2010) findings, we incorporated the presence of close family members (spouse and children) as confidants and economic well-being in our model of SA. The three indicators, namely family confidant, perceived economic status, and financial sufficiency, were as strongly associated with SAI as other variables commonly found in the SA models of Western cultures were (Bowling & Dieppe, 2005; Glass, 2003). Future research may examine the different weight people assign on different SA components across distinct cultures and cohorts. International collaboration and the use of standardized instrument across different centenarian studies may facilitate such inquiries. Finally, future studies may benefit from examining the gene−environment interactions that entail healthy longevity, and translating relevant findings into evidence-based interventions and health promotion programs for SA to the middle-aged and younger elders (Willcox, Willcox, & Ferrucci, 2008).

Despite these limitations, our results suggest that it is possible for centenarians to achieve the prototype of SA, or 'the success of success' (Christensen, Doblhammer, Rau, & Vaupel, 2009). Efforts to minimize life-threatening diseases and functional dependency in late-life, maintain cognitive intactness and psychological well-being, and sustain social and family support and financial security are important. SA is a dynamic stream, rather than a static outcome (Fagerström & Aartsen, 2013) that involves engaging in meaningful activities, sustaining caring relationships, as well as confronting challenges across the lifespan (Cho, Martin, & Poon, 2015; Crosnoe & Elder, 2002; Schulz & Heckhausen, 1996; Stowe & Cooney, 2015). As the segment of the long-lived population is rapidly growing, understanding of their heterogeneity in functioning, the mechanisms behind healthy longevity, and their perceptions on aging with an interdisciplinary approach (Katz & Calasanti, 2015) will help establish a common ground for the effective communication on elderly health care services among policy-makers and practitioner−patron partnerships (Kane, 2003), and the identification of appropriate interventions to promote quality of life.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Notes

1. Out of the original sample of 153 participants, we have included an analysis on the participants with valid answers on any of the indicators of SAI ($N = 120$) and excluded ($N = 33$) in the current study. The breakdowns of missing values cover four participants providing invalid answers on subjective health; one participant on ADL independence; six participants on Geriatric Depression Scale; 13 participants on Mini-Mental State Examination; two participants on frequency of social activities; 10 participants on presence of spousal/children confidant; 14 participants on perceived economic status of household; and nine participants on sufficiency of income. Some participants had missing values overlapped.
2. We also examined the correlations among the 33 biomarkers and the two indicators of physical and functional health (PF) dimension (i.e., good subjective health and ADL independence). It was found that controlling for the effect of age and gender, subjective health was not significantly related to any biomarkers, whereas ADL independence was related to a lower level of platelet ($r = -.26$, $p = .018$) and a higher level of albumin ($r = .27$, $p = .014$). Previous studies on centenarians revealed that higher albumin level was related to better functional health (Gondo et al., 2006) and higher levels of hemoglobin and albumin had a significant positive effect on subjective health (Cho et al., 2011), while lower platelet count was related to lower risk of cardiovascular events (Gangemi et al., 2004). Since the current study is interested in the correlates of a multidimensional SA construct, the patterns and pathways were not elaborated through which biomarkers including albumin and platelets manifest themselves in physical and functional health per se.

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