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Positive affect and mortality risk in older adults: A meta-analysis

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Abstract: We performed a meta-analysis on the relationship between positive affect (PA) and mortality risk in older adults (55 years and older) and reviewed evidence on the Main Effect Model and the Stress-buffering Model of PA. Four databases (ISI Web of Knowledge, APA PsycNET, PubMed, and Embase) were used to identify potential studies. Three types of effect sizes (ESs), odds ratio, relative risk, and hazard ratio (OR, RR, and HR), were calculated and analyzed within a random effects model. The analysis of the studies in which the effects of other variables were not controlled indicated that older adults with higher levels of positive affect had lower mortality risk (75%, HR = 0.75, 95% confidence interval [CI] = 0.66–0.85) than those with lower positive affect. In studies in which the effects of covariates were controlled, this rate was 85% (HR = 0.85, 95% CI = 0.81–0.89), which was still significant. These results suggest that higher positive affect is associated with lower mortality risk in community-dwelling older adults, even after controlling for medical, psychological, and social factors. The results point to potential methods of improving longevity, and to achieving healthy aging in older adults.

Keywords: meta-analysis; mortality; older adults; positive affect.

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Positive affect (PA), such as joy, happiness, and energy, and positive characteristics, such as life satisfaction, hopefulness, and optimism, have been found to be positively related to better health (Bryant et al., 2012; Ruthig, Trisko, & Chipperfield, 2014) and to increase the life expectancy of community-dwelling elders (Danner, Snowdon, & Friesen, 2001; Diener & Chan, 2011; Frey, 2011; Pressman & Cohen, 2005, 2012; Steinhardt et al., 2015; Wiest, Schüz, Webster, & Wurm, 2011; Xu & Roberts, 2010). Three reviews and one meta-analysis related to the current topic concluded that higher levels of PA were related to better health outcomes and lower mortality risk in community-dwelling older adults (Cohen & Pressman, 2006; Diener & Chan, 2011; Howell, Kern, & Lyubomirsky, 2007; Pressman & Cohen, 2005). Despite the similar conclusions, there were several unanswered questions about these reviews, suggesting the need for a new meta-analysis.

First, previous reviews were qualitative syntheses of the PA–mortality literature. Accordingly, they could not provide quantitative information on the association between PA and mortality risk. Furthermore, in the only meta-analysis among the reviews, the authors did not separate the unhealthy from the healthy populations. Therefore, the effects in healthy and unhealthy populations might have been confounded with each other, as studies have found that PA's role in health improvement differed between these two populations (Abel & Kruger, 2010; Bailis, Chipperfield, & Perry, 2005; Janoff-Bulman & Marshall, 1982; Stones, Dornan, & Kozma, 1989; Zuckerman, Kasl, & Ostfeld, 1984). In the present study, we focused on the relationship between PA and mortality in older adults, and excluded samples with participants with severe illnesses. Thus, a quantitative systematic review was needed to synthesize the literature on the association between PA and mortality outcomes in healthy community-dwelling older adults.

Although the conclusions of most studies were consistent, some exceptions could not be ignored. For instance, a hopeful and joyful life were significantly associated with a lower risk of mortality in those over the age of 65 (Moskowitz, Epel, & Acree, 2008), whereas a PA with high

arousal, such as cheerfulness, might be detrimental to one's health (Deeg & van Zonneveld, 1989; Diener & Chan, 2011; Friedman et al., 1993; Papalia, Olds, & Feldman, 2004; Martin et al., 2002). Friedman et al. (1993) found that cheerfulness as assessed in talented children was associated with higher rates of adult mortality. Martin et al. (2002) explained that extremely optimistic and cheerful individuals might underestimate dangers, take few precautions in risky situations, or fail to follow medical advice, resulting in poorer health outcomes. Some researchers even suggested that the arousing nature of an emotion, not only its valence, might contribute to its potential relationship with health outcomes (Cohen & Pressman, 2006). Thus, there is a possibility that there were differences in the relationships across the different types of PA and longevity. Therefore, we compared the effect sizes (ESs) of different types of PA from the studies included in the current meta-analysis to provide preliminary insights into the issue of differences in the association across different types of PA and mortality risk. Currently some researchers tend to categorize PA into three aspects—life evaluation, hedonic PA, and eudemonic PA. Life evaluation refers to peoples' thoughts about the quality or goodness of their lives or their life satisfaction. Hedonic PA refers to everyday feelings or moods, such as the experience of happiness, which can be measured using ecological momentary assessments. Eudemonic PA focuses on judgments about the meaning and purpose of one's life (Steptoe, Deaton, & Stone, 2015). In our present study, we adopted a general definition of PA, which can be brief, longer lasting, or positive feelings that are more stable and trait-like (Pressman & Cohen, 2005). We included both hedonic PA, such as happiness, cheerfulness, and feeling good, and eudemonic PA, such as optimism and positive attitude toward aging. We emphasized subjective positive feelings rather than appraisals related to objective matters because these types of PA might be correlated with many other factors, such as economic status, medical conditions, and social support, which would result in confounding any explanation of a PA–mortality association. As a result, life evaluation (life satisfaction) was not our main concern, except when the measures of life satisfaction included hedonic PA or eudemonic PA. As we did not cover all facets of well-being in this study, we chose the term PA rather than well-being.

The relationship seemed to be complicated because of the presence of different types of covariates and explanations of how PA is associated with longevity from different perspectives. Pressman and Cohen (2005) proposed two possible pathways linking PA and health: a direct pathway (Main Effect Model) and an indirect pathway (Stress-buffering Model). The Main Effect Model suggested a mediating role of physiological, behavioral, and social factors between PA and health. For example, short- and long-term PA are associated with physiological indicators, and the physiological changes resulting from moods are, in turn, related to changes in health (Diener & Chan, 2011). The Stress-buffering Model suggested a moderating role of PA between stress and health. Researchers have found that optimism buffers the detrimental effect of negative self-perceptions of aging on physical and mental health (Wurm & Benyamini, 2014). Thus, it is important to review the empirical evidence on the Main Effect and Stress-buffering Models of PA. We extracted the interaction/mediation effect sizes from studies supporting the two models to review this research evidence.

There were two aims of the present study:

1. To determine the percentage of mortality risk in older adults with higher PA compared to those with lower PA (by computing the synthetic unadjusted and adjusted ESs and their differences).
2. To examine the possible influence of different types of PA and other potential factors on the relationship between PA and mortality using subgroup analysis.

Moreover, we reviewed the supporting evidence on both the Main Effect and Stress-buffering Models by extracting the interaction/mediation effect sizes from the studies. The Main Effect Model indicates a mediating role of physiological, behavioral, and social factors on the association between PA and health, and the Stress-buffering Model indicates a moderating role on the association of PA between stress and health. This was intended to provide us with a preliminary insight into the pathways by which PA is associated with longevity.

Methods

Literature search procedure

Search strategies

We searched four databases, ISI Web of Knowledge and APA PsycNET (including PsycINFO) on 12 May 2014, and PubMed and Embase on 30 January 2015. Year restrictions for the searches were from 1900 to the day when these searches were done. We combined search terms

indicating PA ("positive emotion," "positive affect," "feel good," "happiness," "happy," "optimistic," "optimism," and "cheerful*[1]") with terms indicating mortality ("survival," "mortality," "longevity," and "death"). Both text and keywords were used. We also screened the reference lists from the three review articles and the previous meta-analysis (Cohen & Pressman, 2006; Diener & Chan, 2011; Howell et al., 2007; Pressman & Cohen, 2005). The screening procedures were done by the first and second authors independently, and discrepancies were addressed through discussion.

Inclusion criteria

The inclusion criteria of this study were as follows:

- the source was published as a journal article or book chapter in either English or Chinese;
- the source reported empirical research;
- the study included a measure of PA, and all-cause mortality was an outcome variable;
- the design was prospective, that is, PA was assessed prior to a mortality surveillance period; and
- the mean age of the participants was over 55 years when mortality was observed.

Exclusion criteria

The exclusion criteria were as follows:

- the report was a case study;
- mortality was in inpatients or people with other acute medical conditions; and
- the study did not provide sufficient data to calculate an effect size (ES).

Data extraction and quality assessment

Based on the requirements of this study's analysis and the codebook used by Okun, Yeung, and Brown (2013), nine data-extraction forms (including source form, total sample form, subsample form, death measurement form, PA measurement form, unadjusted ES form, adjusted ES form, interaction ES form, and mediation ES form) were designed to collect detailed information from the articles and to facilitate the data-extraction process. An additional six forms were used to assess the quality of the included studies. A rating scale based on an instrument developed by Hayden, Côté, and Bombardier (2006) was used to evaluate the quality of the prognosis studies. Six sources of potential bias were assessed in our study (Cuijpers, Vogelzangs, et al., 2014; Cuijpers, Weitz, et al., 2014; Hayden et al., 2006): (a) study participation (the study sample represents the population of interest on key characteristics); (b) study attrition (loss to follow up from the sample is not associated with key characteristics; i.e., the study's data represent the sample adequately); (c) PA measurement (the prognostic factor of interest is adequately measured in study participants to sufficiently limit potential bias); (d) outcome measures (the outcomes of interest are adequately measured in study participants); (e) confounding measures and statistical control (important potential confounders are statistically controlled for); and (f) analysis (the statistical analysis is appropriate for the study's design). The first and second authors independently coded five of the articles. We resolved the discrepancies and the first author coded the remaining articles.

Meta-analyses

We calculated three types of ES estimates: hazard ratios (HRs), odds ratios (ORs), and relative risks (RRs). The hazard ratio was used as the ES to determine how often death occurred in participants with higher PA scores compared to those with lower PA scores. We focused on four types of ES. The unadjusted (adjusted) ES measured the magnitude of the relationship between PA and mortality risk in the absence or presence of covariates. The interaction ESs assessed the magnitude of the joint effect of PA and a moderating variable on mortality. The mediating ESs assessed the magnitude of the relationship of a mediating variable and mortality. If different studies were based on the same database, then the same type of ESs would be extracted only from the study with highest quality, whereas different types of ESs would be extracted from different studies. This was done to make the most efficient use of the existing databases.

Data analysis

We used the HR as the ES that was entered into the analysis. An RR and an OR were converted to an HR using equations provided by Okun et al. (2013) and Zhang and Yu (1998). In some studies, two or more ESs could be extracted when the researcher created two or more pairs of PA subgroup comparisons. For example, in the study by

[1]Asterisk (*) following the search terms indicates any (or no) character(s) or numbers. For example, the term "cheerful*" represents "cheerful," "cheerfulness," and so forth.

Jacobs, Maaravi, and Stessman (2012), participants were divided into four groups according to their optimism score. Three adjusted ESs had been reported as three comparisons were made; the three higher quartiles were all compared to the lowest quartile, which yielded three HRs. As Borenstein, Hedges, Higgins, and Rothstein (2009) recommended, we created a synthetic ES and a synthetic variance for the adjusted ESs and unadjusted ESs. The meta-analytic analyses were conducted using Comprehensive Meta-Analysis, Version 2.0 (Borenstein, Hedges, Higgins, & Rothstein, 2006). First, we explored the extent to which PA was associated with mortality (Question 1) using random effect models to show the forest plots of unadjusted ESs, adjusted ESs, and their differences. Second, we examined the significance of the *Q* statistics of both the within- and between-study comparisons to check whether there were differences across the associations between different types of PA and mortality risk (Question 2). Third, the interaction and mediation ESs supporting the Main Effect Model and Stress-buffering Model from the studies were analyzed to explore the underlying mechanisms of the PA–mortality association.

Results

Study descriptions

After a preliminary screening of 901 abstracts (196 duplicates) and full texts if needed, 36 articles on PA and longevity were kept for a second screening. We read the full text of the 36 articles and then excluded six more articles, which failed to meet the inclusion criteria or met some of the exclusion criteria, or for which no HR, RR, or OR could be extracted. Thus, 30 articles were subjected to the data-extraction process. We could not extract any HR effect size due to a lack of data on mortality rates from eight of the 30 articles; therefore, these eight studies were excluded from our analysis. Finally, 22 studies were subjected to the data analysis (Figure 1).

The earliest article was published in 1992, whereas the latest article was in 2013. These studies were all from different data sets, except for the studies of Giltay, Geleijnse, Zitman, Hoekstra, and Schouten (2004) and Koopmans, Geleijnse, Zitman, and Giltay (2010), both of which used data from the Arnhem Elderly Study. For these two studies based on the same data set, the adjusted ES was extracted only from the study by Koopmans and colleagues, which was a higher-quality study than that of Giltay and colleagues. In addition, unadjusted ES and mediation/moderation ESs were extracted from the studies by Giltay et al. (2004) and Koopmans et al. (2010), respectively. Participants in 10 of the 22 samples were recruited from the US, whereas the other samples were from Denmark, the Netherlands, Israel, Finland, Sweden, Germany, Canada, Spain, and England. The sample sizes ranged from 101 to 97,253, with a mean and median sample size

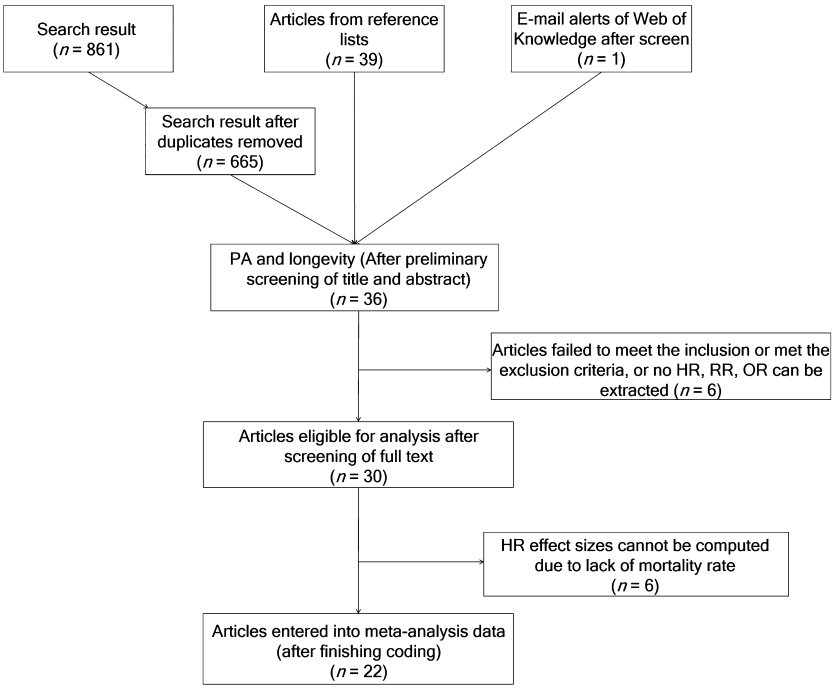

Figure 1. Flow chart of inclusion of studies. HR = hazard ratio; OR = odds ratio; PA = positive affect; RR = relative risk.

of 7,159 and 1,070, respectively. The minimum age of the participants (when PA was measured at baseline) ranged from 12 to 92 years, with a mean age of 58. The years of follow-up ranged from 2 to 64 years, and the mean follow-up was 17 years. Only five studies (Carstensen et al., 2011; Danner et al., 2001; Lyyra, Törmäkangas, Read, Rantanen, & Berg, 2006; Martin et al., 2002; Steptoe & Wardle, 2011) had positive scores on at least four of the six quality criteria; the low-quality profile of the 17 studies was mainly due to their reliance on participants' recall on PA measures and the inadequate reporting of attrition in most of the studies. The types of PA predictors were either a specific PA or a combination of several types of PA. Two types of coding of the PA predictor variables were adopted by the researchers, consisting of (a) continuous scores of PA, and (b) divided categories of the PA scores, such as quartiles, tertiles, and two groups with high versus low scores (Table 1).

The extent to which PA was associated with mortality

Unadjusted effect sizes

A forest plot of the unadjusted ESs was derived from the total samples. As shown in Figure 2, the confidence intervals (CIs) for nine of the 10 unadjusted ESs were all below 1.00. The weighted mean of the ESs was 0.75, 95% CI = 0.66–0.85 ($p < .001$). Thus, in the absence of control variables, the average ES suggests that relative to participants with a low PA, those with a high PA had a 25% decrease in the risk of death, 95% CI = 0.15–0.34. The Q statistic was 105.6 ($df = 9$, $p < .01$), indicating that the ESs were heterogeneous. A large proportion of the observed variance reflected differences in the true ESs across studies ($I^2 = 91\%$).

Adjusted effect sizes

The percentage of use of each type of covariate was 26% (cognitive functioning), 32% (ethnicity and health behavior), 37% (marital status), 47% (socioeconomic status and emotional health), 53% (physical activity), 58% (education), 63% (age), and 68% (sex). As can be seen in Figure 2, the CIs for 14 of the 19 adjusted ESs derived from the total samples were below 1.00. The weighted mean of the ESs was 0.85, 95% CI = 0.81–0.89 ($p < .001$). Thus, in the presence of the controlled variables, the average ES indicates that, relative to participants with a low PA, those with a high PA had a 15% decrease in the risk of death, 95% CI = 0.11–0.19. The Q statistic was 49.5 ($df = 18$, $p < .001$), indicating that the ESs were heterogeneous. A moderate proportion of the observed variance was real rather than spurious ($I^2 = 64\%$).

The association of PA and mortality risk varies across different measures of positive affect and mortality risk

By examining the relationship between different measures of PA and ESs using the Q test (which provides an analysis of variance [ANOVA] analog) of the ESs within the same studies, we found a significant difference only in the Xu and Roberts (2010) study ($Q = 144.9$, $p < .001$). The adjusted ES of global life satisfaction (0.85) was smaller than subjective well-being (0.97), positive feelings (0.96), PA (0.93), and domain life satisfaction (0.93; $ps < 0.05$). This finding indicates that global life satisfaction was associated with lowered mortality risk to a greater degree than the other types of PA in the study.

As for the relationship between different types of PA and ESs between the different studies (Engberg et al., 2013; Giltay et al., 2004; Hoen, de Jonge, Denollet, & Whooley, 2012; Krijthe et al., 2011; Levy, Slade, Kunkel, & Kasl, 2002; Lyyra et al., 2006; Maier & Smith, 1999; Moskowitz et al., 2008; Newall, Chipperfield, Bailis, & Stewart, 2013; Parker, Thorslund, & Nordström, 1992), the Q test revealed a significant difference among the five types of PA (life satisfaction, attitude toward aging, happiness, optimism, and various PAs) in the unadjusted ESs ($Q = 16.0$, $p < 0.05$). The unadjusted ES of life satisfaction (0.54) was smaller than that of attitude toward aging (0.64), happiness (0.72), optimism (0.71), and various PAs (0.84; $ps < .05$); however, there were no significant differences for the adjusted ESs.

Pathway linking PA to mortality risk: Main Effect Model versus Stress-buffering Model

Table 2 provides a summary of the mediating and moderating ESs. An interaction ES less than 1.00 indicated that the relationship between stress and mortality risk was buffered by PA, which was consistent with the Stress-buffering Model. A mediating ES less than 1.00 indicated that the relationship between PA and mortality risk could be explained by the covariate. As indicated in Table 2, the mediating ESs of physical activity, will to live, and social network were significant ($ps < .05$), which supports the

Table 1
Features of the Studies Included in the Meta-Analysis

Author(s) and publication year	Data set	Country	*N*	Min. age	Follow-up years	ES	Quality[a]	Measure of PA	Coding of PA
Blazer and Hybels (2004)	Duke EPESE	USA	4,162	65	10	AES	± − ± + ± ± 6	PA subscales of the Center for Epidemiologic Studies	Positive score 0–4, continuous
Brummett, Helms, Dahlstrom, and Siegler (2006)	University of North Carolina Alumni Heart Study	USA	6,958	18.5 (Mean, *SD* = 2.6)	40	AES	+ − ± + ± ± 7	Depression Scale	(1) Optimistic, mixed, pessimistic; (2) three tertiles
Carstensen et al. (2011)	Emotional Experience and Aging Study	USA	111	46	15	AES	+ − + + ± + 9	Daily samplers (5 per day, 7 days) of 8 positive emotions using 7-point scale	Positive emotional experience score
Danner et al. (2001)	The Nun Study	USA	101	75	57–59	AES	+ ± + + + + 11	Emotional word use in autobiographies	Percentile or quartile rankings of the number of PA sentences; PA words; PA categories
Engberg et al. (2013)	The Danish 1905 Cohort Survey	Denmark	1,682	92	12	UES, AES	+ ± ± + ± ± 8	Whether one had an optimistic outlook on one's future	Optimistic, neutral (reference group), pessimistic
Giltay et al. (2004)	Arnhem Elderly Study	The Netherlands	941	65	9.1	UES	+ ± ± + ± ± 8	Optimism subscale (7 items) from 30-item validated Dutch Scale of Subjective Well-being for Older Persons, 3-point scale	(1) 4 quartiles; (2) pessimist or optimist
Hoen, de Jonge, Denollet, and Whooley (2012)	The Heart and Soul Study	USA	1,017	NS	7.1	UES, AES	± − ± ± ± − 4	PANAS	PA score, continuous
Jacobs et al. (2012)	The Jerusalem Longitudinal Study	Israel	1,122	85	20	AES	± − ± + ± − 5	7 question (0–2 points each) optimism scale	Q1 lowest, Q4 highest optimism
Koivumaa-Honkanen et al. (2000)	Finnish Twin Cohort data	Finland	22,461	18	20	AES	+ ± ± + ± + 9	Scale with four questions on life satisfaction	Three-category variable: the satisfied, the intermediate group, the dissatisfied
Koopmans et al. (2010)	Arnhem Elderly Study	The Netherlands	861	65	15	AES, MES	+ + ± + ± ± 9	Two items from optimism subscale	Unhappy vs. happy

Table 1
Continued

Author(s) and publication year	Data set	Country	*N*	Min. age	Follow-up years	ES	Quality[a]	Measure of PA	Coding of PA
								of Dutch Scale of SSWO	
Krijthe et al. (2011)	Population-based Rotterdam Study	The Netherlands	4,411	61.2	7.19	UES, AES	+ − ± ± ± ± 6	PA subscales of CES-D	PA score, continuous
Levy, Slade, Kunkel, and Kasl (2002)	Ohio Longitudinal Study of Aging and Retirement	USA	660	50	23	UES, AES, MES	+ ± ± + ± ± 8	Attitudes Toward Own Aging subscale	Total score ranging from 0 to 5, continuous
Lyyra et al. (2006)	OCTO-Twin Study	Sweden	320	80	> 10	UES, AES	+ − ± + + + 9	13-item LSIZ, 5-point scale, 3 subscales: zest, mood, congruence	Quartiles (Q1, lowest; Q2–Q3, middle; Q4, highest)
Maier and Smith (1999)	Berlin Aging Study	Germany	516	70	3–6	UES, AES	± ± ± + ± ± 7	PANAS, PGCMS	Standardized score, M = 4, *SD* = 2
Martin et al. (2002)	Terman Life-Cycle Study	USA	1,215	12	64		+ ± + + + ± 10	Parent and teacher rating on cheerfulness–optimism in 13-point scale	High cheerful vs. low cheerful
Moskowitz et al. (2008)	NHANES, NHEFS (follow-up study of National Center for Health Statistics)	USA	334	65	10	UES, AES, MES	+ − ± + ± + 8	CES-D	0 = Rarely or none of the time, 3 = Most or all of the time
Newall, Chipperfield, Bailis, and Stewart (2013)	Aging in Manitoba Study (2001) and the Successful Aging Study (2003)	Canada	228	77	3	UES	+ − ± + ± ± 7	Happiness: 11-item loneliness scale, Happiness in the past week	0 = Rarely or none of the time; 3 = Most or all of the time
Ostir, Markides, Black, and Goodwin (2000)	Hispanic Established Population for the EPESE	Spain	2,282	65	2	AES	± ± ± + ± ± 7	Four-item PA scale	0 = Rarely or none of the time, 3 = Most or all the time
Parker, Thorslund, and Nordström (1992)	Sweden Community-based Elderly Study	Sweden	161	75	4	UES, AES	+ ± ± ± ± ± 7	Question on happiness	Very happy, fairly happy, so-so, could be better, unhappy
Steptoe and Wardle (2011)	English Longitudinal Study of Aging	England	3,853	52	5	AES	+ ± + + + + 11	Ecological momentary assessment (four time-points in a day)	1 = Not at all; 4 = Extremely
Tindle et al. (2009)	Women's Health Initiative	USA	97,253	50	8	AES	+ − ± + ± ± 7	Life Orientation Test Revised	4 quartiles
Xu and Roberts (2010)	Alameda County Study	USA	6,856	62	28	AES	± ± ± + ± + 8	SWB 14 items	SWB score, continuous

Note. AES = adjusted effect size; CES-D = Center for Epidemiologic Studies – Depression; EPESE = Epidemiologic Study of the Elderly; ES = effect size; LSIZ = Life Satisfaction Index Z; MES = moderation or mediation effect size; NHANES = National Health and Nutrition Examination Study I; NHEFS = Epidemiologic Follow-Up Study; NS = not specified; OCTO = octogenarian; PA = positive affect; PANAS = Positive Affect Negative Affect Schedule; PGCMS = Philadelphia Geriatric Center Morale Scale; SSWO = Subjective Well-being for Older Persons; SWB = subjective well-being; UES = unadjusted effect size.

[a] Quality was scored on the following six domains: (1) Study participation; (2) study attrition; (3) PA measurement; (4) outcome measures; (5) confounding measures and statistical control; and (6) analysis. Each item was scored as positive (+), partly (±), or negative (−). We also report the total sum of the quality scores (with 2 for positive, 1 for intermediate, and 0 for negative; range: 0–12).

Main Effect Model. In contrast, the interaction ESs of subjective stress were significant, supporting the Stress-buffering Model. Both models have been examined and used in several previous studies presenting empirical evidence (Koopmans et al., 2010; Levy et al., 2002; Moskowitz et al., 2008; Xu & Roberts, 2010).

Do effect sizes vary with other potential subgroup variables?

We examined the relationship between two categorical subgroup variables (country and negative affect included or not) and the ESs. For all the subgroup analyses, we tested the difference among levels of subgroup variables using the Q statistic, which provides an ANOVA analog. Country had something to do with the adjusted ES ($Q = 3.500$, $p = .06$); the adjusted ES of the US was marginally larger than that of other countries. There was no significant difference between countries in unadjusted ESs ($Q = 2.280$, $p > .05$). Neither the adjusted nor the unadjusted ESs differed irrespective of whether negative affect was included ($Q = 1.972$, $p > .05$; $Q = 2.466$, $p > .05$).

We examined the relationship between eight quantitative subgroup variables (year of publication [M = 2006, SD = 5.51], impact factor of the journal [M = 4.89, SD = 3.77], minimum age of the participants [M = 61.95, SD = 19.23], year of follow up [M = 15.39, SD = 13.31], sample size [M = 7803, SD = 21100.76], percentage of females [M = 0.56, SD = 0.23], mortality rate [M = 0.38, SD = 0.25], and quality ratings of the studies [M = 7.77, SD = 1.74]), and the adjusted/unadjusted ESs using meta-regression with a mixed-effects model estimated using the method of moments. For the unadjusted ESs, the meta-regression model of the year of publication ($Q = 81.884$, slope = 0.036, $p < .05$), follow-up year ($Q = 68.022$, slope = −0.022, $p < .01$), sample size ($Q = 95.308$, slope = 0.000, $p < .01$), and percentage of females ($Q = 52.433$, slope = 2.089, $p < .01$) were statistically significant. For the adjusted ESs, only the model of the year of publication ($Q = 6.313$, slope = 0.007, $p < .05$) was significant. This result suggested that the hazard ratio increased as the publication year increased.

We also examined the correlation between the adjusted effect size and quality rating of each study; the correlation efficient was marginally significant ($r = −0.039$, $p = .089$). This indicated that as the quality of the study improved, the adjusted effect size decreased somehow. This means that when controlling for the other variables, the observed association of lowered mortality risk and positive affect was even stronger in the high-quality studies than in the low-quality studies.

Since the adjusted ESs should be more precise than the unadjusted ESs, we should base our conclusion on the subgroup analyses for the adjusted ESs. In sum, we found that country and year of publication were significant subgroup variables of the PA–mortality association. Quality of study was also correlated with the adjusted ESs. These study characteristics might explain away a large part of the heterogeneity in the adjusted ESs.

Test of publication bias of unadjusted and adjusted effect sizes

The results of the Duval and Tweedie (2000) trim and fill procedure, which was performed separately for the unadjusted ESs (log HR = 0.76, 95% CI = 0.67–0.87) and the adjusted ESs (log HR = 0.85, 95% CI = 0.81–0.89) revealed that the means of the distributions of the ESs did not change, indicating the absence of publication bias (Figure 3).

Discussion

In this study, we examined the synthetic unadjusted and adjusted ESs of 22 studies on PA and mortality risk. Across 10 of the studies, older adults with higher levels of PA had lower mortality risk (75%) than those with lower PA, in the absence of other variables. In the 19 studies that controlled for the effects of covariates, the adjusted ES was 85%, indicating a 15% reduction in the mortality risk of participants with higher PA. It seems that the magnitude of the association between PA and mortality risk was weakened significantly by the inclusion of the covariates, although the study sets were different between the two analyses. These results are consistent with previous reviews (Diener & Chan, 2011; Howell et al., 2007) of the association of PA and lowered mortality risk before and after controlling for the effects of other variables. The present meta-analysis provided us with the percentage of mortality risk in older adults with higher PA by computing the synthetic unadjusted and adjusted ESs. However, it is important to note that these results still do not mean that PA has a causal relationship with mortality. Confounding and reverse causality might exist. Confounding takes place when low PA is associated with a pre-existing factor (such as underlying biological processes or behavioral factors), which itself may predict future survival. In the current

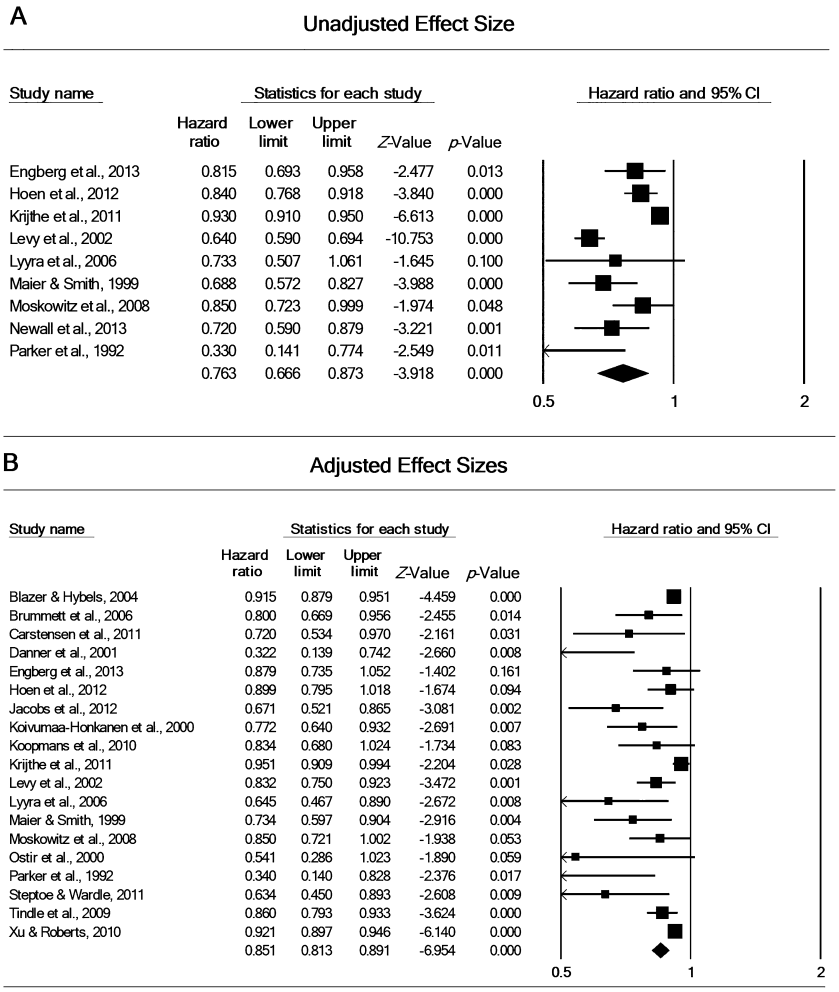

Figure 2. Forrest plots of (A) unadjusted and (B) adjusted effect sizes. For effect sizes less than 1.00, smaller values indicate larger, beneficial effects of positive affect on mortality risk. CI = confidence interval.

analysis, we excluded older adults with severe illnesses to eliminate the possibility of pre-existing illnesses as a source of bias. However, the findings do raise exciting possibilities about PA being involved in reducing mortality risk (Steptoe et al., 2015). Other factors were found to be associated with mortality risk in older adults besides PA. For instance, in the study by Okun et al. (2013), the researchers concluded that volunteering reduced the risk of death in older adults by 25%. The contribution of volunteering to the reduction of mortality risk was larger than that of PA. This difference can be explained by the protective benefits derived from the psychological (Danner, Friesen, & Carter, 2007), social (Wilson & Musick, 1999), and physical (Tan et al., 2009) aspects of volunteering. At the same time, the relationship of PA and morality risk was indirect according to theoretical models of the PA–mortality association. The significant amount of heterogeneity in the unadjusted and adjusted effect sizes revealed that the associations between PA and mortality risk vary, as do many study characteristics. These differences may also be due to country, year of publication, and quality of the study, as our subgroup analyses indicated. Studies published earlier, conducted in countries outside the US, and those of high quality had lower adjusted ESs. However, other variables that were not included in our present analyses may also explain the difference in the PA–mortality association.

We also reviewed evidence supporting the Main Effect and Stress-buffering Models, which both provide explanations of the mechanism of the association between PA and mortality risk. The results provided evidence for both models, suggesting the possibility of the coexistence of two pathways. However, we cannot draw conclusions about this issue because we based our inferences on descriptions rather than on analyses. This finding is consistent with claims regarding potential biological pathways, such that well-being can directly bolster immune functioning and reduce the impact of stress (Howell et al., 2007). The result is not surprising because it is consistent

Table 2
Extracted Interaction ESs and Mediation ESs

Author(s)	Significant moderator (O) or mediator (I)	Measure of moderator or mediator	Coding of moderator or mediator	*N*	ES	Model supported
Koopmans et al. (2010)	Physical activity (I)	A validated questionnaire for classifying activity levels of the elderly	Continuous	861	0.83 (0.67–1.01)	Main effect
Levy et al. (2002)	Will to live (I)	Three items	7-point scale	660	0.81 (0.77–0.86)	Main effect
Moskowitz et al. (2008)	Subjective stress (O)	Three items from the General Well-Being Schedule	Total score of all three items	1,215	0.84	Stress-buffering
	Subjective stress (O)			1,215	0.83	Stress-buffering
	Subjective stress (O)			1,215	0.86	Stress-buffering
Xu and Roberts (2010)	Social network (I)	Including marital status, contact with relatives/ close friends, church attendance, and other group affiliations	Social Network Index, weighted based on the closeness of the relationships	6,856		Main effect
	Social network (I)			6,856		Main effect
	Social network (I)			6,856		Main effect
	Social network (I)			6,856		Main effect

Note. ES = effect size; (I) = mediator; (O) = moderator.

with the broaden-and-build theory proposed by Fredrickson (2001), who suggested that positive emotions broaden people's momentary thought–action repertoires and build their enduring personal resources, including physical, social, and psychological resources. Positive emotions enhance psychological resilience, leading to broad-minded coping and improving physical functioning (consistent with the Main Effect Model); they also extinguish lingering negative emotions (consistent with the Stress-buffering Model). The latter explains how positive affect acts as a moderator between stress and health. Older adults exhibit greater stress-induced immune and cardiovascular dysregulation compared to younger adults (Uchino, Birmingham, & Berg, 2010). It is important to eliminate the adverse effects of stress in older people. Fortunately, previous studies, together with the present meta-analysis, have shown that both trait PA and state PA benefit health by ameliorating and undoing the physiological effects of stress. Ong (2010) explained PA's role as a stress buffer as follows, based on the literature: Positive emotion can alter the severity and duration of stress responses that foster disease vulnerability; in addition, state positive emotion may also facilitate faster recovery from stress-related physiological arousal.

The differences across the associations of different types of PA and mortality risk were compared both within and between studies, revealing a reduction in mortality risk associated with life satisfaction, which was greater than the other measures of PA. This is consistent with the findings of an earlier study by Berkman and Breslow (1983), in which a high level of baseline life satisfaction reduced all-cause mortality by nearly half for men and nearly two-thirds for women during the 9-year study period (Xu & Roberts, 2010). It is premature to conclude that life satisfaction was the most powerful predictor of mortality risk among the different types of PA because there were non-significant results in other within-study comparisons of different PA measures and more importantly, heterogeneity among the different measures of the different studies. Therefore, the relationship between PA and mortality might not depend on PA subgroups alone. It is important to note that the PA–mortality correlation could, in part, be influenced by other potential variables.

Another question concerns whether there are alternative explanations for PA's association with mortality, such as negative affect (NA). We found that NA was not a significant subgroup variable. This finding is consistent with previous suggestions that, despite the fact that many studies do not control for NA because PA is relatively independent of NA over longer periods, NA levels are less likely to be responsible for these associations (Cohen, Doyle, Turner, Alper, & Skoner, 2003; Moskowitz, 2003; Ostir, Markides, Black, & Goodwin, 2000; Ostir, Markides, Peek, & Goodwin, 2001). Therefore, people with lower PA, but not

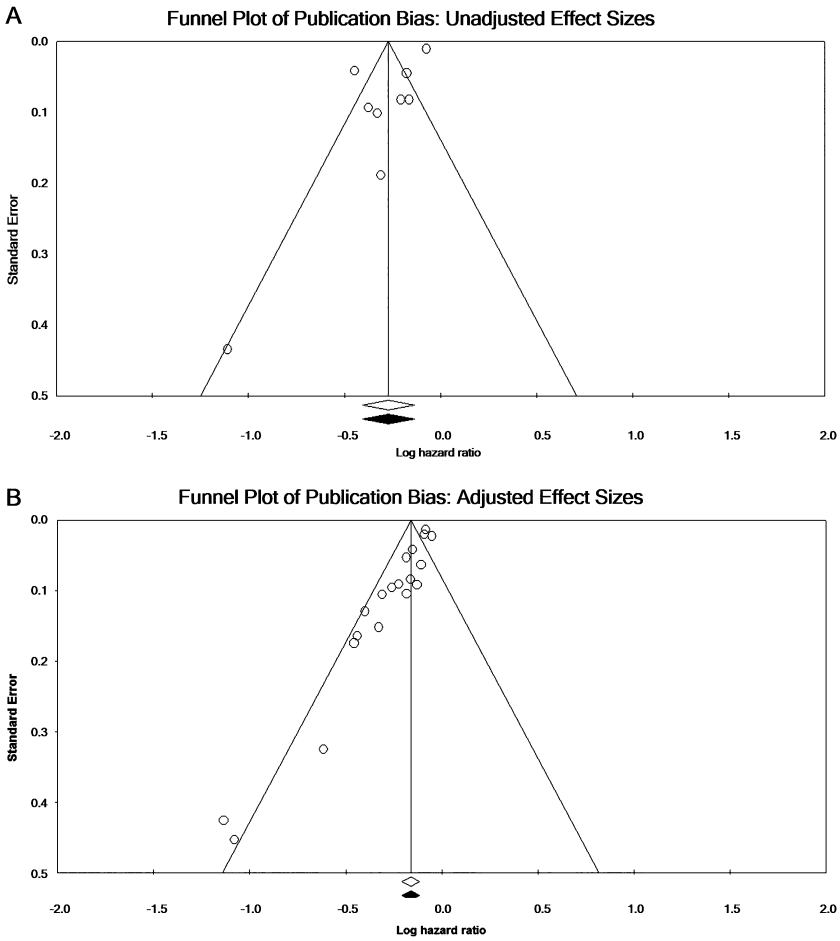

Figure 3. Funnel plots of publication bias: (A) unadjusted and (B) adjusted effect sizes.

higher NA would be expected to have a higher mortality risk compared to people with higher PA.

There are some limitations of our meta-analysis. First, as we have noted in the course of this review, the measures of PA were different from study to study; therefore, this heterogeneity may have led to inaccuracies in the results of the between-study comparisons. Second, almost half of the studies failed to report both the adjusted and unadjusted ESs, and many studies failed to report the interaction ESs, even when they were significant. This allowed us to analyze only the subgroup variables qualitatively, possibly leading to a bias in our results. Third, a substantial number of studies did not assess the arousal of emotion, which may be essential to evaluating the trajectories of mortality as the arousal level of PA increases. This finding also explains, in part, why previous studies did not draw conclusions about the form of the PA–mortality risk relationship. A curvilinear relationship between PA and health might exist (Crowther & Huang, 2012; Diener & Chan, 2011; Friedman et al., 1993; Papalia et al., 2004; Pressman & Cohen, 2005); a recent study found that high arousal PA had a U-shaped association with basal cardiovascular activity (Armon, Melamed, Berliner, & Shapira, 2014). However, we could not answer this question due to the small data set. Finally, the sample in the current analysis was restricted to community-dwelling older adults. Thus, the conclusions cannot be generalized to other populations, such as inpatients. In addition, the studies included in this meta-analysis may be limited because we only examined studies with the specification of OR/RR/HR.

In future studies on the relationship between PA and mortality risk, researchers should attend to the following issues. First, they should assess both the intensity and the frequency of PA. This step is important for quantifying the relationship in order to evaluate the strength of the PA–mortality association and to determine the optimal level of PA for living longer. Socioemotional selectivity theory suggests that emotional lives improve with age (Carstensen et al., 2011). In future studies, it will be important to go beyond single assessments of PA, which are static

snapshots of single points in time, to include estimates of the rate of change in PA over time. Second, researchers should examine both the Main Effect Model and the Stress-buffering Model in the same study and the physiological and social mechanisms to build a comprehensive model to interpret the PA–mortality association. Third, several kinds of PA can be assessed simultaneously in one study to learn which type of PA has greater value as an independent predictor of mortality. Fourth, other populations, such as patients and those in nursing homes, should be studied as the proportion of elders with impairments in physical functioning and the inability to live alone increases rapidly in older adults (Moskowitz et al., 2008). Finally, it is of great importance to test interventions designed to enhance PA and their associations with health and longevity. For example, could interventions designed to increase older adults' gratefulness for what they have accomplished in life affect PA that have effects on health and mortality?

The present meta-analysis offers quantitative information on the ESs of PA on mortality risk and qualitative evidence on the Main Effect and Stress-buffering Models of PA, indicating that mortality risk in community-dwelling older adults with a higher PA was lower. These analyses, which have not been performed previously, provide insight into the cumulative results of current studies on PA and mortality, which should extend knowledge of this topic. The results point to effective methods to improve longevity, and, ultimately, achieve healthy aging.

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