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The exercise effect on psychological well-being in older adults—a systematic review of longitudinal studies

Introduction

The progressively aging population and the corresponding rise in chronic illness in high income nations is widely accepted as a public health challenge (Tunstall-Pedoe, 2006). As people live longer it is crucial to ensure successful aging, thus, ensuring that the additional years are worth living (Heo, Culp, Yamada, & Won, 2013). This aim is consistent with the motto of the Gerontological Society of America, "Adding life to years, not just more years to life." Maintaining the best possible well-being is one crucial part of successful aging in the face of age-related changes in the body (Baltes & Baltes, 1990). Although there is no generally applicable definition of well-being, it is commonly accepted that it is a multidimensional construct including hedonic (pleasure: e.g., positive affect and satisfaction with life) and eudaimonic (control, autonomy, meaning in life, and self-realization) dimensions (Urry et al., 2004). Therefore, well-being includes factors that do not simply reflect the absence of distress, but rather involves the cognitive and affective evaluation of life, and encompasses dimensions such as psychological, physical, and social well-being (Ku, Fox, & McKenna, 2008). Well-being is also defined as one dimension of general quality of life, which further involves domains such as functional ability, socioeconomic status, intellectual activity, cultural and ethical values, religiosity, health, living environment, and daily activities (Vagetti et al., 2014). The psychological domain of well-being, as the dimension of well-being we will focus on in this systematic review, again encompasses constructs such as life satisfaction, positive affect, and happiness (Diener, 2009; McAuley & Morris, 2007; Rejeski & Mihalko, 2001; Ryff et al., 2006; Vagetti et al., 2014).

Aging is accompanied by several physical changes, which can result in functional limitations, disability, and decreasing levels of independence. This in turn might be associated with decreases in psychological well-being (PWB) in older subjects because physical and PWB are interrelated throughout life (Han & Shibusawa, 2015; Rejeski & Mihalko, 2001; Verbrugge & Jette, 1994). Furthermore, some studies indicate that a high PWB may act as a protective factor against frailty. For instance, an investigation with 1558 initially non-frail older adults demonstrated that a high PWB (measured by positive affect) was significantly associated with a lower risk of frailty (Ostir, Ottenbacher, & Markides, 2004). Gale, Cooper, Deary, and Sayer (2014) confirmed these results by revealing that high PWB at the age of 60+ may be a protective factor against becoming frail over a 4-year follow-up period (Gale et al., 2014). Further, a literature review by Nordbakke and Schwanen (2013) reinforces the possible association between greater PWB in older age (irrespective of hedonic or eudaimonic view of well-being) and a lower risk of developing problems with mobility and other activities of daily living. In addition, among subjects who were already frail, a higher PWB was associated with less adverse health outcomes (like nursing home placement or death) (Bilotta et al., 2010; Bilotta et al., 2011).

Even though PWB may decline with increasing age, due to an enhanced risk of dependence as consequences of physical limitations, increased age is not universally accompanied by declines in PWB. In this vein, the German Socio-Economic Panel demonstrated that satisfaction with life is a quite stable construct across the adult lifespan; it may even become more stable in older adulthood (Kunzmann, Little, & Smith, 2000; Schüz, Wurm, Warner, & Tesch-Römer, 2009).

Various behavioral, demographic, and personal factors have been associated with maintaining PWB into older adulthood. In addition to other factors, physical activity (PA) seems to be one important lifestyle factor for promoting PWB (Netz, Wu, Becker, & Tenenbaum, 2005). Most studies proving this positive association between PA and PWB are cross-sectional or intervention studies. Several literature reviews and meta-analyses of these respective studies have been published (e.g., Mavrovouniotis, Argiriadou, & Papaioannou, 2010; McAuley & Morris, 2007; Netz et al., 2005; Rejeski & Mihalko, 2001; Spirduso & Cronin, 2001). However, cross-sectional studies are unable to establish a long-term association between PA and PWB, or to shed light on causality (Ku, Fox, Liao, Sun, & Chen, 2016b). Intervention studies often suffer from quality issues (Pasco et al.,

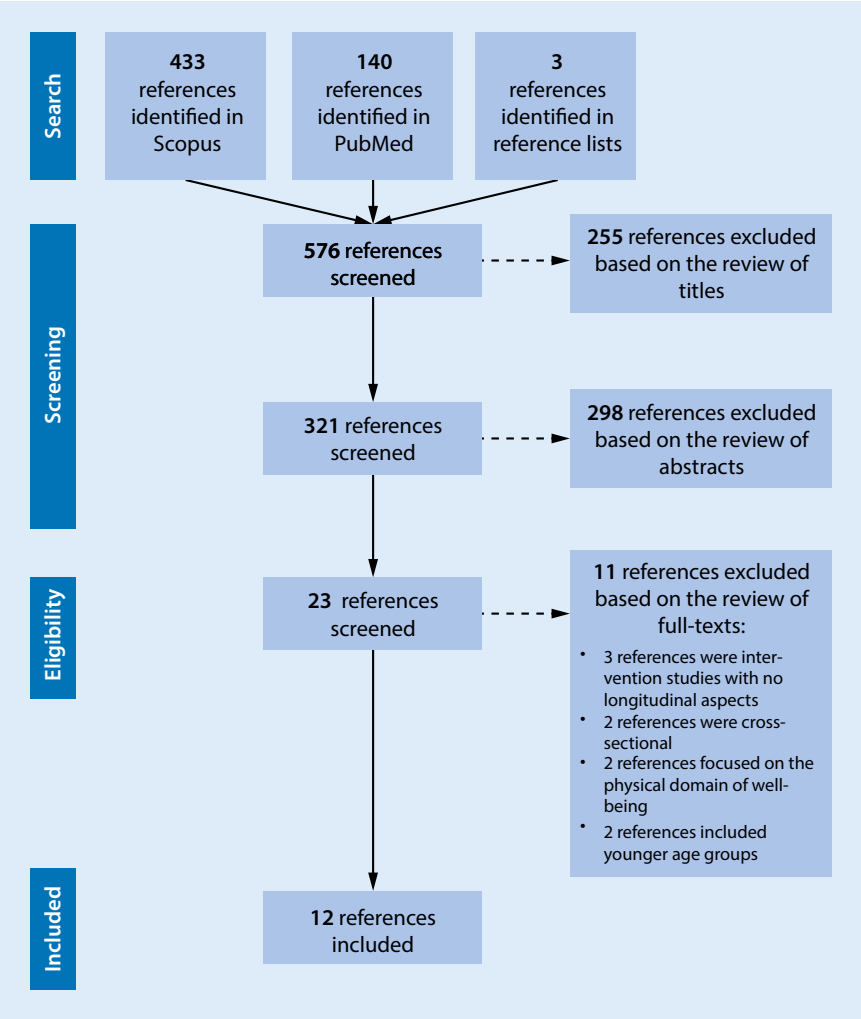

Fig. 1 ▲ Flow chart: different phases of the review

2011), such as methods of randomization and blinding, possible differences between groups in important characteristics at baseline, and participants' compliance and dropout rates. Further, intervention studies increase a certain behavior for a short time, whereas the long-range effects or the maintenance of gains after stopping the intervention remain unclear (Solberg, Halvari, Ommundsen, & Hopkins, 2014). Longitudinal or (prospective/retrospective) cohort studies examining this research question across years have the advantage of providing important insights into the effect of PA in real-life settings, as they collect data over long periods of time using observational methods that do not manipulate the state of the world. This ensures a high level of validity because data acquisition occurs under real-world conditions. However, this type of study is also associated with some limitations. These can be cohort effects, high dropout rates, test–retest effects, and the inability to always clearly identify what is a predictor and what a dependent variable because both might change synchronously. There is currently no systematic review that summarizes the results of longitudinal studies investigating the effect of PA on PWB in older adults. One literature review conducted by Spirduso and Cronin (2001) included cross-sectional, interventional, and longitudinal studies and concluded that cross-sectional and large-scale prospective studies demonstrated that older adults who are more physically active report higher levels of psychological and physical well-being, whereas evidence from intervention studies was mixed. However, this article focused mainly on the association between PA levels and the physical domains of well-being. Hence, our aim was to update and summarize the results of longitudinal studies investigating the relationship between PA and psychological domains of well-being. Furthermore, we discuss possible psychological moderators and mediators of this relationship. Previous studies indicated that self-efficacy, self-esteem, and affect (here affect was regarded as a separate variable that may influence the association between PA and PWB) seem to be crucial variables, which might affect the relationship between PA and PWB (McAuley & Morris, 2007). Identifying these modifiable psychological moderators and mediators is crucial, as these factors may also be positively influenced by future interventions (McAuley & Morris, 2007). Disentangling the PA–wellbeing relationship might help to develop appropriate approaches to further investigate this relationship, and to develop appropriate well-being interventions.

Methods

This systematic review was written according to the Cochrane Handbook for Systematic Reviews of Interventions (Higgins & Green, 2011). Using the databases Scopus and PubMed, we searched the literature for studies that examined (1) the effect of PA on the psychological domains of well-being in a longitudinal design with no focus on physical domains of well-being and (2) the potential moderating/mediating variables of this relationship in older adults. The search strategy was discussed with experts in the field of PA and well-being. The last search update was on August 15th 2017. Each database was searched individually, but all searches were done with a consistent search strategy and search terms. The search terms were: "physical activity" OR "fitness" OR "physical fitness" OR "physical exercise" OR "exercise" OR "energy expenditure" AND "old* age" OR "advanced age" OR "old* adults" OR "elderly" OR "senior*" OR "aging" OR "ageing" AND "psychological well-

being" OR "well-being" OR "satisfaction with life" OR "emotional well-being" OR "psychological wellbeing" OR "wellbeing" OR "emotional wellbeing" AND "*spective" OR "follow-up" OR "longitudinal" OR "observational". The computerized search was completed with manual searches of reference lists for additional studies. The search was limited to English-language longitudinal studies. The literature overview conducted by Spirduso and Cronin (2001) included studies published until 2000. To reduce repetition, we included studies from January 2000 to August 2017. Titles and abstracts of potentially relevant articles were read in view of the inclusion criteria. We included longitudinal studies involving (at least two) repeated observations of the association between PA and psychological components of well-being over periods of at least one year and that were not conducted with a special patient group (e.g., persons with Parkinson's disease, depression, or metabolic syndrome). We focused on healthy older adults; thus, the participants had to be ≥60 years of age.

We identified a great diversity in the applied measuring methods for well-being and decided to include only studies on PWB and synonyms as described above, but not studies on related constructs, such as mental health (absence of mental illness) or quality of life. In total, we identified twelve longitudinal studies referring to the inclusion criteria (see **Fig. 1**). We also included studies which investigated not only the effect of PA, but also of other psychological variables (e.g., optimism) on PWB. However, we focused mainly on results addressing the effect of PA on PWB. We refer to the other psychological variables as moderator/mediator variables if appropriate. We did not include cognitive or non-psychological variables. For other "non-modifiable" variables (e.g., gender), see covariates in **Table 1**.

Results

Twelve longitudinal studies were included in this literature review. The main characteristics of the included studies are summarized in **Table 1**. The number of participants ranged between 62 and 9986. The total number of subjects was 21,611 and their age was between 60 and 93 years. The observation period was between one and eleven years. Measures for PA were the Physical Activity Scale for the Elderly (PASE), the Short Physical Activity Questionnaire, the Godin Leisure-Time Exercise Questionnaire and (presumably) self-developed questions about the frequency and intensity of PA with no literature reference. Measures for PWB were the Satisfaction with Life Scale (SWLS), the quality of life measure CASP-19 (control, autonomy, pleasure, self-realization), the Chinese Aging Profile, the Life Satisfaction Index A (LSIA), the 36-Item Short Form Survey (SF-36), the Louvain Well-Being Scale, the positive and negative affect subscales (PANAS), and a question scale from the Chinese Longitudinal Health Longevity Survey.

In the following, we categorized the included studies based on their research questions. First, we summarized studies which focus on the longitudinal association between PA level (at baseline or over time) and PWB (at follow-up) in general. Then, we presented results

Abstract · Zusammenfassung

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Abstract

The aim of this systematic review was to investigate the longitudinal relationship between physical activity (PA) and the psychological domains of well-being in older adults and to identify possible moderators and mediators of this relationship. Twelve longitudinal investigations were included in this review. The results indicate that there seems to be a positive association between PA and psychological well-being over time. Thus PA may be one possible individual lifestyle factor for the long-term promotion of psychological well-being in older adults. Especially leisure time PA at light intensities conducted in group settings was identified to be beneficial for promoting psychological well-being. Furthermore, longitudinal results indicated that self-efficacy, self-esteem, affect, optimism, and pre-interventional motivation moderated/mediated the relationship between PA and psychological well-being in older adults.

Keywords

Physical activity · Psychological well-being · Quality of life · Longitudinal association

Der Effekt körperlicher Aktivität auf das psychische Wohlbefinden bei älteren Erwachsenen – ein systematisches Review längsschnittlicher Studien

Zusammenfassung

Ziel dieses systematischen Reviews war es, die längsschnittliche Assoziation zwischen körperlicher Aktivität und dem psychischen Wohlbefinden bei älteren Erwachsenen zu untersuchen und mögliche Moderatoren und Mediatoren dieser Beziehung zu identifizieren. Zwölf Längsschnittstudien konnten in das Review einbezogen werden. Die Ergebnisse deuten darauf hin, dass ein positiver Zusammenhang zwischen körperlicher Aktivität und dem psychischen Wohlbefinden über die Zeit besteht. Somit kann körperliche Aktivität als ein potenzieller individueller Lebensstilfaktor für die langfristige Förderung des psychischen Wohlbefindens bei älteren Erwachsenen angesehen werden. Es scheint, dass sich vor allem Freizeitaktivitäten mit niedriger Intensität, die in Gruppen durchgeführt werden, positiv auf das psychische Wohlbefinden auswirken. Des Weiteren zeigen die längsschnittlichen Ergebnisse, dass Selbstwirksamkeit, Selbstwertgefühl, Affekt, Optimismus und die Motivation vor Interventionsbeginn einen Einfluss auf die Beziehung zwischen körperlicher Aktivität und psychologischem Wohlbefinden bei älteren Personen haben.

Schlüsselwörter

Körperliche Aktivität · Psychologisches Wohlbefinden · Lebensqualität · Längsschnittliche Assoziation

Table 1 Main study characteristics

Author (Year)	Participants (*N*, baseline age, M, SD, range, DR, Rep)	Scale to assess PWB	Method to assess PA	Psychological moderators/ mediators	Covariates	Design	Main longitudinal results
Elavsky et al. (2005)	*N* = 123; Age: 60–75, 66.7 ± 5.35 DR ~ 29% Rep: Poor	*Satisfaction with Life Scale* (SWLS)	*Physical Activity Scale for the Elderly* (PASE; assessments for leisure-time activities, household activities, and work-related activities)	Physical self-esteem Self-efficacy Affect	Demographic information, medical history	LA: PA ↔ PWB FU: 4 years	Higher PA associated with higher SWLS. Self-efficacy, physical self-esteem and positive affect influence association between PA and SWLS
Han and Shibusawa (2015)	*N* = 1051; Age: >80, 86.22 ± 6.05 DR ~ 88% Rep: Fair	Scale from the *Chinese Longitudinal Health Longevity Survey*	(Presumably self-developed) questions (exercising presently or in the past; engaging in PA, i.e., housework, outdoor activities, gardening, raising domestic animals, organized activities)	–	Age, sex, birth date, first-born, ethnicity, childhood socioeconomic status, education, occupation before age 60	LA: PA → PWB FU: 7 years	PA was associated with PWB
Kahana et al. (2002)	*N* = 357; Age: >72, 77.64 ± 3.89 DR ~ 64% Rep: Poor	*Positive and negative affect subscales* (PANAS), (Presumably self-developed) questions about having goals in life, and having meaning in life	*Question about the frequency of PA* (Participate in sports or other exercise activities in the last year)	–	Age, sex, education, number of people in household	LA: PA → PWB FU: 9 years	Association between higher PA level and higher levels of positive affect and with having more of a sense of goals and a higher sense of meaning in life
Kim et al. (2016a)	*N* = 9986 at baseline; Age: 63.7 ± 10.6 DR: no information Rep: Fair	Quality of life measure *CASP-19* (Control, Autonomy, Pleasure, Self-realization)	*Short Physical Activity Questionnaire* from the Health Survey for England and the European Prospective Investigation into Cancer and Nutrition (Frequency and duration of moderate and vigorous leisure-time, household, work-related and transport-related activities)	–	Socio-demographic factors (age, sex, race, education, income), health status, and depression	LA: PA ← PWB FU: 11 years	Reverse association between PA and PWB: Higher levels of PWB lead to enhanced levels of PA
Ku et al. (2014)	*N* = 307; Age: >65 DR ~ 87% Rep: Unclear	*Chinese Aging Well Profile*	*Physical Activity Scale for the Elderly* (PASE)	–	Socio-demographic variables (gender, age, education, marital status, living arrangement, main income source), lifestyle behaviors (smoking, drinking), health status (BMI, number of chronic diseases)	LA: PA → PWB FU: 3 years	Leisure-time PA was associated with several dimensions of PWB (psychological, physical, independence, learning and growth, social). Household PA was associated with the social well-being dimension. No association of occupational PA with PWB

Table 1 (Continued)

Author (Year)	Participants (*N*, baseline age, M, SD, range, DR, Rep)	Scale to assess PWB	Method to assess PA	Psychological moderators/ mediators	Covariates	Design	Main longitudinal results
Ku et al. (2016a)	*N* = 1268; Age >70 DR ~ 45% Rep: Fair	*Life Satisfaction Index A* (LSIA)	*Self-reported leisure PA* (walking, group exercise, solitary exercise, and gardening), self-reported *sedentary time* (watching TV, social chatting, reading, listening to radio, and playing chess/cards)	–	Socio-demographic variables (gender, age, education, marital status, living arrangement, main income source), lifestyle behaviors (smoking, drinking), health status (BMI, number of chronic diseases, activities of daily living, depression, cognitive decline)	LA: PA → PWB FU: 8 years	Walking, gardening, group exercise, watching TV, reading and social chatting associated with higher PWB scores
Ku et al. (2016b)	*N* = 295; Age: >65 DR ~ 4% Rep: Unclear	*Chinese Aging Well Profile*	*PA and sedentary time* (Triaxial accelerometer monitors)	–	Socio-demographic variables (gender, age, education, marital status, living arrangement, main income source), lifestyle behaviors (smoking, drinking), health status (BMI, number of chronic diseases)	LA: PA → PWB FU: 18 months	Higher PA levels were associated with higher PWB scores. Different intensities of PA are associated with different dimensions of PWB
Lee and Russell (2003)	*N* = 6472; Age: 70–75 DR ~ 36% Rep: Fair	*Medical Outcomes Study Short Form* (SF-36)	*Self-reported frequency of vigorous and moderate PA and of walking time* (only at follow-up)	–	Age, marital status, BMI, physical well-being, life events	LA: PA ↔ PWB FU: 3 years	Higher PA was associated with higher emotional PWB
Olson et al. (2014)	*N* = 183 women; Mean Age: 68.1, 59–84 DR ~ 26% Rep: Poor	*Satisfaction with Life Scale* (SWLS)	*Physical Activity Scale for the Elderly* (PASE)	Optimism/ pessimism Self-efficacy	Race, age, income, education, health history	LA: PA ↔ PWB FU: 39 months	No PA effect on PWB. Optimism was related with changes in PWB
Solberg et al. (2014)	*N* = 62; Age: 75 ± 5 DR ~ 37% Rep: Poor	*Satisfaction with Life Scale* (SWLS), *Positive and Negative Affect Schedule, Subjective Vitality Scale*	Question about the frequency of PA	Motivational regulation	Baseline level of PA behavior	LA: PA ↔ PWB FU: 1 year	Higher PA and PWB levels after intervention. At one year follow-up PA levels decreased and most improvements in PWB disappeared
van Hoecke et al. (2014a, b)	*N* = 442; Age: 60–93, 69.48 ± 6.71 DR ~ 22% Rep: Poor	*Louvain Well-Being Scale*	Modified version of the *Godin Leisure-Time Exercise Questionnaire* (frequency of mild, moderate and intensive PA of 20-minute bouts in a typical week during the previous month), Number of daily steps (pedometer)	–	Age, gender, marital status, education, health status	LA: PA ↔ PWB FU: 1 year, 2 years	Enhancements in PA might be associated with improvements in PWB

M mean, *SD* standard deviation, *DR* dropout rate (own calculation based on values provided in the papers), *Rep* Representativeness, *PWB* psychological well-being, *PA* physical activity, *LA* longitudinal association, *PA → PWB* Effect of PA on PWB, *PA ↔ PWB* synchronous change of PA and PWB, *PA ← PWB* Effect of PWB on PA, *FU* follow-up period

on the effect of different PA categories, types, and intensities on distinct well-being domains. Further, we reported on possible mediators/moderators of this association. Subsequently we discussed the methodological quality of the included studies.

Relationship between physical activity and psychological well-being

Table 1 shows the differences in study protocols and outcomes. Overall, ten of the twelve studies revealed a positive association between PA and PWB over time (Elavsky et al., 2005; Han & Shibusawa, 2015; Kahana et al., 2002; Ku, Fox, Chang, Sun, & Chen, 2014; Ku, Fox, & Chen, 2016a; Ku et al., 2016b; Lee & Russell, 2003; Solberg et al., 2014; van Hoecke, Delecluse, Bogaerts, & Boen, 2014a, b). One study found no relationship (Olson, Fanning, Awick, Chung, & McAuley, 2014), and another study discussed a reversed causality in the relationship between PA and PWB (Kim, Kubzansky, Soo, & Boehm, 2016a), meaning that not PA led to enhancements in PWB, but higher levels of well-being led to enhanced levels of PA. Further, the studies analyzed different facets of the PA-PWB association: Six of the twelve studies assessed the prospective association of PA with PWB (Elavsky et al., 2005; Lee & Russell, 2003; Olson et al., 2014; Solberg et al., 2014; van Hoecke et al., 2014a, b), five studies the synchronous change of PA and PWB (Han & Shibusawa, 2015; Kahana et al., 2002; Ku et al., 2014, 2016a, b), and one study the prospective association of PWB with PA (Kim et al., 2016a).

In their prospective studies with considerably large samples (N = 123–6472), Elavsky et al. (2005), Lee and Russell (2003) and van Hoecke et al. (2014a, b) demonstrated that participants who are more physically active during the observation periods reached higher PWB scores over time. Similarly, van Hoecke and coworkers (van Hoecke et al., 2014a, b) found that increases in PA were associated with improvements in well-being at the one-year follow-up. However, at the two-year follow-up, levels of well-being were decreased or were even lower than baseline levels (van Hoecke et al., 2014a, b).

Furthermore, Lee and Russell (2003) defined longitudinal transition categories for PA and discussed their association with PWB. That is, participants who changed from some PA at baseline to none after the 3-year study period generally showed changes in emotional well-being that were more negative than those who had always been sedentary. In addition, those who increased or maintained their PA level showed significant improvements in PWB. Olson et al. (2014) identified three different well-being growth patterns over time: (1.) PWB was high and declined over time; (2.) PWB was low and remained low; (3.) PWB was high and remained high. Analyses revealed that PA, self-efficacy, and functional limitations were not associated with these patterns, but optimism was. In all examinations reported in this review so far, PA and PWB may have changed synchronously during the observation periods, thus, identifying which was the predicting variable could not always be clarified. In contrast, in the studies conducted by Han and Shibusawa (2015) and Kahana et al. (2002), baseline PA was used as the predictor for PWB at follow-up. Similar to growth pattern (1.; defined by Olson et al., 2014), both studies reported that, in general, participants' PWB decreased over time. However, a high PA level at baseline was associated with higher well-being scores at follow-up.

Interestingly, E. S. Kim et al. (2016a) discarded the typically observed association between PA and PWB, and demonstrated that a higher PWB at baseline was associated with a higher median PA level over a period of 11 years in a large sample of 9986 older subjects. Further, an evaluation of two separate time-to-event analyses indicated that higher baseline well-being led to a better likelihood of changing PA behavior, regardless of whether subjects were physically active or inactive at baseline. The authors assumed that a high PWB might serve as a health asset by enhancing the likelihood of individuals meeting recommended levels of PA.

Types of activities and exercise, and exercise intensities

Ku et al. (2014) investigated the association of distinct categories (leisure-time, domestic, work-related) of PA with several dimensions of well-being. Their results revealed that leisure-time PA at baseline was positively associated with several dimensions of well-being (psychological, physical, independence, learning and growth, social) three years later. Whereas, household PA was associated only with the 'social' well-being dimension. No associations were evident for occupational PA. In a subsequent study Ku et al. (2016a) examined not only the influence of self-reported leisure-time PA (walking, group exercise, solitary exercise, and gardening), but also the effect of self-reported sedentary leisure-time activities (watching TV, social chatting, reading, listening to radio, and playing chess/cards) on PWB. Longitudinal results revealed that older subjects who reported spending more time with the following leisure-time activities were significantly more likely to exhibit higher PWB scores as they aged: walking, gardening, group exercise (PA activities); watching TV, social chatting, and reading (sedentary activities; Ku et al., 2016a).

The studies presented above asked for the total amount of PA or for distinct categories (leisure-time, domestic, work-related) of PA, but not for the exercise intensity. Only Ku et al. (2016b) examined whether the association between objectively assessed PA (accelerometer) and subjective well-being depended on the exercise intensities (light PA, moderate-to-vigorous PA, sedentary time). Older subjects conducting higher levels of moderate-to-vigorous PA at baseline, regardless of current level of well-being, were more likely to have enhanced levels of general, physical, and independence well-being at the 18-month follow-up. In contrast, those engaging in higher levels of light PA were also more likely to experience higher levels of subsequent psychological, learning and growth, and social well-being.

In addition, some studies discussed types of exercise (aerobic exercise, strength training, and coordinative train-

ing) with ambiguous results. Solberg et al. (2014) investigated the effects of three types of exercise interventions (strength, functional, or endurance training) on PWB and PA across one year after exercise cessation. Beneficial exercise effects on PWB were found for all intervention groups four months after exercise cessation. However, one year after the completion of the trial, PA levels decreased to baseline levels and most of the improvements in PWB induced by the activities disappeared. Only endurance training still seemed to have small beneficial effects on the indices of PWB one year after the intervention.

Possible psychological moderating/mediating variables

Identifying potential psychological variables that can be targeted by tailored interventions and that influence the association between PA and psychological well-being is crucial. Three studies provided information about possible psychological moderators and mediators, namely pre-interventional motivation (Solberg et al., 2014), optimism/pessimism (Olson et al., 2014), physical self-esteem, self-efficacy, and affect (Elavsky et al., 2005). Pre-intervention motivation for exercise influenced the intervention effects in well-being. That is, at follow-up, intrinsically motivated individuals maintained their improvements in PWB and increased their level of PA in comparison to those reported to be extrinsically motivated (Solberg et al., 2014). Further, optimism and pessimism seem to be significant contributors to high PWB over time (Olson et al., 2014). As PA has been shown to have a positive effect on optimism (e.g., J. Kim et al., 2016b), optimism can be assumed to be a mediating variable between PA and PWB. Divergently from our definition of PWB, which includes affect (see introduction), Elavsky and colleagues (2005) defined affect as a separate variable, which might mediate the relationship between PA and PWB. They found that a higher level of PA over time led to improvements in self-esteem and affect. The enhancement of affect was, in turn, associated with increases in life-satisfaction over time (Elavsky et al., 2005).

Quality of the included studies

We evaluated the quality of the included studies by using a modified version of the Newcastle–Ottawa Scale (Wells et al., 2014). The representativeness of the observed subjects, the observation period, the assessment methods for PA and PWB, the included covariates, and the dropout rates were examined (for an overview see **Table 1**).

The representativeness of studies which recruited a non-representative sample via (local) media (e.g., newspapers) or from local retirement communities was regarded as poor; whereas samples recruited within a representative national longitudinal study and used for analysis on PA and subjective well-being were regarded as fair. Subsequently, the representativeness of the studies in this review was as follows: six were poor (Elavsky et al., 2005; Kahana et al., 2002; Olson et al., 2014; Solberg et al., 2014; van Hoecke et al., 2014a, b), four were fair (Han & Shibusawa, 2015; Kim et al., 2016a; Ku et al., 2016a; Lee & Russell, 2003), and the representativeness of two was unclear due to insufficient information (Ku et al., 2014, 2016b). Although different methods were applied to assess PA and PWB, all studies used valid, reliable, and accepted methods. Only Kahana et al. (2002) used (presumably self-developed) questions about having goals and meaning in life (in addition to the positive and negative affect scale [PANAS]) with no information about validity or reliability. Most studies also applied well-established instruments with adequate reliability and validity scores to assess PA. Namely, the Physical Activity Scale for the Elderly (PASE; Elavsky et al., 2005; Ku et al., 2014; Olson et al., 2014), the Short Physical Activity Questionnaire (Kim et al., 2016a), Godin Leisure-Time Exercise Questionnaire (van Hoecke et al., 2014a, b) or summary scores while referring to previous studies using comparable scores (Lee & Russell, 2003; Solberg et al., 2014). Only three studies (Han and Shibusawa, 2015; Kahana et al., 2002; Ku et al., 2016a) did not provide a reference for their instruments of measuring PA level. Using questionnaires without information about validity or reliability leads to a diminished extent of generalization. Ku et al. (2016b) and van Hoecke et al. (2014b) used objective measures, such as triaxial accelerometer monitors or pedometers, to assess PA.

Furthermore, the included studies conducted thorough examinations of possible covariates that might influence the relationship between PA and PWB. All studies, except Solberg et al. (2014), who controlled for PA at baseline only, controlled for relevant sociodemographic variables like gender, age, and education. As typical for longitudinal samples in aging research (Markides, Dickson, & Pappas, 1982), dropout rates due to illness and death were quite high (up to 88%). Only Ku et al. (2016b) had a very low dropout rate (4%). Such great differences in the dropout rates might be explained by different follow-up periods (1–9 years). Even though longer observation periods provide more profound information about the relationship between PA and PWB, they are also associated with higher dropout rates (e.g., Han & Shibusawa, 2015: follow-up after 7 years, dropout rate: 88%; Ku et al. (2016): follow-up after 18 months, dropout rate: 4%).

Despite the different characteristics and methods used in the included studies, ten out of twelve studies revealed a positive association between PA and PWB. Thus, the differences in methodology seems to have only minor influences on the results.

Discussion

The aim of this review was to investigate the longitudinal relationship between physical activity and the psychological domains of well-being, and to identify possible moderators and mediators of this relationship. We found eleven longitudinal studies proving a longitudinal association between PA and PWB, and one that did not. Four of the included studies further investigated the effect of different PA categories, types, and intensities on distinct well-being domains (Ku

et al., 2014, 2016a, 2016b; Solberg et al., 2014). Three studies provided information about the mediating/moderating effects of psychological variables (physical self-esteem, self-efficacy, affect, optimism/pessimism, and pre-intervention motivation) on the association between PA and PWB (Elavsky et al., 2005; Olson et al., 2014; Solberg et al., 2014), and one study found a reverse association between PA and PWB (Kim et al., 2016a). In general, the results of the included studies support the assumption that PA seems to be a promising lifestyle factor for the long-term promotion of PWB. In addition, the results revealed that optimism, self-efficacy, self-esteem, affect, and pre-interventional motivation seem to be important modifiable psychological variables, which moderate/mediate the relationship between PA and PWB in older age.

General effect of physical activity and psychological well-being

As mentioned above, our results confirm earlier reviews showing that PA appears to be a promising lifestyle factor for the long-term promotion of PWB (Rejeski & Mihalko, 2001; Spirduso & Cronin, 2001). However, due to the synchronous change of PA and PWB during the observation periods, and that these two variables seem to be strongly interrelated, it is not completely clear which is the predicting and which the depending variable. Nevertheless, based on previous evidence (e.g., Mavrovouniotis et al., 2010; Rejeski & Mihalko, 2001), and on the results that different PA intensities and categories were associated with changes in different domains of PWB (Ku et al., 2014, 2016b), we assume that PA is an important lifestyle factor which may improve PWB in older adults.

Types of activities and exercise, and exercise intensities

Our results indicated that leisure time PA was associated with PWB, but also with physical and social well-being, independence, learning, and growth over time. Household PA, on the other hand, was not associated with PWB, but rather only with social well-being. This result might be explained by the obligatory characteristic of domestic and work-related activities, whereas leisure-time PA is associated with enjoyment, diversion from stress, and social connection. Further, it seems that activities which include social interaction tend to have more positive effects on PWB in later life than solitary exercises (Ku et al., 2014; Ku et al., 2016a). Related to the assumption that social interaction is a crucial factor for promoting and/or maintaining PWB, some authors found that other non-PA leisure activities, such as watching TV, social chatting, reading, listening to the radio, and playing chess or cards had similar effects on PWB as PA (Ku et al., 2016a). Based on previous studies (Beard & Ragheb, 1980; Lu, 2011; Östlund, 2010), Ku et al. (2016) argued that all activities satisfying aspects of human needs, such as psychological (e.g., accessing interesting activities), social (e.g., getting to know people), educational (e.g., learning new information), and recreational (e.g., feeling relaxed or unwind), are probably associated with subjective well-being. Similarly, there is evidence that PWB in older adults is also modifiable through psychological interventions (Friedman et al., 2017).

Otherwise, there is some evidence for physiological mechanisms, particularly related to the PA effect on PWB. PA has been shown to influence neurotransmitters (e.g., dopamine, norepinephrine, serotonin, and acetylcholine) in neuronal circuits, which in turn are responsible for regulating PWB (Clow & Edmunds, 2014). Thus, it seems that PWB can be affected by various activities, but that the underlying mechanisms might differ; PA seems to be one main instrument. Following this, the *exercise intensity* seems to influence whether PA has an effect on the psychological domain of well-being in older adults (Ku et al., 2016b). Interestingly, PWB was only associated with higher amounts of low intensity PA. Additionally, low intensity PA was associated with learning, growth, and social well-being. Higher extents of moderate-to-vigorous intensity PA, however, were not associated with the psychological domains of well-being, but led to enhanced levels of general well-being, physical well-being, and independence well-being. One possible explanation might be that activities with lower intensities do not affect the biochemical mechanisms mentioned above, but might comprise social and cognitive mechanisms (Buckworth & Tomporowski, 2013). Thus, low-intensity exercise might be particularly related to psychological and social aspects of well-being, whereas activities with higher intensities influence the neuronal circuits and are therefore especially associated with the physical domains of well-being. Whether this is a generalizable result remains questionable and needs further research, as exercise intensity was only investigated in one longitudinal study (Ku et al., 2016b). The study by Ku et al. (2016b) is also one of the few which used objective measures (triaxial accelerometer monitors) and were able to compare different PA intensities. Objective measures provide detailed and reliable information about PA frequency, duration, and intensity (Solberg et al., 2014), whereas subjective measuring methods tend to overestimate and/or underestimate actual PA (Dyrstad, Hansen, Holme, & Anderssen, 2014; Hagstromer, Ainsworth, Oja, & Sjostrom, 2010). For a better understanding of the underlying mechanisms, future studies should focus more on objective measuring methods.

Up to now, there are no longitudinal investigations which examine the effect of *different types of PA* (e.g., endurance, strength, or balance training) on PWB. Solberg et al. (2014) were able to demonstrate that strength, functional training, and endurance training all have positive effects on PWB directly after an exercise intervention. However, after cessation of an intervention activity, solely endurance training (but not strength or functional training) seems to have small long-term effects on PWB. This observation confirms the mentioned limitations of intervention studies, in that this type of study boost a certain behavior for a short time, whereas the long-range effects after cessation of the intervention are limited. Van Hoecke et al. (2014a) confirmed this limitation by demonstrating that PA counseling strategies were able to maintain enhanced levels of well-being (psycho-

logical and physical domain) over a one-year follow-up period, but not over a two-year period. Based on their observation, van Hoecke et al. (2014a) suggested implementing reminder "booster-sessions" on PA to maintain a high motivation and improved levels of PWB over longer periods of time.

In summary, it seems that leisure time PA at light intensities and conducted in group-settings is most beneficial for promoting PWB in older adults. All types of exercise seem to be suitable for promoting PWB and could be chosen on the basis of individual preferences and needs. Depending on the type and/or intensity of exercise, different mechanisms might be involved. However, long-term effects of PA on PWB after exercise cessation are questionable (Solberg et al., 2014). Thus, regularly performed PA seems to be important for the long-range maintenance of a high PWB.

Finally, we would like to reiterate that there also seems to be a reverse association of PA and PWB. This means that not only PA leads to enhancements in PWB, but higher levels of well-being also lead to enhanced levels of PA (E. S. Kim et al., 2016a). Since these two variables are strongly interrelated, it might be effective to enhance PWB through psychological, social, educational, or relaxation strategies, which in turn might lead to increases in PA levels.

Moderator/mediator variables

A second aim of our review was to identify and discuss possible modifiable psychological moderators and mediators of the effect of PA on PWB. PWB seems to be affected not only directly by PA, but also by mediating/moderating mechanisms. Previous cross-sectional and interventional results indicated that self-efficacy, self-esteem, and affect influence the association between PA and PWB (e.g., McAuley & Morris, 2007). The results of this review confirmed the moderating effects (Elavsky et al., 2005).

Further, a person's motivation for PA seems to be another important factor for the association between PA and PWB, as indicated by Solberg et al. (2014). Future efforts to enhance PA and PWB, therefore, could include strategies to increase the intrinsic motivation for exercise in older adults. In this line, van Hoecke et al. (2014a) demonstrated that individually tailored PA coaching which targeted targeting the motivation of the individuals led to greater enhancements in PA than a general information session.

Furthermore, the study conducted by Olson et al. (2014) revealed that optimism/pessimism had a positive influence on the PWB class pattern over time. This supports existing evidence (Carver, Scheier, & Segerstrom, 2010) that being more optimistic plays a protective role in preserving PWB regardless of socio-demographic characteristics (Olson et al., 2014). Additionally, there is evidence that PA has a positive effect on optimism (e.g., J. Kim et al., 2016b). Thus, we propose that optimism may be a mediating variable between PA and PWB. Further, social interaction seems to be a crucial factor, enhancing the beneficial effects of PA on PWB (Ku et al., 2014; Ku et al., 2016a). However, the existing longitudinal studies did not include mediators regarding social interaction. Thus, future studies might address this topic.

Based on the results of our review, optimism, self-efficacy, self-esteem, affect, intrinsic motivation and probably social interaction seem to be important variables, which affect the relationship between PA and PWB. These variables should be taken into consideration for future efforts to increase PWB in older age.

Observation period and measure

There were no differences in the results regarding the association between PA and PWB for observation period (range between one and 11 years). Thus, we conclude that the observation period is not a determining factor in longitudinal designs. In addition, the applied measuring methods for PWB (here Satisfaction with Life Scale, CASP-19, Chinese Aging Profile, LSIA, SF-36, Louvain Well-Being Scale, PANAS, and self-developed questions) and PA (here Physical Activity Scale for the Elderly, Short Physical Activity Questionnaire, Godin Leisure-Time Exercise Questionnaire and self-developed questions) did not affect the evidence for an effect of PA on PWB. In this context, it is important to note that the included studies used several methods to asses PA and PWB. In addition, different covariates and variables to examine moderation/mediation were used (see **Table 1**). This reduces the comparability and the extent to which the studies can be generalized. We regarded studies using validated questionnaires as higher quality than those using self-developed questions or those giving no background information about the used scales. Thus, future studies should use well-established instruments with adequate reliability and validity scores, like SWLS and PASE. For measures of PA, triaxial accelerometer monitors would be preferable.

The only study that did not detect any exercise effect on PWB (Olson et al., 2014) included only women. However, Lee and Russell (2003) also examined only women and were able to report positive exercise effects on well-being. Thus, future research on possible differences between men and women is necessary.

Limitations

We regarded reviewing longitudinal studies to be an appropriate method for investigating the effect of PA on PWB because of their high levels of validity. Regardless of the study design, studies with statistically significant results are, however more likely to be published than studies with no significant results. Nevertheless, in general, studies indicate that PA seems to be one promising lifestyle for promoting PWB in older adults.

Conclusion and outlook

The results indicate that there is a positive association between PA and the psychological domains of well-being in older adults. However, because of the synchronous changes in both variables and their mutual relationship, it is not always possible to clarify whether PA is the predicting variable. Nevertheless, results demonstrated that different intensities and categories of PA influenced different domains of PWB (Ku et al., 2014, 2016a, b), indicating that PWB is indeed

suggestible by PA. It is also important to emphasize that other activities satisfying aspects of human needs seem to be associated with PWB (Beard & Ragheb, 1980; Lu, 2011; Östlund, 2010). Along this line, it needs to be critically discussed whether the activity itself, the setting, or the activity level is the main influencing factor. Based on the findings of our systematic review, low intensity leisure time PA conducted in group-settings seems to be most suitable for promoting PWB. Assuming this to be true, the underlying (explaining) mechanisms are most likely social and cognitive rather than biochemical (Buckworth & Tomporowski, 2013). Thus, we conclude that PA appears to be only one of many possible individual lifestyle factors which have a universal influence on PWB and was possibly overestimated in the past. Although future programs aiming to improve PWB in older adults might consider other activities, PA seems to be a quite robust factor for promoting PWB. All included studies thoroughly controlled for various possible covariates. After adjustments, the association between PA and PWB was weaker, but still significant. Furthermore, a higher intensity of PA was associated with promoting physical domains of well-being (explained by physiological adaptations, Clow & Edmunds, 2014).

Bringing our conclusions into practice, community programs and trainers should focus on the individual needs of their participants and adapt the activities regarding the activity itself, the setting, and the intensity of the activity.

For a deeper understanding and more personalized implementation in the future, the effect of different types and intensities of PA needs to be investigated in more detail (Kim et al., 2016a). To ensure a better comparability of future studies, consistent assessment methods for PA, PWB, possible moderating and mediating variables, and covariates are necessary.

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References

Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful aging: the model of selective optimization with compensation. Successful aging. *Perspectives from the behavioral sciences*, *1*, 1–34.

Beard, J. G., & Ragheb, M. G. (1980). Measuring leisure satisfaction. *Journal of leisure Research*, *12*(1), 20.

Bilotta, C., Bowling, A., Case, A., Nicolini, P., Mauri, S., Castelli, M., & Vergani, C. (2010). Dimensions and correlates of quality of life according to frailty status: a cross-sectional study on community-dwelling older adults referred to an outpatient geriatric service in Italy. *Health and quality of life outcomes*, *8*, 56. https://doi.org/10.1186/1477-7525-8-56.

Bilotta, C., Bowling, A., Nicolini, P., Case, A., Pina, G., Rossi, S. V., & Vergani, C. (2011). Older People's Quality of Life (OPQOL) scores and adverse health outcomes at a one-year follow-up. A prospective cohort study on older outpatients living in the community in Italy. *Health and quality of life outcomes*, *9*, 72. https://doi.org/10.1186/1477-7525-9-72.

Buckworth, J., & Tomporowski, P. (2013). *Exercise psychology: Human kinetics*

Carver, C. S., Scheier, M. F., & Segerstrom, S. C. (2010). Optimism. *Clinical psychology review*, *30*(7), 879–889. https://doi.org/10.1016/j.cpr.2010.01.006.

Clow, A., & Edmunds, S. (2014). *Physical activity and mental health: human kinetics*

Diener, E. (2009). Subjective well-being. In A. C. Michalos & E. Diener (Eds.), *The science of well-being vol. 37* (pp. 11–58). Dordrecht: Springer.

Dyrstad, S. M., Hansen, B. H., Holme, I. M., & Anderssen, S. A. (2014). Comparison of self-reported versus accelerometer-measured physical activity. *Medicine & Science in Sports & Exercise*, *46*(1), 99–106.

Elavsky, S., McAuley, E., Motl, R. W., Konopack, J. F., Marquez, D. X., Hu, L., Jerome, G. J., & Diener, E. (2005). Physical activity enhances long-term quality of life in older adults: efficacy, esteem, and affective influences. *Annals of Behavioral Medicine*, *30*(2), 138–145.

Friedman, E. M., Ruini, C., Foy, R., Jaros, L., Sampson, H., & Ryff, C. D. (2017). Lighten UP! A community-based group intervention to promote psychological well-being in older adults. *Aging & mental health*, *21*(2), 199–205. https://doi.org/10.1080/13607863.2015.1093605.

Gale, C. R., Cooper, C., Deary, I. J., & Sayer, A. A. (2014). Psychological well-being and incident frailty in men and women: the English Longitudinal Study of Ageing. *Psychological medicine*, *44*(4), 697–706. https://doi.org/10.1017/s0033291713001384.

Hagstromer, M., Ainsworth, B. E., Oja, P., & Sjostrom, M. (2010). Comparison of a subjective and an objective measure of physical activity in a population sample. *Journal of Physical Activity and Health*, *7*(4), 541–550.

Han, W.-J., & Shibusawa, T. (2015). Trajectory of physical health, cognitive status, and psychological well-being among Chinese elderly. *Archives of gerontology and geriatrics*, *60*(1), 168–177.

Heo, J., Culp, B., Yamada, N., & Won, Y. (2013). Promoting successful aging through competitive sports participation: insights from older adults. *Qualitative health research*, *23*(1), 105–113. https://doi.org/10.1177/1049732312457247.

Higgins, J. P., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions*. Vol. 4. Hoboken: John Wiley & Sons.

van Hoecke, A.-S., Delecluse, C., Bogaerts, A., & Boen, F. (2014a). Effects of need-supportive physical activity counseling on well-being: a 2-year follow-up among sedentary older adults. *Journal of physical activity & health*, *11*(8), 1492–1502. https://doi.org/10.1123/jpah.2012-0497.

van Hoecke, A.-S., Delecluse, C., Bogaerts, A., & Boen, F. (2014b). The long-term effectiveness of need-supportive physical activity counseling compared with a standard referral in sedentary older adults. *Journal of aging and physical activity*, *22*(2), 186–198. https://doi.org/10.1123/japa.2012-0261.

Kahana, E., Lawrence, R. H., Kahana, B., Kercher, K., Wisniewski, A., Stoller, E., Tobin, J., & Stange, K. (2002). Long-term impact of preventive proactivity on quality of life of the old-old. *Psychosomatic medicine*, *64*(3), 382–394.

Kim, E. S., Kubzansky, L. D., Soo, J., & Boehm, J. K. (2016a). Maintaining healthy behavior: a prospective study of psychological well-being and physical activity. *Annals of Behavioral Medicine: a Publication of the Society of Behavioral Medicine*. https://doi.org/10.1007/s12160-016-9856-y.

Kim, J., Lee, S., Chun, S., Han, A., & Heo, J. (2016b). The effects of leisure-time physical activity for optimism, life satisfaction, psychological well-being, and positive affect among older adults with loneliness. *Annals of Leisure Research*, *8*(1), 1–10. https://doi.org/10.1080/11745398.2016.1238308.

Ku, P.-W., Fox, K. R., & McKenna, J. (2008). Assessing subjective well-being in Chinese older adults: the Chinese aging well profile. *Social Indicators Research*, *87*(3), 445–460.

Ku, P.-W., Fox, K. R., Chang, C.-Y., Sun, W.-J., & Chen, L.-J. (2014). Cross-sectional and longitudinal associations of categories of physical activities with dimensions of subjective well-being in Taiwanese older adults. *Social Indicators Research*, *117*(3), 705–718. https://doi.org/10.1007/s11205-013-0394-8.

Ku, P.-W., Fox, K. R., & Chen, L.-J. (2016a). Leisure-Time Physical Activity, Sedentary Behaviors and

Subjective Well-Being in Older Adults: An Eight-Year Longitudinal Research. *Social Indicators Research*, *127*(3), 1349–1361. https://doi.org/10.1007/s11205-015-1005-7.

Ku, P.-W., Fox, K. R., Liao, Y., Sun, W.-J., & Chen, L.-J. (2016b). *Prospective associations of objectively assessed physical activity at different intensities with subjective well-being in older adults* (pp. 2909–2919). https://doi.org/10.1007/s11136-016-1309-3. Quality of life research: an international journal of quality of life aspects of treatment, care and rehabilitation, 25(11)

Kunzmann, U., Little, T. D., & Smith, J. (2000). Is age-related stability of subjective well-being a paradox?: cross-sectional and longitudional evidence from the Berlin Aging Study. *Psychology and aging*, *15*(3), 511–526. https://doi.org/10.1037//0882-7974.15.3.511.

Lee, C., & Russell, A. (2003). Effects of physical activity on emotional well-being among older effects of physical activity on emotional well-being among older Australian women. Cross-sectional and longitudinal analyses. *Journal of Psychosomatic Research*, *54*, 155–160.

Lu, L. (2011). Leisure experiences and depressive symptoms among Chinese older people: a national survey in Taiwan. *Educational Gerontology*, *37*(9), 753–771.

Markides, K. S., Dickson, H. D., & Pappas, C. (1982). Characteristics of dropouts in longitudinal research on aging: a study of Mexican Americans and Anglos. *Experimental Aging Research*, *8*(3), 163–167.

Mavrovouniotis, F. H., Argiriadou, E. A., & Papaioannou, C. S. (2010). Greek traditional dances and quality of old people's life. *Journal of bodywork and movement therapies*, *14*(3), 209–218. https://doi.org/10.1016/j.jbmt.2008.11.005.

McAuley, E., & Morris, K. S. (2007). State of the art review: advances in physical activity and mental health: quality of life. *American Journal of Lifestyle Medicine*, *1*(5), 389–396. https://doi.org/10.1177/1559827607303243.

Netz, Y., Wu, M.-J., Becker, B. J., & Tenenbaum, G. (2005). Physical activity and psychological well-being in advanced age: a meta-analysis of intervention studies. *Psychology and aging*, *20*(2), 272–284. https://doi.org/10.1037/0882-7974.20.2.272.

Nordbakke, S., & Schwanen, T. (2013). Well-being and mobility: a theoretical framework and literature review focusing on older people. *Mobilities*, *9*(1), 104–129. https://doi.org/10.1080/17450101.2013.784542.

Olson, E. A., Fanning, J. T., Awick, E. A., Chung, H. D., & McAuley, E. (2014). Differential trajectories of well-being in older adult women: the role of optimism. *Applied psychology. Health and well-being*, *6*(3), 362–380. https://doi.org/10.1111/aphw.12033.

Ostir, G. V., Ottenbacher, K. J., & Markides, K. S. (2004). Onset of frailty in older adults and the protective role of positive affect. *Psychology and aging*, *19*(3), 402–408. https://doi.org/10.1037/0882-7974.19.3.402.

Östlund, B. (2010). Watching television in later life: a deeper understanding of TV viewing in the homes of old people and in geriatric care contexts. *Scandinavian journal of caring sciences*, *24*(2), 233–243.

Pasco, J. A., Williams, L. J., Jacka, F. N., Henry, M. J., Coulson, C. E., Brennan, S. L., Leslie, E., Nicholson, G. C., Kotowicz, M. A., & Berk, M. (2011). Habitual physical activity and the risk for depressive and anxiety disorders among older men and women. *International psychogeriatrics*, *23*(2), 292–298. https://doi.org/10.1017/s1041610210001833.

Rejeski, W. J., & Mihalko, S. L. (2001). Physical activity and quality of life in older adults. *Journals of Gerontology: Series A*, *56 A*(Special Issue 11), 23–35.

Ryff, C. D., Dienberg, L. G., Urry, H. L., Muller, D., Rosenkranz, M. A., Friedman, E. M., Davidson, R. J., & Singer, B. (2006). Psychological well-being and ill-being: do they have distinct or mirrored biological correlates? *Psychotherapy and psychosomatics*, *75*(2), 85–95. https://doi.org/10.1159/000090892.

Schüz, B., Wurm, S., Warner, L. M., & Tesch-Römer, C. (2009). Health and subjective well-being in later adulthood: different health states-different needs? *Applied Psychology: Health and Well-Being*, *1*(1), 23–45. https://doi.org/10.1111/j.1745-7254.2007.00657.x-i1.

Solberg, P. A., Halvari, H., Ommundsen, Y., & Hopkins, W. G. (2014). A 1-year follow-up of effects of exercise programs on well-being in older adults. *Journal of aging and physical activity*, *22*(1), 52–64. https://doi.org/10.1123/japa.2012-0181.

Spirduso, W. W., & Cronin, D. L. (2001). Exercise dose-response effects on quality of life and independent living in older adults. *Med. Sci. Sports Exerc*, *33*(6), S598–S608.

Tunstall-Pedoe, H. (2006). *Preventing chronic diseases. A vital investment: WHO global report* (p. 200). Geneva: World Health Organization. CHF 30.00. ISBN 92 4 1563001. Also published on http://www.who.int/chp/chronic_disease_report/en. *International Journal of Epidemiology, 35*(4), 1107. https://doi.org/10.1093/ije/dyl098

Urry, H. L., Nitschke, J. B., Dolski, I., Jackson, D. C., Dalton, K. M., Mueller, C. J., Rosenkranz, M. A., Ryff, C. D., Singer, B. H., & Davidson, R. J. (2004). Making a life worth living: neural correlates of well-being. *Psychological science*, *15*(6), 367–372. https://doi.org/10.1111/j.0956-7976.2004.00686.x.

Vagetti, G. C., Barbosa Filho, V. C., Moreira, N. B., Oliveira, V. D., Mazzardo, O., & Campos, W. D. (2014). Association between physical activity and quality of life in the elderly: a systematic review, 2000–2012. *Revista Brasileira de Psiquiatria*, *36*(1), 76–88.

Verbrugge, L. M., & Jette, A. M. (1994). The disablement process. *Social Science & Medicine*, *38*(1), 1–14.

Wells, G., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M., & Tugwell, P. (2014). *Newcastle-Ottawa quality assessment scale, cohort studies*