Physical activity interventions for treatment of social isolation, loneliness or low social support in older adults: A systematic review and meta-analysis of randomised controlled trials

Anastasia Shvedko[a]*, Anna C. Whittaker[a], Janice L. Thompson[a], and Carolyn A. Greig[a]

[a]School of Sport, Exercise and Rehabilitation Sciences, Birmingham, UK

*Corresponding Author: Anastasia Shvedko, School of Sport, Exercise & Rehabilitation Sciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK, e-mail: AXS1235@student.bham.ac.uk

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Abstract

Objectives: This article reviews the effects of physical activity (PA) interventions on social isolation, loneliness or low social support in older adults.

Design: Systematic review and meta-analysis of randomised controlled trials (RCTs).

Method: MEDLINE, EMBASE, PsycINFO, the Cochrane CENTRAL, *CINAHL*, were screened up to February 2017. RCTs comparing PA versus non-PA interventions or control (sedentary) condition were included. Risk of bias was assessed using the 12 criteria Cochrane Review Book Group risk of bias. The outcome measures were: social isolation, loneliness, social support, social networks, and social functioning. Standardised mean differences (SMDs) with associated 95% confidence intervals (CIs) were calculated for continuous outcomes. Meta-analysis was performed using a random effects model.

Results: The search strategy identified 38 RCTs, with a total of 5288 participants, of which 26 had a low risk of bias and 12 had a high risk of bias. Meta-analysis was performed on 23 RCTs. A small significant positive effect favouring the experimental condition was found for social functioning (SMD=0.30; 95% CI, 0.12 to 0.49; P=0.001) with strongest effects obtained for PA interventions, diseased populations, group exercise setting, and delivery by a medical healthcare provider. No effect of PA was found for loneliness, social support, or social networks.

Conclusion: This review shows, for social functioning, the specific aspects of PA interventions can successfully influence social health. PA did not appear to be effective for loneliness, social support and social networks.

Keywords: Systematic review; Randomised controlled trial; Loneliness; Social isolation; Older adults.

1. Introduction

The absence, or poor quality, of social relations has detrimental effects on mental health and well-being, negatively impacts quality of life (QoL) and leads to the feeling of loneliness (Masi et al., 2011; Netz et al., 2005). According to UK statistics, the prevalence of loneliness among older adults aged 65 years or older has been estimated to be between 6 to 22% in Great Britain in 2015 and is continuing to rise (Office for National Statistics, 2015). Older adults are considered a particularly vulnerable category of people because older adults experience an increased need in the meaningful social contacts that are consequently replaced by the family and close friends after retirement from work (Masi et al., 2011). Given this, special emphasis of healthcare professionals has been placed on the implementation of health promotion interventions to address this problem in society (Jopling, 2015).

Following the analysis of systematic reviews and meta-analyses (Cattan et al., 1998; Cattan et al., 2005; Cohen-Mansfield et al., 2016; Dickens et al., 2011; Hagan et al., 2014; Masi et al., 2011; Pels et al., 2016; Petitte et al., 2015; Smith et al., 2017; Snowden et al., 2014), there is a lack of available evidence for PA intervention effects for social health outcomes in community-dwelling older adults. Some reviews focus either on non-PA interventions in a wide diversity of participants and settings (Masi et al., 2011) or include non-experimental designed interventions, which reduce the methodological rigour of evidence (Hagan et al., 2014; Pels et al., 2016). Other are focusing on only certain social outcomes and do not consider social health as a multifaceted domain (Gillison et al., 2009; Masi et al., 2011; Schechtman et al., 2001). Limitations of current PA interventions include insufficient sample sizes and lack of adjustment for confounding factors resulting in an inability to provide sufficient information about the effectiveness of treatment.

The causal mechanisms that underlie the social health effects of PA are complex comprising many components (Michie et al., 2009). The independent effects of interventions on social outcomes is difficult to determine due to the multidimensional structure of social health that is lacking the precise definition of its domains (Biddle et al., 2011). Sub-components of social health in addition to social isolation and loneliness include social support and its functional and structural domains (Dickens et al., 2011). Loneliness is defined as a discrepancy between a person's desired and actual social relationships (Peplau et al., 1980), that is typically assessed using the UCLA loneliness scale (Russell, 1996). Social isolation is a "a state in which the individual lacks a sense of belonging socially, lacks engagement with others, has a minimal number of social contacts, and they are deficient in fulfilling and quality relationships" (Nicholson, 2012, p. 138). Social support is the comfort, assistance, and information received and shared through formal and informal contacts with others (Wallston et al., 1983).

PA is a health behaviour that can influence social health through a number of mechanisms and behaviour change techniques (Michie et al., 2011). A recent meta-analysis showed that a "self-monitoring" technique combined with one or two other techniques was included in most effective interventions of PA and healthy eating (Michie et al., 2009). However, the causal mechanisms that underlie the social health effects of PA are complex comprising many components or moderating factors (Michie et al., 2009). With this the type of PA intervention, residential settings, delivery format, comorbidity and others are important considerations which will be examined in the present review, where possible.

Mechanisms of how PA interventions might be particularly effective for improving social health outcomes have been suggested to be that, first, PA can facilitate social relationships through social connectedness arising from building friendly and

trusted relationships between people during activities (Lubans et al., 2016). In addition, PA removes the individual barriers to social interaction and generates a sense of self-esteem based on social acceptance and perceived emotional support, leading to further action (Baumeister et al., 1995; Masi et al., 2011). Second, PA changes perceptions of people's lives associated with direct effects on quality of life, sleep volume and self-regulation skills (Lubans et al., 2016). Third, at a biological level, the feel-good effect of PA is associated with the increases in serotonin, monoamine and neurotrophin production, reductions in the stress hormone cortisol, activation of the grey matter, and the release of endogenous opioids referred to a the neurobiological hypothesis (Lubans et al., 2016). However, many PA interventions do not measure all of these aspects as potential mechanisms of effects on social health, or use them as a theoretical basis for intervention.

Several theoretical models that relate to the above mechanisms have been applied to loneliness reduction via physical activity (PA) interventions. Among them is the social compensation effect described by Ferraro et al. (1995)'s model, according to which engagement in a variety of physical and leisure activities by older adults with a loss of meaningful social connections compensates for or replaces this loss by increasing their peripheral social networking. The related theory of active engagement explains loneliness reduction in older adults through engagement in an active lifestyle that generates a sense of purpose through increased social support and lowered depression (Lemon et al., 1972; Rowe et al., 1997). The tripartite model of group identification (Henry et al., 1999; Pels et al., 2016) associated with the exercise-induced change in the experience of living to an advanced age considers three aspects to explain the positive effects of physical activity: cognitive (social categorisation), affective (interpersonal attraction), and behavioural (interdependence) which seems to encompass

much of the aspects of the above theories. Finally, according to the framework of "coping styles" of loneliness (Fokkema et al., 2007), PA may reduce loneliness in two ways: 1) by improving social skills and self-confidence by engaging in a variety of social contacts during PA programmes; and 2) by changing self-perception and "seeing things in perspective" (Fokkema et al., 2007, p. 498). Among these, the most commonly utilised is the tripartite model, which has been successfully applied to a programme of PA in lonely seniors which increased their sense of identification (Henry et al., 1999; Pels et al., 2016). However, despite these convincing theories of how PA might influence health and wellbeing positively, there is a lack of available evidence regarding the effectiveness of PA interventions for psychosocial outcomes, and the available evidence is often contradictory and sparse (Hagan et al., 2014; Pels et al., 2016).

Given that the effect of PA interventions on social isolation, loneliness and low social support in community-dwelling older adults is not well documented, a novel systematic review of RCTs is needed in order to summarise the literature. This systematic review was aimed to examine physical activity intervention effects on loneliness, social isolation or low social support in community-dwelling older adults.

The protocol for this review was registered at PROSPERO; registration number 42016036013, available from: https://www.crd.york.ac.uk/PROSPERO/myprospero.php (Appendix A).

2. Material and methods

This systematic review was guided by the PRISMA statement (Moher et al., 2015) (Appendix B). This is a 27-item checklist that ensures the transparency and clarity of a systematic review (Liberati et al., 2009).

Eligibility criteria

To be included in review interventions had to meet the following conditions (Appendix C):

Population

1. Community-dwelling older adults ≥ 60 years of age.
2. Healthy or with a comorbidity but mobile;
3. Without dementia or moderate to severe cognitive dysfunction. Individuals with cognitive disabilities were excluded as this might confound the measurement of loneliness and social functioning.

Interventions

The following physical activity interventions were included: gym-based, home-based, community-based, web- or telephone-based.

Comparison

PA interventions were compared with a control (or sedentary) group without any exercise or undergoing another non-PA intervention (e.g. art therapy).

Outcomes

The main outcomes for this review were: 1) loneliness; 2) social isolation; 3) social support; 4) social (support) networks; and 5) social functioning as a sub-domain of health-related quality of life (HRQL).

Study design

This review included only randomised controlled trials with a minimum of two comparison arms (PA versus non-PA interventions or versus a control sedentary condition).

Search strategy

The online search of articles using expanded medical subject headings (MeSH) and independent key words was conducted using the following databases: MEDLINE, EMBASE, PsycINFO, the Cochrane Central, CINAHL. Databases were searched twice, with the second search conducted in February 2017, to ensure that newly published articles were included (Moher et al., 2015) (Appendix D). Other resources included the grey literature (PQDT Global, 2017; *Social care institute for excellence*, 2017; *System for Information on Grey Literature in Europe*, 2017; World Health Organization, 2017), and a hand search of the reference lists of relevant reviews, citation tracking, peer reviewed journal articles, books, dissertation theses and conference proceedings. Searches of articles were limited to RCTs. No restrictions were applied to the publication period and the language. For articles awaiting publication, and for study protocols, e-mail alerts were set up. Further, we contacted a life sciences subject-expert librarian, plus physiotherapists and psychologists in our department with experience in systematic reviewing and physical activity interventions for advice on search terms, and reviewing and meta-analysis using software. All papers were screened by two reviewers independently at all stages of the review (i.e., titles/abstracts, full text) applying the screening-selection tool (Appendix E). Any disagreements were resolved by a discussion with the third party until consensus was achieved. Levels of agreement are reported as Kappas. The selection of articles was performed using The EndNote reference manager programme for Windows (version X7, Thomson Reuters).

Risk of bias

The risk of bias in individual studies was assessed independently by two reviewers using the 12-criteria Cochrane Review Book Group (CRBG) risk of bias assessment tool (Furlan et al., 2009) using responses: yes, no, or unclear (Furlan et al., 2009). The 12 criteria CRBG risk of bias assessment tool (Furlan et al., 2009) determines trial adequacy by assessing the reporting of the following outcomes: 1) randomisation; 2) allocation concealment; 3) similarity of baseline characteristics; 4) blinding of the allocated interventions to participants, 5) blinding of care providers; 6) assessment of co-interventions; 7) the acceptable compliance; 8) reporting of drop-out rates; 9) equal assessment of participants across randomised groups; 10) assessment of selective reporting of outcomes; 11) blinding of assessors; and 12) similarity of timing of outcome assessment (Furlan et al., 2009). The CRBG risk of bias tool was pilot tested between reviewers independently for three randomly selected studies. Any disagreements were resolved by a discussion with the third party until consensus was achieved (Milner, 2015). A minimum level of inter-rated agreement between reviewers was set at a 0.8 Kappa coefficient (κ) (Higgins et al., 2011). Interventions meeting a minimum six criteria and above (scored as "Yes" using CRBG tool) and without serious flaws (e.g., over 20% drop-out rate in one intervention group) were rated as having a low risk of bias (Cramer et al., 2013; Furlan et al., 2009). Interventions with fewer than six criteria met were considered to have a high risk of bias (Furlan et al., 2009).

Data extraction and coding of study characteristics

For dichotomous outcomes, relative risk ratios (RRs) or odds ratios (ORs) with 95% confidence intervals (CI) were extracted. For continuous outcomes, means (M)/mean change and standard deviations (SDs) based on the between group values derived from follow-up periods were extracted. If Ms or SDs were not available and

instead studies reported SEs, CI, t- or p-values, effect sizes were computed based on the provided data from between group values (Cramer et al., 2013; Furlan et al., 2009). Where the study reported two interventions compared against the control group meeting the inclusion criteria both interventions were included in the analysis. The data extraction tool preliminarily was pilot-tested independently by two reviewers on 10 randomly selected studies to ensure clarity and transparency of the data reporting until consensus was achieved. Inter-rater agreement coefficients (without pilot studies) were as follows: for recruitment settings κ=1.000, sample size κ=1.000, age κ=1.000, gender κ=1.000, comorbidity κ=1.000, the settings (independent living versus supportive living) κ=1.000, the type of PA κ= 0.849, length of intervention κ=1.000, intervention content κ=1.000, control group comparison κ=1.000, format of delivery (group vs. Individual or mixed) κ= 0.949, information about provider (health professional or not) κ=0.879, delivery settings κ=0.830, outcomes κ=0.839, assessment tools κ=1.000, validity of assessment tools κ=1.000, scoring of assessment tools κ=1.000, main findings κ=1.000 (Appendix F). If any discrepancies were observed, the third party resolved discrepancies by discussion. For missing data, individual authors were contacted (N=8), with a 37.5 % response received. The following information was extracted and coded for each study (Appendix G): a) study reference, country, recruitment settings; b) population characteristics (sample size, age, gender, comorbidity, residential settings); c) intervention characteristics (type of intervention, e.g. physical activity, physical activity and social interactions, length of the intervention, intervention content and a control group comparison, format of the delivery, information about the treatment provider; d) methodological information (main outcomes, assessment tools, information about validation of assessment tools, study design); e) results related to effect size calculation (means or mean change,

standard deviation, number of participants in each treatment group, measurement periods, e.g. immediate or follow up; and f) additional comments (a pilot study, translated from another language, author contacted).

Data analysis and reporting of findings

First, a narrative (descriptive) summary of participant and intervention characteristics containing detailed information about population (sample), interventions, outcomes, and results was made. Second, random effects model meta-analysis was performed if at least three studies quantitatively reported an effect of their intervention for each outcome. If two comparison arms were taken form one study, group sample sizes were halved to avoid double counting of participants and underestimating the variance of the effect size. Analysis of data was conducted using Review Manager Software Version 5.3.5 (RevMan, 5.3.5; the Nordic Cochrane Centre, Rigshospitalet, Denmark). A random effects model assumes that different but, yet related treatment effects are incorporated by different studies (Furlan et al., 2009; Higgins et al., 2011; Liberati et al., 2009) and account for a heterogeneity (Thompson et al., 2002). For continuous outcomes, SMD of 0.2 to 0.5 were deemed to indicate a small effect size, from 0.5 to 0.8, a moderate effect size, and more than 0.8, a large effect size (Cohen, 1988).

Subgroup and sensitivity analysis

If more than 10 studies were included for each outcome, this was deemed adequate (Thompson et al., 2002), and subsequent sub-group analysis was performed to explore effect of following covariates on intervention effects: the type of intervention (physical activity of physical activity with social interactions, e.g. health education, cognitive behaviour therapy, lectures, nurse counselling, etc.), delivery format (individual, group

or mixed), residential settings (independent living or assisted living, e.g. retirement villages), comorbidity (healthy versus ill population), and information about healthcare provider (non-medical (fitness) professional, medical professional, or non-health care provider). For the purpose of the review the medical health professional was considered to be any licenced or certified medical health professional (e.g. physiotherapist, nurse), a fitness (non-medical) healthcare provider was considered to be a qualified fitness professional, i.e. personal trainer, fitness instructor, or a qualified activity leader (e.g. walking group leader). A non-healthcare provider was considered to be anyone without a formal licence or a certificate (e.g. volunteer, research fellow, research assistant).

Statistical heterogeneity was examined by I^2 statistics as well as a visual analysis of forest plots. Based on I^2 statistics, heterogeneity was classified as moderate (I^2 >30%), substantial (I^2 >50%), or considerable (I^2 >75%); $P \leq 0.05$ (Hopkins, 2002). Effect size outliers were identified by examining the externally studentized residuals (Viechtbauer & Cheung, 2010) using SPSS for Windows (V.22, SPSS Inc., Chicago, IL). Subsequent sensitivity analyses was performed by removing high risk RCTs from the analysis (Furlan et al., 2009).

Assessment of publication bias

Publication bias was assessed by inspection of asymmetry measured by Egger's regression, i.e., the intercept from the regression of standard normal deviates on precision (Egger et al., 1997). Where publication bias emerged, "trim and fill" analysis (Duval et al., 2000) was performed using the Stata for Windows (1C, 14.2, Stata Corp LLC, USA).

3. Results

Database search

The database search resulted in 3899 records (Figure 1). After removing duplicates and screening records on titles, abstracts, and full texts, a total of 38 eligible RCTs with the corresponding number of 5288 participants (range 51-82 years) were included in this review (Appendix H). Inter-rater agreement coefficients for screening on titles and abstracts K=0.878, for full text screening K=0.849. Key methodological study characteristics of included studies were categorised by the intervention type (i.e. PA or PA with social interaction component, e.g. health education, cognitive behaviour therapy, lectures, nurse counselling, etc.) are presented in Supplementary Table 1 and Appendix I. The majority of excluded studies were non-PA interventions. Among seven excluded interventions for non-community-dwelling older adults (e.g. for residents of institutional care) two were PA interventions.

Risk of bias

Risk of bias in individual studies revealed that 26 had a low risk of bias and 12 had a high risk of bias (Appendix J). The average inter-rater agreement coefficient was κ = 0.855.

For item “Adequate random sequence generation” 24 out of 38 studies met the condition marked as “yes “answer on the data extraction sheet, 14 studies did not meet the condition marked as “no” or “unclear” answer (Appendix J). For item “Adequate allocation concealment” nine studies met the condition and 29 studies did not. For item “Similar baseline characteristics” 31 studies met the condition and seven did not. For item “Adequate participant blinding” five studies met the condition and 33 studies did not. For item “Adequate provider blinding” none of the studies met the condition. For item “Similar or no cointerventions” 34 studies met the condition.

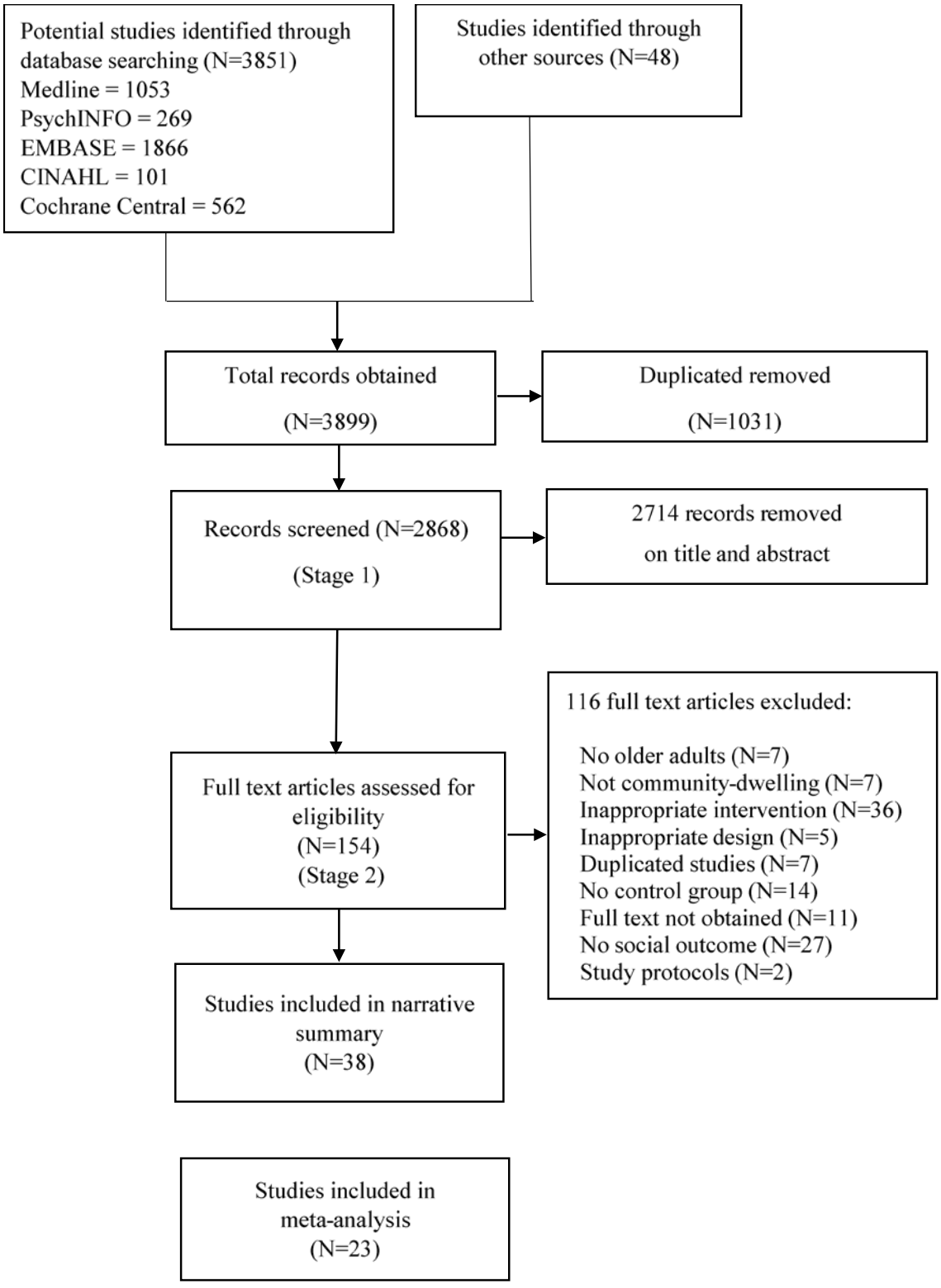

Figure 1. Flow chart of the results of the database search.

For item "Acceptable compliance" 17 studies met the condition. For item "Acceptable and described dropout rate" 32 studies met the condition. For item "Inclusion of an intention-to-treat analysis" 14 studies met the condition. For item "No selective

outcome reporting" 37 studies met the condition. For item "Adequate outcome assessor blinding" 11 studies met the condition. For item "Similar timing of outcome assessment" 35 studies met the condition.

The most common biases were associated with inadequate allocation concealment and not described or non-acceptable compliance and drop-out rates. The intention-to-treat analysis was not reported in 24 interventions which limits the interpretation of the results in the included RCTs due to the low methodological rigour associated with the inadequate randomisation procedures. Detection bias in included studies was mainly high due to the absence of information about adequacy of outcome assessor blinding. Another source of bias was inadequate blinding of the care provider (fitness or medical healthcare provider) but it is likely this is not possible for this type of intervention.

Narrative summary of participant and intervention characteristics

The key methodological study characteristics of included RCTs are presented in Supplementary Table 1.

Population

The geographic spread of included studies showed that seven PA interventions were conducted in the USA, five of each in the UK and Japan, three of each in Australia and Taiwan, two of each in China, Canada and the Netherlands, and one of each in New Zealand, Korea, Sweden, Denmark, Finland, Turkey, Spain, Brazil, Hungary and Georgia (Supplementary Table 1). The mean age of the participants in the included RCTs ranged from 51-82 years, with a higher percentage of females (67%). Twenty-five RCTs were conducted on older adults with common chronic diseases such as

cardiorespiratory diseases, bone health diseases, depression, obesity, insomnia, and cancer. In contrast, 13 RCTs included relevantly healthy community-dwelling older adults. Eleven studies included only female participants. All but one (Cress et al., 1999) included independently living residents, the latter included those in an assisted living village setting. Participants were recruited from general outpatient clinics, through integrated health care systems, a university medical centre, municipal services, community centres, through a breast screening programme, through the Fibromyalgia Association and retirement communities (Appendix G).

Interventions

In terms of an intervention type, half of the included interventions (N=19) had a social interaction component as well as PA, such as health education, social support, sleep hygiene, and recreational activity (e.g. craft activity, cooking classes etc.), and social facilitation by trained ambassadors (Appendix I). Interventions mainly consisted of aerobic exercise training (AET) in 14 RCTs. Six PA interventions included resistance exercise training (RET). Others were of mixed aerobic and resistance exercises (e.g. swimming and Tai Chi exercises). Intervention length varied between six weeks (Turner et al., 2011) and one year (Courneya et al., 2011), with the majority of RCTs lasting for 12 weeks (Table 1). Twenty-three interventions were conducted in a group setting, ten were conducted individually and five interventions were in mixed design settings.

The intensity of AET varied from light-to-moderate (50-65 % of HR_{max}) for people with chronic diseases and to vigorous (85% of HR_{max}) for healthy older adults based on the standard classification of intensity of aerobic exercises by the American College of Sports Medicine (2013). The workload for RET programmes varied from light-to-heavy with only one study quantitatively reporting the range of repetitions (5-10

repetitions per exercise) (de Vreede et al., 2006) (Appendix G). The average frequency of PA interventions was set at three times a week (Chien & Tsauo, 2005 from Appendix H). Other studies included exercise performed from once weekly (Maki et al., 2012; Oken et al., 2006; Stiggelbout et al., 2004) to five times or more weekly (Courneya et al., 2011; Evcik & Sonel, 2002; Hongo et al., 2007; Huang et al., 2011; Oken et al., 2006; Rejeski et al., 2014) (Appendix G). The average duration of a single exercise session ranged between 45-60 min/session (Chan et al., 2017; Cress et al., 2006; Huang et al., 2011; Kamagaya et al., 2014; Kovaks et al., 2013; Kurtner et al., 1997; Oken et al., 2006; Stiggelbout et al., 2004, Appendix G). The minimum duration of an intervention was 10 minutes performed in several bouts throughout the day (Evcik & Sonel, 2002) to over 80 min a day including warm-up and cool down periods (Turner et al., 2011). Interventions were delivered by health care providers (N = 16), medical health providers (N = 22), or non-health care providers (N = 0) (Appendix I).

Comparisons

PA interventions were compared to a control (sedentary) group or usual care (UC). Other comparisons included health education (attention-control group), social visits, recreational or educational activity and sleep hygiene for patients with insomnia (Reid et al., 2010) (Appendix I).

Outcomes and assessment tools

Loneliness was assessed using a 1-item question: “Do you feel lonely?” (Pitkala et al., 2004), Russel’s UCLA loneliness scale and De Jong Gierveld loneliness scale (Appendix G). Social isolation was assessed using the Turkish version of the Nottingham Health Profile questionnaire and revised social support questionnaire. The

majority of studies assessed social functioning (as a sub-domain of health-related quality of life) typically using the Short Form (SF-36) Health Survey (Ware et al., 1992), The World Health Organisation Quality of Life Assessment questionnaire (WHOQOL-BREF), and the 12-item Short Form Health Survey. Social support was assessed using the Multidimensional Scale of Perceived Social Support (MSPSS), the short version of the Medical Outcomes Study (MOS) Social Support Survey, and the Chinese version of the Inventory of Social Supportive Behaviours. Social networks were assessed using the 6-item Lubben's Social Network Scale (LSNS) (Lubben et al., 2006).

Meta-analysis

Effects of physical activity interventions on social support (N=9)

The effect of PA for social support was non-significant (SMD = -0.05; 95% CI, -0.19 to 0.10; P=0.53), heterogeneity was moderate (I^2 =34%, Chi^2 = 12.06, P=0.15) (Supplementary Figure 1).

Effects of physical activity interventions on social networks (N=4)

The effect of PA for social networks was non-significant (SMD = -0.00; 95% CI, -0.28 to 0.27; P=0.99), heterogeneity was substantial (I^2 =68%, Chi^2 =9.35, P=0.02) (Supplementary Figure 2).

Effects of physical activity interventions on social functioning (N= 22)

A small significant positive effect favouring the experimental condition was found for social functioning (SMD=0.30; 95% CI, 0.12 to 0.49; P=0.001), heterogeneity was substantial (I^2 =63, Chi^2 = 56.50, P<0.0001) (Figure 2).

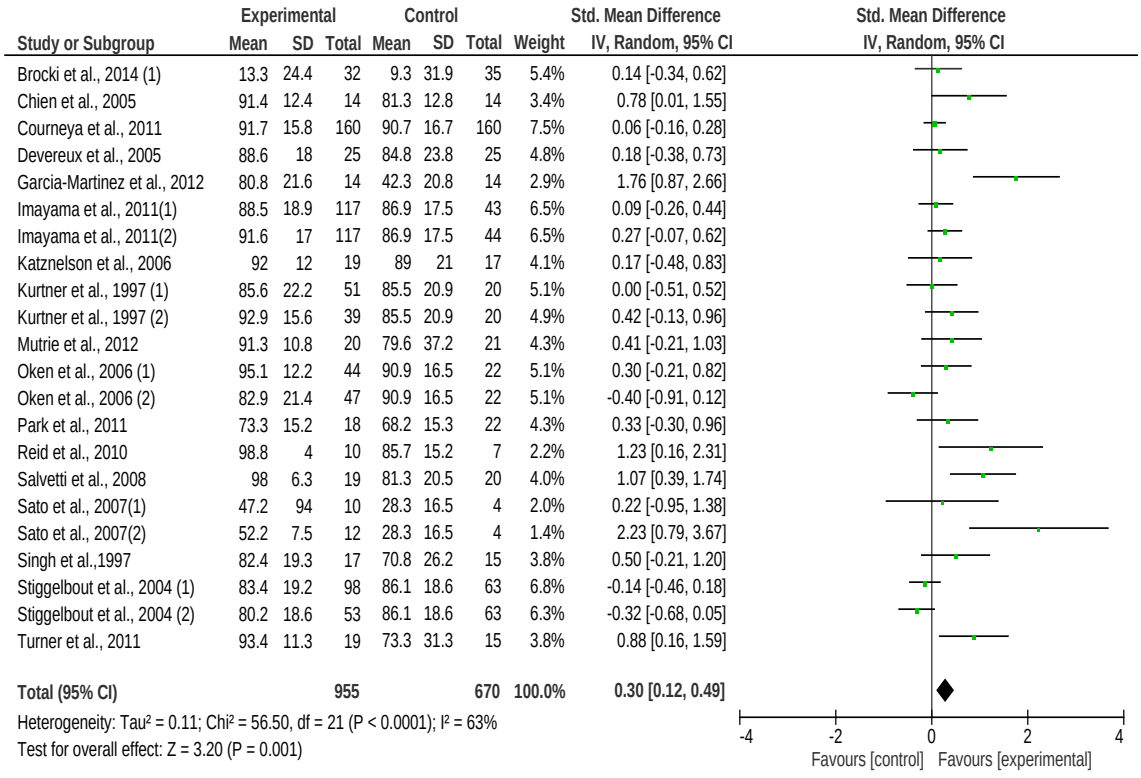

Figure 2. Forest plot of the overall effect of physical activity interventions compared with control (sedentary) conditions on social functioning.

Due to the lack of available data, meta-analysis for loneliness and social isolation outcomes was not performed.

The results of sub-group and sensitivity analysis

Sub-group analyses were performed for social functioning (Supplementary Table 2). The forest plots are available from the authors by request. A meta-analysis comparing PA interventions versus PA interventions with social interactions (PASI) revealed a significant small and positive effect for PA interventions (SMD=0.30; 95% CI, 0.10 to 0.51; P=0.003), but not for the PASI (SMD=0.33; 95% CI, -0.04 to 0.70; P=0.08); a significant moderate positive effect for diseased (SMD =0.55; 95% CI, 0.28 to 0.81; P<0.0001) but not for healthy (SMD =0.00; 95% CI, -0.19 to 0.19; P=0.99) populations; a significant small positive effect for the group format of exercise delivery (SMD =0.34;

95% CI, 0.10 to 0.59; P=0.006) but not for individual settings (SMD=0.21; 95% CI, -0.15 to 0.56; P=0.26) or mixed type (individual and group) settings (SMD=0.25; 95% CI, -0.15 to 0.65; P=0.21); and a significant small positive effect for medical healthcare provider delivery (SMD=0.42; 95% CI, 0.12 to 0.71; P=0.05) but not for other provider delivery (SMD=0.19; 95% CI, -0.04 to 0.43; P=0.11). Total effects significantly differed (Z=3.20, P=0.001; heterogeneity Chi^2 =11.01, df=1 (P=0.0009), I^2 = 90.09) between all comparison groups for the social functioning outcome. It was not possible conduct the sub-group analysis for residential settings (e.g. whether participants were independently living or in assisted living accommodation) as only one study (Cress et al., 1999) included assisted living residents.

The sensitivity analysis for social functioning without outliers revealed a small significant positive effect size (favouring the experimental group) and moderate heterogeneity (SMD =0.20, 95% CI, 0.05 to 0.36; heterogeneity: I^2=47, Chi^2 =35.95, P=0.02), N=20 (Appendix K).

When high risk RCTs (N=9) were removed from the meta-analysis for social functioning, a small significant positive effect size was obtained (SMD=0.23; 95% CI, 0.08 to 0.39; P=0.004), and heterogeneity was small (I^2=15, Chi^2 =11.81, P=0.30) (Appendix L).

The sensitivity analysis for social networks without outliers revealed a small non-significant negative (favouring the control group) effect size (SMD =-0.14, 95% CI, -0.29 to 0.01; heterogeneity: I^2=00, Chi^2 =0.19, P=0.07), N=3 (Appendix M). For social support, no outlier effect sizes were identified.

Publication bias

For social functioning, the Egger's regression was significantly different from 1, suggesting asymmetry (2.76; 95% CI: 1.38-4.14, P<0.001), and thus publication bias was present. A consequent trim and fill analysis added eight new studies that increased the adjusted point estimate but yielded a non-significant p value (SMD= 1.07; 95% CI, 0.87 to 1.31; P=0.535; heterogeneity: Chi^2 = 56.50, P<0.0001). Therefore, the effect of publication bias on social functioning outcome is not trivial (Rothstein et al., 2006).

4. Discussion

The meta-analysis in this review demonstrated positive effects of PA interventions for social functioning. However, there was insufficient evidence of successful PA intervention effects on some social health outcomes in older adults, such as loneliness, and social isolation, which is consistent with previous reviews (Cattan et al., 2005; Dickens et al., 2011; Findlay, 2003; Hagan et al., 2014; Petitte et al., 2015).

Features of effective interventions

Effective PA interventions for social functioning were those delivered by medical healthcare professionals, and among diseased versus healthy older adults. Due to the high correlation between health status and social health shown in the research literature (Hagan et al., 2014), it could be hypothesised that the effect of PA interventions on psychosocial outcomes might be more effective in specific vulnerable groups, which was the case for social functioning outcome. This review supports existing studies, which, in addition, identified effective interventions as being those enabling some level of participant or facilitator control, targeted specific population groups (e.g. sedentary, depressed, ill, with long term caring responsibilities) (Cattan et al., 1998; Cattan et al., 2005; Dickens et al., 2011; Hagan et al., 2014; Masi et al., 2011; Pels et al., 2016).

Intervention settings

Beneficial social health effects of group settings for social functioning were also shown. This is in line with the psychosocial hypothesis (Lubans et al., 2016) which associates intervention effects of PA with social connectedness between participants arising during activities based on shared needs and interests. However, this contrasts with that of other studies, where one-to-one settings using non-PA interventions were more effective in reducing loneliness in older healthy adults (Banks et al., 2008; Findlay, 2003; Kahlbaugh et al., 2011; Tsai et al., 2011), according to Hagan et al. (2014). In the present review, only two studies directly compared the effect of group-based and individual or one-to-one PA interventions on social isolation and social networks (Evcik & Sonel, 2002; Lliffe et al., 2014). However, between group differences at follow-up were not significant in both interventions.

An overall significant small and positive effect for social functioning was obtained for PA interventions versus those with PA and social interactions. This seems somewhat at odds with the theories and mechanisms of how PA might be an effective intervention through increasing social connections, e.g., Lubans et al. (2016) discussed above, given that it would be expected that the more social interaction opportunities are integrated into the interventions, the more successful those would be. However, it is possible that this reflects the diversity of the different types of social interaction opportunities across the interventions which were PA with social interaction, and that not all of these interventions with social interaction components included this being in a group setting, but could be one-to-one.

Components of physical activity interventions

Five out of 13 PA interventions with significant results for psychosocial outcomes had a clear aerobic component of over 30 minutes a day (range 30-60 min) with intensities ranging from 60 to 85% HR $_{max}$ (moderate-to-high) (Chan et al., 2013; Daley et al., 2007; Devereux et al., 2005; Garcia-Martinez et al., 2012; Rejeski et al., 2014) (Appendix G). The most common mode of aerobic exercise in included interventions was supervised walking (Chan et al., 2013; Daley et al., 2007; Rejeski et al., 2014; Sato et al., 2007). Other beneficial PA interventions were resistance exercise training (Katznelson et al., 2006; Park et al., 2011; Singh et al., 1997). These findings are similar to observations of Rejeski et al. (1996) where the most effective PA interventions for QoL included aerobic exercise over 20 min (range 20-50 min) with intensities ranging from 45 to 85% of HR peak. Exploring the effect of dose or intensity of exercise, it has been hypothesised that exercise of lighter intensities (e.g. 55% maximum effort) induce exercise-related affective responses found to have a significant relationship with self-efficacy for exercise (McAuley et al., 2000). However, these relationships do not appear to be maintained during vigorous intensity exercise (70% maximal effort), suggesting a blunted responsiveness at higher intensities (McAuley et al., 2000). Further, exercise of light-to-moderate intensity intuitively provides better opportunities for social interaction, as shown in studies comparing exercise in different environments (McAuley et al., 2000; Turner et al., 1997).

The duration of effective PA interventions in this review varied between six weeks and one year, with the majority of RCTs lasting for 12 weeks (N=13) (Table 1). It was not possible to test the effect sizes of different durations, but given the paucity of significant effects overall, it could be considered that 12 weeks may not be sufficient time to see effects on social health.

Facilitation of intense social contact between participants was either through health education classes, recreational activity, cognitive behavioral therapy, social support and sleep hygiene (Supplementary Table 1).

With respect to the social functioning, there was substantial heterogeneity. Sources of substantial heterogeneity as shown in the sensitivity analysis were high risk RCTs (N=9) that resulted in small heterogeneity after removing these high risk RCTs from the meta-analysis. Outcomes with non-significant effects (e.g. social support and social networks) had moderate and substantial heterogeneity, respectively.

Limitations and strengths of the review

Despite the significant small and positive effect of PA interventions obtained for social functioning, the results of this meta-analysis must be treated with caution. In the presence of publication bias for social functioning, the consequent trim and fill analysis reduced the previous social functioning effect size to being non-significant, which suggests that the effect of publication bias (or unpublished studies) is not trivial and the effect for social functioning that we report is affected by unpublished trials (Sterne et al., 2001).

Among the included RCTs, only one study explicitly targeted lonely or socially isolated people (Chan et al., 2017) which was a pilot study. Included interventions rather targeted sedentary community-dwelling older adults where social outcomes were measured as secondary outcomes. Studies that address social health directly tend to be more behaviourally focused rather than looking at physical activity, and might have more positive effects. One RCT targeted frail older adults whose physical health condition was assumed to lead to loneliness or social isolation due to the increased risk of institutionalisation (Ollonquist et al., 2008). The relative lack of quantitative data and

precise definitions of social health and determination of its domains (Rejeski et al., 1996) were limiting factors in reviewing the effects of PA interventions on the social health of older healthy adults.

A strength of the present review was the focus solely on community dwelling older adults, because there is a lack of available evidence particularly for older adults residing in community settings for loneliness. The majority of interventions are conducted on residents of institutional care (e.g. nursing home residents) as this is a potentially vulnerable group, thus we chose to focus on a different population who may also be in need of intervention. The present study also excluded individuals with cognitive disabilities, as this might confound the measurement of loneliness and social functioning. However, as vulnerable populations such as those with dementia might be more amenable to the effects of PA interventions, this would make an interesting comparison group and should be considered in future reviews.

One limitation is that the coding of the interventions could have been significantly strengthened by the use of a refined behaviour change taxonomy (Michie et al., 2011) in order to categorise the content of each intervention. However, as the focus of the current review included interventions that were therapeutic programmes for ill population or fitness interventions, these did not always include behaviour change techniques which this type of taxonomy is designed to code. However, it was possible to code the content of interventions to an extent, and to examine the impact of these factors such as PA – physical activity alone, versus PASI – physical activity with social interactions. Unfortunately, meta-regression analysis to assess the effects of moderating variables could not be performed as there were insufficient studies for each social outcome to permit such testing (being fewer than 10 studies in each meta-analysis; (Thompson et al., 2002). Also, it was not possible to examine whether differences in

PA effect sizes predict the social outcome effect sizes as there were not enough studies for meta-regression. In summary, careful examination of trials showed that PA results were reported in a total of six studies (Courneya et al., 2003; Courneya et al. 2011; Daley et al.; 2007; DeVreede et al., 2007; Mutrie et al., 2012; Park et al., 2011). Among these studies, only four studies report PA for social functioning (DeVreede et al., 2007; Courneya et al. 2011; Mutrie et al., 2012; Park et al., 2011). The remaining two presented results for the family well-being outcome (Daley et al., 2007; Courneya et al., 2003). Further, PA was measured in three different ways (METs, step counts, hour per week) across the social functioning studies.

It is possible that the residents of the retirement villages (i.e. assisted living) may be prone to more socialising due to the greater opportunities for structured social interactions (Park et al., 2012). However, we were unable to examine this as a potential moderating variable, as only one study in the current review included those in a retirement village setting (Cress et al., 1999). A further limitation is that three studies (Chien et al., 2005; Garcia-Martinez et al., 2012, lliffe et al., 2014) reported only completer analysis, thus the meta-analysis was not performed on solely intention-to-treat data. Further, this review did not include disease-specific analyses (e.g. cardiovascular, metabolic, bone health etc.) due to a limited number of studies and data available for each disease group, and subgroup analyses for exercise type were not performed for similar reasons. Indeed, the high heterogeneity in outcomes in addition to the high risk RCTs (e.g. for social functioning) may be a result of mixed-type exercises combined into one sub-group of PA. However, the inclusion of a broader variety of psychosocial outcomes made it possible to increase the number of available intervention studies.

There is also a limitation in the particular risk of bias tool used; the item "Appropriate blinding of care providers" would not be possible for PA intervention providers in studies comparing this to control or non-PA comparison groups.

A limitation specific to several of the studies included in this review is that most of the interventions assessing psychosocial outcomes included these as secondary outcomes. However, this might be expected given that most studies of PA interventions are likely to have primary outcome such as an increase in PA or fitness and physical function. Nonetheless, as PA can improve psychosocial outcomes as discussed above, it was still deemed important to systematically review the potential effects of PA on social health in order to inform future interventions focusing specifically on loneliness using PA as the intervention strategy.

Another issue is the use of non-composite measures of social health outcomes (i.e. only self-reported loneliness or social isolation without complex assessment of demographic characteristics, level of income, marital status, etc.). However, their use is advised to increase the specificity of self-assessment tools (Wenger et al., 2004). Some interventions were biased by the short duration of follow-up; it is known that the effect of a single exercise session is short-lived (Chodzko-Zajko, 2014) and chronic adaptation is attenuated shortly after the cessation of an exercise programme. The average length of interventions in the included RCTs was 12 weeks (N=13). However, it is known that longer durations may be needed to allow participants to build upon transforming new contacts into meaningful relationships based on trust (Findlay, 2003; McAuley et al., 2000), which might explain the lack of effects in some cases. Further, the majority of interventions included in this review did not assess potential mediators and moderators of PA and social health outcomes, such as social support and self-efficacy for exercise, although it is known that these factors may moderate the relationship between

loneliness and physical activity (Fry, 2001; Fry et al., 2002; McAuley et al., 2000; Taliaferro et al., 2010). Research shows that global (Bandura, 1993; Fry, 2001) and domain-specific self-efficacy (Fry et al., 2002) are moderating factors, and social support was found to be both a moderating (McAuley et al., 2000) and mediating factor (Taliaferro et al., 2010). This review also did not consider the potential moderating effect of a residential setting (e.g. institutional versus community) due to focusing solely on older adults residing in the community. It is likely that older adults from institutional settings (e.g. care homes) may be at increased risk of loneliness due to a lack of contacts with friends and family (Banks et al., 2002; Banks et al., 2008), and may also be more vulnerable due to dementia and other comorbidities than community-dwelling older adults (Banks et al., 2002; Banks et al., 2008). Future reviews might consider comparing across settings, taking into account comorbidities.

Despite the limitations of this review, to the authors' knowledge it is the first to assess the effects of PA interventions on variable domains of psychosocial health, and specifically to target a community-dwelling older adult population aged 60 years and over. Previous reviews have either included older adults as a sub-group of more diverse populations including children, adolescents or the general adult population (Gillison et al., 2009; Masi et al., 2011). Others included non-PA interventions only (Cattan et al., 1998; Cattan et al., 2005; Dickens et al., 2011; Petitte et al., 2015) or included mixed design studies for only one or two outcomes (e.g. RCTs, case-control studies, longitudinal etc.) (Smith et al., 2017). Compared with previously published systematic reviews (Cattan et al., 1998; Cattan et al., 2005; Findlay, 2003; Masi et al., 2011), the current review focused solely on RCTs which increased its methodological rigour, as advised (Masi et al., 2011). The results of this review confirm the need for further research estimating the effects of specific types of PA interventions on social health

outcomes in specific groups of older adults to improve the specificity and effectiveness of targeted interventions.

5. Conclusions

Despite the observations made in this review regarding the features and types of beneficial PA interventions, there is limited evidence that effective PA interventions are specific to particular settings, population sub-groups, intensity, amount or types of activity (Rejeski et al., 1996). However, there are some indications that certain types of setting and intervention delivery can be beneficial, particularly for older adults with comorbidities, and specifically for social functioning. It is hypothesised that exercise induces positive affective responses as a result of enhanced self-esteem and self-worth through group-based exercise activities (McAuley et al., 2000). However, social health effects may also be influenced by the initial fitness of the participants, their age, baseline self-esteem, et cetera, as well as intervention variables (McAuley et al., 2000; McAuley et al., 2003; Rejeski et al., 1996; Wenger et al., 2004) which need to be considered as potential confounders. Further research is required to estimate mechanisms of association between PA and social health outcomes in older adults, using objective measures of PA and comprehensive methods of assessment of social health.

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The authors of this review declare that they have no known conflicts of interest.

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Appendices

Appendix A. PROSPERO registration protocol of the review.

Appendix B. PRISMA checklist.

Appendix C. PICOS statement.

Appendix D. The example of the Medline search strategy (February 2017)

Appendix E. Screening-selection tool.

Appendix F. Kappa coefficients for key participant and intervention characteristics of the included RCTs.

Appendix G. Data extraction sheet.

Appendix H. Reference list of included studies.

Appendix I. The methodological study characteristics of included RCTs with intervention description.

Appendix J. Risk of bias assessment.

Appendix K. The sensitivity analysis for the social functioning when outliers were removed.

Appendix L. The sensitivity analysis for the social functioning when high risk RCTs were removed.

Appendix M. The sensitivity analysis for the social networks when outliers were removed.

Supplementary Figure 1. Forest plot of the overall effect of physical activity interventions compared with control (sedentary) conditions on social support.

Supplementary Figure 2. Forest plot of the overall effect of physical activity interventions compared with control (sedentary) conditions on social networks.

Supplementary Table 1. The methodological study characteristics of included RCTs.

Supplementary Table 2. The sub-group analysis for the selected study and intervention characteristics for social functioning outcome