



Is Sedentary Behavior or Physical Activity Associated With Loneliness in Older Adults? Results of the European-Wide SITLESS Study

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Is Sedentary Behaviour Or Physical Activity Associated With Loneliness In Older Adults? Results Of The European-Wide SITLESS Study.

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Abstract

Research found that social relationships are central to the health and well-being of an ageing population. Evidence exploring the association between physical activity (PA) and sedentary behaviour (SB) with social isolation and loneliness is limited. This study uses objectively measured PA and SB (ActiGraph®) and self-reported measures of loneliness (DeJong Gierveld Loneliness Scale-DGLS-6) and social engagement (Lubben Social Network Scale-LSNS-6) from a European-wide study of community-dwelling older adults from the SITLESS study. Social isolation was associated with SB where higher levels of SB were associated with an increased the level of social isolation, controlling for age, sex, living arrangements, employment status, BMI, educational background, marital status and self-reported general health. In contrast, PA was not associated with social isolation, and neither SB or PA were statistically significant predictors of loneliness. SB may be linked to social isolation in older adults, but PA or SB are not necessarily linked to loneliness in older community-dwelling adults.

Key words

Moderate-Vigorous physical activity; Light physical activity; Objective physical activity; social isolation.

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52 Introduction

53 A decrease in economic resources, an increase in mobility impairment, or a loss of family and friends
54 can increase the risk of social isolation - the quantitative measure of social relationships and contacts
55 (Nicholson, 2012; Victor, 2011), which then can lead to loneliness - the subjective feeling regarding
56 the discrepancy between desired and actual social relationships (Shvedko et al., 2018; Steptoe et al.,
57 2013) in older adults. Statistics suggest that one in fourteen people (7%) experience social isolation
58 across Europe. In the UK, it is estimated that one third of older adults (≥ 65 years) will experience
59 loneliness. This is important as the proportion of older adults is expected to grow by 50% by 2025,
60 resulting in an increased proportion suffering social isolation and loneliness (Age UK, 2018; Bernard,
61 2013).

62 Research has demonstrated that loneliness and social isolation are associated with negative
63 consequences on health and well-being especially for older adults (Cacioppo & Cacioppo, 2014; Holt-
64 Lunstad et al., 2010). Individuals who are socially isolated and lonely are at increased risk of chronic
65 diseases (Lauder et al., 2006; Senez et al., 2004; Shankar et al., 2011; Thurston & Kubzansky, 2009);
66 cognitive impairment (Pitkala et al., 2011); and all-cause mortality (Elovainio et al., 2017; Patterson &
67 Veensta, 2010; Newall et al., 2013). Furthermore, both are linked with potential modifiable negative
68 health behaviours such as poor nutritional intake (Ferry et al., 2005) and low physical activity (PA)
69 levels (Hawkey et al., 2009). It is estimated that the social and healthcare benefits of addressing
70 loneliness in the UK are approximately £900 per person per annum (Bernard, 2013), and so
71 interventions to address this growing public health concern are warranted.

72 The health benefits of PA in older adults are well established (Bangsbo et al., 2019). There is also
73 evidence for the independent health benefits of reducing prolonged sedentary behaviour (SB) (Dogra
74 & Stathokostas, 2012; WHO, 2014; Willmott et al., 2012). Evidence suggests that PA may have an
75 important role for loneliness and social isolation through social, psychological, and biological
76 mechanisms. For example, PA increases social networking during group activities which can

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77 compensate for the loss of meaningful social relationships (Ferraro & Farmer, 1995). PA also generates
78 positive emotions and feelings of well-being (Cohen & Wills, 1985; Newhall et al., 2013) as well as a
79 sense of identification and social attraction to others engaged in the same activities (Henry et al.,
80 1999) which removes the barriers to social interaction and reduces loneliness (Lubans et al., 2016;
81 Milligan et al., 2013). However, evidence supporting the efficacy of interventions to reduce SB with
82 social isolation and loneliness whilst emerging (Schrempf et al., 2019) is limited yet (Dicken et al.,
83 2011; Pels & Kleinert, 2016; Schvedko et al., 2018).

84 Results from existing research exploring the nature of the relationship between PA, SB, social isolation
85 and/or loneliness may still suffer some bias. Firstly, many studies appear to recruit from clinical or
86 senior centre settings which promote or encourage social interaction, and so may potentially fall short
87 of reaching especially socially isolated community-dwelling older adults (Pels & Kleinert, 2016; Robins
88 et al., 2016; Shvedko et al., 2018). Additionally, the use of objective PA measures such as
89 accelerometry is growing and provide a more accurate measure of overall PA levels as well as an
90 understanding of PA intensity required to elicit associated benefits (Doherty et al., 2017: UK Biobank
91 study; n=106,053 participants), but self-reported measures are still more widely used (Pels & Kleinert,
92 2016). Also, those studies that have included an objective measure of PA include PA as a secondary
93 outcome or combined with an additional measure (Schvedko et al., 2018). As a result, the true effect
94 of PA and SB is limited.

95 Consequently, this study aims to understand the relationship between PA and SB with loneliness and
96 social isolation. It considers community-dwelling older adults instead of those in senior centres and
97 considers SB as well as PA using objective measures that provide a more accurate summary of PA level
98 and intensity. Based on these premises, this study aims to bring new insights to the understanding of
99 the association between PA and loneliness and social engagement in older adults.

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102 Method

103 **Participants**

104 This cross-sectional analysis is based on the SITLESS study, which is a prospective cohort study of
105 community-dwelling men and women aged ≥ 65 years from across Denmark, Spain, Germany and the
106 United Kingdom. Participants were eligible if they were able to walk for ≥ 2 min (with or without a
107 walking aid); scored four or above on the Short Physical Performance Battery (SPPB); carried out
108 regular physical activity (PA) ≤ 30 minutes on 5 days per week, where PA is activity that causes
109 breathlessness and excludes regular walking (e.g. jogging or cycling); and/or spend 6–8 hours per day
110 sitting e.g. watching TV or working at the computer. Participants were excluded if they had three or
111 more errors on a six-item cognitive impairment questionnaire to identify moderate or severe
112 dementia; had a medical condition which interfered with the study design, suffered from unstable
113 medical conditions (e.g. elevated blood pressure after medication, uncontrolled hypertension) or
114 symptomatic cardiovascular diseases that contraindicates participation in PA; could not commit to
115 attend 75% of the exercise referral scheme (ERS) sessions throughout the intervention; and/or had
116 participated in an ERS in the six months prior to their entry into the study. A total of 2,660 older adults
117 were recruited across the four countries via media (letters and social media), general practitioners
118 and other health professionals from primary care, and senior centre community groups. Of those,
119 45.15% did not participate in the study (27.3% of those were excluded based on eligibility assessment).
120 A total of 1,360 older adults provided baseline data. Further details can be found in the study protocol
121 (Giné-Garriga et al., 2017). SITLESS has been approved by the various Ethics and Research Committees
122 of each intervention site. Participation was voluntary and all participants provided informed consent
123 before the start of the study.

124 **Assessment of Physical Activity (PA) and Sedentary Behaviour (SB)**

125 All participants were asked to wear an accelerometer (ActiGraph GT3X+; Actigraph, LLC, Pensacola,
126 FL) on their dominant hip during waking hours for seven consecutive days and were told to remove

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127 them during any water-based activities such as bathing or swimming, and during sleep time. The
128 devices were initialized to collect data using 10-second epochs. Non-wear time was defined using the
129 Choi, Liu, Matthews, & Buchowski (2011) algorithm which uses a 2-window system; a 90-minute
130 window for checking for consecutive zero counts and another 30-minute up- and down- stream
131 window for checking for more than 2 minutes of non-zero counts (Choi et al., 2011). The study
132 included the results from participants with at least four valid days including at least one weekend day;
133 to be included each day had to include at least 600 minutes (10h/day) of wear time as in previous
134 studies (Migueles et al., 2017). SB was classified as <100 counts per minute (CPM), daily light physical
135 activity (LPA) was 100-2019 CPM, and daily moderate-physical activity (MVPA) was >2020 CPM. Step
136 counts were also included. Values are the average daily time spent in SB, LPA and MVPA.
137 This study uses MVPA and LPA measured objectively using an ActiGraph® during waking hours only
138 over a one-week period at baseline. SB is also used and is measured objectively as average daily sitting
139 time and the number of minutes spent in activities requiring ≤ 1.5 MET using a hip worn ActiGraph®
140 accelerometer.

141 **Assessment of Social isolation and loneliness**

142 *Social isolation* was evaluated using a structured interview including the Lubben Social Network
143 Scale (LSNS-6) with an internal consistency rating (ICC) of 0.55-0.66 (Lubben & Gironda, 2004;
144 Rutledge et al. 2003). It is a 6-item scale that gauges the level of social isolation using the number
145 and frequency of social contact with friends and family and the perceived social support from these
146 sources. Scores range from 0 to 30 where a score of ≤ 12 delineates “at-risk” for social isolation.
147 Loneliness was evaluated using the DeJong Gierveld Loneliness Scale (DGLS-6) with an ICC of 0.85-
148 0.95 in older adults (De Jong Gierveld & Van Tilburg, 2010). It is a 6-item scale providing an overall
149 measure of loneliness that combines ‘emotional loneliness’, when someone misses an intimate
150 relationship, and ‘social loneliness’, when someone misses a wider social network. Scores range
151 from 0 to 6 where 0 is ‘least lonely’ and 6 is ‘most lonely’.

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152 **Assessment of covariates**

153 Research suggests that there are a number of risk factors for loneliness and social isolation (Schrempft
154 et al., 2019; Shvedko et al., 2018) and so socio-demographic covariates of age (years), sex
155 (male/female), marital status (single, married, widowed, divorced), living arrangements (alone,
156 spouse/partner, son/daughter, other relative, other family, or non-relatives), employment status
157 (employed, unemployed), BMI (underweight, normal weight, over-weight, obese), and education (can
158 read/write, cannot read/write, primary, secondary, university) were included. Additionally, self-rated
159 health status (SF-12) (1 is excellent, 2 is very good, 3 is good, 4 is fair, and 5 is poor); and physical
160 function (Short Physical Performance Battery, SPPB), a group of measures that combines the results
161 of the gait speed, chair stand and balance tests (Guralnik et al., 2000) where scores range from 0
162 (worst performance) to 12 (best performance) were included in the analysis.

163 **Statistical analysis**

164 Firstly, data was assumed to be missing at random and considering the level of missing data of 5-6%
165 in the variables of LSNS-6, DGLS-6, MVPA, SB, and LPA (Table 1), multi-imputation was applied using
166 an Expectation Maximisation approach in SPSS (v.25). Regression analysis was then carried out. A
167 multilevel linear regression to address clustering by couples and countries was used to predict social
168 isolation (LSNS-6) i) SB; ii) SB and MVPA; iii) SB, MVPA and LPA; iv) SB, MVPA, LPA and age, sex, marital
169 status, living arrangements, employment status, BMI, education, self-rated health status (SF-12) and
170 physical function (Short Physical Performance Battery, SPPB).

171 The assumptions of normality was violated by the Loneliness (DGLS-6) measure and also considering
172 the ordinal nature of the dependent variable of loneliness (DGLS-6 at six levels ranging from (1) no
173 social isolation to (6) severe social isolation), an ordinal logistics regression using the proportional
174 odds model as a measure of association between SB, MVPA and LPA and loneliness was calculated
175 (Abreu et al., 2008). SB, MVPA, LPA and age, sex, marital status, living arrangements, employment

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176 status, BMI, education, self-rated health status (SF-12), and physical function (Short Physical
177 Performance Battery, SPPB) were included in the model.

178 Results

179 A total of 1360 participants completed the baseline interview-based, self-reported survey and
180 functional tests. The number of participants, the response mean (standard deviation), and range of
181 responses are reported in **Table 1**. The mean age of the sample was 75.27 (St. dev=6.29) years; 62%
182 were female, 75% had a secondary education or above, 78% were overweight or obese, 53% were
183 married/in a stable relationship, 52% were living with a husband/wife or partner; 69% experienced
184 good-to-excellent health.

185 The mean social isolation score (LSNS-6) (16.63) and loneliness score (DGLS-6) (2.16) indicated that
186 the sample was at low risk of social isolation and loneliness. Daily MVPA was 23.73 (19.99) minutes,
187 daily SB 160.28 (52.69) minutes, and daily LPA was 678.28 (76.01) minutes.

188 ***Physical activity and social isolation (LSNS-6)***

189 The assumptions for linear regression were tested and met where data included no outliers and data
190 was normally distributed. Consequently, a multiple linear regression was calculated using the LSNS-6
191 data (**Table 2**). Separate multiple linear regressions, adjusted for socio-demographic characteristics,
192 were developed to understand the association between SB, MVPA, LPA and social isolation (LSNS-6).
193 Model 1 included the effects of MVPA on LSNS-6 and a significant regression equation was found (F
194 (1, 1278) = 5.18, $p < 0.05$). MVPA explained 10% of the variance in LSNS-6 ($R^2 = 0.1$); Model 2 included
195 the effects of MVPA and SB on LSNS-6 and a significant regression equation was found (F (2, 1277) =
196 5.97, $p < 0.05$). MVPA and SB explained 10% of the variance in LSNS-6 ($R^2 = 0.1$); Model 3 included the
197 effects of MVPA, SB, and LPA on LSNS-6 and a significant regression equation was found (F (3, 1276) =
198 6.04, $p < 0.001$). MVPA, SB and LPA explained 12% of the variance in LSNS-6 ($R^2 = 0.12$); Model 4 included
199 MVPA, SB, LPA, and covariates of age, sex, living arrangements, employment status, BMI, educational

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200 background, marital status. Self-reported general health, and physical function and a significant
201 regression equation was found ($F(12, 1267) = 5.62, p < 0.001$) where 23% of the variance was explained
202 ($R^2 = 0.23$).

203 The analysis of the final model (model 4) showed that SB ($\beta = 0.01, t(1278) = 3.08, p < 0.05$) was a
204 significant independent predictor of social isolation measured using LSNS-6. Additionally, the
205 covariates of sex ($\beta = -0.82, t(1278) = 2.17, p < 0.05$); BMI ($\beta = 0.77, t(1278) = 3.32, p < 0.001$); physical
206 function ($\beta = 0.35, t(1278) = 3.97, p < 0.001$); and self-reported general health ($\beta = -0.71, t(1278) = -3.28,$
207 $p < 0.001$) were also found to be statistically significant predictors of social isolation.

208 MVPA ($\beta = 0.01, t(1278) = 1.29, p = 0.20$); LPA ($\beta = 0.02, t(1278) = 1.52, p = 0.13$); age ($\beta = 0.06, t(1278) =$
209 $1.73, p = 0.08$); marital status ($\beta = -0.08, t(1278) = -0.38, p = 0.71$); living arrangements ($\beta = 0.32, t(1278)$
210 $= 1.43, p = 0.15$); educational background ($\beta = -0.17, t(1278) = -0.76, p = 0.45$); and employment status
211 ($\beta = 0.82, t(1278) = 1.17, p = 0.24$) were not found to be significant for social isolation.

212 Physical activity and loneliness (DGLS-6)

213 Using the DGLS-6 data, multicollinearity was examined using the variance inflation factor (VIF), and all
214 variables had a VIF > 10 , therefore no variables were considered for possible exclusion from the
215 multivariable analysis (O'Brien, 2007). The assumption of proportional odds was rejected using the
216 test of parallel lines ($p \leq 0.000$) but as the number of variables (14) and sample size (1360) is large and
217 also included continuous variables then this was not considered an issue (Allison, 1999; Brant, 1990).
218 The Nagelkerke and McFadden measure (0.10) showed that the model is a reasonable predictor of
219 loneliness for any particular individual by explaining 10% of the variation.

220 MVPA ($p = 0.49$), SB ($p = 0.44$), or LPA ($p = 0.75$) were not significant predictors of loneliness. The
221 following were significant predictors of loneliness where the odds of being lonely were almost the
222 same across regardless of age (OR=0.98; 95% CI, 0.61 to 0.99); and where being female (OR=1.32;
223 95% CI, 1.04 to 1.68); living with non-relatives (OR=21.12; CI 95% 1.15 to 387.61); or being overweight

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224 (OR=5.31;CI 95% 1.08 to 26,31) increased the odds of being lonely; and where being single (OR= 0.02;
225 CI 95% 0.00 to 0.31), married (OR=0.01; CI 95% 0.00 to 0.2), divorced (OR=0.02; CI 95% 0.00 to 0.33);
226 or healthy (OR=0.44; CI 95% 0.2 to 0,97) decreased the odds of feeling lonely (Table 3).

227 Discussion

228 **Statement of findings**

229 This study investigated the association between social isolation and loneliness, and objectively
230 measured PA and SB in a sample of community dwelling older adult men and women, included in the
231 SITLESS study. Social isolation measured using LSNS-6 was associated with SB where higher levels were
232 associated with increased levels of social isolation, controlling for age, sex, living arrangements,
233 employment status, BMI, educational background, marital status and self-reported general health. In
234 contrast, PA intensity (MVPA, SB, or LPA) were not found to be significant predictors of loneliness
235 measured using the DGLS-6. These findings suggest that SB behaviour may be associated with social
236 isolation among older community-dwelling adults, but further research is needed to better
237 understand the relationship between PA and loneliness.

238 **Social Isolation**

239 A substantial body of evidence demonstrates that social connectedness benefits health (Cacioppo &
240 Cacioppo, 2014; Holt-Lunstad et al., 2010). Among older adults, social isolation has been associated
241 with being physically inactive (Dickens et al. 2011) and the findings from the current cross-sectional
242 study identified SB as a statistically significant independent predictor of social isolation. Social isolation
243 was associated with more time spent in SB which support the findings presented in a recent study
244 investigating the association between social isolation and objectively measured PA in community
245 dwelling older adults (Schrempft et al. 2019). However, no association between MVPA and LPA with
246 social isolation was found in our study which contrasts with the findings from Schrempft et al. (2019).
247 The differences in findings may be due to the study population where the sample used in our study

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248 were at low risk of social isolation and high risk of low PA. The effects may be stronger in a sample
249 with a greater range of social integration and higher levels of PA. For example, greater social
250 connectedness has been associated with being physically active, but older adults have demonstrated
251 diminishing participation in recreational PA such as team sports and organised exercise groups (Robins
252 et al. 2016). Furthermore, objective measures of PA do not provide details regarding the type of PA
253 carried out, and research suggests that PA with a social component such as group activities can
254 improve social isolation measures (Dickens et al., 2011). It may well be that the sample are involved
255 in less social PA or perhaps their experience of PA is more individualistic, rather than social. A
256 systematic review of the association of PA and quality of life in older adults demonstrated a link
257 between PA and the quality of life domain for social functioning, prompting further investigation
258 (Vegetti *et al.* 2014). Future research tackling social isolation may also be a target to reduce SB and
259 increase PA among community-dwelling older adults and should focus on PA interventions that
260 consider the functionality of older adults and include a social activity.

261 **Loneliness**

262 Theories have been developed that posit causal mechanisms between PA and loneliness. For example,
263 the social compensation model proposes that engaging in PA can compensate for the loss of social
264 connections that older adults experience, through the networks developed during exercise (Ferraro &
265 Farmer, 1995). However, in keeping with a previous analysis of the relationship between objectively
266 measured PA and loneliness (Schrempft et al., 2019), our findings have not confirmed this theory. This
267 may be because the use of objective measures of PA provide a measure of overall activity and do not
268 allow for the comparison of different types of exercise (group exercise, active travel, domestic physical
269 activity, outdoor recreation) with loneliness :(Rapp et al., 2018). It may be that most of the time spent
270 in PA and SB are done alone, so new social networks are not formed. Future research should attempt
271 to identify if group compared with individual exercise is associated with reduced loneliness in older
272 adults.

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273 **Strengths and limitations**

274 The cross-sectional nature of the study prevents causal conclusions from being drawn. It is possible
275 that greater social isolation leads to reduced PA, but it is also possible that less physically active people
276 withdraw from social contact and may be more likely to become lonely. Additionally, the measures of
277 social isolation and loneliness were secondary outcomes. Nonetheless, PA can improve psychosocial
278 outcomes, so it is still important to explore the association between PA and social health to inform
279 future interventions focusing specifically on loneliness and PA.

280 The measure of social isolation was comprehensive in that it considered contacts with friends and
281 family, but it did not consider the impact of social network size. Also, the DGLS-6 measure of loneliness
282 contained three questions relating to social isolation and three relating to loneliness and therefore
283 may not be a sensitive measure of overall loneliness. Furthermore, the majority of adults within this
284 study were at low risk of social isolation and loneliness, inactive (e.g. ≤ 30 minutes of activity 5 days a
285 week that made them breathless), and overweight or obese (78%), so results may be biased. Future
286 research should explore how the magnitude of the social network might impact on social isolation and
287 explore the subscales of emotional and social loneliness provided by the DGLS-6 measure or a different
288 measure of loneliness. Additionally, the measures used within our study are limited to those available
289 from the SITLESS study and so future studies should also consider including other covariates such as
290 pain (Smith et al., 2019). Furthermore, the SITLESS study includes data from Denmark, Spain, Germany
291 and the United Kingdom, and future research should explore how cultural differences might affect the
292 results.

293 Despite the limitations of this study, to the authors' knowledge, it is one of a few to assess the
294 association of PA and SB on loneliness and social isolation, and specifically to target a community-
295 dwelling older adult population aged 65 years and over, using objective measures of PA and SB
296 (Schrempft et al., 2019; Schvedko et al., 2018). This study measured PA and SB using an accelerometer-
297 based measure of activity rather than self-report in order to provide objective evidence of links with

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298 social isolation and loneliness. Self-report measures are more commonly used in observational
299 epidemiology studies exploring PA and health outcomes. However, bias caused by social desirability,
300 or problems in recall can limit the accuracy of self-reports in older adults (Dyrstad et al., 2014; Murphy,
301 2009; Saelens et al., 2012; Shepherd, 2003). Furthermore, inaccuracy of self-reported PA may be more
302 exaggerated among older adults because of recall error, and because most activity is accumulated
303 through light intensity everyday living activities such as gardening, housework or shopping, rather
304 than specific exercise that is planned, structured and defined such as jogging or weight training
305 (Dyrstad et al., 2014; Murphy, 2009; Saelens et al., 2012). Consequently, the results from this study
306 provide a more accurate reflection of the actual PA carried out by older adults in a community setting.
307 These findings suggest that SB may be linked to social isolation in older adults, but that PA or SB are
308 not necessarily linked to loneliness in older community-dwelling adults. Consequently, the key
309 message from this study is in line with current public health policy which suggests that sitting less and
310 moving more is beneficial to health in older adults. Future interventions should target sitting
311 behaviour by including social components within the intervention such as group activities.
312 Additionally, consideration should be given to tailoring the interventions to address functionality and
313 capability limitations that may prevent older adults from engaging in PA and as a result address both
314 loneliness and social isolation.

References

- 315
316
317 Abreu, M.N.S., Siqueira, A.L., Cardoso, C.S., & Caiaffa, W.T. (2008). Ordinal logistic regression
318 models: Application in quality of life studies. *Cadernos de Saude Publica*, 24(4), SS81-SS91.
319 Doi: 10.1590/s0102-311x2008001600010.
- 320 AgeUK. (2018, 27 May). Campaign to end loneliness.org. Retrieved on May 27, 2019, from:
321 <https://www.campaigntoendloneliness.org/loneliness-research/>.

RISK FACTORS ASSOCIATED WITH LONELINESS IN ADULTS

- 322 Bangsbo, J., Blackwell, J., Boraxbekk, C. et al. (2019). Copenhagen Consensus statement 2019:
323 physical activity and ageing. *British Journal of Sports Medicine*, Published Online First: 21
324 February 2019. Doi: 10.1136/bjsports-2018-100451.
- 325 Bernard, S. (2013). Loneliness and social isolation among older people in North Yorkshire, Working
326 Paper (WP2565). *Social Policy Research Unit, University of York 2013*. Retrieved on April 30,
327 2019 from <https://www.york.ac.uk/inst/spru/research/pdf/lonely.pdf>.
- 328 Cacioppo, J.T., & Cacioppo, S. (2014). Social relationships and health: the toxic effects of perceived
329 social isolation. *Soc Personal Psychol Compass*, 58–72. Retrieved on May 27, 2019 from
330 <https://doi.org/10.1111/spc3.12087>.
- 331 Choi, L., Liu, Z., Matthews, C. E., & Buchowski, M. S. (2011). Validation of accelerometer wear and
332 nonwear time classification algorithm. *Medicine and Science in Sports and Exercise*, 43, 357-
333 364. Doi: 10.1249/MSS.0b013e3181ed61a3.
- 334 Cohen, S., & Wills, T.A. (1985). Stress, social support, and the buffering hypothesis. *Psychol Bull*, 98,
335 310-357 . Retrieved on April 30, 2019 from <https://psycnet.apa.org/record/1986-01119-001>.
- 336 De Jong Gierveld, J., & Van Tilburg T. (2010). The De Jong Gierveld short scales for emotional and
337 social loneliness: tested on data from 7 countries in the UN generations and gender surveys.
338 *European Journal of Ageing*, 7(2), 121–130. Doi:10.1007/s10433-010-0144-6.
- 339 Dickens, A.P., Richards, S.H., Greaves, C.J., & Campbell, J.L. (2011). Interventions targeting social
340 isolation in older people: a systematic review. *BMC Public Health*, 11, 647. Doi:
341 <http://www.biomedcentral.com/1471-2458/11/647>.
- 342 Dogra, S., & Stathokostas, L. (2012). Sedentary Behaviour and physical activity are independent
343 predictors of successful aging in middle-aged and older adults. *Journal of aging research*,
344 190654. Doi: 10.1155/2012/190654.

RISK FACTORS ASSOCIATED WITH LONELINESS IN ADULTS

- 345 Doherty, A., Jackson, D., Hammerla, N., PloÈ, T., Olivier, P., Granat, M.H., White, T., van Hees, V.T.,
346 Trenell, M.I., Owen, C.G., Preece, S.J., Gillions, R., Sheard, S., Peakman, T., Brage, S., &
347 Wareham, N.J. (2017). Large Scale Population Assessment of Physical Activity Using Wrist
348 Worn Accelerometers: The UK Biobank Study. Study. *PLoS ONE*, 12(2), e0169649. Doi:
349 10.1371/journal.pone.0169649.
- 350 Dyrstad, S.M., Hansen, D.M., Holme, I.M., & Anderssen, S.A. (2014). Comparison of self-reported
351 versus accelerometer-measured physical activity. *Med Sci Sports Exec*, 46, 99-106.
- 352 Ferraro, K.F., & Farmer, M.M. (1995). Social compensation in adulthood and later life. Compensating
353 for Psychological Deficits and Declines: Managing Losses and Promoting Gain. Chapter 6,
354 127–145. Retrieved on April 30, 2019 from
355 [https://books.google.co.uk/books?hl=en&lr=&id=P8rlWdFqTuUC&oi=fnd&pg=PA127&dq=Ferraro+KF,+Farmer+MM.+Social+compensation+in+adulthood+and+later+life.+Compensating+for+Psychological+Deficits+and+Declines:+Managing+Losses+and+Promoting+Gain.+1995:127%E2%80%93145.&ots=YyEoQ50C-](https://books.google.co.uk/books?hl=en&lr=&id=P8rlWdFqTuUC&oi=fnd&pg=PA127&dq=Ferraro+KF,+Farmer+MM.+Social+compensation+in+adulthood+and+later+life.+Compensating+for+Psychological+Deficits+and+Declines:+Managing+Losses+and+Promoting+Gain.+1995:127%E2%80%93145.&ots=YyEoQ50C-P&sig=GeyPJwqsF2PQxxzJpJ51OSCfNNE&redir_esc=y#v=onepage&q&f=false)
356 [P&sig=GeyPJwqsF2PQxxzJpJ51OSCfNNE&redir_esc=y#v=onepage&q&f=false](https://books.google.co.uk/books?hl=en&lr=&id=P8rlWdFqTuUC&oi=fnd&pg=PA127&dq=Ferraro+KF,+Farmer+MM.+Social+compensation+in+adulthood+and+later+life.+Compensating+for+Psychological+Deficits+and+Declines:+Managing+Losses+and+Promoting+Gain.+1995:127%E2%80%93145.&ots=YyEoQ50C-P&sig=GeyPJwqsF2PQxxzJpJ51OSCfNNE&redir_esc=y#v=onepage&q&f=false)
357 [P&sig=GeyPJwqsF2PQxxzJpJ51OSCfNNE&redir_esc=y#v=onepage&q&f=false](https://books.google.co.uk/books?hl=en&lr=&id=P8rlWdFqTuUC&oi=fnd&pg=PA127&dq=Ferraro+KF,+Farmer+MM.+Social+compensation+in+adulthood+and+later+life.+Compensating+for+Psychological+Deficits+and+Declines:+Managing+Losses+and+Promoting+Gain.+1995:127%E2%80%93145.&ots=YyEoQ50C-P&sig=GeyPJwqsF2PQxxzJpJ51OSCfNNE&redir_esc=y#v=onepage&q&f=false)
358 [P&sig=GeyPJwqsF2PQxxzJpJ51OSCfNNE&redir_esc=y#v=onepage&q&f=false](https://books.google.co.uk/books?hl=en&lr=&id=P8rlWdFqTuUC&oi=fnd&pg=PA127&dq=Ferraro+KF,+Farmer+MM.+Social+compensation+in+adulthood+and+later+life.+Compensating+for+Psychological+Deficits+and+Declines:+Managing+Losses+and+Promoting+Gain.+1995:127%E2%80%93145.&ots=YyEoQ50C-P&sig=GeyPJwqsF2PQxxzJpJ51OSCfNNE&redir_esc=y#v=onepage&q&f=false)
359 [P&sig=GeyPJwqsF2PQxxzJpJ51OSCfNNE&redir_esc=y#v=onepage&q&f=false](https://books.google.co.uk/books?hl=en&lr=&id=P8rlWdFqTuUC&oi=fnd&pg=PA127&dq=Ferraro+KF,+Farmer+MM.+Social+compensation+in+adulthood+and+later+life.+Compensating+for+Psychological+Deficits+and+Declines:+Managing+Losses+and+Promoting+Gain.+1995:127%E2%80%93145.&ots=YyEoQ50C-P&sig=GeyPJwqsF2PQxxzJpJ51OSCfNNE&redir_esc=y#v=onepage&q&f=false)
- 360 Ferry, M., Sidobre, B., Lambertin, A., & Barberger-Gateau, P. (2005). The SOLINUT study: analysis of
361 the interaction between nutrition and loneliness in persons aged over 70 years. *Journal of*
362 *Nutrition, Health & Aging*, 9(4), 261-268.
- 363 Giné-Garriga, M., Coll-Planas, L., Guerra, M., et al. (2017). The SITLESS project: exercise referral
364 schemes enhanced by self-management strategies to battle sedentary behaviour in older
365 adults: study protocol for a randomised controlled trial. *Trials*, 18:,21. Doi:10.1186/s13063-
366 017-1956-x.
- 367 Guralnik, J. M., Ferrucci, L., Pieper, C. F., Leveille, S. G., Markides, K. S., Ostir, G. V., et al. (2000).
368 Lower extremity function and subsequent disability: Consistency across studies, predictive

RISK FACTORS ASSOCIATED WITH LONELINESS IN ADULTS

- 369 models, and value of gait speed alone compared with the short physical performance
370 battery. *Journal of Gerontology: Medical Sciences*, 55A, M221–M231.
- 371 Hawkey, L.C., Thisted, R.A., & Cacioppo, J.T. (2009). Loneliness predicts reduced physical activity:
372 Cross-sectional & longitudinal analyses. *Health Psychology*, 28(3): 354–363.
373 Doi:10.1037/a0014400.
- 374 Henry, K.B., Arrow, H., & Carini, B. (1999). A tripartite model of group identification theory and
375 measurement. *Small Group Res*, 30, 558–581. Retrieved on April 30, 2019 from
376 <https://doi.org/10.1177/104649649903000504>
- 377 Holt-Lunstad, J., Smith, T.B., & Layton, J.B. (2010). Social relationships and mortality risk: A meta-
378 analytic review. *PLoS Medicine*, 7(7): e1000316.
- 379 Lauder, W., Mummery, K., Jones, M., & Caperchione, C. (2006). A comparison of health behaviours in
380 lonely and non-lonely populations. *Psychology Health & Medicine*, 11(2), 233-245.
- 381 Lubben, J., & Gironde, M. (2004). Measuring social networks and assessing their benefits. In *Social*
382 *Networks and Social Exclusion: Sociological and Policy Perspectives*. Eds. Phillipson, C., Allan,
383 G., Morgan, D. Ashgate.
- 384 Migueles, J. H., Cadenas-Sanchez, C., Ekelund, U., Delisle Nyström, C., Mora-Gonzalez, J., Löf, M., &
385 Ortega, F. B. (2017). Accelerometer Data Collection and Processing Criteria to Assess Physical
386 Activity and Other Outcomes: A Systematic Review and Practical Considerations. *Sports*
387 *Medicine*, 47, 1821–1845. Doi: 10.1007/s40279-017-0716-0.
- 388 Milligan, C., Dowrick, C., Payne, S., et al. (2013). Men’s sheds and other gendered interventions for
389 older men: improving health and wellbeing through social activity-a systematic review and
390 scoping of the evidence base. Lancaster University Centre for Ageing Research: Lancaster.
- 391 Murphy, S.L. (2009). Review of physical activity measurement using accelerometers in older adults:
392 considerations for research design and conduct. *Preventive Medicine*, 48, 108–114.

RISK FACTORS ASSOCIATED WITH LONELINESS IN ADULTS

- 393 Newall, N.E., Chipperfield, J.G., Bailis, D.S., et al. (2013). Consequences of loneliness on physical
394 activity and mortality in older adults and the power of positive emotions. *Health Psychology*,
395 32:921. Downloaded on April 30, 2019 from: <https://doi.org/10.1037/a0029413>.
- 396 Nicholson, N.R. (2012). A review of social isolation: An important but underassessed condition in
397 older adults. *The Journal of Primary Prevention*, 33(2–3), 137–152.
- 398 O’Brien, R.M. (2007). A caution regarding rules of thumb for variance inflation factors. *Quality &*
399 *Quantity*, 41, 673–690. Doi:10.1007/s11135-006-9018-6.
- 400 Patterson, A.C., & Veenstra, G. (2010). Loneliness and risk of mortality: a longitudinal investigation in
401 Alameda County, California. *Social Science & Medicine*, 71(1), 181-186.
- 402 Pels, F. & Kleinert J., (2016). Loneliness and physical activity: A systematic review. *International*
403 *Review of Sport and Exercise Psychology*. 9(1), 231-260. Doi:
404 10.1080/1750984x.2016.1177849.
- 405 Pitkala, K.H., Routasalo, P., Kautiainen, H., Sintonen, H., & Tilvis, R.S. (2011). Effects of socially
406 stimulating group intervention on lonely, older people's cognition: a randomized, controlled
407 trial. *American Journal of Geriatric Psychiatry*, 19(7), 654-663.
- 408 Rapp, K., Mikolaizak, S., Rothenbacher, D., Denking, M.D., & Klenk, J. (2018). Prospective analysis
409 of time out-of-home and objectively measured walking duration during a week in a large
410 cohort of older adults. *European Review of Aging and Physical Activity*, 15(8). Downloaded
411 on April 30, 2019 from <https://doi.org/10.1186/s11556-018-0197-7>.
- 412 Robins, L.M., Jansons, P., & Haines, T. (2016). The impact of physical activity interventions on social
413 isolation among community-dwelling older adults: A systematic review. *Research & Reviews:*
414 *Journal of Nursing and Health Sciences*. Downloaded on April 30, 2019 from:
415 [http://www.rroij.com/open-access/the-impact-of-physical-activity-interventions-on-social-](http://www.rroij.com/open-access/the-impact-of-physical-activity-interventions-on-social-isolationamong-community--dwelling-older-adults-a-systematic-review-.php?aid=70173)
416 [isolationamong-community--dwelling-older-adults-a-systematic-review-.php?aid=70173](http://www.rroij.com/open-access/the-impact-of-physical-activity-interventions-on-social-isolationamong-community--dwelling-older-adults-a-systematic-review-.php?aid=70173).

RISK FACTORS ASSOCIATED WITH LONELINESS IN ADULTS

- 417 Rutledge, T., Matthews, K., Lui, L.-Y., Stone, K. L., & Cauley, J. A. (2003). Social Networks and Marital
418 Status Predict Mortality in Older Women: Prospective Evidence From the Study of
419 Osteoporotic Fractures (SOF). *Psychosomatic Medicine*, 65(4), 688-694. Doi:
420 10.1097/01.psy.0000041470.25130.6c.
- 421 Saelens, B.E., Sallis, J.F., Frank, L.D., Cain, K.L., Conway, T.L., Chapman, J.E., Slymen, D.J., & Kerr, J.
422 (2012). Neighborhood environmental and psychosocial correlates of adults' physical activity.
423 *Medical Science of Sports Exercise*, 44, 637–646.
- 424 Schrempft, S., Jackowska, M., Hamer, M., & Steptoe, A. (2019). Associations between social isolation,
425 loneliness, and objective physical activity in older men and women. *BMC Public Health*,
426 19(74). Doi: <https://dspace.lboro.ac.uk/2134/36669>.
- 427 Schvedko, A.V., Thompson, J.L., Greig, C.A., & Whittaker, A.C. (2018). Physical activity interventions
428 for treatment of social isolation, loneliness or low social support in older adults: A systematic
429 review and meta-analysis of randomised controlled trials. *Psychology of Sports Exercise*, 34,
430 128-137.
- 431 Senez, B., Felicioli, P., Moreau, A., & Le Goaziou, M.F. (2004). Quality of life assessment of type 2
432 diabetic patients in general medicine. *Presse Medicale*, 33(3), 161-166.
- 433 Shankar, A., McMunn, A., Banks, J., & Steptoe, A. (2011). Loneliness, social isolation, and behavioral
434 and biological health indicators in older adults. *Health Psychology*, 30 (4), 377-385.
- 435 Smith, T.O., Dainty, J.R., Williamson, E., Martin, K.R. (2019). Association between musculoskeletal
436 pain with social isolation and loneliness: analysis of the English Longitudinal Study of Ageing.
437 *British Journal of Pain*, 2, 82-90. Doi: 10.1177/2049463718802868.
- 438 Steptoe, A., Shankar, A., Demakakos, P., & Wardle, J. (2013). Social isolation, loneliness, and all-
439 cause mortality in older men and women. *PNAS*, 110(15), 5797–5801. Downloaded on April
440 19, 2018 from www.pnas.org/cgi/doi/10.1073/pnas.1219686110.

RISK FACTORS ASSOCIATED WITH LONELINESS IN ADULTS

- 441 Thurston, R.C., & Kubzansky, L.D. (2009). Women, loneliness, and incident coronary heart disease.
442 *Psychosomatic Medicine*, 71(8), 836-842.
- 443 Victor, C. (2011). Loneliness in old age: the UK perspective. Safeguarding the Convoy: a call to action
444 from the Campaign to End Loneliness. Age UK Oxfordshire. Downloaded on April 30, 2019
445 from [https://www.campaigntoendloneliness.org/wp-content/uploads/Safeguarding-the-](https://www.campaigntoendloneliness.org/wp-content/uploads/Safeguarding-the-Convoy.-A-call-to-action-from-the-Campaign-to-End-Loneliness.pdf)
446 [Convoy.-A-call-to-action-from-the-Campaign-to-End-Loneliness.pdf](https://www.campaigntoendloneliness.org/wp-content/uploads/Safeguarding-the-Convoy.-A-call-to-action-from-the-Campaign-to-End-Loneliness.pdf).
- 447 World Health Organization (WHO) (2014). Ten facts about physical activity. Geneva.
448 www.who.int/features/factfiles/physical_activity/facts/en.
- 449 World Health Organization (WHO) (2002) Active ageing: a policy framework. Downloaded on April
450 16, 2019 from
451 [https://apps.who.int/iris/bitstream/handle/10665/67215/WHO_NMH_NPH_02.8.pdf;jsessio](https://apps.who.int/iris/bitstream/handle/10665/67215/WHO_NMH_NPH_02.8.pdf;jsessionid=A1CE0BEE1B24B35555EA7DF1F58F24D1?sequence=1)
452 [nid=A1CE0BEE1B24B35555EA7DF1F58F24D1?sequence=1](https://apps.who.int/iris/bitstream/handle/10665/67215/WHO_NMH_NPH_02.8.pdf;jsessionid=A1CE0BEE1B24B35555EA7DF1F58F24D1?sequence=1).