

RISK FACTORS ASSOCIATED WITH LONELINESS IN ADULTS

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

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29 Abstract

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

42 Key words

43 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 ( $\geq 65$  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 & Kubzanskv, 2009);  
66 cognitive impairment (Pitkala et al., 2011); and all-cause mortality (Elovanio 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  $\geq 65$  years from across Denmark, Spain, Germany and the  
106 United Kingdom. Participants were eligible if they were able to walk for  $\geq 2$  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)  $\leq 30$  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  $\leq 1.5$  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  $\leq 12$  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.  $\leq 30$  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.

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