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Loneliness Predicts Reduced Physical Activity: Cross-Sectional & Longitudinal Analyses

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Abstract

Objective—To determine cross-sectional and prospective associations between loneliness and physical activity, and to evaluate the roles of social control and emotion regulation as mediators of these associations.

Design—A population-based sample of 229 White, Black, and Hispanic men and women, age 50 to 68 years at study onset, were tested annually for each of 3 years.

Main Outcome Measures—Physical activity probability, and changes in physical activity probability over a 3-year period.

Results—Replicating and extending prior cross-sectional research, loneliness was associated with a significantly reduced odds of physical activity (OR = 0.65 per *SD* of loneliness) net of sociodemographic variables (age, gender, ethnicity, education, income), psychosocial variables (depressive symptoms, perceived stress, hostility, social support), and self-rated health. This association was mediated by hedonic emotion regulation, but not by social control as indexed by measures of social network size, marital status, contact with close ties, group membership, or religious group affiliation. Longitudinal analyses revealed that loneliness predicted diminished odds of physical activity in the next two years (OR = 0.61), and greater likelihood of transitioning from physical activity to inactivity (OR = 1.58).

Conclusion—Loneliness among middle and older age adults is an independent risk factor for physical inactivity and increases the likelihood that physical activity will be discontinued over time.

Keywords

loneliness; physical activity; self-regulation; social control; longitudinal

Social isolation plays an important role in health and longevity (Peel, McClure, & Bartlett, 2005), in part through its association with poor lifestyle behaviors such as lack of physical activity. Even small increases in physical activity have large effects on mortality (Kokkinos et

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al., 2008). Social isolation predicted declines in level of physical activity over a 9-year period among 4,025 adults in the Alameda County study (Kaplan, Lazarus, Cohen, & Leu, 1991). Social rejection and isolation in childhood predicted significantly less exercise behavior in young adulthood (Caspi et al., 2006).

Social isolation tends to promote feelings of loneliness, which can be defined as the distressing feeling that occurs when one's social relationships are perceived as being less satisfying than what is desired (Peplau & Perlman, 1982). Although social isolation is associated with loneliness, loneliness is more closely related to qualitative than quantitative aspects of social relationships (Hawkley, Burleson, Berntson, & Cacioppo, 2003; Peplau & Perlman, 1982; Russell, Peplau, & Cutrona, 1980). A cross-sectional study of loneliness in 1,289 Australian adults between 18 and 89 years of age revealed that those in the lonely group were more likely than those in the nonlonely group to be smokers and overweight, and were less likely to believe that walking was a desirable way to lose weight (Lauder, Mummery, Jones, & Caperchione, 2006), although the groups did not differ in the proportion classified as sedentary. Page, Frey, Talbert, & Falk (1992, Page & Hammermeister, 1995; Page & Tucker, 1994), on the other hand, found that loneliness was associated with lower levels of physical activity among grade school (Grades 1–6), high school (Grades 9–12), and college age students. In the current study, we examine the degree to which loneliness predicts physical activity cross-sectionally and prospectively in a population-based sample of middle-age adults.

Social control differences may explain lower activity levels in lonely individuals. Social control theory holds that internalized obligations to, and the overt influence of, network members tend to discourage poor health behaviors and encourage good health behaviors (Umberson, 1987). For instance, among women, direct social control (i.e., "how often does anyone tell or remind you to do anything to protect your health?") predicted increased physical activity 3 years later (Umberson, 1992). Being married is associated with an increased likelihood of engaging in health-promoting behaviors such as exercise (Pettee et al., 2006; Satariano, Haight, & Tager, 2002; but see also Schmitz, French, & Jeffery, 1997), presumably because marital partners exert some influence over these behaviors (Umberson, 1987, 1992). Data from the Alameda County study indicated that men and women with a large social network were more likely to be classified as moderately active than least active, whereas individuals with a small social network were more likely to be classified as least active than moderately active (Berkman & Syme, 1979). To the extent lonely individuals have few social connections and therefore lack the health-promoting influences of social others, they may be less likely to engage in physical activity.

A second explanation for lower activity levels in lonely individuals is impaired self-regulation. Self-regulation refers to the capacity to change one's cognitions, emotions, and/or behavior to better meet social standards (e.g., physically active people garner more respect than "couch potatoes") and personal goals (e.g., maintain health and fitness into old age). Behavioral self-regulation has been shown to influence physical activity in a health promotion study (Anderson, Wojcik, Winett, & Williams, 2006) and in convenience samples of older adults (Umstattd, Wilcox, Saunders, Watkins, & Dowda, 2008). Loneliness and the threat of social isolation have been shown to impair attentional self-regulatory processes (Baumeister, DeWall, Ciarocco, & Twenge, 2005; Cacioppo et al., 2000), but the effect of loneliness on other forms of self-regulation has not been examined to date. Emotion self-regulation may be a particularly important regulatory domain because the effort involved in regulating emotions takes precedence over, and can reduce the ability to regulate, other self-control behaviors (Tice & Bratslavsky, 2000). Self-regulation in the affective domain involves active or passive modification of emotion-eliciting conditions, emotional experiences, and/or emotion-associated behaviors to optimize a personal or social goal (Lawton, 2001). For instance, fearful and preoccupied romantic attachment styles are associated with less optimization of positive

affect (Labouvie-Vief & Medler, 2002), and positive affect has been shown to predict greater physical activity over the long-term (McAuley et al., 2007). Ironically, although physical activity has been shown to improve mood (Ekkekakis & Petruzzello, 1999), negative mood diminishes motivation to engage in physical activity (Dergance, Mouton, Lichtenstein, & Hazuda, 2005). Lonely individuals are known to exhibit chronically elevated levels of negative affect and lower levels of positive affect than their socially connected counterparts (Hawkley, Preacher, & Cacioppo, 2007), and this may contribute to a reduced motivation to engage in physical activity.

The first purpose of the present study was to examine cross-sectional associations among loneliness, social integration/control, emotion regulation, and physical activity in a population-based sample of middle-age adults, and to determine whether social control or emotion regulation helps to explain associations between loneliness and physical activity. The second purpose was to examine whether initial loneliness predicts changes in physical activity over a 2-year period, and to test whether social control and emotion regulation contribute to loneliness-related changes in physical activity. We also examine whether participants' health contributes to loneliness-related differences in physical activity.

Throughout, we examine the degree to which loneliness is a risk factor for physical inactivity independent of its associations with a constellation of related psychosocial variables. Specifically, past research has shown that loneliness is associated with, but conceptually independent of, greater depressive symptomatology, hostility, and perceived stress, and poorer social support (Cacioppo, Hawkley, et al., 2006; Cacioppo, Hughes, et al., 2006; Russell, 1996). Each of these psychosocial variables has been associated with a lower likelihood of physical activity (Anderson, Wojcik, Winett, & Williams, 2006; Dergance et al., 2005; Ng & Jeffery, 2003; Siegler et al., 2003). By including these related psychosocial variables as covariates in analyses, we are able to assess the extent to which loneliness is an independent risk factor for physical inactivity.

Method

Participants

A population-based sample of 229 English-speaking Blacks/African Americans (37 males, 44 females), non-Black Hispanics (33 males, 33 females), and non-Hispanic Whites (39 males, 43 females) between the ages of 50 and 68 years (M = 57.4, SD = 4.5) from Cook County, IL, participated in the first year of the longitudinal Chicago Health, Aging, and Social Relations study (CHASRS). Participants had to be ambulatory and able to speak English; no other exclusionary criteria were imposed. The sampling design and recruitment strategies have been reported elsewhere (Hughes, Waite, Hawkley, & Cacioppo, 2004).

Procedures

Annually, for each of three consecutive years reported in the present study, participants arrived at the laboratory between 8:00 and 9:00 a.m. for comprehensive testing.[1] Upon arrival, they provided informed consent and began a day of assessments that included standard psychological surveys, an exercise behavior survey, interviews, lunch, and a cardiovascular

[1]Data are collected across the entire calendar year, with the majority of participants (>75%) being tested during the first 6 months of the year, and virtually all participants tested in the same season each year. For Years 1 and 2, 81% of subjects were tested within 2 months of each other; for Years 2 and 3, and for Years 1 and 3, 89% and 73% of subjects, respectively, were tested within a 2-month window. For each of Years 1, 2, and 3, a comparison by testing season (winter: Jan–Mar; spring: April–June; summer: July–Sept; fall: Oct–Dec) and a second comparison by testing month revealed no seasonal or monthly differences in exercise probability, nor in measures of loneliness, social isolation, and emotion self-regulation.

protocol. Participants were paid $90 US for their day in the laboratory completing components of the study.

Measures

Physical activity—We used a modified version of the Minnesota Leisure Time Physical Activity Questionnaire (MLTPA) which inquired whether, in the past 14 days, participants had engaged in any of 14 exercises, sports, or physically active hobbies, and the frequency (how many times in the past 2 weeks) and duration (in minutes) of each activity episode (McPhillips, Pellettera, Barrett-Connor, Wingard, & Criqui, 1989).

Our primary measure of interest was a dichotomous variable indicating presence or absence of any physical activity. We chose this measure because we place greater reliance on participants' memories of whether or not they engaged in any of these activity types during the last 2 weeks than on their memories of how frequently they were active and how much time they spent doing each activity. Retrospective reports about physical activity duration are particularly susceptible to biases (e.g., misremembering, forgetting, or misrepresenting), and this may have contributed to a greater proportion of missing data for activity duration than for the dichotomous variable (i.e., in Year 1, about 33% of the sample did not report exercise duration, whereas only 1% to 2% of the sample failed to report whether or not they engaged in any physical activity during the prior 14 days). Activity frequency also exhibited a high rate of missing data (i.e., in Year 1, about 24% of the sample failed to report exercise frequency), and because of missing data, our analyses of activity frequency and duration are exploratory only.

R-UCLA Loneliness Scale (R-UCLA)—The R-UCLA is a measure of general loneliness and degree of satisfaction with one's social network, and has good construct validity (Russell, Peplau, & Cutrona, 1980). Examples of the items are, "I lack companionship" and "I feel in tune with the people around me." Each of the 20 items is rated on a scale of 1 (never), 2 (rarely), 3 (sometimes), and 4 (often). After reverse scoring appropriate items, loneliness scores are calculated by summing all items. The range of possible scores is 20 to 80, with higher scores signifying greater loneliness. In Year 1, Cronbach's alpha across all 20 items was .91 in this sample.

Social network variables—Participants were asked about their current marital status and, in the present study, being married or living with a partner was contrasted with all other marital status conditions (separated, divorced, widowed, or never married). Participants were also asked to report the number of close friends and relatives with whom they speak at least every 2 weeks, whether they belong to a nonreligious group (e.g., civic group, neighborhood organization, sports club), and whether they are affiliated with a religious group. Nonreligious and religious group memberships were dichotomized such that at least one group membership and affiliation with a religious group were contrasted with having no group memberships and no religious group affiliation, respectively. Following as closely as possible the procedure described by Berkman and Syme (1979), values on the dichotomous measures of group membership and religious group affiliation were combined with a composite index of intimate contacts with spouse, friends, and relatives to create the Social Network Index (SNI). Values on the SNI range from 1 to 4, with higher numbers reflecting a greater number of social connections.

Emotional Regulation Inventory (ERI)—The ERI scale is a 34-item questionnaire that asks participants to respond to the statement "Imagine a situation when you are in a *good* mood, how do you handle your emotions in such circumstances?" followed by the same prompt about a bad mood (Mohiyeddini, 2005, in-house translation from German; see also Wirtz et al.,

2006). Emotion regulation is assessed along three dimensions: hedonic regulation, distress-augmenting regulation (i.e., intensifying of negative emotions), and emotion moderation (i.e., buffering of emotions). Hedonic emotion regulation (HER) is represented by 12 items that include the subdimensions of positive mood maintenance (e.g., "I freely express my feelings as they are") and intensification (e.g., "I try to intensify my feelings (e.g., through appropriate music)"), and repair of negative mood (e.g., "I try to improve my mood by thinking about something pleasant"). Distress-augmenting regulation (DAR) is represented by 12 items that include the subdimensions of negative mood maintenance (e.g., "I accept my feelings as they are") and intensification (e.g., "I try to experience my feelings to their fullest"). Emotion moderation (EM) is represented by 10 items that reflect attempts to buffer positive or negative emotional states (e.g., "I try to dampen my feelings to avoid going over the top," and "I try to moderate my feelings to avoid making a bad impression on others"). For each item, participants respond on a 6-point Likert scale from 1 (hardly ever) to 6 (almost always). Item responses are averaged to provide scores for each dimension of emotional regulation, with higher scores corresponding to greater hedonic emotion regulation, greater distress-augmenting regulation, and greater emotion moderation or buffering (EM). The construct validities of these three subscales have been established through correlations with conceptually relevant constructs (Wirtz et al., 2006). In data from Year 1 of our study, Cronbach's alphas for the three subscales were 0.84 (HER), 0.79 (DAR), and 0.82 (EM).

Loneliness-Related Psychosocial Covariates

Center for Epidemiologic Studies Depression Scale (CESDML)—The CES-D is a 20-item self-report questionnaire that assesses depressive feelings and behaviors experienced during the past week (Radloff, 1977). The CESD demonstrates good construct validity in correlations with other measures of depressed affect (Radloff, 1977). One item in the CES-D asks whether the respondent felt lonely so this item was deleted before calculating a total score on the CES-D to reduce overlap between the CES-D and the R-UCLA loneliness measure. A depressive symptom score was computed by summing the responses to the remaining 19 items, yielding a scale score range of 0 (low depressed affect) to 56 (high depressed affect). We refer to this measure of depressive symptoms as the CESD-ML. In Year 1, this scale had a Cronbach's alpha of .89, and a mean of 9.8 (*SD* = 8.4).

Perceived Stress Scale (PSS)—The PSS (Cohen & Williamson, 1988) is a 10-item self-report questionnaire that assesses, on a Likert scale that ranges from 0 (never) to 4 (very often), how unpredictable, uncontrollable, and overloaded respondents find their lives (e.g., "how often have you been upset because of something that happened unexpectedly"). The PSS demonstrates good construct validity as indicated by significant correlations with other measures of experienced stress (Cohen & Williamson, 1988). In our study, we inquired about the frequency of stress-related feelings and thoughts during the past week. Scale scores for each participant were calculated by summing the responses to all items, yielding a scale range of 0 (low perceived stress) to 40 (high perceived stress). In Year 1, Cronbach's alpha was .84, and the total score was 13.3 (*SD* = 6.4).

Cook-Medley Hostility Scale (CMHo)—The CMHo (Cook & Medley, 1954) is a 50-item scale developed from the MMPI that assesses hostile attributional tendencies. Construct validity of the CMHo has been demonstrated in significant correlations with measures of cynicism and distrust (Barefoot, 1992). Each item is endorsed as either true (1) or false (0). After reverse scoring appropriate items, responses were summed to generate a hostility score for each participant. Scores range from 0 (low hostility) to 50 (high hostility). In Year 1, Cronbach's alpha was .85, and the total score was 17.4 (*SD* = 7.7).

Interpersonal Support Evaluation List (ISEL)—The ISEL consists of 12 statements that assess, on a 4-point Likert scale ranging from 1 (definitely false) to 4 (definitely true), the perceived availability of potential social resources (Cohen, 2008; Cohen & Hoberman, 1983; Cohen, Mermelstein, Kamarck, & Hoberman, 1984). The 12-item ISEL demonstrates good construct validity as indicated by significant correlations with measures of social network size and marital relationship quality (Cohen, 2008). After reverse scoring appropriate items, values were averaged to compute an overall social support score that ranged from 4 (low support) to 16 (high support). In Year 1, Cronbach's alpha was .87, and the mean social support score was 12.9 (*SD* = 2.2).

Self-Rated Health

Health status could influence both loneliness and physical activity, and we included a measure of self-rated health to determine whether associations between loneliness and physical activity were independent of health differences. Self-rated health was assessed using a single item from the RAND 36-item health survey (version 1.0) developed as part of the Medical Outcomes Study (Ware & Sherbourne, 1992). Participants were asked to rate their health as poor, fair, good, very good, or excellent (scale range = 1–5). The median response was "good;" 84% of participants rated their health as good or better.

Covariates

Sociodemographic covariates were gender, ethnicity, age, education (years completed), and household income. Household income was measured in 12 categories ranging from less than $5,000 to more than $200,000, and the median of each category was used to represent the continuum of income levels. Missing values for education (6) and household income (13) were replaced with means for the corresponding gender by ethnic group combination. The distribution of the household income variable was positively skewed but responded well to a natural log transformation that was employed in analyses.

Data Analysis

Cross-sectional and longitudinal analyses were conducted. Cross-sectional analyses were based on Year 1 data. Binary logistic regression analysis was used to test loneliness as a predictor of the odds of engaging in any kind of physical activity. Explanatory variables (i.e., social network index and emotion regulation measures) were tested in separate models to evaluate their role as potential mediators of the association between loneliness and physical activity probability and duration, and any one that was a significant predictor of physical activity was then entered in a model with loneliness to determine whether the effect of loneliness was explained by the mediator variable. Physical activity may be influenced by sociodemographic factors that are not the primary focus in this study, so all models began with a block of sociodemographic covariates that held constant the effects of age, gender, ethnicity, years of education, and household income. Follow-up models added depressive symptoms, perceived stress, hostility, social support, and self-rated health to determine the extent to which loneliness predicted differences in physical activity net of these variables. For the subset of the sample with data on activity frequency and duration, exploratory analyses were conducted to examine how these activity measures were associated with loneliness, social network measures, and emotion regulation.

Longitudinal analyses of exercise probability were conducted using latent variable growth models. Loneliness can operate like a trait and a state (Cacioppo, Hawkley, et al., 2006), and our interest is at the level of trait as indexed by initial levels of loneliness. Thus, we examined loneliness-related differences in the odds of being physically active in Years 2 and 3, conditional on Year 1 physical activity. Using a multilevel logistic model, we included the fixed effects of the sociodemographic variables and Year 1 values for loneliness and physical

activity, together with the random effects of a linear time trend (i.e., slopes and intercepts were permitted to vary among participants).

In addition, we used a multilevel logistic model to predict the odds of transitions in physical activity (no activity to some activity, and vice versa) over a 1-year period. Year 1 and Year 2 loneliness values were used as predictors of physical activity transitions from Year 1 to 2 and from Year 2 to 3, respectively. In addition to loneliness values, this model included the fixed effects of the sociodemographic variables and the random effects of a linear time trend. In models where loneliness was a significant predictor, Year 1 social network and emotion regulation measures were examined to evaluate their role as explanatory variables in longitudinal associations between loneliness and physical activity probability and/or transitions. Follow-up models added depressive symptoms, perceived stress, hostility, social support, and self-rated health to determine the extent to which loneliness predicts differences in physical activity net of these psychosocial and health variables.

Loneliness, emotion regulation variables, and each of the loneliness-related psychosocial variables were standardized to a mean of 0 and standard deviation of 1 for analyses. Coefficients and logits are therefore interpretable as effects of a 1 *SD* increase in these predictor variables. Logits are converted to odds ratios (ORs) for ease of interpretation. Statistical significance was set at $p < .05$, two-tailed, unless otherwise noted.

Results

Table 1 provides means (*SD*s) and percentages for criterion and predictor variables at baseline (i.e., Year 1). Approximately 89% of participants endorsed some type of activity ($N = 201$), leaving 25 participants who reported no physical activity at all. Cross-sectional correlations among Year 1 values for loneliness, social network contacts, emotion regulation, and physical activity are shown in Table 2. Loneliness was inversely correlated with the probability of any physical activity ($r = -.16$), activity frequency, activity duration, social network size, the index of close ties, and group membership, and was positively correlated with hedonic regulation, but not with distress-augmenting regulation or emotion moderation. Social network size did not exhibit a significant association with physical activity probability ($r = .12$, $p > .05$). Hedonic regulation, on the other hand, was associated with a greater probability of physical activity ($r = .22$). The latter results are consistent with the pattern of associations we hypothesized, and subsequent regression analyses provided a test of direct and indirect effects of loneliness on physical activity.

Cross-Sectional Regression Analyses

Physical activity probability—A logistic regression model ($N = 214$) revealed that the odds of having engaged in any activity during the previous 2 weeks was greater among more educated and higher income individuals (see Table 3), and that, net of these effects, loneliness was associated with lower odds of having engaged in any physical activity, OR = 0.65, 95% CI = 0.42–1.01, $p < .05$, one-tailed (consistent with our directional hypothesis). None of the psychosocial covariates (i.e., depressive symptoms, perceived stress, hostility, and social support) were associated with odds of physical activity (*p*s > .05), nor was self-rated health associated with physical activity odds ($p > .05$), when sociodemographic variables were held constant. Moreover, simultaneous addition of self-rated health and the loneliness-related psychosocial variables to a model with loneliness continued to show lower odds of physical activity associated with loneliness, OR = 0.46, 95% CI = 0.22– 0.97.

Explanatory variables—A set of logistic regression models showed that the social network index and its constituent elements (marital status, close social ties, group membership, religious group affiliation) were not associated with the odds of physical activity (*N*s = 201, *p*s > .2)

when sociodemographic covariates were held constant. These indices of potential social control therefore do not qualify as mediators of the association between loneliness and physical activity probability.

Among the emotion regulation variables, hedonic regulation was associated with greater odds of having engaged in any activity, OR = 2.49, 95% CI = 1.40–4.43 (N = 214), net of sociodemographic covariates. A logistic model showed that hedonic regulation explained a significant portion of the association between loneliness and physical activity. With hedonic regulation in the equation, the coefficient for loneliness was reduced by 49% from $B = -0.43$ to $B = -0.22$, $SE = 0.25$, and was no longer statistically significant (OR = 0.81, 95% CI = 0.50 –1.31; $p > .3$), whereas the coefficient for hedonic regulation remained sizable and statistically significant, $B = 0.83$, $SE = 0.30$ (OR = 3.13, 95% CI = 1.38 –7.09). Simultaneous addition of self-rated health and the psychosocial covariates to the model with loneliness and hedonic regulation (N = 197) did not alter the mediational pattern of associations: only hedonic emotion regulation remained a significant predictor of physical activity probability, $B = 1.15$, $SE = 0.38$.

Physical activity frequency and duration—Exploratory analyses of activity frequency and duration in the subsample with valid data on these measures (Ns = 172 and 154, respectively) revealed a significant inverse association between loneliness and physical activity frequency ($B = -0.17$, $SE = 0.06$, $p < .01$) and duration ($B = -0.32$, $SE = 0.08$, $p < .05$), net of sociodemographic variables. A larger social network tended to be associated with greater activity duration ($B = 0.13$, $SE = 0.07$, $p < .09$), but was unrelated to activity frequency ($B = 0.07$, $SE = 0.05$, $p > .2$). The social network measures did not explain associations between loneliness and activity frequency or duration. Hedonic emotion regulation was associated with greater activity frequency ($B = 0.20$, $SE = 0.06$, $p < .01$), and showed a modest mediational effect in the association between loneliness and activity frequency ($B_{\text{loneliness}} = -0.12$, $SE = 0.06$, $p = .052$; $B_{\text{hedonic emotion regulation}} = 0.16$, $SE = 0.06$, $p < .05$). Hedonic emotion regulation was also associated with greater activity duration ($B = 0.32$, $SE = 0.08$, $p < .05$), but had only a small effect on the association between loneliness and activity duration ($B_{\text{loneliness}} = -0.24$, $SE = 0.08$, $p < .01$; $B_{\text{hedonic emotion regulation}} = 0.26$, $SE = 0.08$, $p < .01$).

Longitudinal Analyses

Before conducting longitudinal analyses, we examined the degree and sources of missing data on physical activity and loneliness in Years 2 or 3. Physical activity data (i.e., yes/no) were missing in Years 2 or 3 for 26 cases (i.e., 11.5% of subjects who had provided valid activity data in Year 1). Loneliness data were missing in Years 2 or 3 for 20 cases (i.e., 8.9% of subjects who had provided valid loneliness data in Year 1). Participants missing loneliness or physical activity data in Year 2 or Year 3 were significantly ($p < .05$) less educated and had lower income than those with data in Year 2 and/or Year 3. Missingness was not associated with initial loneliness, physical activity, age, gender, or ethnicity. Longitudinal analyses of activity frequency and duration were not conducted because of increasing prevalence of missing data across years in these already small subsamples.

Temporal stability of physical activity/inactivity—Among active individuals in Year 1 with valid physical activity data for Years 2 and 3 (N = 156), 86% remained active in Years 2 and 3. Of those who became inactive, 8% became inactive in Year 2, 39% of these remained inactive in Year 3, and an additional 6% became inactive in Year 3. Among inactive individuals in Year 1 with valid physical activity data for Years 2 and 3 (N = 19), 42% remained inactive in Years 2 and 3. Of those who became active, 53% became active in Year 2, 60% of these remained active in Year 3, and an additional 5% became active in Year 3.

Physical activity probability—Results of the multilevel logistic analysis of physical activity probability are summarized in Table 4. There was no evidence for between-subjects variability about the average slope, nor was there a correlation between intercepts and slopes. As a result, we report findings from the model in which only intercepts vary between subjects. Net of sociodemographic variables and Year 1 physical activity, Year 1 loneliness predicted a significantly lower likelihood of physical activity in subsequent years (OR = 0.61). Given that this is a nonlinear model, the OR of physical activity at 2 *SD*s above the mean loneliness value is 0.37 (i.e., 0.61 * 0.61).

Among the psychosocial covariates, perceived stress and depressive symptoms predicted lower odds of physical activity ($\text{logit}_{\text{perceived stress}} = -0.427$, $SE = 0.207$, $p < .05$; $\text{logit}_{\text{depressive symptoms}} = -0.501$, $SE = 0.206$, $p < .05$). In addition, self-rated health predicted an increased odds of physical activity net of sociodemographic variables, logit = 0.492, $SE = 0.283$, $p < .05$. However, when depressive symptoms, perceived stress, hostility, social support, and self-rated health were added to the model with loneliness, only loneliness retained a significant effect on physical activity odds, logit = −0.669, $SE = 0.330$, OR = 0.51, $p < .05$.

Explanatory variables—Year 1 measures of social control and hedonic emotion regulation were not associated with the odds of physical activity in subsequent years (*p*s > .05) and were therefore not examined further as mediators of the longitudinal association between loneliness and physical activity.

Physical activity transitions—Results of the multilevel logistic analysis for physical activity transitions from active to inactive are summarized in Table 5. Because there was no evidence for between-subjects variability about the average slope, we report findings from the model in which only intercepts vary between subjects. Sociodemographic variables were not associated with transitions from physical activity to nonactivity or vice versa. Net of sociodemographics, loneliness predicted an increased odds of transitioning from physical activity to physical inactivity (OR = 1.57). Loneliness was not associated with transitions from physical inactivity to activity (logit = −0.003, $SE = 0.360$, $p > .05$; $N = 37$).

None of the loneliness-related psychosocial variables were associated with transitions from activity to inactivity. Better self-rated health predicted lower odds of transitioning from activity to inactivity, logit = −0.870, $SE = 0.285$, $p < .05$. When added to the model with loneliness and related psychosocial variables, both loneliness and self-rated health were significant predictors of transitions from physical activity to inactivity, $\text{logit}_{\text{loneliness}} = 0.884$, $SE = 0.357$, $p < .05$, and $\text{logit}_{\text{self-rated health}} = -0.904$, $SE = 0.331$, $p < .05$.

Explanatory variables—Year 1 measures of social control and hedonic emotion regulation were not associated with physical activity transitions (*p*s > .05) and were therefore not examined further as mediators of loneliness-related transitions from physical activity to inactivity.

Alternative models—Multilevel latent growth models were tested to determine whether physical activity predicted subsequent loneliness or social isolation (i.e., the SNI). These pathways were not supported. Holding constant sociodemographics and Year 1 loneliness, Year 1 physical activity (yes/no) did not predict changes in loneliness, $B = -0.212$, $SE = 1.441$, $p > .05$, or changes in the SNI, $B = -0.047$, $SE = 0.140$, $p > .05$, over the subsequent 2 years.

Additional multilevel latent growth models tested whether self-rated health predicted subsequent loneliness or the SNI. These pathways were also not supported. Self-rated health in Year 1 did not predict changes in loneliness, $B = -0.04$, $SE = 0.54$, $p > .9$, or changes in the SNI, $B = 0.03$, $SE = 0.05$, $p > .5$, over the subsequent 2 years.

Sensitivity Analyses

A multiple imputation approach (Schafer, 1999) was used to simultaneously impute values for missing data on all covariates (but not the outcome variable) to test the sensitivity of our results to missing data in longitudinal analyses. In analyses of the probability of physical activity in subsequent years, results based on 10 of 500 generated data sets produced a "robust" effect of Year 1 loneliness (log odds= −.446, *SE* = .182) that was very similar to the estimate reported for the observed data in Table 4 (log odds = −.494, *SE* = .198).

In addition, the imputed data sets were used to generate a series of "worst case" and "best case" scenarios in which missing physical activity data in Year 2 or Year 3 were treated as not physically active or physically active, respectively (*N*s = 226). When we assumed that all cases with missing physical activity data in Year 2 and/or Year 3 were not physically active in the corresponding year, the loneliness effect was reduced, but maintained a tendency to predict physical inactivity (log odds= −.24, *SE* = 0.13, $p < .08$). When we assumed that all cases with missing physical activity data in Year 2 and 3 were physically active in the corresponding year, the loneliness effect was also slightly reduced, but retained statistical significance (log odds = −.38, *SE* = 0.18, $p < .04$).

Discussion

Data from this population-based study of middle-age adults in the CHASRS show that feelings of loneliness are associated with a lower probability of engaging in physical activity. These associations were observed in cross-sectional and longitudinal analyses, the latter providing evidence consistent with a causal role for trait loneliness in reducing the likelihood of engaging in any physical activity. First, initial levels of loneliness predicted reduced probability of physical activity over the subsequent 2-year period. Second, an examination of changes in physical activity from year to year over a 3-year period showed that loneliness predicted transitions from physical activity to inactivity over the subsequent year. These results were obtained using a dichotomized outcome variable to reduce missing data and recall bias, yet despite the somewhat reduced power to detect effects, we still found significant effects. Moreover, exploratory analyses based on the subset of subjects who reported physical activity frequency and duration produced similar loneliness effects as those described for the dichotomous activity variable.

Sensitivity analyses in which missing data on covariates were imputed revealed only slightly attenuated results relative to those obtained with observed data, indicating that the reported effects of loneliness were unlikely to have been a consequence of missing data related to the outcome. When missing data on the physical activity outcome were conservatively imputed as active, or as inactive, loneliness effects were diminished but retained an inverse association with physical activity. Replication of these findings in an independent sample would lend additional confidence in the reliability of these effects.

We posited that self-regulation could explain the influence of loneliness on the probability of physical activity. Loneliness was associated with poor self-regulation of emotion, and in particular, with diminished hedonic emotion regulation. This finding extends prior research that has shown loneliness-related impairments in self-regulation of attentional processes (Cacioppo et al., 2000), and is consistent with research showing that the threat of social exclusion/isolation impairs self-regulation of hedonic processes such as eating (Baumeister et al., 2005). In the present study, lonely middle-age adults reported themselves to be less likely than non-lonely individuals to express, enjoy, and enhance positive feelings, or to use pleasant thoughts and memories to alleviate a bad mood. These characteristics of diminished hedonic emotion regulation were associated not only with loneliness, but also with a lower likelihood of physical activity. Moreover, hedonic emotion regulation mediated the cross-sectional

association between loneliness and physical activity. These data are the first to show that diminished hedonic emotion regulation processes contribute to the link between loneliness and a lower probability of physical activity, at least cross-sectionally.

Loneliness also exhibited significant inverse associations with activity frequency and duration. These were exploratory analyses because of missing data but results were in accord with findings from our other analyses. Additional research is needed to replicate these effects and identify explanatory mechanisms: explanations for lower probability of activity in lonely individuals may differ from those that explain lower activity frequency and duration.

We also posited that social control exerted by social network members could explain the association between loneliness and physical activity probability. Social network size exhibited a graded inverse association with loneliness, thereby satisfying a prerequisite condition for a mediational role. Components of the social network (i.e., close ties, group membership) showed corresponding patterns of association. Moreover, and replicating prior literature (e.g., Berkman & Syme, 1979; Kaplan et al., 1991), social network size and group membership were positively correlated with the probability of physical activity. However, neither social network size nor group membership showed an association with physical activity when sociodemographic variables were held constant. Thus, social network size and group membership were not viable mediators of the association between loneliness and the probability of engaging in any physical activity.

Based on cross-sectional studies alone, one could argue that lack of physical activity reduces opportunities to establish and maintain social ties. Present longitudinal data do not support this argument, however. Physical activity did not predict subsequent social network size or feelings of loneliness. In addition, although health status contributed to the likelihood of becoming inactive across years, the progression of lonely individuals into the physically inactive category was independent of health status. Prior research indicates that aging and the development of chronic health conditions, as well as the exacerbation of previously existing conditions lead to greater feelings of loneliness (Pinquart & Sörensen, 2003). In our CHASRS sample of middle-age adults, however, health status did not predict subsequent loneliness or a shrinking social network size across a period of 3 years. To the extent loneliness and health operate independently to influence physical activity likelihood, lonely individuals are at risk for accelerated loss of physical functioning and health with age (Hawkley & Cacioppo, 2007).

Given the importance of physical activity to the maintenance of health and fitness, and assuming that lonely and nonlonely individuals are equally cognizant of the health risks associated with sedentary living, transitions to inactivity may represent poor self-regulation and/or inadequate social control among lonely individuals. Although the 2-year longitudinal analyses provided evidence for a prospective association between loneliness and physical activity, no support was found for either social control or hedonic emotion regulation as the mediator. Specifically, neither hedonic emotion regulation nor social network ties predicted subsequent physical activity or transitions from activity to inactivity. In contrast, the Alameda County Study showed that social isolation, the lack of a group membership, and not being married predicted declines in physical activity level over a 9-year period (Kaplan et al., 1991). The differences between that study and ours include their large sample size ($N > 4{,}000$), a longer longitudinal study period, the prediction of activity level versus presence/absence, and perhaps more importantly, changes in awareness and attitudes toward physical activity during the 40 years since the Alameda County residents were interviewed for the Kaplan et al. study (1965 and 1974). In the 1960s and 1970s, physical activity in adulthood was an unavoidable part of life only for those who had a physically demanding job (e.g., farming), and a chosen social activity (i.e., group or team) only for the few who had the time and skills to enjoy sports. Not surprisingly, in an increasingly urban society, physical activity experienced a decline. Not

until 1972, and the establishment of the Presidential Fitness award, were Americans of all ages encouraged “to participate regularly in fitness/sports activity” (The President’s Council on Physical Fitness & Sports, 2007). These societal changes have moved physical activity outside the routine experiences of daily life and have made self-discipline essential for the achievement of personal fitness.

If self-discipline is the primary determinant of engaging in physical activity, then other types of self-regulation than hedonic emotion regulation may be important in predicting physical activity over the long-term. For instance, in a church-based cross-sectional study of health-promoting activities, physical activity was strongly associated with self-regulation in the form of behavioral strategies such as setting aside time for activity, walking instead of driving, and scheduling physical activity plans (Anderson, Wojcik, Winett, & Williams, 2000). To the extent emotion regulation supersedes and effectively regulates the success of other regulatory processes (Tice & Bratslavsky, 2000), behavioral regulation may be a more proximal prospective predictor of physical activity than hedonic emotion regulation. Additional research is needed to explore this possibility. Lonely individuals may struggle to regulate their behaviors much as they struggle to regulate attention and emotion, however, and knowing that behavioral regulation enhances success in initiating and/or maintaining a physically active lifestyle does not guarantee that lonely individuals will derive success in this domain. Additional research is needed to explore specific strategies that may be effective in supporting lonely individuals’ desires to increase physical fitness (e.g., group vs. solitary activities).

An alternative possibility is raised by a recent study showing that reductions in physical activity diminish self-regulatory capacity. Oaten and Cheng (2006) found that a 2-month program of regular physical exercise improved performance on a visual tracking task following a thought-suppression task, and this enhancement of self-regulatory capacity was not evident in the control group. Given the lower rate of physical activity in lonely adults, self-regulatory capacity may also be on the decline in this group. Ancillary analyses of our data did not indicate an effect of physical activity on subsequent hedonic emotion regulation, but to the extent behavioral self-regulatory processes are affected by physical activity, lonely individuals may be spiraling downward into an ever-diminishing ability to engage self-regulatory and exercise behaviors.

Does physical inactivity help to explain poorer health and a more rapid loss of physiological resilience among lonely individuals? That is a question for future research as we continue to follow the CHASRS sample over time. Interestingly, related research has shown that physical activity and social interactions have independent effects on health and functional decline (Berkman & Breslow, 1983; Unger, Johnson, & Marks, 1997). If loneliness has an additive effect beyond that associated with the known health-compromising effects of sedentary living, then the rising rate of social isolation in the U.S. (McPherson, Smith-Lovin, & Brashears, 2006) adds to the urgency of motivating physical activity in an increasingly sedentary society.

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Table 1

Means (SDs) or Percentages for Participant Characteristics at Baseline

Measure	*N*	Mean (*SD*)/Percentage
Physical activity: any in past 2 weeks	226	88.9%
Physical activity frequency: occasions in past 2 weeks	172	15.3 (14.2)
Physical activity duration: min/day in past 2 weeks	154	31.7 (28.7)
UCLA loneliness	225	36.0 (9.8)
Social network index	205	2.8 (1.2)
Married or cohabiting with partner	229	61.6%
Number of close friends	217	7.9 (5.0)
Number of close relatives	215	6.4 (5.0)
Group member	229	73.4%
Religious group affiliation	229	33.2%
ERI: Hedonic emotion regulation	217	3.7 (0.7)
ERI: Distress-augmenting emotion regulation	218	2.7 (0.7)
ERI: Emotion moderation	202	3.4 (0.8)

Table 2

Correlations (N) Among Predictor Variables and Physical Activity

	1	2	3	4	5	6	7	8	9	10
1. Loneliness	1.00 (223)									
2. Social network index	−.42** (203)	1.00 (205)								
3. Married/partnered	−.10 (225)	.22** (205)	1.00 (229)							
4. Friends & relatives index	−.47** (203)	0.73** (205)	−.08 (205)	1.00 (205)						
5. Member of a group	−.25** (225)	.53** (205)	.02 (229)	.20** (205)	1.00 (229)					
6. Religious group affiliation	−.13† (225)	.59** (205)	.15* (226)	.23** (205)	.23** (229)	1.00 (229)				
7. Hedonic regulation	−.28** (216)	.17* (197)	−.09 (217)	.25** (197)	.07 (217)	.00 (217)	1.00 (217)			
8. Distress-augmenting regulation	.11 (216)	−.08* (197)	−.07 (218)	.07 (197)	−.17* (218)	−.15* (218)	.41** (216)	1.00 (218)		
9. Emotion moderation	.02 (201)	−.09 (185)	−.11 (202)	−.01 (185)	−.10 (202)	−.04 (225)	.55** (202)	.23** (202)	1.00 (202)	
10. Any physical activity in past 2 weeks	−.16* (223)	.12 (202)	.04 (226)	.07 (202)	.18* (226)	.04 (226)	.22** (215)	.08 (216)	.02 (200)	1.00 (226)
11. Physical activity frequency (LN transform)	−.20* (172)	.09 (155)	−.06 (172)	.11 (155)	.16* (172)	.08 (172)	.22* (171)	.17* (172)	.01 (164)	1.00 (172)
12. Physical activity duration (LN transform)	−.27* (154)	.13 (141)	−.02 (154)	.16 (141)	.11 (154)	.06 (154)	.23* (149)	.07 (149)	.01 (141)	1.00 (154)

* $p < .05$.

** $p < .01$.

† $p < .06$.

Table 3

Coefficients and Standard Errors From Regression of Cross-Sectional Physical Activity Probability on Loneliness and Covariates in a Logistic Regression Model (N = 214)

	B (*SE*)	OR (95% CI)
Female	−0.55 (0.50)	0.58 (0.22–1.53)
Black[a]	0.07 (0.61)	1.07 (0.33–3.51)
Hispanic[a]	0.56 (0.68)	1.75 (0.47–6.58)
Age in years, mean-centered	0.07 (0.06)	1.07 (0.96–1.19)
Years education	0.24 (0.09)**	1.27 (1.08–1.50)
Household income, natural log	0.58 (0.25)**	1.78 (1.10–2.88)
Loneliness[b]	−0.43 (0.22)*[c]	0.65 (0.42–1.01)
Constant	−6.84 (2.84)	

[a] Reference category is White.

[b] Standardized to a mean of 0 and a *SD* of 1.

[c] $p < .05$, one-tailed.

* $p < .05$.

** $p < .01$.

Table 4

Coefficients and Standard Errors From Regression of Prospective Physical Activity Probability on Loneliness and Covariates in a Multilevel Logistic Model (N = 189)

	Log odds (*SE*)	OR
Any physical activity Year 1	2.014 (0.517)*	7.49
Loneliness Year 1[b]	−0.494 (0.198)*	.61
Year of study	−0.168 (0.341)	.85
Female	−0.608 (0.424)	.54
Black[a]	−0.024 (0.480)	.98
Hispanic[a]	0.334 (0.542)	1.40
Age in years, mean-centered	0.005 (0.048)	1.01
Years education	0.138 (0.075)	1.15
Household income, natural log	0.028 (0.244)	1.03
Constant	−0.600 (2.918)	.55
Variance components		
Constant	1.500 (0.681)	

[a] Reference category is White.

[b] Standardized to a mean of 0 and a *SD* of 1.

* $p < .05$.

Table 5

Coefficients and Standard Errors From Regression of Physical Activity Transitions (Active to Inactive) on Loneliness and Covariates in a Multilevel Logistic Model (N = 182)

	Log odds (*SE*)	OR
Loneliness Year 1[b]	0.457 (0.207)*	1.58
Year of study	−0.069 (0.395)	.93
Female	0.196 (0.432)	1.22
Black[a]	0.252 (0.513)	1.29
Hispanic[a]	−0.265 (0.587)	.77
Age, mean-centered	0.012 (0.051)	1.01
Years education	−0.131 (0.074)	.87
Household income, natural log	−0.180 (0.263)	.84
Constant	1.166 (3.168)	3.21
Variance components		
Constant	0.764 (0.746)	

[a] Reference category is White.

[b] Standardized to a mean of 0 and a *SD* of 1.

* $p < .05$.