The Reciprocal Relationship between Physical Activity and Depression in Older European Adults: A Prospective Cross-Lagged Panel Design Using SHARE Data.

Magnus Lindwall
University of Gothenburg, Gothenburg, Sweden
Pernilla Larsmann
University of Gothenburg, Gothenburg, Sweden
Martin S. Hagger
Curtin University, Perth, Western Australia

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Correspondence concerning this article should be addressed to: Magnus Lindwall, Department of Psychology, University of Gothenburg, P.O. Box 500, SE- 405 30 Gothenburg, Sweden, email: Magnus.Lindwall@psy.gu.se

Abstract

Objective: The aim of this prospective study was to investigate the reciprocal nature of the physical activity-depressive symptoms relationship in 17 593 older adults from 11 European countries older adults (*M* age = 64.07, SD = 9.58) across two-year follow-up. Also, gender and age was examined as potential moderators of this relation. Methods: A two-wave cross-lagged panel design and latent change score models with structural equation modelling was used to analyse data. Depressive symptoms were measured at baseline (T1) and follow-up (T2) using the EURO-D scale, capturing the two factors of affective suffering and motivation. Physical activity was measured at T1 and T2 as frequency of moderate physical activity and vigorous physical activity. Results: Cross-sectional latent variable analyses revealed that higher levels of physical activity at T1 and T2 were associated with lower levels of affective suffering and motivation at T1 and T2. Physical activity at T1 was significantly associated with affective suffering and motivation at T2. The relations of depressive symptoms at T1 with physical activity at T2 were not significant. However, a cross-lagged model showed best model fit, supporting a reciprocal prospective relationship between physical activity and depressive symptoms in older adults. Latent change in depressive symptoms factors was related to latent change in physical activity indicating complex and dynamic associations across time. Conclusions: Regular physical activity may be a valuable tool in the prevention of future depressive symptoms in older adults and depressive symptoms may also prevent older adults from engaging in regular physical activity.

Keywords: depression; physical activity; cross-lagged design; prospective studies; gender

The Reciprocal Relationship between Physical Activity and Depression in Older European Adults: A Prospective Cross-Lagged Panel Design Using SHARE Data

Depressive disorders are associated with major suffering, high morbidity and mortality and psychosocial functional impairment, thereby being a significant public health issue (Cassano & Fava, 2002). Depression in older adults is an important public health problem as well as it is related to an increased risk of morbidity and suicide (Chapman & Perry, 2008) and decreased physical, social, and cognitive functioning (Blazer, 2003). In behavioural models of onset and maintenance of depression in late life (Fiske, Wetherell, & Gatz, 2009) it has been suggested that factors such as stressful life events and changes in health, physical ability and cognitive ability may lead activity limitations and thereby a lower rate of positive outcomes, increasing risk of depression.

Physical activity has well- documented associations with health, physical and cognitive ability and positive outcomes in older adults (Chodzko-Zajko et al., 2009; Taylor et al., 2004). In the context of understanding depression onset and maintenance in later life, the relation between physical activity and depression across time, and the relation between change in these two variables, should be of high relevance to older adults.

Several cross-sectional studies have demonstrated that higher levels of physical activity are generally related to lower levels of depression (Kritz-Silverstein, Barrett-Connor, & Corbeau, 2001; Lindwall, Rennemark, Halling, Berglund, & Hassmen, 2007; Stephens, 1988). A number of longitudinal studies have also found that regular physical activity at baseline is related to lower risk for subsequent depression in elderly (Camacho, Roberts, Lazarus, Kaplan, & Cohen, 1991; Lampinen, Heikkinen, & Ruoppila, 2000; Strawbridge, Deleger, Roberts, & Kaplan, 2002). However, other studies have found that physical activity does not protect depression longitudinally, although a cross-sectional effect was identified (Kritz-Silverstein et al., 2001; Weyerer, 1992).

Apart from physical activity being associated with lower risk of future depression, other studies (Kaplan, Newsom, McFarland, & Lu, 2001; Patten, Williams, Lavorato, & Eliasziw, 2009; Roshanaei-Moghaddam, Katon, & Russo, 2009; Rosqvist et al., 2009; van Gool et al., 2003) have found a longitudinal effect of depression on physical activity participation at follow-up in older adults. For example, Van Gool and colleagues reported that the development of depression was related to increased risk of becoming sedentary and was also related to a decrease in minutes of physical activity in community-dwelling individuals. A recent review of the literature demonstrated that eight of eleven included longitudinal studies found that depression at baseline was significantly associated with subsequent decline in physical activity (Roshanaei-Moghaddam et al., 2009). In addition to this, studies published after the review found that major depressive episodes were associated with an increased risk of moving from an active to an inactive pattern of activity (Patten et al., 2009).

As evidenced by previous research there is support both for a physical activity-to-depression model, positing that inactivity at baseline is associated with greater risk for later depression (Camacho et al., 1991; Lampinen et al., 2000; Strawbridge et al., 2002), as well as for a depression-to-physical activity model where depression at baseline being related to an increased risk for a later sedentary lifestyle (Patten et al., 2009; Roshanaei-Moghaddam et al., 2009). Put together, previous work support the potential reciprocal nature of the physical activity-depression relationship. Viewing this relation as reciprocal highlights both the relation of physical activity with psychological health as well as the role of psychological health status as a motivating factor, or barrier, for a future physically active life. As such, examining the reciprocal nature of the physical activity-depression longitudinally is important from a basic research point of view as well as from an applied perspective. A highly relevant question is whether one direction, or model, is more evident than the other or if data show equal support for both directions, resulting in a reciprocal association model. Although the issue of a reciprocal relationship has been highlighted in the discussion of the results in several papers (Farmer et al., 1988; Kritz-Silverstein et al., 2001), few previous studies have examined it in the same sample. Hence, the issue of the reciprocal nature of the physical activity-depression relationship has been discussed rather than properly examined in previous work. Only two exceptions to this trend exist, to our knowledge. The first is a Japanese study that examined the reciprocal nature of walking and depression across two years in elderly using a cross-lagged panel design (Fukukawa et al., 2004). They found daily walking (using pedometers) at baseline to predict depressive symptoms at follow up two years later in a sample of 1,151 community dwelling older adults between the ages 65 and 79. Although the model with walking predicting depression better fit the data compared to the model with depression predicting walking, both models fit the data adequately. The second study is a 30-month follow-up study on the relation between walking and depression in 217 older Hispanic adults (Perrino, Mason, Brown, & Szapocznik, 2010). Walking was unrelated to subsequent depressive symptoms, but depressive symptoms were related to subsequent walking behavior at every time-point, such that higher levels of depressive symptoms were predictive of less walking. Thus, one of the two studies found stronger support for the physical activity-to-depression model (Fukukawa et al., 2004) whereas the other (Perrino et al., 2010) instead showed more support for the depression-to-physical activity model.

A number of possible physiological as well as psychosocial pathways have been identified to explain why physical activity may act as a protective factor against future depression. These include effects on central monoamines/serotonin and regulation of hypothalamic-pituary-adrenal (HPA) axis, improved overall self-esteem, domain-specific self-evaluations linked to the body and self-efficacy, perceptions of mastery, competence and control over ones health and body (Biddle, 2000; Brosse, Sheets, Lett, & Blumenthal, 2002; Dishman et al., 2006; McAuley, Elavsky, Jerome, Konopack, & Marquez, 2005; Wipfli, Landers, Nagoshi, & Ringenbach, 2009). Studies have also found that enhanced feelings to cope with one's depression mediate the effect of exercise on depression (Craft, 2005). Moreover, physical activity may help in counteracting several of the factors contributing to the onset and maintenance of depression in later life (Fiske et al., 2009). These factors include a lack of behavioral activation and limitation of activities, low rate of positive outcome, deterioration in physical ability and health, and self-critical cognition (through enhance mastery and perceived competence). Conversely, several hypotheses have also been proposed to explain why depression may increase risk of physical inactivity (Roshanaei-Moghaddam et al., 2009). For example, some of the common symptoms of depression, such as lack of energy, decreased motivation, and disturbed eating and sleeping patterns, may increase risk of inactivity. Also, depression has been associated with several other maladaptive health behaviors (e.g., smoking, obesity, early development of chronic disease) and health behaviors tend to cluster together in populations. Also, it is also possible that both depression and inactivity may be related to a third mediating factor, such as inflammatory markers.

Gender and age have been identified as potential moderating factors in the relation between depression and physical activity. Robust gender differences in depression and physical activity patterns among older adults have been found (Kaplan et al., 2001; Lindwall et al., 2007; Piccinelli & Wilkinson, 2000; Prince et al., 1999a), with women demonstrating higher incidence of depression and depressive symptoms and less physical activity than men. Therefore it has been suggested that the relation between physical exercise and mental health should be analyzed separately for men and women as different patterns may be evident (Hirvensalo, Lampinen, & Rantanen, 1998; Lindwall et al., 2007). Some cross-sectional studies that have reported gender-specific relations have found that exercise was associated with less depression for both men and women (Camacho et al., 1991). However, others found that strenuous exercise was related to lower depression scores for men but not women, whereas the opposite was true for light intensity exercise.

From a life-span developmental perspective (Fiske et al., 2009; Kuh, 2007), risk and protective factors linked to depression may become more or less significant over the course of the lifespan age as they change in frequency or importance. Therefore, there may be differences in the relationship across time between physical activity and depression across age-groups of older adults. Supporting this notion, Fukukawa and colleagues found a significant association between daily walking measured at baseline and depressive symptoms measured two years later, but only among older adults (65-79 years old) and not middle aged adults (40-64 years old). Unfortunately, the majority of previous studies (Fukukawa et al., 2004; Kritz-Silverstein et al., 2001; Perrino et al., 2010; Roshanaei-Moghaddam et al., 2009; Strawbridge et al., 2002) on the prospective relationship between physical activity and depression have used gender and/or age as covariates instead of examining their potential moderating effect on the physical activity-depression relationship.

In the present study we explore the reciprocal nature of the physical activity-depression relationship across time in older adults and evaluate the moderating effects of gender and age for this relationship. To investigate mutual causation and interindividual change or covariance stability over time (Finkel, 1995), we used a two-wave cross-lagged panel design with a two year follow up. This design allows us to examine the hypothesized direction of the associations in the same model and simultaneously control for baseline values and covariates. However, cross-lagged models have limitations in terms of inferring cause and effect (Rogosa, 1980) and are not suitable to use when analysing more complex relations between change in different variables across time. Such analyses tend to inflate relations between level in one factor at an initial timepoint and level in another variable at another later timepoint.

Therefore we also used a latent change score model (LCSM; Ferrer & McArdle, 2010) to analyse correlations between change in latent factors of depressive symptoms and physical activity across time, as these models highlight assessment of change and may capture dynamic features of the relationships examine. As previous studies have demonstrated support both for a physical activity-to-depression model and depression-to-physical activity-model, we hypothesized that: (a) in cross-sectional analyses at both baseline (T1) and two-year follow up (T2), higher levels of physical activity would be associated with lower levels of depressive symptoms; (b) higher levels of physical activity at T1 would be prospectively related to lower levels of depressive symptoms at T2; and (c) the prospective association of depressive symptoms at T1 with physical activity at T2 would also be significant; (d) both the physical activity-to-depression model and depression-to-physical activity models will fit data better compared with the stability model, positing no cross-lagged associations (e) the cross-lagged model will make better fit with data compared with the physical activity-to-depression model, depression-to-physical activity model and stability model (f) there will be significant correlations between change (as defined by latent changes scores) between T1 and T2 in depressive symptoms factors and physical activity.

Method

Participants and Procedure

In the present study we used data from the first and second wave of the Survey of Health, Aging and Retirement in Europe study (SHARE). SHARE is a multidisciplinary and cross-national panel database of data on a wide range of variables spanning from health behavior and psychological health to socio-economic status and social and family networks. The sample in SHARE represents a non-institutionalized population. The first wave (T1), collected in 2004, included individuals aged 50 and over from eleven European countries. The second wave data (T2) was collected in 2006-2007. The SHARE study has been more fully described elsewhere (Börsch-Supan, 2005; Börsch-Supan et al., 2008). From 26 788 participants who responded to the first wave, 17 593 (65.6%) who responded also to the second wave were included in the analyses in the present study. Preliminary analyses suggest that no certain groups of individuals were overrepresented among non-responders at T2 (Börsch-Supan et al., 2008). The sample (see Table 1) included 7994 men (45.4%) and 9599 women (54.6%). The participants were between the ages of 50 and 102 years (*M* age = 64.07, SD = 9.58).

Measures

Depression. The EURO-D scale was originally developed to be able to compare depressive symptoms across European countries (Prince et al., 1999b). It consists of 12 binary items (no/yes) scored 0 to 1, where higher values indicate depressive symptoms. Early studies found support for a two-factor structure (Prince et al., 1999a; Prince et al., 1999b). The *affective suffering* factor comprises the *depression*, *tearfulness*, *suicidality*, *sleep*, *guilt*, *irritability*, and *fatigue* items from the scale and motivation factor includes the *interest*, *enjoyment*, *concentration*, *pessimism*, and *appetite* items. Later studies on the SHARE samples, however, demonstrate that there is evidence to support both the unidimensional and two-dimensional factor structures for the EURO-D scale (Castro-Costa et al., 2008). In the present study we adopted the two-factor structure. The psychometric properties of the EURO-D scale have been thoroughly examined and it has demonstrated criterion validity in the cross-cultural context as well as internal robustness (Castro-Costa et al., 2007; Prince et al., 1999a).

Physical activity. Physical activity was measured as “frequency of moderate physical activity” (such as gardening, cleaning the car, doing a walk) and “frequency of vigorous physical activity” (sports, heavy housework, a job involving physical labour). The response alternatives both for moderate and vigorous activity were: 1 = more than once a week; 2 =once a week; 3 up to three times a month; 4 = hardly ever or never. Higher values thus represent less activity.

Covariates. Education, marital status, and number of chronic diseases measured at baseline were used as covariates. Age was used as a continuous covariate. Education was categorized according to the International Standard Classification of Education Degrees (ISCED 1997) and divided into four levels: 1 = ISCED code 0 (no education); 2 = ISCED codes 1 and 2 (low education); 3 = ISCED codes 3 and 4 (mid-education); 4 = ISCED codes 5 and 6 (high education). Marital status was classified into: married (including in a registered partnership) or not married (including widowed, divorced, separated, or never married). Number of chronic diseases was derived from participants' answers to questions about the presence of the following conditions: heart attack or other heart problems; stroke or cerebral vascular disease; diabetes; chronic lung disease; asthma, arthritis or rheumatism; osteoporosis; cancer or malignant tumour; stomach, duodenal, or peptic ulcer; Parkinson disease; cataract; hip or femoral fracture; and other conditions. The total number of chronic diseases was summed to produce a single score.

Statistical Analysis

A two-wave cross-lagged design and structural equation modeling was used to analyze data. Before testing the cross-lagged structural model, confirmatory factor analyses (CFAs) were performed in order to test for factorial invariance across measurement waves. For the purpose of investigating factorial invariance of the latent variables across waves in the present study (Affective Suffering, Motivation, and Physical Activity), a hierarchy of increasingly stringent tests of factorial invariance (Meredith, 1993) was employed. The invariance routine started with testing a baseline model only requiring the number and pattern of factors to be equal across waves (configural invariance). This baseline model was subsequently compared to progressively more constrained models including equality of factor loadings (weak factorial invariance), manifest variable intercepts (strong factorial invariance), and manifest variable error terms (strict factorial invariance). In accordance with previous research (Cheung & Rensvold, 2002) a decrease in CFI of more than .01 was considered representative of a decrease in model fit to the extent that the additional constraints imposed on the model (compared to the previous model) could not be justified. In order to set the scale of the latent variables one factor loading per latent variable was set to unity.

Thereafter the proposed cross-lagged model with was tested. This model is presented in Figure 1. As in the invariance testing the scales of the latent variables were set by constraining one factor loading within each latent variable to unity. For all analyses the full information maximum likelihood estimation (FIML) method was employed. Considering the large sample in the present study, and the (over-) sensitivity of the χ^2 measure to sample size, model fit was primarily assessed based on the comparative fit index (CFI), and the root mean square error of approximation (RMSEA).

For gender and age invariance analyses a multiple-group approach was employed, with a similar strategy as for the invariance analyses across waves. Thus, a baseline model without constraints was compared with more constrained models.

In order to test our fourth and fifth hypotheses, a number of nested models were compared to the proposed model of cross-lagged mutual causality. In our fourth hypothesis we proposed a reciprocal effects model, positing cross-lagged effects and autoregressive paths would better fit the data than the stability model, including only autoregressive paths. In our fifth hypothesis we proposed that the physical activity-to-depression model and depression-to-physical activity model would better fit the data compared to the stability model but worse than the reciprocal effecgs model. In our sixth hypothesis, we proposed that latent change scores of depression factors would be significantly correlated with the latent change score of physical activity. In order to test this hypothesis, we reconfigurated the cross-lagged models into a LCSM (J. J. McArdle & Nesselroade, 1994) to be able to examine correlations between physical activity latent change score (PALC) and affective suffering latent change score (AFLC) and motivation latent change score (MOLC).

Results

Descriptive Data

Descriptive data for the variables used in the study in wave 1 and 2 are provided in Table 1. The level of physical activity declined both for vigorous and moderate activities between T1 and T2. Fewer individuals reported moderate or vigorous activity more than once a week at T2 compared with T1 and more individuals reported that they hardly ever or never engage in physical activity at T2 compared with T1 ($p < .001$).

In terms of missing cases, 2738 (15.5%) and 791 (4,5%) of participants had missing values on at least one of the affective suffering and motivation items respectively at T2. Similarly, 130 and 132 individuals did not report physical activity with moderate intensity and vigorous intensity respectively at T2. Participants with missing value on at least one item for Affective Suffering and Motivation factors at T2 had more depressive symptoms and were less physically active at T1. Similarly, participants who did not report physical activity at T2 reported more depressive symptoms and less physically active at T1. (p*s*<.001)

Invariance Testing

Tests of factorial invariance over measurement occasions demonstrated weak factorial invariance for the measurement model. Similarly, the factorial invariance tests across age and gender indicate weak factorial invariance. This means that factor loadings did not differ across time or between men and women or between age-groups while intercepts and error term variances were significantly variant.

The Cross-Lagged Model

The measurement components of the proposed final cross-lagged model were constrained in accordance with weak factorial invariance. The cross-lagged model exhibited acceptable model fit (χ^2 = 6118.01, df = 407, CFI = .93, RMSEA = .028; 90% CI of RMSEA = .030; .029). Selected parameter estimates are presented in Table 2.

[Please insert Table 2 about here]

In line with our first hypothesis, higher levels of physical activity at T1 were associated with lower levels of affective suffering (ϕ = .19, p <.001) and motivation (ϕ = .43, p < .001) at T1 (see Table 5). Similarly, higher levels of physical activity at T2 were associated with lower levels of affective suffering (ϕ = .24, p <.001) and motivation (ϕ = .39, p <.001) at T2. As lower values in physical activity represent more activity, the standardized estimates between higher levels of activity and lower levels of depression are positive.

All of the autoregressive regression weights were positive, strong (β = 0.57 -0.79) and significant. Supporting our second hypothesis, a higher level of physical activity at T1 was related to lower depression at T2 for affective suffering (β = 0.13, p < .001) and motivation (β = 0.20, p < .001). Contrary to our third hypothesis, affective suffering (β = 0.03, p > .05) and motivation (β = 0.03, p > .05) at T1 was not significantly related to physical activity at T2.

Invariance Testing of Cross-Lagged Estimates

The four cross-lagged estimates of largest interest, linking physical activity at T1 to depression factors at T2 and vice versa, were not invariant across age ($\Delta\ \chi^2$=106.37/ 8 df). More specifically, there were significant differences in the relations between affective suffering T1 and physical activity T2 ($\Delta\ \chi^2$=35.59/ 2 df) and between motivation T1- Physical Activity T2 ($\Delta\ \chi^2$=74.13/ 2 df) across age-groups. For example, in the youngest age-group, a higher score on Motivation at T1 (more depression) was significantly related to a higher score on physical activity at T2 (less activity), whereas these relation were negative and not significant in the two older age-groups. Moreover, there were also significant differences across age-groups in the relation between physical activity at T1 and motivation at T2 ($\Delta \chi^2$=23.18/ 2 df), with the relation being stronger in the two older groups compared with the youngest group. The relation between physical activity at T1 and affective suffering at T2, however, did not differ significantly across age groups.

For gender there was a non-significant trend (p = .096) in the decline of the model (χ^2=7.87/ 4 df) constraining the four cross-lagged estimates to be equal. However, only the relation between motivation at T1 and physical activity T2, being positive and significant for men but not for women, was significantly different (χ^2=5.41/ 1 df) between men and women.

Comparing Models

In order to test our fourth and fifth hypotheses a number of nested models were compared to the proposed model of cross-lagged mutual causality. The results of these model comparisons are reported in Table 3. Supporting our fourth hypothesis, both the physical activity-to-depression model and depression-to-physical activity model fit the data better than the stability model, including only autoregressive paths. Hypothesis five was also supported. The cross-lagged model showed better model fit than the stability model, depression-to-physical activity model, and physical activity-to-depression model, supporting a reciprocal relationship across time between depression and physical activity.

To test if the size of associations were larger in one direction (e.g., from Physical activity T1 to Motivation at T2) than the other (from Motivation at T1 to Physical activity at T2) we also imposed equality constraints on these regression weights and compared the fit of these models to models without constraints. We conducted separate analyses for the relation between physical activity and the Motivation and Affective Suffering factors. These constraints however did not lead to deterioration in model fit, indicating that the associations were not stronger in any direction.

[Please insert table 3 about here]

Correlations between Latent Change Scores

The correlations between latent changes in depression factors and physical activity, divided by gender and age-groups, are reported in Table 4. For the full sample, the correlation between PALC and MOCL and PALC and AFLC was .32 and .25 respectively. These associations are illustrated by the two graphs in Figure 2. We conducted a number of analyses where we compared baseline models without constraints with models where we imposed equality constraints on latent change correlations to investigate whether these correlations differed across gender and age-groups. Although both the PALC-MOLC and the PALC-AFLC correlations were stronger for men, these differences were not significant as constraining these correlations to be equal across men and women did not lead to a significant decline in model fit compared to the baseline models without constraints.

However, there was a significant decline in model fit ($\Delta\ \chi^2$=9.32/ 2 df) for the model in which the correlation between PALC and AFLC were constrained to be equal across age-groups. The correlation was stronger for the 66-78 years agegroup ($\Delta\ \chi^2$=8.13/ 1 df) compared to the 50-65 years age group. A non-significant trend indicated that the correlation was stronger in the oldest age group compared with the 50-65 years age group ($\Delta\ \chi^2$=2.81/ 1df; p = .094). The difference between the correlation in the oldest age group and the 66-78 years age group was however not significant. Similarly, there were significant differences in the PALC and MOLC correlation between age-groups ($\Delta\ \chi^2$=18.72/ 2 df). More specifically, this correlation was stronger in the oldest group compared to the 66-78 years age group ($\Delta\ \chi^2$=13.27/ 1 df) and the 50-65 years age group ($\Delta\ \chi^2$=33.96/ 1 df). Moreover, the PALC-MOLC correlation was stronger in the 66-78 years age group compared to the 50-65 years age group ($\Delta\ \chi^2$=12.08/ 1 df).

Discussion

In the present study we examined the reciprocal nature of the physical activity-depression relationship across a two-year period. We used a large representative sample of 17 593 older adults from 11 European countries included in the SHARE-study. Given both the sample size and heterogeneity of our sample in terms of culture, age and gender, the generalizability of our results should be viewed as strong. Moreover, we used an advanced cross-lagged panel design that allowed us to examine the reciprocal effects over time and simultaneously control for baseline values and factorial invariance as well as covariates in the same model. We also conducted the analyses using latent variables, thereby enabling us to control for measurement error. Finally, we also conducted latent change analyses, examining the relation of changes in the latent depression factors and changes in the latent physical activity factor. Our study, therefore, advances knowledge and understanding of the nature of the depression-physical activity relationship and improves upon the design of previous prospective studies (Camacho et al., 1991; Lampinen et al., 2000; Strawbridge et al., 2002) that tested unidirectional prospective relationships between these.

In support of our first hypothesis, higher physical activity was associated with lower depressive symptoms scores in cross-sectional analyses both for affective suffering and motivation at T1 and T2 when controlling for education, marital status, and chronic disease. These results provide additional support for the well-documented cross-sectional link between physical activity and depression (Kritz-Silverstein et al., 2001; Lindwall et al., 2007; Stephens, 1988).

We also found support for our second hypothesis. The cross-lagged analyses showed that a higher baseline physical activity was related to less depressive symptoms at two year follow-up. These results are in line with previous studies (Camacho et al., 1991; Lampinen et al., 2000; Strawbridge et al., 2002) and the notion of the protective role of regular physical activity against future depressive symptoms for older adults. Higher physical activity was related to less subsequent depressive symptoms, both in terms of affective suffering and motivation.

The association of depressive symptoms at T1 with future physical activity was not significant, contradicting our third hypothesis. Some of the previous studies finding an association between depression and physical activity have been cross-sectional (Kaplan et al., 2001; Rosqvist et al., 2009) and therefore cannot be directly compared with the prospective results of this study. Other prospective studies that demonstrated that emergent depression was related to an increased risk of becoming sedentary included not only older adults (Patten et al., 2009) and did not use latent analyses or control for baseline physical activity and depression in their analyses (Patten et al., 2009; van Gool et al., 2003). Therefore, differences between results of these previous studies and ours may depend on analytical and design aspects as well as characteristics in the measurement or sample.

The two-wave cross-lagged panel design and prospective data allowed us to examine the reciprocal nature of the physical activity-depression relationship across time; an important research question that has, to our knowledge, been investigated by only two previous studies (Fukukawa et al., 2004; Perrino et al., 2010). Our results are in line with those reported by Fukukawa and colleagues as we found significant associations of physical activity at T1 on depression at T2, for both affective suffering and motivation factors, whereas there was a lack of significant association of depression at T1 on physical activity at T2. The patterns of findings in both our study and the Fukukawa and colleagues study seem to indicate a stronger support for the relation of physical activity with subsequent depression than the relation of depression with future physical activity, at least for older adults. However, in our study, the cross-lagged model better fit the data compared with the physical activity-to-depression, depression-to-physical activity model, and autoregressive effects-only models. Also, the size of associations was not larger in one direction than the other. Therefore, despite the abovementioned results indicating stronger support for the physical activity-to-depression model, over the depression-to-physical activity model, the overall results yet clearly support a reciprocal model of the relationship between physical activity and depressive symptoms. Future studies should investigate this issue further.

In terms of interpreting the results as physical activity playing a protective role against future depression, we should acknowledge the fact that we did not test whether baseline physical activity was related to changes in depressive symptoms. However, we found moderately strong correlations between latent change in depression factors and the physical activity factor, indicating moderately strong couplings between change in depressive symptoms and physical activity over time in old age. Hence, not only are depressive symptoms and physical activity prospectively related across time, changes in these factors appear to be related, pointing to the notion of stronger and more dynamic associations than previously been documented in cross-sectional and prospective studies.

To move beyond first generation research questions (i.e., is there a relationship between physical activity and depressive symptoms over time?), we targeted age and gender as potential moderators in the relationship between physical activity and depressive symptoms. Although there were trends showing that the relation between depressive symptoms and physical activity over time was somewhat more evident in men, supporting previous cross-sectional studies (Lindwall et al., 2007), the overall differences between men and women were not significant. Also, most previous prospective studies that conducted gender-specific analyses of the relation between physical activity and depression did not find gender differences, (Camacho et al., 1991). However, given the documented gender differences in depression as well as physical activity patterns among older adults (Kaplan et al., 2001; Lindwall et al., 2007; Piccinelli & Wilkinson, 2000; Prince et al., 1999a), future studies should continue to examine gender as a potential moderating factor rather than controlling for it. We did however find significant age-differences, both in terms of cross-lagged associations and latent change correlations over time, in the relationship between physical activity and depressive symptoms. More depressive symptoms at T1, for the Motivation factor, was related to less physical activity at follow-up for the younger age-group only whereas higher physical activity at baseline was only significantly related to less depressive symptoms (also in terms of the Motivation factor) for the older age-groups over 65 years. The latter result is in line with the results of Fukukawa and colleagues (Fukukawa et al., 2004). Hence, the depression-to-physical activity was primarily supported in the youngest age-group whereas the physical activity-to-depression model received stronger support in the older age-groups. Moreover, the correlation between change in physical activity and change in depressive symptoms linked to the Motivation factor was significantly stronger in the older age groups. A preliminary conclusion may therefore be that the association of changes in physical activity behavior and depressive symptoms may be more important in older adults (> 65 years) compared with younger groups of middle-aged to old individuals (e.g., < 65 years).

The results of the study fit well with theoretical frameworks and models on the onset and maintenance of depression in older adults (Fiske et al., 2009). Less activity at baseline was related to higher load of depressive symptoms at follow-up, mirroring the theoretical premise that limitations in activities (in this context, physical activity) may lead to an increased risk for future depression. Also, from a dynamic change perspective our results also show that change in physical activity may be related to change in depressive symptoms, highlighting the complex and dynamic interplay across time of these two variables. From a developmental lifespan perspective, these dynamic couplings across time, and the finding that these correlations were stronger in the older age-groups provided preliminary support for the notion that protective behaviors (e.g., physical activity) and risk factors for chronic illness (e.g., depression) may change in importance across time and age (Fiske et al., 2009).

In general, the results again highlight regular physical activity as a valuable tool in the prevention of future depression in old age. Further, as concluded by randomized controlled trials (Blumenthal et al., 2007) and meta-analyses of RCTs (Mead et al., 2009), structured physical activity programs seem generally as effective as traditional treatments (medication or therapy), and more effective than placebo effects, when it comes to improving depressive symptoms in patients suffering from clinical depression. Hence, physical activity has an important role to play in the promotion of psychological health as well as in the prevention and treatment of mental illness (Fox, Boutcher, Faulkner, & Biddle, 2000). Moreover, age may moderate this effect, suggesting that regular physical activity may be most important for the oldest groups of elderly.

Although used by the majority of previous prospective studies, the use of self-report measures in regards to physical activity could be viewed as a limitation of our study. Also, the rather crude measures of physical activity used in SHARE, where the highest possible response alternative for the most active group was “more than once a week”, may have created a ceiling effect and failed to distinguish between relevant group of more active individuals. For example, individuals being active 4-5 times a week and individuals being active just once a week was rated as similarly active in the study, although the real difference in activity frequency between these individuals could have relevant impact on the relationship to depression. Future prospective studies on physical activity and depression that adopt cross-lagged designs should conduct gender-separate analyses and incorporate genetic information as well as measures of physical fitness and potential mechanisms.

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Table 1.

Descriptive Statistics at Baseline and Follow-up for the Full Sample (N =17593)

Variable	*Baseline* *M* (SD)	*Follow-up* *M* (SD)
Age	64.07 (9.58)	--
Education n(%)		
ISCED code 0	878 (5.0)	
ISCED codes 1 and 2	8114 (46.1)	
ISCED codes 3 and 4	5031 (28.6)	
ISCED codes 5 and 6	3450 (19.6)	
Marital status n(%)		
Not married	4694 (26.7)	
Married	12899 (73.3)	
Number of chronic diseases	1.51 (1.40)	
Affective suffering[a]	1.64 (1.63)	1.45 (1.57)
Motivation[a]	0.61 (0.92)	0.53 (0.90)
Moderate physical activity n(%)		
More than once a week	12731 (72.4)	12184 (69.8)
Once a week	2327 (13.2)	2377 (13.6)
One to three times a month	900 (5.1)	948 (5.4)
Hardly ever or never	1634 (9.3)	1954 (11.2)
Vigorous physical activity n(%)		
More than once a week	6420 (36.5)	5844 (33.5)
Once a week	2591 (14.7)	2516 (14.4)
One to three times a month	1763 (10.0)	1778 (10.2)
Hardly ever or never	6818 (38.8)	7323 (41.9)

[a]Values for affective suffering and motivation are based on manifest mean level factors (not latent variables).

Table 2

Selected Parameter Estimates for The Cross-Lagged Model (correlations and regression weights) and the Latent Change Score Model (fixed effects) (N = 17 593)

	Parameter estimate		*SE*	Critical ratio[a]
	US	S		
Fixed effects (Means and Variances)				
Physical activity latent change, Mean	0.16		0.01	14.16*
Physical activity latent change, Variance	0.24		0.01	19.54*
Motivation latent change, Mean	0.03		0.00	6.58*
Motivation latent change, Variance	0.01		0.00	21.69*
Affective suffering latent change, Mean	0.02		0.01	2.70*
Affective suffering latent change, Variance	0.03		0.00	32.39*
Correlations				
Affective suffering T1↔ Motivation T1	0.01	0.65	0.00	33.26*
Affective suffering T1↔ Physical activity T1	0.02	0.19	0.00	13.20*
Physical activity T1↔ Motivation T1	0.02	0.43	0.00	22.83*
Affective suffering T2↔ Motivation T2	0.01	0.68	0.00	29.63*
Affective suffering T2↔ Physical activity T2	0.01	0.24	0.00	10.87*
Physical activity T2↔ Motivation T2	0.01	0.39	0.00	14.41*
Regression weights				
Education → Affective suffering T1	-0.02	-0.09	0.00	-9.99*
Education → Motivation T1	-0.04	-0.25	0.00	-23.14*
Education → Physical activity T1	-0.13	-0.19	0.01	-18.47*
Married → Affective suffering T1	0.06	0.13	0.00	14.94*
Married → Motivation T1	0.04	0.14	0.00	14.18*
Married → Physical activity T1	0.19	0.15	0.01	15.00*
Chronic diseases → Affective suffering T1	0.05	0.31	0.00	32.96*
Chronic diseases → Motivation T1	0.02	0.25	0.00	22.69*
Chronic diseases → Physical activity T1	0.13	0.32	0.00	30.94*
Affective suffering T1→ Affective suffering T2	0.68	0.68	0.02	37.73*
Affective suffering T1→ Motivation T2	-0.01	-0.01	0.01	-0.59
Affective suffering T1→ Physical activity T2	0.08	0.03	0.06	1.26
Motivation T1→ Affective suffering T2	-0.12	-0.06	0.04	-2.77*
Motivation T1→ Motivation T2	0.60	0.57	0.03	19.62*
Motivation T1→ Physical activity T2	0.15	0.03	0.15	1.02
Physical activity T1→ Affective suffering T2	0.05	0.13	0.01	8.16*
Physical activity T1→ Motivation T2	0.04	0.20	0.00	10.41*
Physical activity T1→ Physical activity T2	0.91	0.79	0.02	37.77*

[a]Critical ratio (the ratio of the unstandardized parameter to its standard error). US = Unstandardized estimate; S = Standardized estimate.* $p < .001$

Table 3

Comparisons between Different Structural Models (N = 17 593)

Model	df	χ^2	RMSEA	CFI	AIC	Δmodel	$\Delta\chi^2$
Cross-lagged, mutual causality	407	6118.01	0.028	0.932	6358.01		
Physical activity - depression	409	6128.61	0.028	0.932	6364.61	2 vs 1	10.60*
						4 vs 2	132.18*
Depression - physical activity	409	6244.76	0.028	0.931	6480.76	3 vs 1	126.75*
						4 vs 3	16.03*
Structural null model, auto-regressions only[a]	411	6260.79	0.028	0.931	6492.79	4 vs 1	142.78*

[a] This model contains autoregressive paths, as well as paths from affective suffering T1 to motivation T2, and from motivation T1 to affective suffering T2.
*$p < .01$

Table 4

Correlations between Latent Change Scores in Physical Activity and Depression Factors (Motivation and Affective Suffering) across Gender and Age-Groups

Model	Full sample[a]	Women[b]	Men[c]	50 -65 Years[d]	66-78 Years[e]	79+ Years[f]
Physical activity latent change-Motivation latent change	.32*	.29*	.34*	.19*	.36*	.46*
Physical activity latent change-Affective suffering latent change	.25*	.22*	.26*	.18*	.29**	.24*

*p<.001; [a] n=17593; [b] n=9599; [c] n=7994; [d] n=10439; [e] n=5560; [f] n=1594

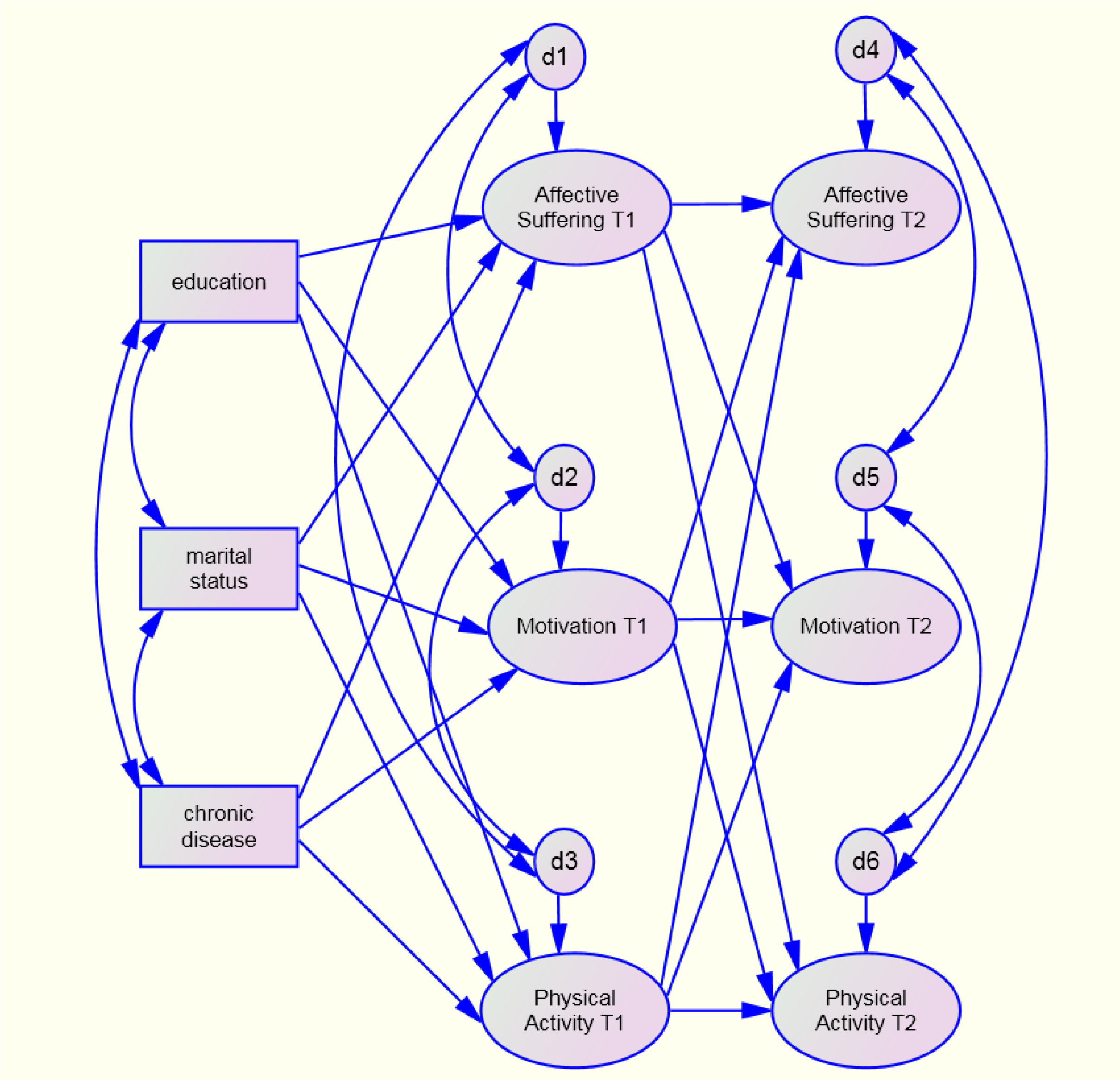

Figure 1. Specification of the tested cross-lagged structural model. The measurement models are not shown.

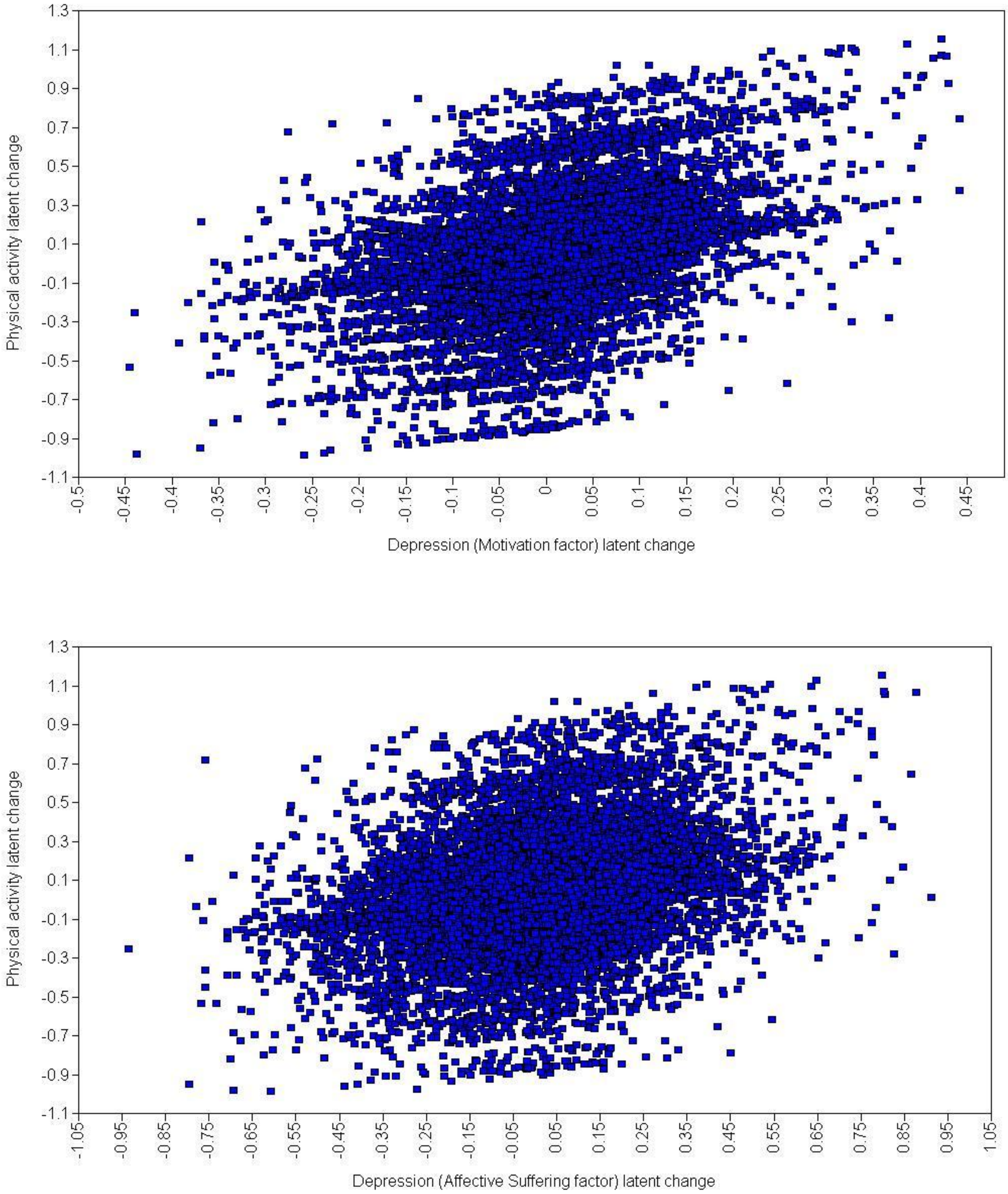

Figure 2. Associations between latent change in the depression factors (Motivation in upper graph, Affective Suffering in lower graph) and latent change in the physical activity factor.