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Age Differences in the Effect of Physical Activity on Depressive Symptoms

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This study examined associations between physical activity and depressive symptoms in 1,151 community-dwelling adults in Japan. Physical activity was measured using a pedometer, whereas depressive symptoms were assessed with the Center for Epidemiological Studies—Depression Scale. A structural equation modeling with a cross-lagged panel design revealed that for the older adults (65–79 years of age), daily walking at baseline predicted fewer depressive symptoms at the 2-year follow-up, even after adjusting for confounders. In contrast, the association was not confirmed for the middle-aged adults (40–64 years of age). Findings suggest that age should be considered when estimating the effect of physical activity on psychological well-being.

People aged 65 years or older constitute the fastest growing segment of many populations, especially in industrialized countries, and a significant percentage of the older population experiences psychological distress such as depression. In fact, with major depression affecting approximately 1% of older adults within a community, and another 8%–15% showing depressive symptoms (Blazer, 1994), promoting mental health is a top priority among professionals working with the aged.

The antidepressant effect of physical activity has been examined in recent years. Evidence indicates that the benefits of exercise are not restricted to experimental studies for moderately or clinically depressed persons (McNeil, LeBlanc, & Joyner, 1991; Singh, Clements, & Fiatarone, 1997) but extend to epidemiological studies of nonclinical community populations as well. Indeed, although cross-sectional analyses have consistently shown that active individuals report fewer depressive symptoms than those who are less active (Hassmen, Koivula, & Uutela, 2000; Herzog, Franks, Markus, & Holmberg, 1998; Ross & Hayes, 1988), longitudinal studies have also demonstrated that physical activity reduces subsequent depressive symptoms (Camacho, Roberts, Lazarus, Kaplan, & Cohen, 1991; Lampinen, Heikkinen, & Ruoppila, 2000). Camacho et al. (1991) found that regular physical exercise by individuals at baseline reduced their risk for depression at the 9-year follow-up, even after adjusting for confounding variables. Lampinen et al. (2000) reported that those who had reduced their intensity of physical exercise during the intervening 8 years were more depressed at the follow-up than those who had remained active or who had increased their physical activity.

Although previous findings are valuable, most of these studies have focused on younger or middle-aged Caucasian adults (Brosse, Sheets, Lett, & Blumenthal, 2002; Brown, 1992). Because it has been established that body size and composition differ by age and ethnicity and that the differences affect physical performance (Shephard, 2002), age should be considered when estimating the effects of physical activity on psychological well-being.

To our knowledge, two empirical studies directly addressed the question of whether the relationship between exercise and psychological well-being varies across age groups. Stephens (1988) conducted a secondary analysis of four surveys among household populations of the United States and Canada and found that the relationship between physical activity and mental health was stronger for persons 40 years and older than for those ranging in age from 20 to 39 years. Ruuskanen and Ruoppila (1995) found that intensive and regular physical exercise was significantly associated with a lower prevalence of depressive symptoms in two of the study's older age groups (65–69 and 70–75 years) but not in the oldest age groups (75–79 and 80–84 years). Although these findings suggest that there is an age difference in the effect that physical activity has on depressive symptoms, both studies have some methodological concerns: The analyses were cross-sectional, and physical activity was assessed by self-report measures.

Self-reporting is the most feasible approach to large population surveys for assessing physical activity, primarily because of its low cost, ease of administration, and potential for nonreactivity (Tudor-Locke, Williams, Reis, & Pluto, 2002). However, when using self-report measures, respondents and investigators must have a shared understanding of ambiguous terms such as *leisure, physical activity, moderate,* and *vigorous* (Sallis & Saelens, 2000). Furthermore, self-report measures can lead to information bias due to inaccurate recall or intentional misreporting, especially for older adults (Stone, 1995). In the present study, to avoid the issues for self-report measures, we used pedometers for a more objective

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monitoring of daily physical activity. Objective quantification of ambulatory activity via simple and inexpensive pedometers allows researchers and practitioners to easily assess activity levels along a continuum (Tudor-Locke, Bell, et al., 2002). In addition, because this portable monitoring device directly counts the number of steps walked, the data obtained are independent of a person's recall or misreporting and are substantially free of errors (Tsubono et al., 2002).

In the present study, we used longitudinal data from community-dwelling adults in Japan to expand on previous research regarding the relationship between physical activity and psychological well-being. More specifically, we addressed the question of whether physical activity affects depressive symptoms differently among middle-aged and older adults by incorporating the widely used Center for Epidemiological Studies—Depression Scale (CES–D; Radloff, 1977) and measuring individuals' regular walking activities.

Method

Participants

The data for the present study were collected as part of the National Institute for Longevity Sciences–Longitudinal Study of Aging (NILS-LSA). The population of the NILS-LSA was a sex- and age-stratified random sample of Japanese community-dwelling adults, who were between 40 and 79 years of age at baseline. We recruited the participants from the neighborhood of the Institute (Obu City and Higashiura Town), in cooperation with the local governments. Informed consent was obtained from each participant at the study entry. Details of the NILS-LSA have been described elsewhere (Shimokata, Ando, & Niino, 2000).

Because physical disability can preclude walking activity, 4 persons with any of six functional disabilities (bathing, dressing, toileting, transfer, continence, or feeding) were excluded from the analyses. The baseline assessment of Katz's Index of Activities of Daily Living (Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963) was used for the exclusion procedure. The study sample was then 1,151 men and women who had completed both the baseline (Wave 1: from 1997 to 2000) and the 2-year follow-up (Wave 2: from 2000 to 2002) surveys, with no missing data in the study variables. The average age for the entire sample was 57.4 years ($SD = 10.2$ years). For the analyses presented in this article, the sample was divided into two groups according to their age upon entering the study (middle-aged adults: 40–64 years old, $n = 837$; and older adults: 65–79 years old, $n = 314$).

Measures

Physical activity. Daily walking steps were counted by an electronic digital pedometer (Select II, Suzuken Co., Nagoya, Japan) at both Wave 1 and Wave 2. The reproducibility and validity of the tool were fully evaluated (Niimi, 1999). We supplied a pedometer to each participant on the examination day (the NILS-LSA requires participants to visit the Institute and spend 1 day for extensive examinations regarding medical, psychological, and other health-related domains). Participants were given instructions for wearing the device firmly at the belt line over 7 consecutive days, from waking up to falling asleep. After completing the assessment, participants returned the device by mail. To estimate the participants' usual walking activity, we discarded the maximum and minimum daily records from the entire data. The data for the remaining 5 days were summed up and divided by 5, generating average daily walking steps for use in the analyses.

Depressive symptoms. We measured depressive symptoms at both Wave 1 and Wave 2 by means of a Japanese version of the CES–D Scale (Shima, Shikano, Kitamura, & Asai, 1985). The scale was mailed to participants to complete and bring to the Institute on the examination day. Participants indicated how often during the previous week they had experienced any of the 20 symptoms included in the scale. Each item was rated on a 4-point scale ranging from 0 (*rarely or none of the time*) to 3 (*most or all the time*). Four positively worded items were reverse scored. The points were added together so that a higher score represented a higher level of depressive symptoms. Cronbach's alphas were .86 and .86 for the middle-aged group and .89 and .85 for the older group at Waves 1 and 2, respectively.

Control variables. We controlled for the following characteristics in the statistical analyses. Gender was coded as a contrast effect (men were assigned a score of 0 and women a score of 1). Annual family incomes at Wave 1 were rated on an 11-point scale (1 = *income less than ¥1,500,000,* 11 = *income greater than ¥20,000,000*). The presence and history of seven diseases (stroke, hypertension, cardiovascular disease, diabetes, bronchitis, arthritis, and cancer) at Wave 1 were also totaled and were used as an index of participants' chronic conditions.

Results

Sample Characteristics

Table 1 presents the sample characteristics by age group. Compared with the middle-aged group, the older group consisted of more men, $\chi^2(1, N = 1,151) = 4.38$, $p < .05$, and had participants with lower incomes, $t(492) = 15.39$, $p < .01$. The older group also reported more chronic conditions, $t(426) = -9.70$, $p < .01$, than the middle-aged group. Daily walking steps in the middle-aged group were significantly greater than in the older group at both Waves 1 and 2, $ts(1149) = 7.08$ and 7.98, respectively, $ps < .01$. In contrast, the CES–D scores did not differ between the age groups at either baseline or follow-up.

Longitudinal Analyses

We used a structural equation modeling (SEM) procedure with a cross-lagged panel design to test the relationships between walking activity and depressive symptoms. All analyses were conducted using the AMOS 4.0 computer program (Arbuckle & Wothke, 1999). Figure 1 illustrates the possible relationships between four study variables: walking steps at Waves 1 and 2 and depressive symptoms at Waves 1 and 2. Walking steps at Waves 1 and 2 are enclosed in boxes as observed variables. Depressive

Table 1
Descriptive Information for Study Variables by Age Group

Variable	Middle-aged ($n = 837$) *M*	Middle-aged ($n = 837$) *SD*	Older ($n = 314$) *M*	Older ($n = 314$) *SD*
Gender (% male)	51.4		58.3	
Income	7.1	2.1	4.7	2.4
Chronic conditions	0.3	0.6	0.8	0.8
Steps per day (Wave 1)	6,395	2,438	5,281	2,214
Steps per day (Wave 2)	8,436	3,087	6,764	3,375
CES–D (Wave 1)	6.5	6.0	6.7	6.9
CES–D (Wave 2)	7.1	6.3	7.2	6.3

Note. Score ranges of income, chronic conditions, and the CES–D scores are 1–11, 0–7, and 0–60, respectively. CES–D = Center for Epidemiological Studies—Depression Scale.

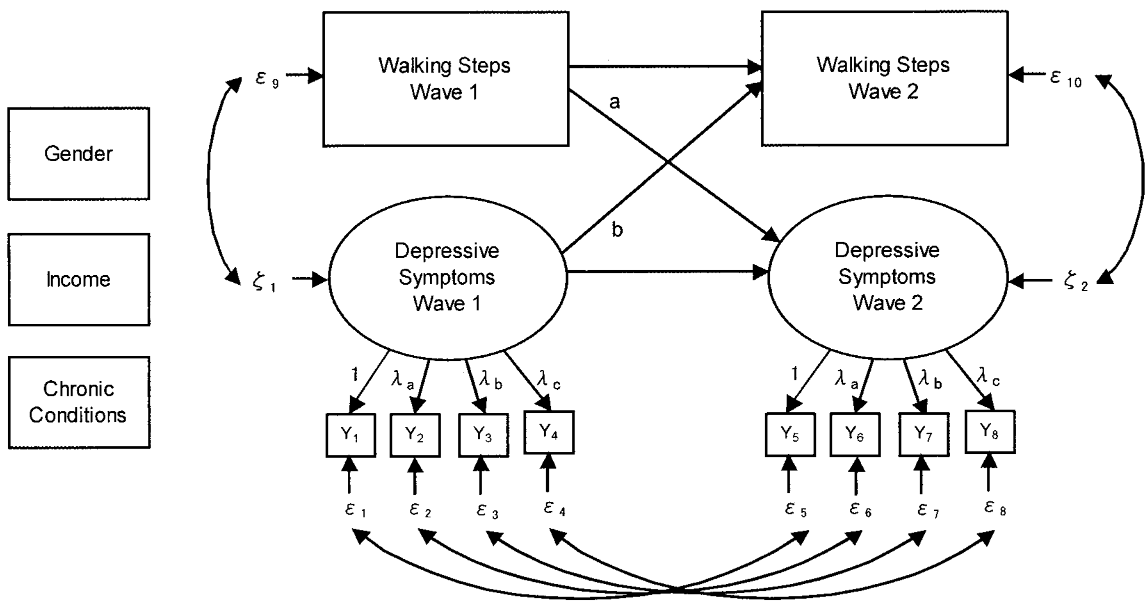

Figure 1. Cross-lagged regression model (saturated model) for testing longitudinal relations between walking steps and depressive symptoms. Y is the mean of each CES–D subscale (Y_1 and Y_5: Depressed Affect; Y_2 and Y_6: Positive Affect; Y_3 and Y_7: Somatic and Retarded Activity; and Y_4 and Y_8: Interpersonal). The epsilons and zetas signify error variables. The 12 direct effects of gender, income, and chronic conditions on walking steps and depressive symptoms at Waves 1 and 2 are not shown in the figure. CES–D = Center for Epidemiological Studies—Depression Scale. The letters a and b denote cross-lagged parameters.

symptoms at Waves 1 and 2 are enclosed in ellipses as latent variables on which the means of each CES–D subscale (Depressed Affect, Positive Affect, Somatic and Retarded Activity, and Interpersonal) loaded as indicators (see Radloff, 1977, for a fuller description of the factor structure of the scale). We constrained the indicators to load on the depression construct equally between the surveys and allowed their error terms to correlate across time. Other parameters were freely estimated, except two cross-lagged parameters (Parameters a and b in Figure 1), which were constrained in some way for model comparisons, as described below. The direct effects from exogenous variables (gender, income, and chronic conditions) on the walking steps and depressive symptoms at Waves 1 and 2 were also freely estimated in all analyses (arrows not shown in the figure).

To determine the most likely direction and time frame of the relationship between walking steps and depressive symptoms, we first developed the non-age-specific model for an overall sample. That is, using the data from all participants, we started the SEM procedure with a saturated model in which the two cross-lagged effects of walking steps on depressive symptoms and depressive symptoms on walking steps were both released (i.e., freely estimated). In the next step the following three models were statistically compared with the saturated model.

1. The stability model specified that both cross-lagged effects (Parameters a and b in Figure 1) were constrained to be zero.

2. The depression-to-step model specified that the effect of depressive symptoms on steps (Parameter b) was released, and the effect of steps on depressive symptoms (Parameter a) was constrained to be zero.

3. The step-to-depression model specified that the effect of steps on depressive symptoms was released, and the effect of depressive symptoms on steps was constrained to be zero.

Table 2 presents the summary statistics. The chi-square goodness-of-fit tests suggested that all models provided good fits with the observed data; however, the fitness indices of the step-to-depression model (goodness-of-fit index [GFI] = .975, adjusted GFI = .954, comparative fit index = .997, Akaike information criterion = 136.833) suggested that this model was the most likely to be equivalent with the saturated model.

Differences in fit between the models were also examined to determine which model provided the best representation of the data. The results indicated that the stability model and the depression-to-step model provided significantly worse fits than the saturated model. The step-to-depression model, however, was not significantly different from the saturated model, and it provided a significantly better fit than the stability model, $\chi^2(1, N = 1{,}151) = 5.87$, $p < .05$. Although the step-to-depression model and the depression-to-step model are not nested and cannot be directly compared, the pattern of findings favored the step-to-depression model.

On the basis of the aforementioned model-testing procedure, we applied a multigroup analysis to the step-to-depression model to test whether the effect of walking steps on depressive symptoms is consistent between the middle-aged and the older groups. This procedure is similar to the process used to evaluate the overall predictive model. That is, the saturated model (having no constraints of the cross-lagged effect of walking steps at Wave 1 on

Table 2
Chi-Squares and Fit Indices of All Models, Controlling for Gender, Income, and Chronic Conditions

Model	Parameter constraints[a]	χ^2	*df*	χ^2_{diff}[b]	GFI	AGFI	CFI	AIC
Saturated		50.96	48		.976	.954	.997	136.963
Stability	a = b = 0	58.70	50	7.74*	.973	.950	.992	140.702
Depression-to-step	a = 0	56.83	49	5.86*	.973	.951	.993	140.827
Step-to-depression	b = 0	52.83	49	1.87	.975	.954	.997	136.833

Note. GFI = goodness-of-fit index: AGFI = adjusted goodness-of-fit index; CFI = comparative fit index; AIC = Akaike information criterion.
[a] The letters a and b denote cross-lagged parameters. [b] Comparison with the saturated model.
* $p < .05$.

depressive symptoms at Wave 2 in both age groups) was compared with the following three possible models:

1. The non-age-specific model stipulated that the cross-lagged effect of steps on depressive symptoms was identical across age groups (Parameter a in Figure 1 was constrained to be equal between the middle-aged and the older groups).

2. The middle-aged-specific model stipulated that the steps were effective only on the middle-aged group (Parameter a in the older group was constrained to be zero, whereas Parameter a in the middle-aged group was freely estimated).

3. The older-specific model stipulated that the steps were effective only on the older group (Parameter a in the middle-aged group was constrained to be zero, whereas Parameter a in the older group was freely estimated).

Table 3 indicates the results of testing. Although all models, including the saturated model, could be rejected as statistically different from the observed data, the fit indices indicated that each model provided a good fit. Differences in fit among the models revealed that the non-age-specific model, $\chi^2(1, N = 1{,}151) = 5.70$, $p < .05$, and the middle-aged-specific model, $\chi^2(1, N = 1{,}151) = 5.73$, $p < .05$, provided significantly worse fits than the saturated model. The older-specific model, however, was statistically comparable to the saturated model, $\chi^2(1, N = 1{,}151) = 0.53$ (*ns*). The inference from these results is that the older-specific model fits the data best.

Parameter estimates of the older-specific model indicated that the two lagged effects (autoregressive paths from walking steps at Wave 1 to walking steps at Wave 2, and depressive symptoms at Wave 1 to depressive symptoms at Wave 2) were strong in both age groups, indicating that walking steps and depressive symptoms remained fairly stable over the 2 years (βs = .64 and .71 for walking steps and .62 and .74 for depressive symptoms in middle-aged and older groups, respectively, $p < .01$ in each case). Additionally, the older group showed a significant cross-lagged effect ($\beta = -.11$, $p < .05$) of walking steps at Wave 1 on depressive symptoms at Wave 2, suggesting that older participants who walked more at baseline reported fewer depressive symptoms at follow-up.

Discussion

In this study we used longitudinal data from a large community sample in Japan to examine the relationships between physical activity and psychological well-being. Cross-lagged panel analyses demonstrated that the baseline daily walking activity estimated by a pedometer was associated with depressive symptoms at the 2-year follow-up in older adults, even after adjusting for potential confounding variables. This is in line with the results of other studies conducted in Western countries (e.g., Camacho et al., 1991; Hassmen et al., 2000; Herzog et al., 1998, Lampinen et al., 2000; Ross & Hayes, 1988). In contrast, the analyses did not support the antidepressant effect of physical activity in middle-aged adults. Thus, as we predicted, the findings provide evidence for age

Table 3
Multigroup Testing of the Step-to-Depression Model, Controlling for Gender, Income, and Chronic Conditions

Model	Parameter constraints[a]	χ^2	*df*	χ^2_{diff}[b]	GFI	AGFI	CFI	AIC
Saturated		145.43	95		.981	.964	.987	319.43
Non-age-specific	m = o	151.13	96	5.70*	.981	.963	.986	323.13
Middle-aged-specific	o = 0	151.16	96	5.73*	.981	.963	.986	323.16
Older-specific	m = 0	145.96	96	0.53	.981	.964	.988	317.96

Note. GFI = goodness-of-fit index; AGFI = adjusted goodness-of-fit index; CFI = comparative fit index; AIC = Akaike information criterion.
[a] Alphabetic notations indicate age groups: m = middle-aged, o = older. [b] Comparison with the saturated model.
* $p < .05$.

differences in the beneficial effect of physical activity on psychological well-being.

In general, people become less active as they age (Shephard, 1997), as demonstrated in our study: Participants from the older group accumulated fewer walking steps than participants from the middle-aged group. However, it is unclear whether a decrease in habitual activity is a normal part of aging (Shephard, 1997), because studies have also reported that older adults can achieve excellent exercise adherence and maintenance (Emery, Hauck, & Blumenthal, 1992; McAuley, Jerome, Elavsky, Marquez, & Ramsey, 2003). In other words, it is likely that older adults' physical capacity may be underestimated because they are ostensibly inactive in their daily lives. Consequently, one possible explanation for the age difference we saw in this study is that individuals who are far below physical capacity in fitness (i.e., older adults) gain greater benefit from exercise. Our results may also suggest that the daily walking activity was too mild to affect the depressive symptoms of midlife adults. In fact, some studies (McGowan, Pierce, & Jordan, 1991; Rehor, Dunnagan, Stewart, & Cooley, 2001) have reported that vigorous aerobic exercise (e.g., running) or resistance training (e.g., weight lifting) improves psychological well-being in younger persons. Thus, the results in the present study suggest that a reasonable match between age and the type of exercise may be necessary for there to be an antidepressant effect.

Although some studies have suggested that older people can improve their psychological well-being by vigorous aerobic and resistance training (Blumenthal et al., 1991, 1999; Singh et al., 1997), too much physical activity can provoke cardiac risks or cause musculoskeletal injury, especially for an older person (Shephard, 1997). In addition, Penninx et al. (2002) found that a walking exercise intervention was more effective than a resistance exercise intervention for reducing depressive symptoms in older adults. In this regard, modest activity such as walking would be a secure and effective exercise for preventing depressive symptoms in older persons.

One of the greatest limitations in the present study is that the antidepressant effect of walking was not extremely strong ($\beta = -.11$). It should also be noted that the model comparisons using SEM revealed that the step-to-depression model was better, but the stability and depression-to-step models also fit the observed data well. Future analyses should attempt to refine our findings. For example, according to Williamson and Schulz (1992, 1995), illness and its resultant pain are related to depression because they restrict patients' routine activities. Although we excluded possibly disabled individuals from the data and adjusted for the effect of chronic health conditions in the analyses, prior health factors may still play an important role in the relationship between walking and depressive symptoms. It should also be noted that although the final model, predicting depression from baseline walking scores, fit the data the best, all of the models provided an adequate fit to the data on the basis of the goodness-of-fit indices. As such, the final model was based on the best-fitting model, within the context of a number of good-fitting statistical models.

It would also be valuable to consider the factors that mediate the relationship between walking and depressive symptoms. Both physiological and psychosocial pathways have been hypothesized as mediating the antidepressant effect of physical activity (Brown, 1992; Paluska & Schwenk, 2000). For example, physical activity is believed to have an effect by enhancing brain aminergic synaptic transmission (Ransford, 1982) or by reducing activity of the hypothalamic–pituitary–adrenal axis (van der Pompe, Bernards, Meijman, & Heijnen, 1999). The psychosocial explanation posits that individuals who exercise improve their psychological well-being by increasing self-efficacy (McAuley, Blissmer, Katula, Duncan, & Mihalko, 2000) or because the activity acts as a diversion from unpleasant stimuli (Hill, 1987). Modeling complex multistep pathways that consider these and other factors (e.g., gender) would be a fruitful approach for improving the predictive effect of physical activity on psychological well-being.

Nevertheless, an advantage of the present study is that it showed the availability of a simple measure of walking steps for predicting depressive symptoms in community-dwelling adults. Although there is increasing evidence regarding the importance of physical activity in maintaining mental health in older people, past findings were generally based on subjective, self-report measures of physical activity (e.g., Herzog et al., 1998; Lampinen et al., 2000) or on experimental works using small samples (e.g., McNeil et al., 1991; Singh et al., 1997). The use of an objective, low-cost, and user-friendly measure such as a pedometer makes assessing physical activity easier and thus more feasible to consider as a mental health factor in large community surveys.

Furthermore, a recent study (Talbot, Gaines, Huynh, & Metter, 2003) reported that a pedometer-driven walking program with a self-management educational program increased physical activity, muscle strength, and functional performance in older adults with osteoarthritis, as opposed to the educational program alone. This implies that a pedometer can also be used as a motivator for exercise adherence. From this viewpoint the results in the present study are small but important steps that warrant further research to clarify the availability of this tool to promote psychological well-being in older adults.

In conclusion, the present study partially confirmed the protective effect of physical activity on depressive symptoms in community-dwelling adults. The findings suggest that age should be taken into account when incorporating a walking exercise in research and daily practice for mental health.

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