Contribution of Genetic and Environmental Factors to Individual Differences in Maximal Walking Speed With and Without Second Task in Older Women

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Background. Among older people, distraction while walking may increase the risk of falls. Factors underlying individual differences in dual tasking are not fully understood. Our aim was to study the effect of a second task on maximal walking speed and to examine whether individual differences in walking speed measured with and without a second task are accounted for by genetic and environmental influences shared across tasks or specific to each task.

Methods. The data were collected from the 101 monozygotic and 116 dizygotic twin pairs aged 63–76 years recruited from the Finnish Twin Cohort. Maximal walking speed (MWS) over 10 m was measured on a laboratory corridor and timed with photocells. The test was repeated while subjects performed, first, a manual task (MWSmanual) and, second, a verbal task (MWSverbal).

Results. Mean walking speed without a simultaneous task was 1.72 m/s (standard deviation [SD] 0.33), with a manual task it was 1.52 m/s (SD 0.26), and with a verbal task it was 1.36 m/s (SD 0.27). Multivariate genetic analysis showed that an additive genetic factor in common accounted for 17% of individual differences in MWS, 19% in MWSmanual, and 12% in MWSverbal. In addition, MWSverbal had a genetic factor specific to it accounting for 10% of the variance. Shared environmental influences, common to all three traits, accounted for 39%, 27%, and 21% of the individual differences, respectively.

Conclusion. Approximately half of the individual differences in walking with or without another task were accounted for by genetic and nongenetic familial effects in common, and the rest of the variation was accounted for by unique environmental factors in common and factors specific to walking tests.

Walking limitation is a common problem in older age groups, and can lead to increased risk of falls and disability (1,2). In particular, among older people with mobility limitation, a distraction while walking may become a risk factor for falls (3,4). As walking is an automated skill, people typically engage in other tasks at the same time such as mental problem solving, conversing, or carrying an object. Again, among older people especially, dual tasking may lead to modifications in walking performance, such as slowing down, which indicate an increasing need for directing attentional resources to walking (5–7).

Currently, there is lack of knowledge about the possible genetic factors underlying individual differences in walking ability, particularly in more complex situations. Previous studies on customary walking speed and self-reported mobility suggest a moderate genetic component accounting for variation in mobility (8,9). To the best of our knowledge, no previous studies have presented heritability estimates of walking at maximal speed or walking while performing another task. In twin studies, by comparing the similarity of monozygotic (MZ) and dizygotic (DZ) twin siblings it is possible to estimate to what extent genetic and environmental factors underlie variability in a trait. Understanding genetic and environmental factors contributing to individual differences in walking ability of older people provides information about the etiology of functional limitations and disability. This knowledge is advantageous when planning targeted interventions to prevent walking limitation.

The aim of the present study was to investigate how adding another task to a test of maximal walking speed affects walking performance among 63- to 76-year-old women, and to examine whether individual differences in these tasks are accounted for by genetic and environmental effects in common or by factors specific to these tasks.

METHODS

Participants

Research participants were recruited from the Finnish Twin Cohort (10,11), which comprises all same-sex twin pairs born before 1958 with both co-twins alive in 1975. The recruitment procedure is described in detail elsewhere (12). Briefly, 178 MZ twin pairs, 212 DZ twin pairs, and 24
twin pairs of previously undetermined zygosity (XZ), aged 63–76 years, were invited to participate in the present study. Eventually, both sisters of 98 MZ, 106 DZ, and 13 XZ pairs attended at the laboratory measurements. Zygosity in XZ pairs was ascertained by 10 highly polymorphic genetic markers. The final sample of this study consisted of 99 MZ and 113 DZ twin pairs.

On presenting at the laboratory, participants provided written informed consent. The study protocol was approved by the committee on Ethics of the Central Hospital of Central Finland as a part of the Finnish Twin Study on Aging (FITSA).

Maximal Walking Speed With and Without Second Task

Maximal walking speed over 10 meters was measured in the laboratory corridor. Participants were instructed to “walk as fast as possible, without compromising your safety.” Three meters were allowed for acceleration. Timing was done using photocells. Participants wore walking shoes or sneakers, and use of a walking aid was allowed if needed. Maximal walking speed without a second task was tested twice, and the faster performance was documented as the result. After that, dual tasking was tested on the same track by adding a simultaneous second task. During the first test, the participant carried a glass full of water (MWSmanual). In the second test, the participant was asked to recite as many male or female names starting with a given letter (K, S, or T) as possible (MWSverbal). One of these letters was randomly selected for each participant. K, S, and T were used because, in the Finnish language, the number of first names beginning with these letters is large and approximately equal in number. Participants were encouraged to perform as best they could on all parts of the test. During each test, an examiner walked behind the participant to ensure safety. The test order was the same for all participants. Three trained physiotherapists working on alternate days conducted testing. Tests were always administered during the afternoon.

The reliability of the walking tests was studied among a sample of 20 women aged 60–70 years by replicating the tests after an interval of 1–2 weeks. The coefficients of variation for MWS, MWSmanual, and MWSverbal were 4.6%, 7.2%, and 8.7%, respectively. For the analyses, walking speed (m/s) was calculated by dividing the 10-m distance by the time taken to walk it. The effect of a second task on walking speed was examined by calculating the absolute difference in speed between walking with and without the second task. The percentage loss in the walking speed was computed using the formula [(single task – dual task) / single task] × 100 (13,14).

Descriptive Variables

Habitual physical activity.—Habitual level of physical activity was assessed using the scale of physical activity developed by Grimby (15). Participants were classified as sedentary (indicating no other regular activity but light walking two or fewer times a week), moderately active (walking or other light exercise at least three times a week, but no exercise more intensive than that), or active (moderate or vigorous exercise at least three times per week).

Body mass index.—Body height and weight were measured in the laboratory using calibrated scales. Body mass index (BMI) was calculated by dividing body weight by the squared body height in meters.

Mini-Mental State Examination.—A trained research assistant carried out a MMSE at the laboratory. The maximum Mini-Mental State Examination (MMSE) score is 30, whereas scores below 17 are considered an indication of dementia (16).

Chronic conditions.—Information on diseases was gathered first by a questionnaire. The participant indicated the chronic conditions she had from the following list: coronary heart disease, cardiac failure, hypertension, pulmonary diseases, asthma, multiple sclerosis, Parkinson’s disease, arthritis, rheumatoid arthritis, fibromyalgia, gout, deficiency or hyperactivity of the thyroid gland, diabetes, and cancer. A physician then ascertained disease status during a clinical examination.

Statistical Methods

Equality of the means between the MZ and DZ twins was compared by the adjusted Wald test using STATA (17). This software allows a sample to include correlated observations, such as observations for co-twins. Correlations between the walking test results and within-pair intraclass correlation coefficients for MZ and DZ twins were computed using SPSS (18).

Model fitting.—In the genetic models, the observed variance in a phenotype can be decomposed into additive genetic (A), nonadditive genetic (D), shared environment (C), and nonshared environmental (E) variance. ACE, ADE, AE, CE, and E models are fitted to the data using the knowledge that correlations for A, D, and C are 1.0 between the co-twins of a MZ pair, whereas for DZ pairs the correlation for A is 0.5, for D 0.25, and for C 1.0. For both MZ and DZ twin sisters, E effects are uncorrelated (19,20). In the present analyses, D was not included in the models because the phenotypic correlations between the sisters of the twin pairs suggested no contribution from D.

Genetic and environmental influences contributing to MWS, MWSmanual, and MWSverbal were estimated first with univariate models. Strong phenotypic correlations between walking tests suggested that at least in part, the same genetic and/or environmental influences contributed to individual differences in all three tests of walking. This was studied first by fitting bivariate Cholesky models for MWS and MWSmanual and MWS and MWSverbal. Then, by fitting the independent pathway model (including MWS, MWSmanual, and MWSverbal) to data, we examined whether variance and covariance in these walking tests is explained by genetic and environmental influences in common and/or factors specific to each test.

Models were estimated using the full information maximum likelihood method. As we used raw data input, the five MZ and five DZ pairs with partially incomplete walking test data were also included in these analyses. A saturated model was fitted first and was used to evaluate the
fit of the ACE model. In the saturated model, the means are modeled in the same way as in the ACE model, but the variance and covariance structure are unconstrained for MZ and DZ groups. As the aim is to find the most parsimonious model explaining the sources of variance, nonsignificant paths were dropped one at a time. The fit of the nested models was tested by subtracting the –2 Log Likelihood (LL) of each model from the –2 LL and df of the full ACE model. In all models, age was used as a covariate. Modeling was done using the Mx program (21).

### RESULTS

No significant differences by zygosity were observed for the means and variances of the walking speed test results, BMI, chronic conditions, or level of physical activity (Table 1). Mean MMSE score was 27.1 (SD 2.2), and none of the participants had an MMSE score below 17. Based on self-reported level of physical activity, 27% of the participants were classified as sedentary, 52% as moderately active, and 22% as active.

Mean MWS was 1.72 m/s (SD 0.33), MWSmanual was 1.52 m/s (SD 0.26), and MWSverbal was 1.36 m/s (SD 0.27). Mean number of names recited in the verbal task was 1.52 (SD 0.24). The verbal task slowed it by 20.8% (SD 1.9). Expressed as percentages, compared to walking without a second task, the manual task slowed walking speed by 11.2% (SD 0.33), MWSmanual was 1.52 m/s (SD 0.24), and the verbal task slowed it by 20.8% (SD 10.4).

The MZ intraclass correlation for MWS was 0.61, for MWSmanual 0.53, and for MWSverbal 0.47, whereas the correlations for DZ twins were 0.48, 0.29, and 0.27, respectively, suggesting that genetic influences may contribute to these traits. The high phenotypic correlations between the walking tests (from 0.72 to 0.88) suggested that MWS, MWSmanual, and MWSverbal covariance is accounted for by genetic or environmental influences in common.

### Genetic Modeling

The univariate model fitting results with standardized parameter estimates and 95% confidence intervals (CI) are presented in Table 2. Differentiating between the importance of genetic and shared environmental influences became difficult due to minor statistical differences between the ACE, AE, and CE models. However, because the pattern of twin correlations implies the presence of genetic influences, we considered the ACE models for MWS, MWSmanual, and MWSverbal to provide the most appropriate description of the present data.

The bivariate models showed overlap of genetic and shared environmental influences contributing to walking speed with or without another task. The reduced ACE models for MWS and MWSmanual and for MWS and MWSverbal were selected because they provided the best description of the present data. The model for MWS and MWSmanual showed that a genetic factor in common accounted for 17% (95% CI, 0%-51%) of the variance in MWS and 18% (95% CI, 0%-47%) of that in MWSmanual, and, furthermore, that a shared environmental factor in common accounted for 39% (95% CI, 8%-60%) of the variance in MWS and 28% (95% CI, 4%-49%) of that in MWSmanual. Similarly, in the model for MWS and MWSverbal, an additive genetic factor in common accounted for 7% (95% CI, 0%-43%) of the individual differences in MWS and 25% (95% CI, 0%-50%) of those in MWSverbal and that a shared environmental factor in common accounted for 47% (95% CI, 16%-60%) of the variance in MWS and 18% (95% CI, 0%-44%) of that in MWSverbal. Both bivariate models showed that nonshared environmental influences accounting for individual differences in MWS also accounted to some extent for individual differences in MWSmanual and MWSverbal: the nonshared environmental correlation for the model with MWS and MWSmanual was 0.61, and for the model with MWS and MWSverbal it was 0.42.

With the trivariate model our aim was to further specify

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**Table 1. Mean Values (SD) for MZ and DZ Twin Pairs**

<table>
<thead>
<tr>
<th>Variable</th>
<th>MZ Twins Mean (SD)</th>
<th>DZ Twins Mean (SD)</th>
<th>Equality of Means p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>195 68.2 (3.6)</td>
<td>223 68.9 (3.1)</td>
<td>.074</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>195 27.9 (4.7)</td>
<td>223 28.0 (4.8)</td>
<td>.899</td>
</tr>
<tr>
<td>No. of chronic conditions</td>
<td>191 2.0 (1.5)</td>
<td>223 1.9 (1.4)</td>
<td>.774</td>
</tr>
<tr>
<td>MWS</td>
<td>195 1.74 (0.35)</td>
<td>223 1.70 (0.31)</td>
<td>.305</td>
</tr>
<tr>
<td>MWSmanual</td>
<td>193 1.52 (0.28)</td>
<td>222 1.52 (0.24)</td>
<td>.837</td>
</tr>
<tr>
<td>MWSverbal</td>
<td>192 1.35 (0.29)</td>
<td>222 1.37 (0.25)</td>
<td>.472</td>
</tr>
</tbody>
</table>

**Table 2. Univariate Models for MWS, MWSmanual, and MWSverbal**

<table>
<thead>
<tr>
<th>Model</th>
<th>Model Fit</th>
<th>Model Comparisons</th>
<th>Standardized Estimates (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MWS</td>
<td>ACE 166.625 413 * *</td>
<td>11 (0–49) 43 (10–61) 46 (34–58)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AE 172.818 414 6.193 1 .013 58 (46–67) — 42 (33–54)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CE 166.999 414 0.374 1 .542 — 52 (41–61) 48 (39–59)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MWSmanual</td>
<td>ACE –3.742 410 * *</td>
<td>34 (0–58) 12 (0–46) 54 (42–69)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AE –3.339 411 0.343 1 .558 47 (33–59) — 53 (41–67)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CE –1.567 411 2.175 1 .140 — 39 (26–50) 61 (50–74)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MWSverbal</td>
<td>ACE 58.191 409 * *</td>
<td>27 (0–56) 15 (0–46) 58 (44–74)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AE 58.721 410 0.530 1 .467 44 (29–56) — 56 (44–71)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CE 59.524 410 1.333 1 .248 — 36 (24–48) 64 (52–77)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** Fit statistics of the model and model comparisons. Standardized estimates describe the proportion of additive genetic component (a²) of variance, and shared environmental (c²) and unique environmental components (e²) of variance with 95% confidence intervals (CI).

A, C, and E refer to variance due to additive genetic, shared, and unique environmental influences, respectively.

*There are no values for these fields because ACE is the full model against which other models are compared.

— = Fixed to zero in the fitted model.

LL = Log Likelihood; df = degrees of freedom; ∆LL = difference between –2 LL of ACE model and the fitted model; ∆df = difference of degrees of freedom of ACE model and the fitted model. MWS = maximal walking speed without another task; MWSmanual = maximal walking speed with simultaneously performed manual task; MWSverbal = maximal walking speed with simultaneously performed verbal task.
ACE model, although the statistical superiority of the ACE sources of variance in walking speed was provided by the line with those of previous studies on customary walking tested in dual-task conditions. Our results are, however, in individual differences in maximal walking speed or walking of genetic and environmental factors contributing to previous studies have presented estimates of the proportions for 10% of the variance. To the best of our knowledge, no showed genetic influences specific to this test, accounting the risk of walking limitation and is highly correlated with genetic factors. Another genetic mechanism influencing walking may be mediated through genetic influences on body weight and obesity. Obesity increases the dual-task cost may be more pronounced in our study because walking at maximal speed may require more attention in our sample of relatively healthy older women. We assume that the dual-task cost may be more pronounced in our study because walking at maximal speed may require more attention than may walking at customary speed (34). Regardless of differences in research methods, our observations are in line with previously reported results showing slowing in walking in dual-task situations among older persons (13).

Our results showed that, according to the univariate models, 27%–34% of the individual differences in walking while engaged in another task were accounted for by genetic influences, whereas genetic influences accounted for only 11% of the variance in walking without a second task. Furthermore, our independent pathway model showed that variance in walking speed measured while doing a verbal task was partially accounted for by task-specific genetic influences. Previous studies have shown that additional attention and cognitive resources are needed when dual tasking (7,13,32,34). In addition, heritability in cognitive functions has been found to remain substantial even in very old age (35,36). Consequently, in more complex dual-task situations, the cognitive resources underlying mental performance may become another important determinant of walking performance.

**Discussion**

The present study showed that, among older women, approximately 50% of the individual differences in maximal walking speed performed with or without a simultaneous second task were accounted for by familial factors in common. An additive genetic factor in common accounted for 12%–19% of the variance, whereas the proportions of shared environmental factors varied between 21% and 39%. In addition, walking speed measured with the verbal task showed genetic influences specific to this test, accounting for 10% of the variance. To the best of our knowledge, no previous studies have presented estimates of the proportions of genetic and environmental factors contributing to individual differences in maximal walking speed or walking tested in dual-task conditions. Our results are, however, in line with those of previous studies on customary walking speed and self-reported mobility (8,9).

In this study, we found that the best explanation for the sources of variance in walking speed was provided by the ACE model, although the statistical superiority of the ACE model over the AE or CE models could not be unambiguously determined due to limitations of the power of the statistical analysis imposed by sample size. However, we felt it was justified to select a model including A, because traits underlying walking performance, such as postural balance and muscle strength, are at least moderately heritable (12,22,23). In our previous report, we showed that genetic influences accounted for 35% of individual differences in balancing ability (12). Moreover, among the twin sisters of the present study, Tainen and colleagues (23) showed that 31% of the variance in knee extension strength was accounted for by genetic influences. Another genetic mechanism influencing walking may be mediated through genetic influences on body weight and obesity. Obesity increases the risk of walking limitation and is highly correlated with genetic factors (24,25). Overweight was relatively common in the present sample, with 28% of the women having BMI > 30; consequently, it is possible that in the current study part of the genetic effects on walking speed were mediated through obesity. Presence of diseases may also underlie the genetic effects explaining individual differences in walking. For example, diabetes or arterial and venous diseases (26–28) have familial background and are known risk factors for walking limitation (24,29,30). Among participants of the present study, the prevalence of diseases was relatively low and no systematic differences were observed between MZ and DZ groups (12); however, we can not rule out that genetic predisposition to specific diseases may also underlie the genetic effects on walking limitation.

It has been suggested that, among older adults with impaired postural control, the dual-task cost is particularly high, probably due to the prioritization of safety in mobility (13,31,32). However, among those adults without balance impairment, the second task would need to be rather difficult to impose a load on the attention capable of leading to deterioration in performance (33). In our study, the cognitive tasks used in dual-tasking tests were quite simple, yet a significant slowing down in maximal walking speed was observed even in our sample of relatively healthy older women. We assume that the dual-task cost may be more pronounced in our study because walking at maximal speed may require more attention than may walking at customary speed (34). Regardless of differences in research methods, our observations are in line with previously reported results showing slowing in walking in dual-task situations among older persons (13).
The result of the present study suggests that, in addition to genes, environmental influences make a substantial contribution to walking ability. As environmental influences were largely in common for walking speed regardless of whether it was tested without or with a second task, interventions to improve the mobility of older people may also have positive effects on managing dual-task situations. Genetic and environmental factors are, however, in a continuous interplay where changing one component will change the relative role of the others, too, in explaining individual differences. In the present study, we were able to determine the relative proportion of the familial and environmental influences that contribute to variance in walking test results among older women. Specifying the most important environmental factors that contribute to walking ability independent of genetic influences warrants further study. More information also is needed about the nature of the interaction between genetic and environmental factors in determining walking ability before interventions to modify this interaction can be developed. However, it is likely that in particular those people with genetic predisposition to risk factors for walking limitation will benefit most from environmental modifications, such as exercise and lifestyle interventions.

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