Low Socioeconomic Status and Disability in Old Age: Evidence From the InChianti Study for the Mediating Role of Physiological Impairments

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Background. Low socioeconomic status (SES) has been associated with increased risk of disability in later life. The purpose of this study was to determine if SES has an impact on mobility functioning and to explore which physiological impairments are also associated with SES and may explain its relationship with mobility.

Methods. The study sample consisted of 1025 individuals aged 65 years or older residing in the Chianti area (Italy). Number of years of education was used as an indicator of SES. Mobility functioning was assessed using gait speed (400 m) and the Short Physical Performance Battery (SPPB). Mobility-related physiological impairments were assessed with tests of executive functioning, nerve conduction velocity, muscle power, hip–ankle range of motion, Ankle–Brachial Index, and visual acuity. Linear regression models were used to study the association between number of years of education and mobility and to estimate the contribution of each of the selected physiological impairments to this association.

Results. Adjusting for age and sex, slower gait speed (1.16 vs 1.26 m/s, \( p < .0001 \)) and lower SPPB scores (9.55 vs 10.11, \( p = .006 \)) were seen in persons with ≤5 years of total education compared with those persons with >5 years of total education. Leg power and executive function decreased the strength of the association between educational level and gait speed by more than 15%. Controlling for all selected impairments (full model) decreased the education–gait speed association by 49%. Low education continued to be significantly associated with gait speed (\( p < .01 \)). Adjusting for all physiological impairments substantially reduced the low education–SPPB score association by 100%, and this association was no longer significant.

Conclusions. Low SES is related to multiple physiological impairments, which explain a large amount of the association between education and gait limitations. Further work must be done to understand the mechanisms whereby low SES translates into the impairments that play an important role in mobility.

Socioeconomic inequalities have been recognized as having a large impact on health outcomes in both old and younger individuals. Previous research has shown that older individuals with lower socioeconomic status (SES), as measured by several indicators such as educational attainment, income, occupation, and personal wealth, have significantly higher morbidity and mortality rates compared to individuals with higher SES (1–8). Recent work has shown that SES is related to functional decline and mobility disability in later life (6,7,9,10). Levels of education and/or income have been significantly associated with a decrease in both total and active nondisabled life expectancy among older persons (2,5,11).

Previous work on socioeconomic differences in mobility limitations and disability prevalence have used self-reported measures of physical functioning, such as ability to perform activities of daily living or selected mobility-specific tasks, such as walking up stairs, walking a half mile, or carrying objects (1,6). However, the mechanisms by which SES affects mobility functioning assessed with objective measures of physical performance remain largely unexplored. In fact, no previous research evaluates the impact of SES on the full range of physiological subsystems that are critical for mobility. The development of impairments in any of the several physiological subsystems could potentially have an important impact on an individual’s ability to be mobile. Ferrucci and colleagues (12) developed a reference model that identified six main physiological subsystems that are critical for walking: (i) central nervous system; (ii) peripheral nervous system; (iii) muscular system; (iv) bones and joints; (v) energy production and delivery; and (vi) sensory system. Impairments in any of these subsystems can be easily measured in a geriatric setting, and their assessment should be an important component of the comprehensive evaluation of older patients who are experiencing progressive deterioration of their ability to walk (12). In this study we examine the association between educational level and objectively measured lower extremity function and the extent to which physiological impairments associated with poor functioning are or could be associated with SES and explain its relationship with physical disability.
Methods

Study Population
This research used baseline cross-sectional data from the InChianti study, which is a prospective, population-based epidemiological study of factors that can contribute to the decline of mobility in later years. The InChianti study was designed by the Laboratory of Clinical Epidemiology of the Italian National Research Council of Aging (INRCA) in collaboration with the Laboratory of Epidemiology, Demography and Biometry at the National Institute on Aging (NIA). The survey was conducted in two Italian towns: Greve in Chianti and Bagno a Ripoli, both located in the Chianti geographic area. The baseline data were collected between September 1998 and March 2000. The InChianti study design and main objectives have been extensively reported elsewhere (12,13). The study population for these analyses initially consisted of 1025 men and women ages 65–102 who were randomly selected using a multistage stratified sampling method. Due to missing data on the 400-meter walk test \( n = 757, 17.07\% \) (mainly because the test could not be performed during in-home examinations that were necessary for certain participants) and on the Short Physical Performance Battery (SPPB) \( n = 20, 1.95\% \), the present analyses only included data from 850 participants for the gait speed model (400-meter walk) and from 1005 participants for the SPPB model. In general, participants with missing data were significantly older (82.4 vs 74.1 years, \( p < .0001 \) and were more likely to have \( \leq 5 \) years of formal education (85.7% vs 72.1%, \( p < .001 \)) than were those participants included in the gait speed (400-meter walk) analyses.

Measures of Physical Performance
The 400-meter walk test measures walking endurance. The participants were asked to complete 20 laps of a 20-meter-long course as quickly as possible and at a steady pace. The time and number of completed laps were recorded. The SPPB, which was originally developed for the Established Populations for the Epidemiologic Studies of the Elderly (EPSE) (14), is a global functional measure that provides a physical performance score (range 0–12) by aggregating an individual’s performance in a short timed walking test conducted at usual speed (4 meters), five repeated chair stands, and a set of standing balance tests (14–16). Walking speed was defined as the faster of two 4-meter walks. For the chair stands, participants were asked to fold their arms and stand up and sit down in a chair five consecutive times as quickly as possible. Individual performance in this test was timed. Standing balance tests included side-by-side, semitandem, and tandem stands. The participants initially were asked to stand with their feet side by side, then with the heel of one foot placed to the side of and touching the first toe of the other foot (semitandem stand), and finally, with the heel of one foot directly in front and touching the toes of the other foot (tandem stand). Each standing position was timed. The timing was stopped if the individual moved his or her feet, reached for support, or was unable to hold the position for the required time (10 seconds). Each individual performance test was scored. An individual unable to perform a task received a score of 0; the ability to complete a task was scored from 1 (worst performance) to 4 (best performance). The cutoff points for the SPPB are based on a series of performance-based normative data developed from previous community-based population studies (14). A summary performance score was created by summing the individual categorical scores for the walking, balance, and chair stand tests.

Sociodemographic Characteristics
Sociodemographic variables included age, gender, and educational level. In this study we used years of education completed as the primary marker of SES. Participants were classified as having \( \leq 5 \) years of education (elementary education) versus \( >5 \) years of education. Educational level has been widely used as a basic SES indicator in several health, disability, and mortality studies (3,6,11,17–20). Unlike occupation and income, which are not always present or reported, particularly among older women, educational level can be determined for nearly all persons, is established during childhood and early adulthood, and remains mostly stable over the life course (17). It is considered to be closely related to an individual’s long-term economic position and is less likely to be affected by the impact of later life health impairments or poor health status on employment and income (3,6,17).

Measures of Physiological Impairments

Cognitive status (central nervous system).—Cognitive function was assessed using the Trail Making Test (TMT), a well-established test commonly used because it is considered to be highly sensitive to the presence of impairments in multiple cognitive domains (21). The TMT is a paper-and-pencil instrument that is administered in two parts. In Part A, the participant is required to draw lines to connect consecutively numbered circles (1–25) randomly arranged on a page as quickly as possible. In Part B, the participant is asked to connect the same number of circles in an alternating sequence of numbers and letters (1, A, 2, B, etc). Both parts of the tests are timed, and a maximum performance time of 600 seconds is allowed. During the administration of this test (22) the interviewer pointed out errors as they occurred, which allowed the participants to complete the test without errors and be scored based on time alone (22). Slower performance on Part B has been considered to be indicative of impaired executive function. Overall performance in the TMT can be affected by educational attainment, age, visual impairments, motor speed, conceptual confusion, and poor motivation (22–24).

For this analysis we calculated a difference score defined as Delta TMT that is equal to the difference between times, calculated as Part B – Part A. The Delta TMT score removes the motor speed element from the test evaluation (22,25) and is considered to be a more accurate measure of executive function than the performance on Part B alone (24). Delta TMT scores were included in this analysis as a continuous variable.
Nerve conduction velocity (peripheral nervous system).—Nerve conduction velocity and potential amplitude were assessed in the right peroneal nerve through surface electroneurography using standard neurophysiological equipment (13,26).

Lower extremity muscle power (muscles).—Leg power was evaluated using a leg extensor power rig device (27). Measurements were obtained bilaterally, and the higher of two repetitions was used. For this analysis we used only data obtained for the right leg due to the high correlation between the power measurements obtained for each leg ($r = .94$).

Lower extremity range of motion (bones and joints).—The range of articular excursion of the lower limb was measured using a flexible plastic universal goniometer. The measurements were recorded in degrees. For these analyses hip flexor–extensor and ankle dorsiflexion–plantarflexion movements were included based on the importance of full range of motion of these movements in walking.

Peripheral arterial circulation: Ankle–Brachial Index (energy production and delivery).—The Ankle-Brachial Index (ABI) was measured with a wave Doppler probe (8 MHz) and a standard mercury sphygmomanometer (28). Systolic blood pressure was measured twice in the right brachial artery and twice in the posterior tibial arteries of both legs. For this analysis the highest pressure in each measurement was used to calculate the ABI. Individuals with an ABI greater than 1.50 were excluded because these values indicate poorly compressible leg arteries and can lead to inaccurate measurements (13,28).

Hemoglobin levels.—Peripheral blood collection was performed in the morning and after a 12-hour fast. Hemoglobin levels were analyzed using the hematology autoanalyzer (Sysmex SE-9000; Kobe, Japan) (29).

Visual acuity (sensory system).—Visual acuity was evaluated with distance and close-up tests. For the distance test, a Snellen-type acuity chart adjusted for 3 meters was used (range, 0.04–0.50). For the short-distance test, a chart specifically designed for the InChianti study was used (range, 0/10–11/10). As in the previous test, the participant used his or her best corrective lenses. The chart was placed at about 35 centimeters from the eyes of the individual.

Statistical Analysis
General linear models (GLM) were initially used to obtain age-adjusted means stratified by gender and educational level for the selected measures of physiological impairments. GLM were also used to study the association between educational level and lower extremity function. Separate GLM regression models were estimated for gait speed (400 m walk) and SPPB scores. To estimate the contribution of each physical impairment to the association between low educational level ($\leq 5$ years) and objective measures of lower extremity functioning (gait speed, SPPB scores), we compared the point estimate measure of the association for low education in the basic model (adjusting only for age and gender) with the point estimates for low education in separate models in which each selected physiological impairment was individually included (30). The percent reduction in the low education beta coefficients was then calculated for each individual GLM model with the following formula:

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\text{Percent reduction} = 1 - \left(\frac{\hat{\beta}_{\text{adjusted}}}{\hat{\beta}_{\text{unadjusted}}}\right) 
\times 100
\]

RESULTS
The total study sample had a mean age of 75.5 years (standard deviation 7.3) and was predominantly female (56.2%, 576). Overall, 74.4% (763) participants reported having $\leq 5$ years of total education, and 25.6% (262) reported having $> 5$ years of total education. Figure 1 shows the mean gait speed (measured as meters per second from the 400-meter walk) and SPPB score (range 0–12) stratified by level of education, age, and gender. Adjusting for age and sex, gait speed (1.16 vs 1.26 m/s, $p < .0001$), and SPPB score (9.55 vs 10.11, $p = .006$) mean values were significantly lower among individuals reporting lower levels
of education. Age-adjusted means of selected physiological impairments according to gender and level of education are shown in Table 1. Delta TMT and leg muscle power were significantly associated with lower educational level. ABI (among men) and near visual acuity were also significantly associated with lower education. Table 2 shows age- and sex-adjusted coefficients for associations of lower education level with the two main physical performance outcomes, with additional adjustment for the selected individual physiological impairments and for all impairments together. In the gait speed model, low education continued to be significantly associated with gait speed after adjusting for each of the individual impairments. Additionally, this association persisted even after adjusting for all impairments included in the full model (p < .01). In contrast, although low education was also significantly associated with SPPB score (p < .05) after the initial sex and age adjustment, this association remained significant only after individually adjusting for nerve conduction velocity (p < .05), and hip and ankle range-of-motion measures (p < .05). The association between low education and SPPB scores was no longer significant after adjusting for the other individual impairments and for all the selected physiological impairments together (full model). It is interesting that when we analyzed the data using separate GLM regression models for men and women the results were consistent with those obtained with the combined sample. Figure 2 shows the percent reduction in the association between education and physical performance that is related to adjusting for each of the selected physiological impairments individually and then adjusting for all of the impairments together. After adjusting for age and sex, only leg power and executive cognitive function (Delta TMT) decreased the strength of the association between education and gait speed by more than 15%. The contributions of the rest of the measures of physiological impairments were modest. Controlling for all selected impairments (full model) decreased the low education and gait speed association by 49%. However, lower educational level continued to be significantly associated with gait speed (p < .01). Finally, adjusting for all selected measures of physical impairments completely reduced the association between low education and SPPB summary scores (100%), and the education coefficient was no longer significant.

**DISCUSSION**

This research examined the dynamics of SES impact on objectively measured lower extremity functioning by evaluating whether impairments in any of six physiological subsystems related to walking ability (12) could explain differences in the association between educational level and disability. Previous studies have shown the existence of significant differences in disability prevalence and disability-free life expectancy associated with an individ-
ual’s level of education (6,11,31). This study is unique because, unlike studies that used self-reported measures of physical function, in this research we used performance-based measures of lower extremity function, which have been shown to provide objective information across a broad spectrum of physical functioning, particularly among older adults (15). This research is also unique because the impact of selected physiological impairments (12) on the association between SES and mobility function was concurrently evaluated, allowing us to assess the extent to which reduced integrity of one or more of the physiological subsystems relevant to walking are mediators of this association.

Overall the results showed that, for all age and sex strata, mean values of gait speed and SPPB scores were lower among individuals reporting lower educational level. These findings are consistent with past studies that have reported the existence of an association between years of completed education and self-reported mobility functioning, as well as significant increments in disability prevalence among less educated older adults (2,6,31,32). Lower educational level was significantly associated with gait speed (400 m) even after controlling for all the selected physiological impairments included in the full model. It is interesting that the association between SPPB scores and lower educational status, although significant when adjustments for age and gender were made in the basic model, was reduced to a nonsignificant level by the inclusion of physiological impairments. We found that lower educational status was no longer associated with SPPB scores after adjusting for all impairments. Regarding the actual impairment–functional status relationship, the results of the full regression models show that after controlling for age and sex, both functional outcomes were associated with leg power, Delta TMT, nerve conduction velocity, and range of motion of the hip (flexor). SPPB score was also associated with range of motion of the ankle (dorsiflexion), and gait speed was also associated with ABI.

The inclusion of all the selected physiological impairments in the full model explained approximately half of the association between lower educational level and gait speed (49%) and 100% of the association between lower educational level and SPPB scores. It is likely that the physiological impairments we studied serve as important mediators in the SES–physical performance pathway. These physiological measures can be considered “mediators” because they reduced the strength of the low education–physical performance association, and there is biological plausibility that they themselves have an impact on physical function. These results are consistent with previous studies that have identified these impairments either individually or combined as important determinants of lower extremity disability among older adults (13,33,34,35).

Our findings further support the idea that some physiological impairments could selectively have a stronger differential impact on the SES–lower extremity function relationship. For example, leg power, visual tests, and TMT scores had a greater impact on the association between lower educational level and performance on the SPPB than did nerve conduction velocity or range-of-motion measures. These findings therefore suggest that SES differences in disability outcomes are indeed related to differences in physiological parameters. Future studies are needed that examine the biological mechanisms by which SES differences have an impact on physiological impairments to gain a better understanding of one of the pathways whereby low SES affects health and functional status.

An interesting finding of this study was the significant impact of the TMT-A and -B Delta score on the association between education and physical performance. This finding is consistent with those from previous studies that have reported the existence of an association between cognitive function and physical performance, particularly among older adults (35,36). However, the mechanisms whereby the central nervous system affects physical performance in old age are not completely understood and continue to be a complex but important research area requiring further exploration and consideration as potential targets for preventive interventions.

One limitation of this study is that we used cross-sectional data to assess the relationship between educational status and old-age mobility functioning, although the time sequence of these two variables does support causality. Longitudinal research aimed at assessing the predictive value of SES and physiological impairments on mobility functioning is needed to better understand the physiological pathway leading to disability among socioeconomically disadvantaged older adults. Overall, our findings support the idea that educational level is inversely associated with lower extremity function limitations, and highlight the impact of selected physiological impairments on the association between SES and physical function.

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