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Research Article

Leg and Trunk Impairments Predict Participation in Life Roles in Older Adults: Results From Boston RISE

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Abstract

Background: The physical impairments that affect participation in life roles among older adults have not been identified. Using the International Classification of Functioning Disability and Health as a conceptual framework, we aimed to determine the leg and trunk impairments that predict participation over 2 years, both directly and indirectly through mediation by changes in activities.

Methods: We analyzed 2 years of data from the Boston Rehabilitative Impairment Study of the Elderly, a cohort study of 430 primary care patients with self-reported mobility limitation (mean age 77 years; 68% female; average of four chronic conditions). Frequency of and limitations in participation were examined using the Late-Life Disability Instrument. Baseline physical impairments included: leg strength, leg speed of movement, knee range of motion (ROM), ankle ROM, leg strength asymmetry, kyphosis, and trunk extensor endurance. Structural equation modeling with latent growth curve analysis was used to identify the impairments that predicted participation at year 2, mediated by changes in activities. Models were adjusted for baseline participation, age, and gender.

Results: Leg speed and ankle ROM directly influenced participation in life roles during follow-up (βdirect = 1.39–4.53 and 4.70, respectively). Additionally, ankle ROM and trunk extensor endurance contributed indirectly to participation score at follow-up via effects on changes in activities (βindirect = −1.06 to −4.24 and 1.01 to 4.18, respectively).

Conclusions: Leg speed, ankle ROM, and trunk extensor endurance are key physical impairments predicting participation in life roles in older adults. These results have implications for the development of exercise interventions to enhance participation.

Key Words: Disablement—Disability evaluation—Geriatric assessment—Social participation—Rehabilitation

Participation is recognized as a key component of health associated with successful aging and with survival (1,2). Defined as a person's involvement in life situations, participation is one of the three main components in the World Health Organization's International Classification of Functioning, Disability and Health (ICF) (3). Up to 52% of adults aged above 50 years have restrictions in participation and this number increases with age (4). Importantly, participation restrictions represent the broad impact of health on people's lives; a concept more meaningful to individuals than problems in performing basic physical tasks and activities (5)—areas that have traditionally been emphasized in both geriatric care and gerontological research.

Within the ICF framework, participation is described as resulting from the complex interaction between a health condition or disease, body functions, and structures (anatomic and physiologic functioning of organs and body systems), activities (execution of actions by an individual), and personal and environmental factors (3). Examples of participation include involvement in home or community life such as taking care of the home or taking part in active recreation, while the activity domain includes discrete physical tasks such as walking and getting up from a chair. The ICF thus provides a useful framework for studying critical health outcomes and their determinants. Despite its recognized importance, gaps in evidence on the determinants of participation hinder efforts for disability prevention among older adults. While medical, demographic, and socioeconomic factors as well as some aspects of physical function have been shown to be associated with participation in prior work (6–11), less attention has been paid to the physical impairments at the body functions and structures level that may influence participation. This is important for informing evidence-based exercise interventions targeting the impairments most critical for participation in life roles among older adults. Although it is well established that exercise-based interventions improve activity limitations, evidence that exercise can improve participation is mixed (12,13). In part, this may be due to the lack of understanding of the specific impairments that underlie participation and can be targeted as part of interventions. To date, most exercise studies of older adults have emphasized leg strength and aerobic capacity (14,15); it is possible that interventions targeting other physical impairments would have greater effects.

The Boston Rehabilitative Impairment Study of the Elderly (Boston RISE) is a prospective cohort study of older primary care patients with the specific aim of identifying the physical impairments amenable to rehabilitation that are most relevant for activities and participation (16). The primary aim of this analysis of Boston RISE is to investigate the most important leg and trunk impairments that predict an older adult's subsequent level of participation at 2 years. This information is critical for informing evidence-based exercise interventions to enhance participation in life roles among older adults. In addition, although the ICF is widely accepted as a framework for describing factors that influence the disablement process, little empirical evidence exists confirming the pathways between impairments, activities, and participation. Prior work has shown that both impairments and activities affect participation; however, the limited work evaluating the interplay among these constructs suggests that the main influence of impairments is through an intermediary effect on activities which in turn, has a direct impact on participation (8,17). Therefore, our secondary aim is to determine whether changes in activities mediate the impact of leg and trunk impairments on participation over 2 years. Our structural model of disability tested the following hypotheses: (i) baseline leg and trunk impairments will be identified that predict participation at year 2, both directly and indirectly through changes in activities and (ii) there is a direct relationship between changes in activities over 2 years and participation at year 2. A conceptual model illustrating these relationships is provided in Figure 1.

Methods

Design and Participants

We analyzed 2 years of follow-up data from Boston RISE, a cohort study of 430 older adults. The study was approved by the relevant Institutional Review Boards and all participants provided written informed consent. Details of the methods have been described previously (16). Briefly, primary care patients in the Greater Boston Area who met the following criteria were recruited: age ≥65 years, ability to communicate in English, self-reported difficulty or task modification walking ½ mile and/or climbing stairs, no planned major surgery, and expectation of remaining in the area. Exclusion criteria comprised: significant visual impairment, uncontrolled hypertension, lower-extremity amputation, use of supplemental oxygen, myocardial infarction or major surgery in the previous 6 months, Mini-Mental State Exam score <18 and Short Physical Performance Battery (SPPB) score <4. Baseline assessments were conducted during an initial screening visit and a subsequent visit within 2 weeks. Follow-up assessments were conducted at 12 and 24 months.

Measures

Physical Impairments

Five categories of physical impairments were evaluated in Boston RISE: strength, speed of movement, range of motion (ROM), asymmetry, and trunk stability. This analysis focused on the following

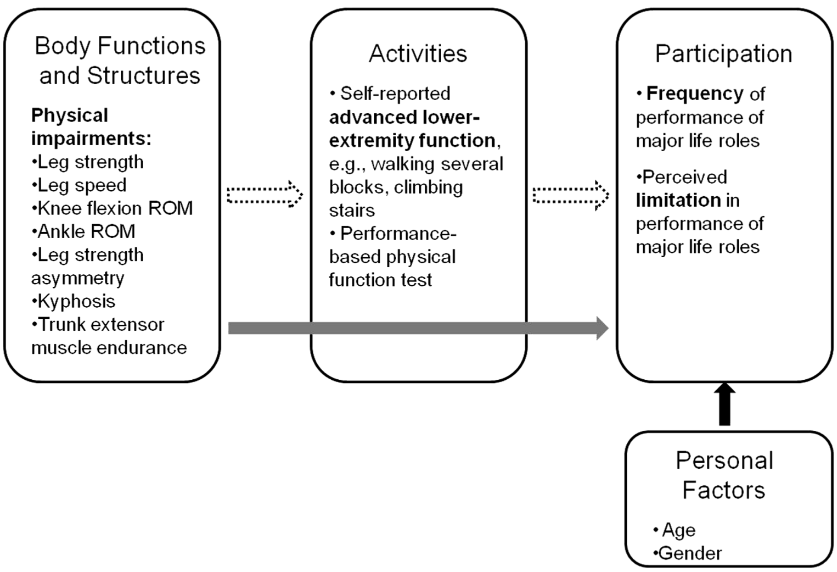

Figure 1. Conceptual model for the hypothesized relationships between physical impairments, activities, and participation. The solid arrow represents the direct effect of the impairment on participation and the dotted arrow represents the indirect effect mediated by activities.

leg and trunk impairments selected from each category based on their association with mobility activities shown previously (18): leg strength, leg speed, knee flexion ROM, ankle ROM, leg strength asymmetry, kyphosis, and trunk extensor endurance.

Participants underwent physical impairment testing during the second baseline visit; all measures were collected by a trained assessor using a standardized protocol. Assessment sessions lasted 2 hours and participants were permitted to rest as needed. Leg strength was the maximum value obtained from either leg using a 1-repetition maximum test on a Keiser A420 pneumatic leg press machine. Leg speed was calculated by dividing peak leg press power by the concurrently recorded force obtained from a single leg press repetition pushing out as quickly as possible (18). Knee and ankle ROM were measured with a goniometer. Ankle ROM was defined as intact or impaired based on dorsiflexion less than 90° or plantarflexion less than 20°. Strength asymmetry was calculated by dividing the higher leg strength value from the two sides by the lower strength value. Trunk extensor endurance was assessed by recording the time a participant was able to maintain a neutral trunk position with their lower body supported on a specialized plinth leaning forward at a 45° angle (19). Kyphosis was measured using a validated flexible ruler technique (20).

Activities

Activities were assessed using the advanced lower-extremity scale of the Late-Life Function Instrument (LLFI) (21). The LLFI assesses a broad range of activity limitations, consistent with the ICF model. Participants are asked to report their current degree of difficulty in performing 32 physical activities on a typical day without the help of someone else and without the use of assistive devices. Response options include: none, a little, some, quite a lot, and cannot do. The advanced lower-extremity function scale includes activities involving a significant degree of physical ability and endurance such as walking several blocks and climbing a flight of stairs without a handrail. The scale is calibrated from 0 to 100, where 0 indicates poor function and 100 indicates good function. Evidence supports the validity, reliability, and responsiveness of the LLFI in community-dwelling older adults (21–23).

The SPPB (24) was used as a secondary measure of activity in order to identify any additional physical impairments that might affect participation through a performance-based test of basic lower-extremity mobility.

Participation

Participation was assessed with the Late-Life Disability Instrument (LLDI) that measures both *frequency* of participation in 16 major life tasks and *limitations* in capability to perform each task consistent with the ICF model (25). Frequency dimension questions ask, "How often do you" do a specific task while limitation dimension questions ask "To what extent do you feel limited" in doing the task. Questionnaire items encompass a wide variety of participation tasks including: personal care; mobility and travel; exchange of information; social, community, and civic activities; home life; paid or volunteer work; and involvement in economic activities. Raw scores for each dimension are transformed to scaled scores from 0 to 100 with higher scores indicating a greater level of participation. The LLDI has strong construct validity and reliability, and is predictive of poor self-rated health, hospitalizations, and emergency room visits (23,25,26).

Statistical Analysis

We used structural equation modeling based on latent growth curve analysis to determine the baseline leg and trunk impairments that predicted participation directly at year 2, and indirectly through their effect on changes in activities (Figure 1). Two-step procedures were used to build the models. First, we used the unconditional latent growth model to describe the change in activity across the three time-points (baseline, year 1, and year 2). Second, we used a series of mediation models to examine whether change in activities would mediate the impact of the physical impairment on participation. To facilitate interpretation, the impairments were dichotomized using the median as the cut-point; this approach also yielded the best model fit. Results are presented in terms of performance on the physical impairment test above the median (ie, less impairment). For each physical impairment, the mediation effect was calculated as the product of the impact of that impairment on change in activities and the impact of change in activities on the participation outcome. Based on 5,000 bootstrap samples, the bias-corrected confidence interval was used to determine the statistical significance of the mediation effect. A mediation (indirect) effect was established if the 95% confidence interval did not include 0, indicating that change in activity mediates the impact of the impairment on participation. Models were adjusted for age, gender, and baseline level of participation. An effect size (ES) estimate for the impairments that predicted participation was calculated as $ES = \beta/SD$; where β is the direct/indirect coefficient for the impairment and *SD* is the standard deviation of the participation score at year 2. As a sensitivity analysis to examine the effect of missing data for the entire sample (n = 430), we applied two-stage maximum likelihood estimation (27): in the first stage, we estimated the saturated mean and covariance matrix of the observed variables based on the expectation–maximization algorithm. In the second stage, the mediation model parameters were estimated based on the saturated mean and covariance matrix generated from the first stage; the bias-corrected bootstrap method was used to create the confidence intervals (CIs) (28).

Overall model fit was examined using the chi-square test (non-significant p value indicates good model fit), comparative fit index (CFI) and Tucker Lewis index (TLI) (values >0.95 indicate acceptable fit), and root mean square error of approximation (*RMSEA*; values <0.05 indicate good model fit). Maximum likelihood estimation implemented in MPlus was used in the analysis.

Results

Participants' baseline characteristics and values for the leg and trunk impairments are provided in Table 1. Demographics were consistent with census data for older adults living in the recruitment area. At baseline, 430 Boston RISE participants had a mean age of 76.6 years, 68% were female and 82.6% were white. At 2 years, 366 participants remained in the study; 15 were deceased, 17 withdrew due to medical reasons and 32 withdrew due to non-health reasons or were lost to follow-up. Over 2 years, the mean change in activities measured by the LLFI was −3.23 ± 10.26 points; the mean change in SPPB score was 0.53 ± 1.77. At 2 years, mean participation scores were 51.12 ± 6.27 for the LLDI frequency scale and 69.11 ± 13.84 for limitation.

The direct and indirect effect coefficients and 95% CI for the leg and trunk impairments that predicted frequency of and limitations in participation are shown in Tables 2 and 3, respectively. Positive coefficients indicate a positive relationship between the physical impairment and subsequent participation; that is, better scores on the physical impairment tests predict higher participation in life roles. Specifically, the interpretation of β is the expected change in participation score associated with baseline performance above the median on the physical impairment test when holding all other model parameters constant. Both the participation frequency and limitation models met criteria for good model fit. For participation frequency χ^2 (df = 13) = 13.98, p = .3753; CFI = 0.999; TLI = 0.997; and $RMSEA$ = 0.015. For participation limitation χ^2 (df = 13) = 12.834, p = .4607; CFI = 1; TLI = 1; and $RMSEA$ = 0.

Participation Frequency Model

Change in activities measured with the LLFI had a significant direct effect on frequency of participation in life roles (standardized β = 2.19). Leg speed was the only physical impairment that had a direct effect on frequency of participation at year 2 (βdirect = 1.39, ES = 0.22) (Table 2). Ankle ROM (βindirect = −1.06, ES = −0.17) and trunk extensor endurance (βindirect = 1.01, ES = 0.16) had indirect effects on frequency of participation acting though changes in activities.

Table 1. Baseline Characteristics

Variable	*n*	mean ± *SD* or %
Age (years)	430	76.6 ± 7.0
Sex: women (%)	291	67.7
Race: white (%)	355	82.6
Number of chronic medical conditions	430	4.0 ± 1.9
Hypertension (%)	297	69.1
Osteoarthritis (%)	293	68.3
Heart disease (%)	158	36.8
Cancer (%)	140	32.6
Lung disease (%)	98	22.8
Diabetes (%)	82	19.1
Neurologic disease (%)	80	18.6
Mini-Mental State Exam (18–30)	430	27.4 ± 2.4
Habitual gait speed (m/s)	430	0.9 ± 0.2
Physical Activity Scale for the Elderly (0–793)	429	174.9 ± 69.6
Number using assistive device	118	27.4
Leg strength (N/kg)	387	9.45 ± 2.54
Limb velocity (m/s)	381	1.00 ± 0.25
Maximal knee flexion (°)	425	124.6 ± 13.6
Ankle range	429	
Intact (%)	307	71.6
Impaired (%)	122	28.4
Leg strength asymmetry	372	1.18 ± 0.29
Kyphosis (height/length × 100 of flexicurve instrument)	430	10.52 ± 3.08
Trunk extensor endurance (s per kg)	405	1.30 ± 0.88
Lower-extremity activities (0–100)	430	41.8 ± 14.7
SPPB (4–12)	430	8.7 ± 2.3
Participation frequency (0–100)	430	52.3 ± 5.7
Participation limitation (0–100)	430	68.9 ± 11.8

Note: SPPB = Short Physical Performance Battery.

Participation Limitation Model

Change in activities measured with the LLFI had a significant direct effect on limitations in participation in life roles (standardized β = 8.43). Leg speed (βdirect = 4.53, ES = 0.32) and ankle ROM (βdirect 4.70, ES = 0.34) both had a direct effect on limitations in participation at year 2. Ankle ROM (βindirect = −4.24, ES = −0.31) and trunk extensor endurance (βindirect = 4.18, ES = 0.30) had indirect effects on limitations in participation acting though changes in activities.

Models Using SPPB

In the models in which the LLFI was replaced with the SPPB for the activity measure, trunk extensor endurance had a significant indirect effect (βindirect = 6.0, 95% CI 0.91–20.67, ES = 0.43) on limitations in participation mediated by changes in the SPPB. No other physical impairments contributed to participation acting through the SPPB. Change in the SPPB had a direct effect on limitations in participation (β = 0.17, 95% CI 0.06–0.46) but no effect on participation frequency.

Sensitivity Analysis

In the models using maximum likelihood estimation for missing data, the same physical impairments predicted participation frequency and limitations, with the exception of ankle ROM, which did not predict either dimension of participation.

Discussion

To our knowledge, this is the first study to investigate the specific leg and trunk impairments amenable to treatment that are most predictive of an older person's participation in major life roles. Our results identified leg speed, ankle ROM, and trunk extensor endurance as key physical impairments predicting participation levels both directly and indirectly through changes in activities over 2 years of follow-up. In addition, these results validate a clinically relevant model of disablement with implications for late-life disability prevention.

Further understanding of the factors underlying the disablement process has been highlighted as a key research priority in geriatric rehabilitation (29). Despite widespread acceptance of the ICF as a framework for studying health and disability, there is scarce empirical evidence confirming the associations between impairments,

Table 2. Leg and Trunk Impairments Predicting Frequency of Participation in Life Roles Mediated by Changes in Activities Over 2 Years

Variable	Beta Coefficient (95% CI)		
	Direct Effect	Indirect Effect	Total
Changes in lower-extremity activities	0.82 (0.28 to 1.93)*	—	—
Ankle ROM	0.96 (−0.63 to 2.96)	−1.06 (−3.56 to −0.07)*	−0.10 (−1.29 to 1.11)
Leg speed	1.39 (0.05 to 3.28)*	−0.52 (−2.4 to 0.47)	0.86 (−0.25 to 2.00)
Trunk extensor endurance	−0.32 (−2.4 to 1.03)	1.01 (0.05 to 3.50)*	0.68 (−0.36 to 1.78)

Notes: Models adjusted for baseline participation, age, and sex. Coefficients are presented for physical impairment test performance above the median. Participation and activity score range: 0–100; higher is better. ROM = range of motion.

*95% CI does not contain 0

Table 3. Leg and Trunk Impairments Predicting Limitations in Participation in Life Roles Mediated by Changes in Activities Over 2 Years

Variable	Beta Coefficient (95% CI)		
	Direct Effect	Indirect Effect	Total
Changes in lower-extremity activities	2.87 (1.78 to 5.58)*	—	—
Ankle ROM	4.70 (0.15 to 10.70)*	−4.24 (−10.73 to −0.5)*	0.46 (−2.80 to 3.73)
Leg speed	4.53 (0.58 to 9.65)*	−1.81 (−6.81 to 1.80)	2.72 (−0.52 to 6.08)
Trunk extensor endurance	−0.86 (-6.05 to 3.13)	4.18 (0.93 to 10.81)*	3.33 (0.21 to 6.57)*

Notes: Models adjusted for baseline participation, age, and sex. Coefficients are presented for physical impairment test performance above the median. Participation and activity score range: 0–100; higher is better. ROM = range of motion.

*95% CI does not contain 0.

activities and participation. Our results support the hypotheses proposed in our conceptual model (Figure 1) and demonstrate that leg and trunk impairments have both a direct and indirect influence on subsequent participation in life roles acting through changes in activities. These data add to previous work on the disablement process (8,17) and provide a framework through which interventions to enhance participation can be identified. This is particularly important given the limited evidence demonstrating that exercise has a beneficial impact on participation in life roles (12,13,30).

A recent statement from the Australian and New Zealand Society for Geriatric Medicine (31) emphasized the need for research to determine the most effective types of exercise to optimize outcomes in older adults. There are two major trials to date showing that exercise in older adults can prevent or delay the onset of limitations in activities of daily living (15) and walking ability (14), respectively: the Fitness Arthritis and Seniors Trial (15) and the Lifestyle Interventions and Independence for Elders Study (14). Common to both studies is exercise focusing primarily on improving aerobic capacity and muscle strength. The current analysis from Boston RISE makes two important contributions that have the potential to inform future exercise trials: (i) we consider a comprehensive set of leg and trunk impairments linked to mobility status and (ii) we identify their impact on participation in life roles- a broader disability outcome of significance to individuals (5). Our results suggest that if the goal is to have an impact on participation, leg speed, ankle ROM, and trunk endurance are specific physical impairments that could be targeted to maximize the benefits of exercise for older adults.

It is interesting to note that leg speed had a direct effect on both frequency of participation in life roles and perceived limitations in participation. There is increasing literature documenting the importance of leg speed as a predictor of walking ability and other activity outcomes (32–35); however, ours is the first study to demonstrate its prospective association with participation, a global disability outcome. Given that leg speed was directly associated with participation, exercises aimed at increasing the speed generating capacity of the muscle (eg, repeated chair-stands where the patient is asked to stand up as quickly as possible) might have a positive impact on participation in life roles. While there is preliminary evidence demonstrating the potential of task-specific training emphasizing speed of movement for improving activity limitations (36), there is a need to evaluate exercise directly targeting this attribute as part of interventions designed to enhance participation in older adults.

Trunk extensor endurance had a consistent indirect effect on subsequent participation in life roles acting through changes in self-reported activities. It was also the only neuromuscular attribute to have an effect on participation acting through changes in a performance-based measure of activity (the SPPB). A hypothesized mechanism through which trunk endurance may influence participation is through its association with balance (34)—a complex skill required for daily living to avoid falls. Trunk endurance is likely critical for supporting activities requiring a higher degree of balance control which in turn, may have a significant impact on participation in life roles. This theory is supported by a recent meta-analysis which found that exercise interventions designed to reduce falls—many of which included balance exercises challenging trunk stability—had a small effect on participation in life roles (12). Regardless of the specific mechanism, our results suggest that activity-specific functional training with an emphasis on tasks that require trunk endurance might have a positive impact on participation.

Although the direct effect of ankle ROM on participation was positive, its indirect effect mediated by changes in activity was negative. This is a reflection of the negative association between baseline ankle ROM and change in activities; those with impaired ankle ROM at baseline showed greater improvement in activities over 2 years than those with intact ROM. These patients may have had more room to improve and possibly underwent rehabilitation. Further research is necessary to confirm this theory; however, the positive direct effect on participation limitation nevertheless highlights ankle ROM as another understudied target for geriatric research.

A unique strength of our analysis is that we evaluated two key dimensions of participation: frequency of and limitations in participation in major life roles. Although leg speed, ankle ROM, and trunk endurance had modest effects on both participation dimensions, the magnitude of their effect was greatest on limitations in participation. Of note, changes in advanced lower-extremity activities had an almost fourfold greater influence on limitations in participation than on frequency of participation. In addition, the SPPB, reflecting a more basic measure of activity, had no effect on participation frequency. These results extend prior work which showed differences in the responsiveness and predictive value of the LLDI limitation and frequency dimensions in older adults (26), and point to the need for further understanding of the myriad of other potential factors that might underlie the different dimensions of participation (11). This is particularly important for frequency of participation given its association with adverse outcomes such as hospitalizations and emergency room visits (26) and its tendency to show less improvement following interventions (23).

A limitation of this study is that our findings may not be generalizable to primary care patients living outside the Boston area. However, the participation scores in Boston RISE are similar to those of the LLDI development study (25), which included a more general sample of community-dwelling older adults. A small proportion of participants were unable to complete all the baseline impairment tests and, although loss to follow-up was low (16%), there were some missing outcome data at the 2-year assessment. Our sensitivity analysis using two-stage maximum likelihood estimation to account for both missing data and attrition suggested this had little impact on our findings, with the exception of ankle ROM, which was not retained as a predictor of participation. This finding along with our observation of a negative indirect effect of ankle ROM on participation warrant further investigation. Although patients with severe cognitive impairment were excluded from Boston RISE, it is unclear the extent to which error may have been introduced in the self-report measures by those with milder cognitive impairment. Finally, the Boston RISE study did not include a direct measure of aerobic capacity or a comprehensive evaluation of upper extremity impairments; further research is required to evaluate their impact on participation.

In summary, our results demonstrating the relationships between trunk and lower-extremity physical impairments, activities, and participation validate a conceptual model of disability in older adults that highlights opportunities for geriatric research and practice. In particular, we have shown that leg speed, ankle ROM, and trunk extensor endurance have direct and indirect effects on participation—a key component of health. Investigation of interventions for enhancing participation in life roles among older adults should include task-specific exercise emphasizing trunk stability and training directly targeting leg speed and ankle ROM.

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