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Meaningful Improvement in Gait Speed in Hip Fracture Recovery

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Abstract

OBJECTIVES—To estimate meaningful improvements in gait speed observed during recovery from hip fracture and to evaluate the sensitivity and specificity of gait speed changes in detecting change in self-reported mobility.

DESIGN—Secondary longitudinal data analysis from two randomized controlled trials

SETTING—Twelve hospitals in the Baltimore, Maryland, area.

PARTICIPANTS—Two hundred seventeen women admitted with hip fracture.

MEASUREMENTS—Usual gait speed and self-reported mobility (ability to walk 1 block and climb 1 flight of stairs) measured 2 and 12 months after fracture.

RESULTS—Effect size–based estimates of meaningful differences were 0.03 for small differences and 0.09 for substantial differences. Depending on the anchor (stairs vs walking) and method (mean difference vs regression), anchor-based estimates ranged from 0.10 to 0.17 m/s for small meaningful improvements and 0.17 to 0.26 m/s for substantial meaningful improvement. Optimal gait speed cut-points yielded low sensitivity (0.39–0.62) and specificity (0.57–0.76) for improvements in self-reported mobility.

CONCLUSION—Results from this sample of women recovering from hip fracture provide only limited support for the 0.10-m/s cut point for substantial meaningful change previously identified in community-dwelling older adults experiencing declines in walking abilities. Anchor-based estimates and cut points derived from receiver operating characteristic curve analysis suggest that greater improvements in gait speed may be required for substantial perceived mobility improvement in female hip fracture patients. Furthermore, gait speed change performed poorly in

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Dr. Magaziner consults with Eli Lilly, Amgen, and Glaxo SmithKline Pharmaceuticals; has served on advisory boards for Novartis and Glaxo SmithKline; and has grants from Novartis, Eli Lilly, and Merck.

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discriminating change in self-reported mobility. Estimates of meaningful change in gait speed may differ based on the direction of change (improvement vs decline) or between patient populations.

Keywords

physical function; physical performance measures; mobility; minimum clinical difference; meaningful change

Performance-based measures of physical function have become the criterion standard for evaluating the health of older persons, in large part because of their responsiveness to change and associations with future health and function in older adults.¹ As performance measures are increasingly used as surrogate end points,^{2,3} there is growing interest in determining what constitutes clinically meaningful change in these measures⁴ (change that a patient would perceive as beneficial⁵ or that is closely associated with important outcomes).

Poor functional performance as measured by slow or declining gait speed is related to risk of disability, hospitalization, and mortality,^{6–9} but improvements in gait speed are also observed in the older population and are related to reductions in mortality risk.¹⁰ Previous estimates of meaningful change have been primarily based on report of declines,⁴ but functional ability in older adults is dynamic, involving decline and recovery,^{11,12} so it is important to identify what constitutes meaningful improvement in performance measures.

Hip fracture provides a useful context in which to study the recovery process in older adults. Hip fractures typically result in lost mobility and functional independence, with as many as 45% of those who are community dwelling at the time of their fracture discharged to institutions after hospitalization,¹³ but most areas of function improve in the year after fracture, including activities of daily living (ADLs) disability, gait, and balance.¹⁴

The purpose of this study was to estimate meaningful improvements in gait speed during the first year of hip fracture recovery. Data from women admitted to Baltimore-area hospitals with a diagnosis of hip fracture who participated in two exercise intervention trials were used to generate meaningful change estimates using distribution- and anchor-based methods. Additional analysis evaluated the utility of gait change cutpoints in discriminating improvements in self-reported mobility.

METHODS

Participants

Participants were women with hip fracture drawn from the fourth and fifth cohorts in the Baltimore Hip Studies (BHS-4 & BHS-5). BHS-4 was a clinical trial designed to test the effects of an exercise intervention (the Exercise Plus (EP) program) on bone and muscle loss after hip fracture.^{15,16} BHS-5 was a clinical trial with a two-by-two factorial design intended to isolate the effects of motivation and exercise in the EP program.^{17,18} In both studies, gait speed was evaluated 2 and 12 months after fracture. Data from BHS-4 and BHS-5 were combined for the current study to increase sample size and reliability of estimates. For the purposes of this analysis, 2 months was used as the baseline, and analysis focused on the change in gait speed between the 2- and 12-month follow-up visits.

There were 180 participants recruited for BHS-4 between 1998 and 2004 and 208 participants enrolled in BHS-5 between 2000 and 2004 from 12 hospitals in the Baltimore area.

Eligible participants for both studies were community-dwelling women aged 65 and older who sustained a nonpathological fracture within 72 hours before hospital admission and had the fractured hip surgically repaired. Participants had to be able to walk without human assistance before the fracture and to score 20 points or higher on the Folstein Mini-Mental State Examination (MMSE). Individuals were excluded on the basis of medical conditions that are a contraindication to exercise (cardiovascular disease, respiratory problems, neuromuscular conditions, bone disease, metastatic cancer, cirrhosis, end-stage renal disease, and other conditions that increase the risk of falls during exercise or increase the risk of injury after a fall). Exclusion criteria in the two studies were the same except for one item: BHS-4 excluded participants who had surgical hardware in the contralateral hip. To increase comparability across the samples, 14 BHS-5 participants with surgical hardware from a prior fracture were excluded. These selection criteria resulted in a relatively high-performing sample of women with hip fracture. The institutional review boards of the hospitals and the University of Maryland, Baltimore, approved the study protocols. Of the 374 potentially eligible participants, one died before the 2-month interview, 16 were unable to complete the measures, and 95 were missing data 2 months after their fracture. Of the remaining 262 participants with complete 2-month data, 13 died before the 12-month interview, 10 were unable to complete the measures, and 22 were missing, for a final sample of 217 participants with complete 2- and 12-month gait speed and self-reported mobility data.

Gait Speed

Gait speed was measured in BHS-4 and BHS-5 2 and 12 months after hip fracture by timing participants walking 3 m at their usual pace. Participants were instructed to stand with both feet together at the starting line, to walk to the other end of the course “at your usual speed, just as if you were walking down the street to go to the store,” and to continue walking past the end of the course, stopping only after they had crossed the line. A practice walk was performed, and gait speed was then recorded using a stopwatch in a single trial. Participants were allowed to use walking aids (e.g., cane, walker) if their physician had told them to do so. Otherwise, they were encouraged to walk unassisted.

Anchor Measures

Self-reported physical function was measured using the Physical Function domain of the Medical Outcomes Study 36-item Short-Form questionnaire (PF-SF36). Consistent with previous research,⁴ two mobility items were used as anchors: ability to walk one block and ability to climb one flight of stairs. Improvements in these self-reported mobility items may represent differences in physical function that are salient to the individual. Additionally, self-reported difficulty walking up stairs or walking a short distance is frequently used as a definition of mobility disability,^{8,19–21} and gait speed is an important predictor of this outcome.⁸ Therefore, it is of interest to identify meaningful gait speed improvement based on its association with changes in self-reported mobility. Participants rated their ability as limited a lot, limited a little, or not limited at all.²² Small improvement between 2 and 12 months was defined as change from limited a lot to limited a little or from limited a little to not limited. Substantial improvement was defined as movement from limited a lot to not limited. Because only a small number of participants reported declines in ability to climb stairs ($n=14$) or walk ($n=16$) between 2 and 12 months, participants who declined were excluded from anchor-based analysis, which focused only on improvements in gait speed.

Data Analysis

Distribution-based methods use the standard deviation of the measure (gait speed) to define meaningful differences, whereas anchor-based methods relate change in gait speed to change in some measure thought to reflect important differences in function (the anchor, i.e.,

self-reported mobility) from the view of the individual.⁴ Distribution-based approaches were used to calculate meaningful differences based on effect size. Effect size-based estimates were computed as $0.2 \times \sigma$ for a small change and $0.5 \times \sigma$ for a substantial change (σ = the standard deviation).⁴ These effect sizes correspond to small and moderate effects as previously defined by Cohen.²³

Two types of longitudinal comparisons of change in gait speed for deriving anchor-based estimates were considered. *Meaningful change* is used to refer to analysis of longitudinal within-person change scores (with a focus on meaningful improvement) and *meaningful difference in change* to refer to differences in within-person change scores across groups. Although these terms have been treated similarly in existing research on meaningful changes in performance measures,²⁴ they have different implications for study design and interpretation of results. For example, an intervention that aims to improve walking speed might be considered effective if it resulted in increased walking speed within individuals (meaningful change) or if patients in the intervention group increased their walking speed more than patients in the control group (meaningful difference in change), depending on the study design. Said another way, meaningful difference in change is assessed by comparing a particular level of change with “background” change.

Anchor-based estimates of meaningful change used two analytical approaches. First, descriptive statistics were used to compare change in gait speed within and between categories of change in SF-36 mobility measures used as anchors (ability to walk 1 block and ability to climb 1 flight of stairs). Participants who reported no difficulty at 2 months were excluded from anchor-based analysis, because they were not eligible to improve. For this analysis, improvement was operationalized as a three-level categorical variable (no change, small improvement, substantial improvement). Small and substantial meaningful improvements were estimated as the average gait speed change score occurring in improvement groups. In addition to estimating meaningful changes, meaningful differences in change were estimated by comparing the difference in gait speed change across improvement groups. In this case, the mean change in gait speed of those who did not report improved mobility was treated as the background change, and the mean gait speed change of those who experienced self-reported improvements was compared with the background change.

Second, the gait speed change threshold that optimized sensitivity and specificity for prediction of change in SF-36 anchors was identified using receiver operating characteristic (ROC) curves. The graph of the ROC curve provides the sensitivity (the proportion of participants correctly classified as showing improvement) on the *y*-axis and 1–specificity (the proportion of participants incorrectly classified as showing improvement) on the *x*-axis. A cut point that yields the minimal value for the equation $(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2$ is considered optimal.²⁵ For ROC analysis, change in self-reported mobility was operationalized as two dichotomous outcome variables: any improvement (including small and substantial) versus no change and substantial improvement versus no change. For all analyses, $P < .05$ was considered statistically significant.

Sensitivity analysis was conducted to address missing data using weighted estimating equations (WEEs).²⁶ WEEs address potential selection bias from item nonresponse by weighting participants based on the inverse probability of being observed. Weights were developed from a logistic regression predicting the odds of having complete data based on age, Charlson comorbidity index, race, marital status, education, and prefracture lower extremity ADL difficulties. Results of weighted analysis upweight participants most similar to those with missing data.

RESULTS

Table 1 provides sample characteristics for participants with complete data at the 2- and 12-month follow-up visits ($n = 217$). The mean age of participants was 81.0, and the mean gait speed at baseline (2 months after fracture) was 0.36 m/s. The majority of participants were at least somewhat limited in stair climbing (73%) and walking one block (67%) at baseline. By 12 months after fracture, gait speed had increased to a mean of 0.52 m/s, and fewer than half of participants were limited in stair climbing (41%) or walking one block (36%).

Participants' self-reported functional change is shown in Table 2. Only 14 participants reported declines in stair climbing ability, and 16 reported declines in walking one block. Approximately half of participants ($n = 106$, 49%) reported no change in stair climbing ability between 2 and 12 months after fracture, but 45% reported improvement. Similarly, 45% of participants reported improvement in walking ability between 2 and 12 months after fracture.

Based on the standard deviation of gait speed at baseline (0.17), the distribution-based (effect size-based) estimate of a small difference in walking speed was 0.03 m/s, and the estimate of a substantial difference was 0.09 m/s. Anchor-based estimates are provided in Table 3. Participants who reported no change in stair climbing ability had an average 0.11-m/s increase in gait speed. Participants who reported a small improvement and those who reported a substantial improvement in ability to climb stairs had an average 0.17-m/s increase in gait speed. Participants who reported no change in ability to walk one block experienced an average 0.12-m/s increase in gait speed. Gait speeds increased by an average of 0.17 m/s in participants with small improvements in reported walking ability and by 0.24 m/s in participants with substantial improvements in reported walking ability.

Meaningful differences in change were estimated as the difference between gait speed change in those with no self-reported mobility change and those with improvements in reported mobility. For stair climbing, gait speed in the small- and substantial-improvement groups increased an average of 0.05 to 0.06 m/s more than in the no-change group, but neither of these differences was statistically different from 0, as indicated by the confidence intervals. Gait speed increased 0.06 m/s more in participants whose self-reported ability to walk one block showed small improvements than in those with no change, but this difference was not statistically significant. Gait speed improved significantly more (0.13 m/s) in participants who experienced substantial improvements in walking ability than in those with no improvements.

Results of ROC curve analysis are shown in Figure 1. The gait speed change cut point that maximized sensitivity and specificity with respect to any improvement in reported stair climbing ability was 0.10 m/s, which had sensitivity of 61.9% and specificity of 57.1%. The positive likelihood ratio was 1.44, indicating that participants with a gait speed increase of at least 0.10 m/s were 44% more likely to have had some improvement in their stair climbing ability than those who did not. The cut point for substantial improvements in stair climbing ability was 0.26 m/s, which had sensitivity of 38.5% and specificity of 75.6%, yielding a positive likelihood ratio of 1.58. The area under the ROC curve (AUC) in models predicting improvements in self-reported stair climbing ability based on changes in gait speed was between 0.52 and 0.59.

Results were similar for self-reported walking ability. The optimal gait speed change cutpoint identified for any improvement in reported walking ability was 0.13 m/s, which had sensitivity of 61.9% and specificity of 63.4%, yielding a positive likelihood ratio of 1.69. The optimal cutpoint for substantial improvements in walking ability was 0.26 m/s, which had sensitivity of 55.6% and specificity of 75.8%, yielding a positive likelihood ratio of

2.30. The AUC in models predicting improvements in self-reported walking ability was between 0.61 and 0.64.

Descriptive analyses and ROC analyses were repeated using WEE to address missing data. Results of these sensitivity analyses were similar to results presented in Table 3 and Figure 1.

DISCUSSION

The purpose of this analysis was to estimate meaningful improvements in gait speed during hip fracture recovery. This article extends prior research on meaningful change by focusing specifically on improvement in a patient population and by using ROC curves to estimate the sensitivity and specificity of gait speed change cutpoints for predicting changes in self-reported mobility difficulty. Distribution-based analysis provides some support for the 0.10-m/s cutpoint previously identified in the literature in community-dwelling older adults,^{4,10} but anchor-based estimates and cutpoints derived from ROC curve analysis suggest that the commonly used 0.10-m/s cut point might be considered a small change during hip fracture recovery. In this sample of women with hip fracture, the results suggest that a substantial improvement in self-reported function was associated with much larger changes (up to 0.26 m/s). This is consistent with the perspective that clinically meaningful differences are dynamic and context specific, such that they may vary between populations and stages of disability and recovery.²⁷

Comparison with Prior Studies

Much of the existing research on meaningful change in gait speed has been based on community-dwelling samples in which the majority of participants experienced declines in observed gait speed and self-reported mobility.⁴ At least three existing studies have specifically examined meaningful improvements in gait speed. One examined meaningful change in gait speed in the Lifestyle Interventions and Independence for Elders (LIFE) pilot, a randomized clinical trial of a physical activity intervention in sedentary older adults. It reported estimates of meaningful differences in gait speed ranging from 0.06 to 0.10 for small improvements and 0.03 to 0.10 for substantial improvements after subtracting estimates from the group that did not change (i.e., calculating the meaningful difference in change), but it had limited power to determine whether these effects differed from estimates of meaningful decline.²⁴ Another study examined meaningful change in gait speed after hip fracture using the minimum detectable change on the Timed-Up-and-Go (TUG) test as an anchor and identified 0.10 m/s as the change in gait speed most predictive of improvements on the TUG.²⁸ This approach is different from the focus of the current analysis, which is to identify changes that are meaningful to the patient as identified according to patient self-report of mobility. The third study examined meaningful change in gait speed within 60 days after stroke using improvement on the modified Rankin Scale (mRS) as an anchor and identified 0.16 m/s as the change in gait speed most predictive of improvements on the mRS. It also reported low sensitivity (73.9%) and specificity (57.0%) for gait speed as a predictor of changes in functional status.²⁷

Results are compared with prior studies that used similar analytical approaches in Table 4. Estimates of meaningful differences based on effect size are similar to those from other studies,^{4,24} although anchor-based estimates are higher in the current study, particularly for substantial change, than in previous research. Additionally, ROC curve estimates suggest that gait speed changes most predictive of substantial increases in self-reported mobility were approximately 0.26 m/s. These results suggest that a cut point of 0.10 m/s may be reasonable in planning an intervention in which the goal is to detect a minimally significant change. However, if the goal of an intervention is to produce substantial improvements (e.g.,

in an expensive intervention that needs to produce large effects to be cost effective), the larger cut point may be a more-appropriate outcome.

Increases in gait speed are consistent with recovery from hip fracture, and even individuals who reported no change in mobility limitations experienced increases in gait speed. Prior research has also documented increases in gait speed in the absence of changes in self-reported mobility.²⁴ When gait speed is changing for an entire population, one approach to determining meaningful change is to compare differences in the rate of change between groups. (Did one group increase more than another?) The estimates of meaningful differences in change from the current study are consistent with this approach and are similar to those found in an analysis of the LIFE pilot.²⁴

Gait Speed Recovery in the Context of Fracture

Mean improvement in gait speed of participants reporting no change in stair-climbing ability or walking ability was 0.11 to 0.12 m/s, which previous research suggests should be meaningfully associated with change in reported mobility.²⁴ Gait speed may function differently as an indicator of mobility in a hip fracture population experiencing dynamic changes in physical function than it does in typical community-dwelling older persons. For example, baseline gait speed in the sample was 0.36 m/s, compared with 0.7 to 0.9 m/s in previous studies,^{4,24} and it is possible that what constitutes “meaningful” change may depend on baseline function or on the direction of change (improvement vs decline). Additionally, the process of recovery from hip fracture may uniquely influence women’s perceptions of changes in walking ability, such that meaningful improvements in this group may differ from improvements in other types of recovery or experienced as a result of an intervention. It is also possible that hip fracture may influence perceptions of the meaning of “limited” walking and stair climbing ability in ways that alter the usefulness of self-reported mobility as an anchor in older adults with hip fracture. For instance, even if participants have experienced substantial gains during the recovery process, if they are experiencing more limitations than they were before the fracture, they may not perceive that their physical function has improved since the fracture. Alternately, people with hip fracture may adjust to new impairments and no longer report being limited, even if they have experienced little or no improvement. Finally, gait speed improvements in people with hip fracture may not represent maximum improvement in functional capacity during recovery, because participants may intentionally slow gait speed to reduce fall risk. Nonetheless, these findings raise questions about the applicability of existing estimates of meaningful change in gait speed across diverse patient populations when evaluated against perceived limitations in climbing stairs or walking one block.

Additionally, gait speed change performed relatively poorly as an indicator of change in self-reported mobility. This was especially true for changes in stair climbing, for which the AUC suggested that gait speed change performed little better than chance in predicting changes in reported stair climbing ability (AUC =0.52–0.59) and positive likelihood ratios (LR+) were less than 2, indicating a small shift in probability that a participant would be likely to report a true change in stair-climbing ability.²⁹ Gait speed change performed slightly better in predicting changes in self-reported walking ability (AUC =0.61–0.64, LR +=1.69–2.30). Although gait speed is widely regarded as a proxy for disability risk, gait speed improvements in this population of women recovering from hip fracture did not correspond well to improvements in self-reported limitations in walking or stair-climbing ability.

Limitations

There are important limitations to this analysis. First, the sample was confined to women who had experienced a hip fracture. As noted above, hip fracture may influence the association between gait speed and self-reported mobility in important ways. Second, the restrictive selection criteria for the intervention study data used here limit the sample to healthy women with hip fracture, so results may not be generalizable to frailer women with hip fracture. Third, missing data may have influenced the estimates. Gait speed measures were completely unavailable for 30% of participants, and an additional 12% did not complete gait speed measurement at follow-up, although sensitivity analyses showed robust study conclusions. Fourth, the anchor-based approach used relies on patients' experiences and reports of mobility limitations. Performance measures have become the criterion standard in part because of concerns about self-report bias. Using self-reports to validate change in performance measures is useful in determining how changes in walking speed are associated with patients' experience of mobility disability, but the limitations of self-reported measures continue to be of central importance. Finally, measurement error in gait speed may play a role in understanding meaningful changes. Unfortunately, information on test-retest reliability was not available in the present study, so it was not possible to calculate the standard error of the measurement. In another study of gait speed after hip fracture, the standard error of the measurement was 0.04 m/s.²⁸

CONCLUSION

There is increasing interest in the use of change in performance measures as primary end points in clinical trials.^{4,30} The results of the current study suggest that estimates of meaningful change in gait speed in this context should be applied to diverse patient populations with caution. An estimate that is based on the average difference in gait speed between two groups (e.g., improvement vs no change) may not be optimal for predicting group membership, as shown by ROC analysis. Additionally, cutpoints may differ based on the direction of change (improvement vs decline) or between patient populations. Mobility decline is a complex, multifactorial process,^{31,32} and a single predictor, even one as closely linked to mobility difficulty as walking speed, may not adequately identify older persons likely to experience improvements in perceived mobility function.

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References

1. Guralnik J, Ferrucci L. Assessing the building blocks of function: Utilizing measures of functional limitation. *Am J Prev Med.* 2003; 25:112–121. [PubMed: 14552934]
2. Morey MC, Peterson MJ, Pieper CF, et al. The Veterans LIFE Study: A randomized trial of primary care based physical activity counseling for older men. *J Am Geriatr Soc.* 2009; 57:1166–1174. [PubMed: 19467149]
3. LIFE Study Investigators. Effects of a physical activity intervention on measures of physical performance: Results of the Lifestyle Interventions and Independence for Elders Pilot (LIFE-P) Study. *J Gerontol A Biol Sci Med Sci.* 2006; 61A:1157–1165.

4. Perera S, Mody S, Woodman R, et al. Meaningful change and responsiveness in common physical performance measures in older adults. *J Am Geriatr Soc.* 2006; 54:743–749. [PubMed: 16696738]
5. Jaeschke R, Singer J, Guyatt GH. Measurement of health status: Ascertaining the minimal clinically important difference. *Control Clin Trials.* 1989; 10:407–415. [PubMed: 2691207]
6. Studenski S, Perera S, Patel K, et al. Gait speed and survival in older adults. *JAMA.* 2011; 305:50–58. [PubMed: 21205966]
7. Guralnik J, Ferrucci L, Pieper C, et al. Lower extremity function and subsequent disability consistency across studies, predictive models, and value of gait Speed alone compared with the short physical performance battery. *J Gerontol A Biol Sci Med Sci.* 2000; 55A:M221–M231. [PubMed: 10811152]
8. Cesari M, Kritchevsky SB, Penninx BWJH, et al. Prognostic value of usual gait speed in well-functioning older people; Results from the Health, Aging and Body Composition Study. *J Am Geriatr Soc.* 2005; 53:1675–1680. [PubMed: 16181165]
9. Perera S, Studenski S, Chandler JM, et al. Magnitude and patterns of decline in health and function in 1 year affect subsequent 5-year survival. *J Gerontol A Biol Sci Med Sci.* 2005; 60A:894–900. [PubMed: 16079214]
10. Hardy S, Perera S, Roumani Y, et al. Improvement in usual gait speed predicts better survival in older adults. *J Am Geriatr Soc.* 2007; 55:1727–1734. [PubMed: 17916121]
11. Crimmins EM, Saito Y. Getting better and getting worse: Transitions in functional status among older Americans. *J Aging Health.* 1993; 5:3–36.
12. Hardy SE, Gill TM. Recovery from disability among community-dwelling older persons. *JAMA.* 2004; 292:2115–2124. [PubMed: 15523072]
13. Magaziner J, Simonsick EM, Kashner TM, et al. Predictors of functional recovery one year following hospital discharge for hip fracture: A prospective study. *J Gerontol Med Sci.* 1990; 45:M101–M107.
14. Magaziner J, Hawkes W, Hebel JR, et al. Recovery from hip fracture in eight areas of function. *J Gerontol A Biol Sci Med Sci.* 2000; 55A:M498–M507. [PubMed: 10995047]
15. Orwig DL, Hochberg M, Yu-Yahiro J, et al. Delivery and outcomes of a year-long home exercise program after hip fracture: A randomized controlled trial. *Arch Intern Med.* 2011; 171:323–331. [PubMed: 21357809]
16. Yu-Yahiro JA, Resnick B, Orwig D, et al. Design and implementation of a home-based exercise program post-hip fracture: The Baltimore Hip Studies experience. *PM&R.* 2009; 1:308–318.
17. Resnick B, Orwig D, Yu-Yahiro J, et al. Testing the effectiveness of the Exercise Plus Program in older women post hip fracture. *Ann Behav Med.* 2007; 34:67–76. [PubMed: 17688398]
18. Resnick B, Magaziner J, Orwig D, et al. Evaluating the components of the Exercise Plus Program: Rationale, theory and implementation. *Health Educ Res.* 2002; 17:648–658. [PubMed: 12408209]
19. Fried LP, Bandeen-Roche K, Chaves PHM, et al. Preclinical mobility disability predicts incident mobility disability in older women. *J Gerontol A Biol Sci Med Sci.* 2000; 55A:M43–M52. [PubMed: 10719772]
20. Stenholm S, Koster A, Alley DE, et al. Joint association of obesity and metabolic syndrome with incident mobility limitation in older men and women—Results from the Health, Aging, and Body Composition Study. *J Gerontol A Biol Sci Med Sci.* 2009; 65A:84–92. [PubMed: 19822624]
21. Stenholm S, Alley D, Bandinelli S, et al. The effect of obesity combined with low muscle strength on decline in mobility in older persons: Results from the In-CHIANTI Study. *Int J Obes.* 2009; 33:635–644.
22. Ware JF, Sherbourne CD. The MOS 36-item Short-Form Health Survey (SF-36): Conceptual framework and item selection. *Med Care.* 1992; 30:473–483. [PubMed: 1593914]
23. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences.* 2. Hillsdale, NJ: L. Erlbaum Associates; 1988.
24. Kwon S, Perera S, Pahor M, et al. What is a meaningful change in physical performance? Findings from a clinical trial in older adults (the LIFE-P Study). *J Nutr Health Aging.* 2009; 13:538–544. [PubMed: 19536422]
25. Akobeng AK. Understanding diagnostic tests 3: Receiver operating characteristic curves. *Acta Paediatr.* 2007; 96:644–647. [PubMed: 17376185]

26. Shardell MD, Miller RR. Weighted estimating equations for longitudinal studies with death and non-monotone missing time-dependent covariates and outcomes. *Stat Med*. 2008; 27:1008–1025. [PubMed: 17579923]
27. Tilson JK, Sullivan KJ, Cen SY, et al. Meaningful gait speed improvement during the first 60 days poststroke: Minimal clinically important difference. *Phys Ther*. 2010; 90:196–208. [PubMed: 20022995]
28. Palombaro KM, Craik RL, Mangione KK, et al. Determining meaningful changes in gait speed after hip fracture. *Phys Ther*. 2006; 86:809–816. [PubMed: 16737406]
29. Jaeschke R, Guyatt GH, Sackett DL. Users' guides to the medical literature, III: How to use an article about a diagnostic test, B: What are the results and will they help me in caring for my patients? The Evidence-Based Medicine Working Group. *JAMA*. 1994; 271:703–707. [PubMed: 8309035]
30. Working Group on Functional Outcome Measures for Clinical Trials. Functional outcomes for clinical trials in frail older persons: Time to be moving. *J Gerontol A Biol Sci Med Sci*. 2008; 63A:160–164.
31. Guralnik JM, LaCroix AZ, Abbott RD, et al. Maintaining mobility in late life. I. Demographic characteristics and chronic conditions. *Am J Epidemiol*. 1993; 137:845–857. [PubMed: 8484376]
32. Ferrucci L, Bandinelli S, Benvenuti E, et al. Subsystems contributing to the decline in ability to walk: Bridging the gap between epidemiology and geriatric practice in the InCHIANTI study. *J Am Geriatr Soc*. 2000; 48:1618–1625. [PubMed: 11129752]

Figure 1.

Receiver operating characteristic curves predicting (A) any and (B) substantial improvement in climbing one flight of stairs and (C) any and (D) substantial improvement in walking one block according to change in gait speed in women with hip fracture: test characteristics (95% confidence interval).

Table 1**Participant Characteristics (N =217)**

Characteristic	Value
Before fracture	
Age, mean $\pm$ SD	81.0 $\pm$ 6.9
Charlson Comorbidity Index, mean $\pm$ SD	1.1 $\pm$ 1.3
Lower extremity activity of daily living difficulties, mean $\pm$ SD	1.4 $\pm$ 2.0
Education, years, mean $\pm$ SD	12.4 $\pm$ 3.2
Nonwhite, n (%)	8 (4)
Married, n (%)	73 (34)
Baseline (2 months after fracture)	
3-m gait speed, m/s, mean $\pm$ SD	0.36 $\pm$ 0.17
Climbing one flight of stairs, n (%)	
Limited a lot	74 (34)
Limited a little	84 (39)
Not limited at all	59 (27)
Walking one block, n (%)	
Limited a lot	49 (23)
Limited a little	95 (44)
Not limited at all	73 (34)
Follow-up (12 months after fracture)	
3-m gait speed, m/s, mean $\pm$ SD	0.52 $\pm$ 0.24
Climbing one flight of stairs, n (%)	
Limited a lot	36 (17)
Limited a little	52 (24)
Not limited at all	129 (59)
Walking one block, n (%)	
Limited a lot	17 (8)
Limited a little	61 (28)
Not limited at all	139 (64)

SD = standard deviation.

Table 2
Distribution of Change in Self-Reported Function from 2 to 12 Months After Fracture

Mobility Indicator	n (%)					Total
	Substantial Decline	Small Decline	No Change	Small Improvement	Substantial Improvement	
Climbing one flight of stairs	1 (0.5)	13 (6.0)	106 (48.8)	71 (32.7)	26 (12.0)	217 (100.0)
Walking one block	1 (0.5)	15 (6.9)	104 (47.9)	79 (36.4)	18 (8.3)	217 (100.0)

Table 3

Anchor-Based Meaningful Change Estimates from 2 to 12 Months After Fracture

Anchor Change	Gait Speed, Mean (95% Confidence Interval) (n)	
	Limitations Climbing One Flight of Stairs	Limitations Walking One Block
Meaningful change [*]		
No change	0.11 (0.06–0.16) (56)	0.12 (0.05–0.18) (41)
Small improvement	0.17 (0.12–0.22) (71)	0.17 (0.12–0.22) (79)
Substantial improvement	0.17 (0.07–0.27) (26)	0.25 (0.15–0.34) (18)
Meaningful difference in change [†]		
Small improvement versus no change	0.05 (– 0.02–0.13)	0.06 (– 0.03–0.14)
Substantial improvement versus no change	0.06 (– 0.04–0.16)	0.13 (0.02–0.25)

^{*} Calculated as mean change in gait speed between 2 and 12 months in groups identified according to change in self-reported limitations.

[†] Calculated as difference in mean change in gait speed between mobility groups identified according to change in self-reported limitations.

Table 4

Comparison of Meaningful Change Estimates Between Studies

Estimate Characteristics	Meaningful Difference			Meaningful Decline		Meaningful Improvement		Meaningful Difference in Improvement	
	Perera et al. ⁴	Kwon et al. ²⁴	Current Study	Perera et al. ⁴	Kwon et al. ²⁴	Current Study	Current Study	Kwon et al. ²⁴	Current Study
Method	Effect size	Effect size	Effect size	SF-36 anchor	Mobility anchor	SF-36 anchor	Receiver operating characteristic curve with SF-36 anchor	Mobility anchor	SF-36 anchor
Distance, m	4	4	3	4	4	3	3	4	3
Small change, m/s	0.05	0.03	0.03	0.00–0.04	0.02–0.03	0.17	0.10–0.13	0.06–0.10	0.06
Substantial change, m/s	0.12	0.08	0.09	0.08–0.11	0.01–0.06	0.17–0.25	0.26	0.03–0.10	0.06–0.13

SF-36 = Medical Outcomes Study 36-item Short-Form Survey Mobility Items.