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Functional Improvement After One- and Two-Eyed Cataract Surgery in the Salisbury Eye Evaluation

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Abstract

Purpose—To determine the impact cataract and cataract surgery have on clinical measurements of vision, reading speed, objective mobility performance, and subjective visual functioning.

Design—Prospective, population-based study

Participants—1,739 Salisbury Eye Evaluation (SEE) participants without previous cataract surgery with bilateral baseline best corrected visual acuity (BCVA) of logarithm of the Minimum Angle of Resolution (logMAR) 0.3 (20/40 or better) or cataract surgery between round 1 and 2.

Methods—Participants were categorized based on cataract surgery by round 2 into: no surgery, unilateral surgery, or bilateral surgery. Visual performance, mobility-based tasks, and the Activities of Daily Vision Scale (ADVS) were measured at baseline and two years. Mobility score was converted into a z-score, by subtracting the participant's time from the population baseline average then dividing by the standard deviation. Comparisons were made between the no surgery and surgery groups using multivariate linear regression.

Main Outcome Measures—Change in bilateral best corrected visual acuity in logMAR, contrast sensitivity, reading speed in words per minute (wpm), mobility score, and ADVS.

Results—During the study period, 29 participants had cataract surgery on both eyes, 90 had unilateral surgery, and 1,620 had none. After adjusting for baseline value, demographics, depression and mental status, the unilateral surgery group BCVA improved 0.04 logMAR ($p=0.001$) and the bilateral group improved 0.13 compared to no surgery ($p<0.001$). Overall mobility declined in all groups. The unilateral group z-score declined 0.18 more than the no surgery group ($p=0.02$), while the bilateral group showed a 0.18 z-score improvement compared to no surgery ($p=0.19$). Change in reading speed significantly improved in the unilateral and bilateral groups compared to no surgery (12 and 31 words per minute, respectively). The bilateral surgery group showed significant positive change in ADVS compared to no surgery (5 points relative improvement, $p = 0.01$), while the unilateral group showed a 5-point relative decline ($p<0.001$).

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Conclusions—Cataract negatively affects both subjective quality of life and objective performance measures. Unilateral cataract surgery improves visual functioning, but the largest gains are found in patients who undergo second-eye cataract surgery. This finding supports second-eye cataract surgery for patients with visual or functional complaints even after successful first-eye surgery.

Introduction

Vision impairment has been shown to increase physical disability, decrease mobility, and even has been correlated with increased mortality.^{1,2} It also has been associated with decreased physical and mental health on the generic Short Form-36 quality of life measure.³ Cataract, the most common cause of vision impairment in the elderly, affects over 20 million Americans, and cataract surgery is the most common surgery in the United States Medicare population.⁴

Previous research has well established that cataract surgery improves visual acuity. Additionally, substantial research has investigated the impact of cataract surgery on self-reported quality of life. Most of this previous research has focused on surveys or questionnaires to assess subjective quality of life. A variety of questionnaires have been used to evaluate different aspects of quality of life, ranging from glare disability, acuity/spatial vision, depth perception, peripheral vision, visual search, and visual processing speed, and most have shown subjective increases in quality of life following cataract surgery.^{5–12} One of these questionnaires, the Activities of Daily Vision Scale (ADVS), assesses the difficulty patients have in distance and near activities as well as from glare. Multiple studies report ADVS improvement after cataract surgery.^{13–15} Research focusing on first- versus second-eye surgery has often evaluated the absolute gains in visual acuity and self-reported functioning outcomes. Several studies have reported smaller absolute gains after second eye surgery, given that first eye surgery has already led to substantial improvement. However, most studies of first and second-eye surgery have generally concluded that second-eye surgery is beneficial, at least for a subset of patients.^{7,16–25}

Despite the amount of subjective, questionnaire-based data available, relatively few studies have tested actual performance to evaluate the impact of cataract and cataract surgery on functioning, quality of life, and performance of activities of daily living. The Salisbury Eye Evaluation (SEE) is a longitudinal, population-based study that measured not only clinical visual function and subjective quality of life measures, but also performance on multiple tasks at different time points.²⁶ This paper reports on the impact cataract surgery has on visual function, reading speed, self-reported functioning, and measured mobility and compares unilateral versus two-eyed surgery.

Methods

Population

SEE enrolled community-dwelling residents of Salisbury, Maryland who were chosen randomly from an age- and race-stratified sample of residents in selected Maryland zip codes whose names were on the national Medicare eligibility list. Participants were required to be able to travel to clinic visits and to have a Mini-Mental Status Examination (MMSE) score of 18 or higher at baseline. Participants were 65 to 84 years old at the time of enrollment. Data collection and detailed methods have been described in depth elsewhere.^{26,27}

The analyses here utilize data from the first (1993–95) and second rounds (1995–97). These two time points were chosen because a standard set of performance-based measures were

collected for both visits. To be included in this analysis, data from both rounds was required. In addition, participants needed a baseline bilateral Best Corrected Visual Acuity (BCVA) of logarithm of the Minimum Angle of Resolution (logMAR) ≤ 0.3 or better (Snellen 20/40 equivalent) or to undergo cataract surgery in at least one eye by round 2. Individuals with previous cataract surgery were excluded from the primary analysis. Participants were divided into one of three groups: individuals that did not have cataract surgery during the study period, individuals who underwent cataract surgery on one eye between round 1 and 2, and those that had surgery on both eyes between round 1 and 2. We did not record whether participants had a yttrium-aluminum-garnet capsulotomy following cataract surgery, but this was allowed.

Testing

Participants undertook multiple objective and subjective measures of vision and visual functioning. They completed a two-hour in-home interview followed a few weeks later by an in depth clinic evaluation. All participants gave informed consent, and the procedures were approved by the Johns Hopkins University School of Medicine Institutional Review Board.

Researchers tested binocular visual acuity using Early Treatment Diabetic Retinopathy Study (ETDRS) charts under standardized conditions with usual correction. Contrast sensitivity was measured monocularly as the number of correct letters using a Pelli-Robson test. Better-eye contrast was used in this manuscript since previous work showed that the worse-seeing eye had a negligible contribution for contrast sensitivity.²⁸

ADVS, intended for use in evaluating cataract surgery, was the primary tool for assessing participants' self-reported functioning for visually-oriented tasks.²⁷ This tool includes five subscales that measure near vision, far vision, glare disability, night driving and day driving.

The functional tests were grouped into mobility and vision-related manual tasks. As previously described, the timed mobility measures involved a four-meter walk, stair ascent, stair descent, and get-up-and-go (getting up from a chair with arms and stepping away from it).²⁸ Each of these performance measures was then converted into a z-score so that changes in the different performance-based mobility measures were on a comparable scale. Z-scores were calculated by subtracting the baseline mean score for the entire study population from the individual's score and then dividing the difference by the standard deviation of the study population. At follow up, z-scores were calculated using the individual's score at follow up and the baseline population mean and standard deviation. A higher z-score indicates better performance, and a score of zero represents the mean value for the entire study population at baseline.

Vision related testing took place in the clinic with standardized conditions, including lighting between 400 to 600 lux. Participants read standardized texts aloud for 15 seconds each at four different letter sizes (0.13, 0.21, 0.33, and 0.52 degrees) at a distance of 1 meter using customary distance glasses. The texts were at a sixth-grade reading level, and illiterate patients were excluded from this test.²⁹

The comorbidity index was calculated by summing the number of diagnoses that a doctor had given the patient from the following list: arthritis, broken hip, back problem, heart attack, angina, congestive heart failure, intermittent claudication, hypertension, diabetes, emphysema, asthma after age 50, stroke, Parkinson's disease, vertigo, and cancer. Data on years of education, MMSE, and depression also were collected.

Mean change for each of the values were calculated, and differences across groups were compared using analysis of variance (ANOVA). Linear regression models were used to evaluate the association between each outcome of interest and surgery group after controlling for baseline level of the outcome of interest, sex, age, race, education, comorbidity, MMSE, and depression. The relationship between baseline mobility measurements and change in mobility was not linear, so a spline term for the baseline mobility score was included in the regression models evaluating mobility measurements.

A secondary analysis was conducted of SEE participants who had undergone one- or two-eyed cataract surgery prior to baseline. Those who had prior unilateral surgery were divided into those who underwent second-eye surgery during the study period and those who did not. Identical visual and mobility-related tasks were assessed for these participants, offering longer post-operative follow-up and the opportunity to examine functionality in the time period between first and second-eye surgery for a portion of this group.

Results

1,739 SEE participants without prior cataract surgery met the inclusion criteria and completed the testing at both selected time points. Approximately 7% (n=119) underwent cataract surgery on one or both eyes between the first two visits (Table 1). Participants who had unilateral surgery during the study period were significantly older than the group that did not undergo surgery ($p<0.001$). Slightly over 50 percent of participants in each group were female, with the exception of the bilateral cataract surgery group, of which 69 percent were female. The majority of participants were Caucasian.

Baseline Vision and Physical Functioning Measures

As expected, at baseline the group without subsequent cataract surgery had significantly better binocular BCVA, contrast sensitivity, reading speed, and ADVS than the groups that subsequently had surgery. The unilateral group had significantly worse mobility, both overall and on all subscales than the no surgery group, which had z-scores above the study population mean (Table 1).

Change in Vision and Subjective Measures by Round 2

Comparing baseline and two-year follow-up data for the no surgery group provided the opportunity to evaluate the natural decline associated with aging, thus establishing the context for evaluating changes associated with surgery. Although the no surgery group experienced a decline in bilateral BCVA of 0.05 logMAR by the two-year follow up, both the unilateral and bilateral surgery groups had statistically significant improvements (0.02 and 0.17 logMAR improvement, respectively; Table 2). Adjusting for baseline values, both surgery groups had significantly better change in contrast sensitivity than the no surgery group, with a small decline in the unilateral surgery group and a 1.3 letter improvement in the bilateral surgery group. Similarly, change in reading speed was significantly better for both surgery groups, with less decrease for the unilateral group than the no surgery group (-4.9 vs. -26.7 words, $p = 0.006$) and substantial improvement for the bilateral group (28 wpm improvement; $p<0.0001$), bringing overall average two-year values to 144 wpm for the no surgery group, 129 wpm for unilateral surgery and 140 wpm for bilateral surgery.

ADVS was essentially unchanged for the unoperated group, while the unilateral group showed an insignificant small decline, and the bilateral group showed significant improvement (Table 2). The bilateral surgery group also showed a significant improvement compared to the unilateral surgery group ($p=0.003$).

Change in Mobility by Round 2

At Round 2, mean mobility z-scores declined for both the no surgery and unilateral surgery groups and were essentially unchanged for the bilateral surgery group. The unilateral surgery group, which was the oldest on average, had a significant decrease in mobility, even after adjusting for age and baseline score. The bilateral group showed a trend toward less mobility decline than either of the other two groups and improvement in all individual mobility tasks besides get up and go; however, likely due to sample size, these differences were not statistically significant (Table 3).

Regression Models

Multivariate linear regression models showed the unilateral and bilateral groups to have a statistically significant improvement in BCVA compared to the no surgery group, with the bilateral surgery group benefiting more (0.04 versus 0.13 logMAR improvement, Table 4), even after adjustment. Multivariate analyses comparing the unilateral versus the bilateral group also showed greater improvement in the bilateral group (0.12 logMAR improvement, $p = 0.0005$). The unilateral group had a small, nonsignificant improvement in contrast sensitivity compared to the no surgery group (0.16 letters), while the bilateral surgery group had a statistically significant improvement (0.93 letters, $p=0.03$) compared to the no surgery group. Reading speed significantly improved for both the unilateral (11.6 wpm, $p = 0.003$) and bilateral surgery groups (31.1 wpm, $p<0.0001$) compared to the no surgery group.

The unilateral surgery group had a statistically significant decrease in ADVS compared to the no surgery group, even after adjustment for age and other potential confounders. By contrast, the bilateral surgery group improved significantly in ADVS and showed a consistent but not statistically significant trend toward improved mobility on each of the mobility tasks compared to the no surgery group (Table 4).

A subset of the unilateral surgery group ($n=14$) had BCVA > logMAR 0.3 in the unoperated eye at baseline. This subset had worse vision and physical functioning scores at baseline than the rest of the unilateral surgery group. It had a slightly larger improvement in BCVA after surgery than the rest of the unilateral surgery group (0.07 logMAR) and an equal improvement in reading speed (12.2 wpm), but it had less improvement in contrast sensitivity and much larger declines in ADVS and mobility. Thus, this subgroup may not have benefited from surgery in the same way that participants with good contralateral vision did. Conducting the same primary analyses described above after removing these participants from the unilateral surgery group does not alter the results substantially. All interpretations remain the same for both the analyses comparing the unilateral group to no surgery and comparing them to bilateral surgery.

Secondary Analysis of Participants with Surgery at Baseline

Four hundred fifty-six participants entered the SEE with prior cataract surgery at baseline. Although 218 had prior surgery in both eyes, 189 had unilateral surgery without second-eye surgery before round 2, and 49 had second-eye surgery in the study period. The average age was more similar across these groups than in the primary analysis, making them well-suited for comparisons that may be influenced by age. Secondary analyses showed that the group with second-eye surgery between rounds 1 and 2 enjoyed the greatest improvement in BCVA and ADVS and the least decline in contrast sensitivity, reading speed, and mobility (data not shown), confirming the findings from the primary analyses.

Discussion

The results of this study demonstrate an objectively measureable benefit of cataract surgery on visual performance, reading speed, and relative mobility. This study also confirms the subjective benefit that patients undergoing cataract surgery may experience as measured by the ADVS, verifying previously published.^{13–15} work. Results also suggest that participants who have second-eye surgery are likely to function better than those who have only unilateral surgery. The fact that the SEE is a population-based study gives particular strength to the conclusions drawn here in comparison to the previously published work on cataract surgery outcomes; however, the number of patients having cataract surgery was only a small percentage of the study population. Further evaluation is needed in a larger population.

The baseline values agree with prior reports demonstrating the significant deleterious impact that cataract has on performance of everyday activities. The round 2 results showed objectively measureable performance benefits from cataract surgery, but the impact differed depending on whether participants had one- or two-eyed surgery. Those who had bilateral cataract surgery performed better, enjoying larger increases in BCVA, contrast sensitivity, and reading speed in the multivariate analysis (Table 4). Furthermore, the bilateral group had better mobility and ADVS at follow up, while the unilateral surgery group had significant declines in both. Thus, at follow up, the bilateral surgery group had higher overall mobility and ADVS scores than the unilateral surgery group.

This finding supports the conclusion that second-eye cataract surgery provided a significant additional benefit to first-eye cataract surgery in this community-based study, where participants underwent cataract surgery in the course of their normal eye care. One relevant limitation of the study is that follow-up visits are time-specific and not intervention-based, so separating out the incremental benefit of operating on the first eye and second eye is difficult. However, the secondary analysis helps in this regard. The group with unilateral surgery at baseline that had second-eye surgery by round two outperformed its peers who remained unilateral surgery in all tested measures. A future study could perform a comprehensive assessment of physical functioning before first-eye surgery, between eyes, and after the second eye to answer this more directly.

This study makes a new contribution to the literature because previous work on second-eye surgery has not reported this type of performance-based, measureable functional benefit. Other researchers have shown that patients undergoing bilateral cataract surgery have greater subjective satisfaction along with clinical improvement in acuity and stereopsis than those undergoing unilateral surgery.^{7,16–17,23–25} Moreover, those who undergo second-eye surgery have a higher likelihood of meeting the driver's license field of vision requirement,³⁰ and one study showed a non-significant trend toward fewer falls in patients with prior unilateral cataract surgery randomized to second-eye surgery versus no surgery.²⁴

One may argue that individuals who do not undergo second-eye surgery make this decision because their second eye will not benefit from surgery, or that they have attained sufficient satisfaction from first-eye surgery. However, our subgroup analysis that removes unilateral surgery patients with poor vision in the contralateral eye shows that even among those who have good fellow eye vision, unilateral surgery patients do not perform as well at follow up as those who had second-eye surgery done.

Studies that have investigated differences between first and second-eye cataract surgery have generally reported greater *absolute* improvements in bilateral acuity and self-reported quality of life following first-eye surgery. However, these studies have generally shown a benefit from second eye surgery as well. In most cases, individuals undergoing second-eye surgery have already experienced large gains associated with first-eye surgery, and

improvement following second-eye surgery is limited by the upper limit of measuring full function. For example, on the ADVS, the maximum score is 100; thus individuals who begin closer to 100 (such as those who have already had first-eye surgery) have less opportunity for large absolute improvements than individuals starting further away from 100 (such as those undergoing first eye surgery). Therefore, in making such comparisons, it is important to evaluate the final level of function, not just the amount of change.

Although individuals having second-eye surgery may have a smaller absolute increase in a particular outcome, that increase may be equally or more important than the initial increase, such as reaching a level of visual acuity that allows a person to drive again. In the current study, we evaluated individuals before surgery and then either after one-eyed or two-eyed surgery. Thus, the two-eyed surgery group is not directly comparable to the second-eye surgery groups from previous studies. Instead, it is more likely to show the combined effects of first and second-eye surgery. Our finding is consistent with a previous clinical trial in which patients undergoing two-eyed surgery had better acuity, stereopsis, and Visual Function (VF)-14 score than one-eyed surgery of individuals with bilateral cataracts.⁷

Future research should continue to explore ways to understand the impact of cataract surgery on quality of life. For instance, the mobility z-scores in all groups declined from round 1 to round 2, suggesting the importance of many aspects of aging besides visual impairment. However, many of these aging-related factors, such as cardiovascular disease, neurologic disease, or joint disease, are more difficult to treat than cataract, which requires a relatively brief episodic intervention. As the elderly population increases, cataract surgery may allow more patients to live independently longer and more safely.

Given the greater benefit seen in patients who had bilateral cataract surgery, providers should closely follow patients who may benefit from surgery. This includes carefully asking patients who have already had unilateral cataract surgery if they are experiencing continued difficulty with contrast sensitivity, reading, mobility, or other visual needs, even if their visual acuity appears satisfactory. When treating a patient with diminished visual function, providers should not assume that operating on only one eye has restored maximum function, even if the outcome of the first surgery was excellent.

Cataract is a widespread eye disease, and cataract surgery is a commonly-performed surgery. Because of the significant Medicare expenditures on cataract surgery, it will come under scrutiny as health care costs continue to increase. The health reform legislation passed in 2010 establishes a Patient-Centered Outcomes Research Institute at the national level, and states are also implementing measures in an effort to pay only for evidence-based medicine.^{31,32} This paper demonstrates in a large, population-based prospective study not only that cataract surgery provides functional benefit but also that bilateral cataract surgery appears to benefit patients in ways that unilateral surgery does not.

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Table 1

Baseline Characteristics of Participants without Prior Cataract Surgery Grouped by Operative Status at Round 2 (Two Years)

	Surgical Status by Round 2		
	No Cataract Surgery	Unilateral Cataract Surgery	Bilateral Cataract Surgery
Number	1,620	90	29
Demographics			
Age (median years)	71.6	76.1 *	73.0
Female (%)	57	52	69
Caucasian (%)	72	81	72
Education (years)	11.4	10.6	11.9
Health Status Measures			
Mini-mental Status Exam	27.4	27.1	27.0
Number of Comorbidities	2.3	2.4	2.7
Depression (%)	4.1	7.1	3.7
Vision Measures			
Binocular Best Corrected Visual Acuity (logMAR)	−0.04	0.11 *	0.22 *
Contrast Sensitivity (letters)	35.7	32.9 *	31.6 *
Reading Speed (words per minute) [‡]	170	131 *	109 *
Mobility and Perceived Function Measures			
Activities of Daily Vision Scale (ADVS)	91.9	84.9 *	80.2 *
Overall Mobility Z-score	0.09	−0.22 *	−0.29
Walking Speed Z-score	0.12	−0.20 *	−0.22
Get Up and Go Z-score	0.12	−0.15 *	−0.13
Going Up Stairs Z-score	0.08	−0.24 *	−0.29
Going Down Stairs Z-score	0.11	−0.25 *	−0.38 *
Avg. Z-score for up and down stairs	0.10	−0.24 *	−0.28

All values shown are means. Best-corrected visual acuity was measured with both eyes together and is shown in logarithm of the Minimum Angle of Resolution (logMAR). Contrast sensitivity is the number of correct letters in the better-seeing eye with correction on a Pelli-Robson chart. The 0.21 degree text, the size of newspaper print, was used for the reading speed. Z-score is the difference between the measured time and the baseline mean time for the entire study population divided by the baseline standard deviation, so a positive z-score denotes better performance.

* statistically significant difference compared to no cataract surgery group ($p < 0.05$)

[‡] reading speed was not tested in 95 participants in the no surgery group, 4 in the unilateral group, and 2 in the bilateral group

Table 2

Change in Visual Performance, Reading Speed and Subjective Evaluation of Performance on Daily Tasks

Parameter	Surgical Status by Round 2		
	No Cataract Surgery	Unilateral Surgery	Bilateral Cataract Surgery
Visual Acuity Improvement (logMAR)	−0.05	0.02 *	0.17 *
Contrast Sensitivity (letters)	−1.6	−0.48 *	1.3 *
Reading Speed (wpm)	−26.7	−4.9 *	28.2 *
Activities of Daily Vision Scale	0.14	−2.0	9.0 *

For all measurements, a positive change denotes improvement.

Best-corrected visual acuity was measured with both eyes together and is shown as improvement in logarithm of the minimum angle of resolution (logMAR). Contrast sensitivity is the number of correct letters in the better-seeing eye with best correction on a Pelli-Robson chart. The 0.21 degree text, the size of newspaper print, was used for the reading speed.

* Statistically significant (p-value <0.05) difference comparing that group to no cataract surgery, adjusting for baseline value.

Table 3

Mean Change in Performance on Mobility Tasks between Baseline and Round 2 (2 years) Among Individuals without Surgery at Baseline

Change in z-score for:	Surgical Status By Round 2		
	No Cataract Surgery	Unilateral Surgery	Bilateral Cataract Surgery
Overall Mobility Score[†]	−0.13	−0.32 [*]	−0.02
Walking Speed	−0.09	−0.26 [*]	0.13
Get Up and Go Speed	−0.21	−0.42 [*]	−0.21
Going Up Stairs Speed	−0.10	−0.33 [*]	0.09
Going Down Stairs Speed	−0.03	−0.30 [*]	0.04
Average Stair Speed	−0.07	−0.34 [*]	0.18

Z-score is the difference between the measured speed to perform the task and the baseline mean speed for the entire study population divided by the baseline standard deviation. So, a positive z-score denotes better performance than the average.

^{*} p<0.05 compared to no surgery group, with p-value adjusted for baseline z-score.

[†] calculated by averaging the z-scores for all mobility-related tasks.

Table 4

Multivariate Analyses Evaluating Change in Each Measure Compared to the No Surgery Group for Previously Unoperated Participants[†]

Change in:	Surgical Status by Round 2	
	Unilateral Surgery	Bilateral Cataract Surgery
Visual Acuity (logMAR improvement)	0.04 *	0.13 *
Contrast Sensitivity (letters)	0.16	0.93 *
Reading Speed (words per minute)	11.6 *	31.1 *
Mobility:		
Average Mobility Score (z-score)	-0.18 *	0.18
Walking Speed (z-score)	-0.18 *	0.15
Get Up and Go Speed (z-score)	-0.19 *	0.01
Going Up Stairs Speed (z-score)	-0.24 *	0.22
Going Down Stairs Speed (z-score)	-0.26	0.08
Overall Stair Speed (z-score)	-0.27 *	0.28
Activities of Daily Vision Scale (ADVS):		
Overall	-5.0 *	4.9 *
Distance	-4.8 *	2.2
Near	-4.7	4.5
Glare	-8.4 *	5.5 *
Day Driving	-9.0 *	-1.0
Night Driving	-8.4 *	5.9

All values shown are the change compared to the reference group after adjusting for the variables as discussed below. Visual acuity was measured with best correction using both eyes together and is shown in logarithm of the Minimum Angle of Resolution (logMAR). Contrast sensitivity is the number of correct letters in the better-seeing eye with correction on a Pelli-Robson chart. The 0.21 degree text, the size of newspaper print, was used for the reading speed. Z-score is the difference between the measured time and the baseline mean time for the entire study population divided by the baseline standard deviation, so a positive z-score denotes better performance.

* Statistically significant difference compared to no surgery group (p-value < 0.05)

[†] For each variable, the regression model controlled for sex, age, race, education, comorbidity, Mini-Mental State Examination, depression, and the baseline value for the outcome being evaluated. The walking score also included a spline term to adjust for baseline walking speed.