

A Classification Regression Tree Analysis to Reduce Balance Impairments and Falls in the Older population: Impact on Resource Utilization and Clinical Decision-Making in USA Rehabilitation Service Delivery

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ABSTRACT

Background/Purpose: Over 1/3 of adults over age 65 experiences at least one fall each year. This pilot report uses a classification regression tree analysis (CART) to model the outcomes for balance/risk of falls from the Gentiva® Safe Strides® Program (SSP). **Methods/Outcomes:** SSP is a home-based balance/fall prevention program designed to treat root causes of a patient's balance problems. Analysis starts with the cohort of patients enrolled in SSP having a Berg Balance Assessment completed (n=165) and sequentially divides it into subgroups, creating a regression tree model. Descriptive statistics were calculated to summarize demographics, self-reported pain measure, foot sensation, and initial exam and discharge scores for tests of impaired balance/risk of falls. **Results/Discussion:** Average (+SD) age for fallers was 82.6 (+8.3) years with 39.8% (n=37) male and 60.2% (n=56) females, and 77.3 (+10.1) years for non-fallers with 43.5% (n=30) males and 56.5% (n=39) females, respectively. 43% of patients demonstrated improved balance on discharge from home health. The CART yielded a tree model after 12 partitions. The best discriminating variable was BBS score of < or > 33 on initial examination. **Conclusion:** This pilot case analysis enables Gentiva® and policy makers to improve efficiency and effectiveness of service delivery.

Keywords: balance, falls, CART analysis, clinical decision making, physical therapy

INTRODUCTION

One-third of older adults over the age of 65 will experience at least one fall during the year [1, 2]. Of those older adults that fall, 20-30% sustain a moderate to severe injury making it difficult for independent mobility and increasing the risk of an early death [3]. In 2010, 2.3 million nonfatal fall injuries were treated in emergency departments and greater than 662,000 of these patients were hospitalized [2]. In 2010, the direct medical costs of falls, adjusted for inflation was \$30.0 billion. [4]. Falls

are the leading cause of fatal and non-fatal injuries for older adults age 65 and older [5]. Complaints of imbalance [6], risk of falling and sustaining an injury secondary to a falling [7-8], increase with age. Age related changes have been demonstrated in common tests and measures of balance impairments [9], normal movement patterns [10], and self-report of imbalance [11].

Balance is achieved through a coordinated effort of body systems including sensory and motor systems [12-14]. The external environment provides information through a person's visual, somatosensory, and vestibular systems. Sensory information is subsequently interpreted in the central nervous system. In response, an appropriate motor response is developed, and a motor strategy is activated in order for a person to remain upright [12-14]. Preserving an upright position includes maintaining, achieving, or restoring the body center of mass relative to the limits [14] of stability. The functional goals of balance include maintaining a position, successfully transitioning between movements or positions, and reacting to an external perturbation in order to stay upright [14-15].

A fall is commonly defined as unintentionally coming to the ground or other lower surface not caused by a loss of consciousness, sudden paralysis, seizure, or a strong perturbation [16]. Falls are typically caused from a multitude of factors including both intrinsic and extrinsic risk factors that can often be corrected or managed [17]. Intrinsic risk factors (within the person) such as weakness, visual impairments, gait and balance problems, depression, urinary incontinence, orthostatic hypotension, cognitive function, sensory deficits, and comorbidities contribute to a person's risk of falling. Extrinsic risk factors (outside the person) consist of environmental factors (e.g. inadequate lighting, loose rugs) and polypharmacy also lead to increasing a person's fall risk. Interventions focused on environmental changes, balance, strength training, functional

mobility, decrease in medications with management of visual changes and orthostatic hypotension have been recommended as effective treatments to decrease fall risk [18]. Treatment of balance dysfunction in older adults has been shown to be most effective when the approach is multifaceted and individualized [18].

MATERIALS AND METHODS

Gentiva® Safe Strides®

Home health care services are commonly available to patients that are unable to leave their home to receive outpatient medical services. Most often, home care is provided to Medicare beneficiaries over the age of 65. Gentiva® Safe Strides® (SSP) is a comprehensive fall risk reduction program developed for patients over the age of 65 years who experience a taxing effort to leave their home and have a history of falls, and/or present with > two modifiable fall risk factors. Physical therapists were trained and verified on how to systematically collect the SSP data including neuropathic pain ratings, the Berg Balance Scale (BBS), and Performance Oriented Mobility Assessment (POMA) and the Dynamic Gait Index (DGI). All clinicians recording sample data had successfully completed Gentiva's Outcome and Assessment Information Set (OASIS) B documentation and respective specialty clinical training. Gentiva® collected SSP outcome information on initial evaluation and at discharge. At discharge, paperwork was reviewed for quality assurance and keyed into a companywide secure database per standardized processes. Data retrieval was achieved through database query, extrapolating and matching all completed cases, and de-identified through an honest, independent data-broker.

Balance Assessment

The purpose of utilizing clinical balance assessment tools is to identify the presence of a balance problem and assist in determining the underlying cause of a balance problem [15]. Measurements utilized in the SSP program are as follows:

Tinetti Performance Oriented Mobility Assessment (POMA) was developed as a measure to screen older adults for balance and gait impairments [19]. The POMA consists of 16 items including 9 balance activities and 7 gait items. Lower scores on the Tinetti balance significantly predicted occurrence of falling and ADL decline [20]. Minimal detectable change (MDC) has been determined to be 5 in older adults [21]

Berg Balance Scale (BBS) consists of 14 functional activities including sitting, standing, and postural transitions [22, 23]. Score of < 45 on the BBS have been associated with increased risk of falling [24].

Dynamic Gait Index was developed as a measure to assess and document a patient's ability to respond to changing task demands during walking [25]. It consists of eight items that vary the walking task by changing walking speeds, walking with head turns, turning and stopping, walking over and around obstacles, and ascending and descending steps [25]. Scores < 19 have demonstrated increased risk of falling in older adults [26].

Modified Clinical Test for Sensory Interaction on Balance was developed to systematically test the influence of visual, vestibular, and somatosensory input in standing balance without the use of computerized equipment. Standing balance is assessed under four different somatosensory and visual conditions including firm surface eyes open and closed, and foam surface eyes open and eyes closed [27]. SSP documented results of the mod CTSIB if a patient successfully completed 30 seconds of each of the four trials.

Foot Sensation is evaluated utilizing the Semmes-Weinstein Monofilament (SWMF) testing [28]. Sensation on the plantar surface of the foot was tested in 5 locations bilaterally (10 total). A score < 7/10 served as a trigger for the implementation of monochromatic infrared energy (MIRE) to be used in branches where it was available.

Neuropathic pain was assessed utilizing an 11 point visual numeric rating scale of 0 (no pain) – 10 (intolerable pain). For this analysis, initial and discharge neuropathic pain measurements were utilized.

Subjects. Participants in an IRB approved trial were 455 with 165 patients in the BBS sub group enrolled in the SSP program from January 1, 2009 to December 31, 2009 from 11 Gentiva® branches across the USA.

Statistical Analyses

Analyses were performed with IBM SPSS® version 19 (Chicago, IL) and SAS STAT® system Version 9.1 (SAS Institute Inc., Cary, NC, USA) and JMP® Version 9 (Cary, NC). The tests of significance between the two groups (MIRE and No MIRE) by time (baseline and discharge) was a two-way repeated measures ANOVA of Group x Time with the alpha level set at $p < 0.05$. The second analysis was on a subset of the balance impairment data from the BBS with groups that were determined by discharge BBS Scores of less than 45 (group 1 - balance impaired) or equal to greater than 45 (group 2 – no balance impairment) and assessment of clinical factors, self-reported neuropathic pain, foot sensation, and other balance performance measures at baseline and upon discharge from the Safe Strides program. A model was developed for these two groups for the CART analysis. Descriptive statistics were used to summarize patient demographics, baseline and discharge assessments of foot sensation, neuropathic pain, sensorimotor test of balance (Modified CTSIB), and other balance impairment measures (POMA, DGI) (Table 1). Means and standard deviations were calculated for the continuous variables; medians and interquartile ranges were calculated for the ordinal variables, and frequencies and percentages were calculated for the nominal variables. Binary logistic regressions were used to compare differences between the two groups BBS impairment groups (Discharge BBS Scores of < 45 = group 1) balance impaired versus no BBS impairment (Discharge BBS Scores of ≥ 45 = group 2) at discharge from the SSP for each independent variable.

Logistic regression analyses were used to calculate 95% confidence intervals and odds ratios for the associations between demographics, neuropathic pain, foot sensation and balance impairment measure (95% CI and OR shown in Table 3). Results were considered significant at $p \leq 0.05$, 2-sided. In subsequent analyses, CART was conducted to develop a model for identifying factors and measures from baseline and discharge assessments that characterized the 2 groups (balance impairment vs. no balance impairment). The CART determines the best combination of demographics, physical performance measures and self-reported symptoms to yield a more effective classification model than logistic regression models.

CART analysis is a nonparametric statistical procedure that will classify subgroups of patients with no balance impairment and those with balance impairment within a cohort/sample, each with its own set of risk factors and cut points. The analysis starts with the entire cohort and sequentially splits the dataset into 2 subgroups that are the most different with respect to the balance impairment, creating a tree model. The CART model relies on statistically optimum recursive splitting of the patients

into smaller and smaller subgroups, based on the critical levels of the predictor variables (Figure 1). The best discriminating variable is selected first and provides the first partition. After this, the remaining variables are examined to determine whether they can provide further discrimination, and this process continues until no further significant discrimination (partitioning) is possible. CART analysis splits a continuous variable into two groups (balance impairment versus no balance impairment) based on an exhaustive search aiming to find the split (including nonlinear splits) producing the largest improvement in goodness of fit for the model created. The probability and rate are calculated for each group in the base and branches of the regression tree. The percentages of patients with no balance impairment vs. balance impairment were calculated for the base branches of the regression tree. Due to a small study sample, cross validation using k fold technique was performed. k fold is useful for cross-validation in smaller samples to prevent over fitting data and failing to generalize to new data.

RESULTS

Demographics

SSP cohort (n=455) were males (n= 200, 44.0%), female (n= 255, 56.0 %) with a mean age of 79.7 +10.4; patients were included who had both baseline and discharge assessments of balance.

Table 1. Demographic and Balance Characteristics of SSP cohort

| Subjects | MIRE (Group 1) (n=183) | No MIRE (Group 2) (n=272) | P value |
|---|------------------------|---------------------------|--------------|
| | n (%) | n (%) | |
| Male | 76 (41.5 %) | 124 (45.6%) | |
| Female | 107 (58.5%) | 148 (54.4%) | |
| | Mean ±Stand. Deviation | Mean ±Stand. Deviation | |
| Age (years)* | 78.3 ± 10.6 | 80.6 ± 10.4 | 0.022 |
| Number of visits* | 14.5 ± 5.7 | 16.2 ± 8.5 | 0.021 |
| Berg Score Pre – Treatment | 27.6 ± 11.2 | 27.5 ± 10.0 | |
| Berg Score Post-Treatment** | 39.1 ± 13.3 | 39.7 ± 10.3 | 0.564 |
| Modified CTSIB Score | 0.9 ± 0.9 | 1.0 ± 1.0 | 0.538 |
| mCTSIB Score Post-Treatment | 2.4 ± 1.2 | 2.4 ± 1.1 | |
| Pain Score Pre-Treatment (VAS)* | 3.4 ± 3.6 | 1.4 ± 2.7 | 0.000 |
| Pain Score Post-Treatment (VAS) | 1.5 ± 2.4 | 0.8 ± 1.9 | |
| Foot Sensation Score Pre-Treatment (SWM)* | 2.5 ± 2.1 | 3.2 ± 2.2 | 0.001 |
| Foot Sensation Score Post-Treatment (SWM) | 5.4 ± 3.5 | 5.2 ± 3.2 | |

* significance set at p < 0.05 from one-way ANOVA (Group)

**significance set at p < 0.05 from two-way repeated measures ANOVA of Group x Time

Foot sensation (loss of protective sensation) (p=0.001) and neuropathic pain significantly (p=0.000) improved in both groups with Group1 (SSP +MIRE) improving more.

Table 2. Group comparison of foot sensation and loss of protective sensation (LOPS)

| | LOPS initial | LOPS discharge | LOPS improvement |
|--------------------|----------------|----------------|------------------|
| Group 1 (MIRE+SSP) | 183/183 = 100% | 99/183 = 54% | 46% |
| Group 2 (SSP) | 272/272 = 100% | 176/272 = 65% | 35% |

CART model for balance impairment versus no balance impairment on discharge

Table 3 shows the two BBS balance impairment groups' means and standard deviations or frequency and percent for each independent variable, with associated 95% confidence intervals and odds ratios. Average (+SD) age for fallers was 82.6 (+8.3) years with 39.8% (n=37) male and 60.2% (n=56) females, and 77.3 (+10.1) years for non-fallers with 43.5% (n=30) males and 56.5% (n=39) females, respectively. Forty-three percent of patients demonstrated improved balance on discharge from home health.

Logistic regression analyses in Table 3 show that the group classified with balance impairment (Group 1) which was older and had more women had significantly greater balance impairment on initial BBS score and modified CTSIB score. Only statistically significant (p< 0.05) explanatory variables from the binary logistic regressions were entered into the final CART BBS model.

Table 3. Demographics for Subgroup of Subjects Who Were Tested With BBS (n=165)

| | All BBS (n=165) | Group 1 (<45 BBS) (n= 95) | Group 0 (>45 BBS) (n=69) | 95% CI (OR)* |
|-------------------------------------|-----------------|---------------------------|--------------------------|---------------------|
| Male | 67 (40.6%) | 37 (39.8) | 30 (43.5) | |
| Female | 98 (59.4%) | 56 (60.2) | 39 (56.5) | 0.578-2.022 (1.081) |
| Mean + SD | | | | |
| Age | 80.3 ± 9.4 | 82.6 (8.3) | 77.32 (10.1) | 1.028-1.109 (1.068) |
| Number of treatments | 16.4 ± 8.4 | 16.7 (8.2) | 16.4 (8.7) | 0.972-1.048 (1.009) |
| Berg Score Pre - Treatment | 27.5 ± 10.4 | 22.3 (8.5) | 33.9 (8.6) | 0.810-0.896 (0.852) |
| Berg Score Post-Treatment | 39.4 ± 11.5 | 31.7 (9.3) | 49.3 (2.9) | |
| Modified CTSIB Score Pre-Treatment | 1.0 ± 1.0 | 0.7 (0.9) | 1.5 (1.0) | 0.287-0.590 (0.412) |
| Modified CTSIB Score Post-Treatment | 2.3 ± 1.1 | 1.8 (1.0) | 3.0 (0.7) | |
| Pain Score Pre-Treatment (VAS) | 2.2 ± 3.2 | 1.9 (3.0) | 2.6 (3.4) | 0.835-1.015 (0.921) |
| Pain Score Post-Treatment | 0.8 ± 1.7 | 0.7 (1.7) | 0.8 (1.7) | |

| | All BBS | Group 1 (<45 BBS) | Group 0 (>45 BBS) | 95% CI (OR)* |
|-------------------------------------|-----------|-------------------|-------------------|---------------------|
| Sensation Score Pre-Treatment (SWM) | 3.0 ± 2.2 | 2.7 (2.1) | 3.2 (2.2) | 0.768-1.024 (0.887) |
| Sensation Score Post-Treatment | 5.3 ± 3.4 | 4.8 (3.4) | 5.8 (3.1) | |

*95% Confidence Interval (Odds Ratio)

Of the 17 variables that were entered into the CART analysis for the 2 groups, the JMP program selected 6 for the tree for balance impairment versus no balance impairment. The fit of the CART model for BBS groups during splitting is shown in Figure 2 with an $r=0.648$.

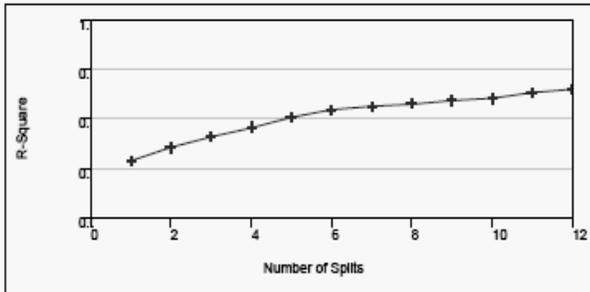
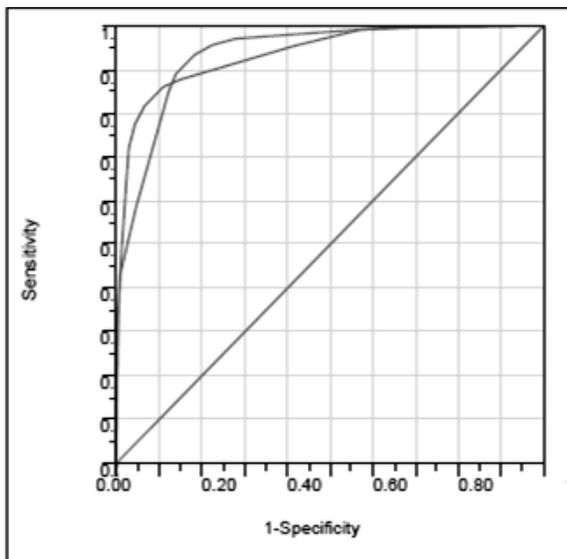


Figure 2. Split History for CART Model for BBS Groups

The Sensitivity and specificity of the CART model for BBS groups were assessed using receiver operating characteristics (ROC) curves and models with sensitivity and specificity greater than 90% are considered clinically useful for classification of patients. The accuracy of the CART model for BBS groups was expressed in terms of sensitivity ($=0.935$), specificity was expressed in terms of sensitivity ($=0.935$), 1-specificity ($=0.935$) (See figure 3), and overall accuracy and misclassification rate (Table 4).



| Legend | BBS Impairment Groups | Area |
|--------|-----------------------|--------|
| — | 0 | 0.9353 |
| — | 1 | 0.9353 |

Figure 3. Receiver Operating Characteristic Curves for Group 0 (Unimpaired balance on BBS) and Group 1 (Impaired balance on BBS)

Table 4. Fit Details of CART Model for BBS Groups

| Measure | Training | Definition |
|------------------------|----------|---|
| Entropy | 0.6475 | $1 - \text{Loglike}(\text{model}) / \text{Loglike}(0)$ |
| RSquare | | $(1 - L(0) / L(\text{model}))^{(2/n)} / (1 - L(0))^{(2/n)}$ |
| Generalized R-Square | 0.7880 | |
| Mean -Log p | 0.2405 | $\sum -\text{Log}(\rho[j]) / n$ |
| RMSE | 0.2670 | $\sqrt{\sum (y[j] - p[j])^2 / n}$ |
| Mean Abs Dev | 0.1611 | $\sum y[j] - p[j] / n$ |
| Misclassification Rate | 0.0926 | $\sum (\rho[j] \neq \rho \text{Max}) / n$ |

DISCUSSION

Among older adults over the age of 65, falls are the leading cause of nonfatal injuries, hospital admissions secondary to trauma, and death due to injury [29]. Falls may occur in an older adult secondary to intrinsic and extrinsic risk factors [17]. An individualized multifaceted intervention focused on environmental modifications, balance, strength training, functional mobility, medication management, appropriate vision care, and management of orthostatic hypotension have been recommended as effective treatments to decrease fall risk [18]. SSP is a comprehensive fall risk reduction program delivered by Gentiva® that incorporates individualized care based on the results of a comprehensive assessment.

Currently, there is a lack of evidence that assists physical therapists in determining frequency and duration of treatment [30]. The CART analysis completed on the SSP outcomes provides information that may assist a physical therapist in making decisions regarding determining treatment parameters that deliver the most effective and efficient care to maximize a patient's potential.

The results in table 2 and CART analysis shown in figure 1 demonstrates that the SSP was effective in improving a person's fall risk. The analysis provides the clinician information that may assist in determining intensity of services and identifying individuals at greater risk from baseline clinical and demographic data routinely collected by physical therapists. BBS was able to explain 81% of all the risk that would place a patient into risk or no risk of falling. Patients that score >39 on the BBS intervention may require less visit intensity with a focus on education and self-management to decrease their fall risk. Patients that score in the range of < 33 seem to require a higher frequency and intensity of care and may benefit from more than the average visits provided to the patients with loss of protective sensation who are included in this study. Patients that score between 33-39 on the initial BBS appear to need services that are less intense in frequency and duration as those patients who score <33.

The Tinetti POMA as compared to the BBS was less robust at an $r^2=0.73$. The DGI was slightly less at $r^2=0.69$. For the modified CTSIB, the classification was dependent on the number of conditions that were scored as impaired.

Misclassification of a patient may have negative effects. The overall misclassification rate was less than 10 percent. If a patient is identified as being high risk but is actually low risk, there is an increased cost to the health care system. A more devastating misclassification occurs when a patient is identified as being a low fall risk when in actuality the patient is at high risk, and sustains a fracture secondary to a fall. In the 9 patients that were misclassified utilizing the Berg, all patients were over the age of 82 and were misclassified as low risk when in

actuality they were at high risk of falling. Based on this finding, the BBS may not be sensitive enough and further balance testing using the POMA, modified CTSIB, or DGI is recommended in order to determine fall risk.

CONCLUSIONS

This pilot analysis serves to improve health care service delivery outcomes and resource utilization in a fall risk reduction program. Information gathered from CART enables Gentiva®, physical therapists and policy makers to maximize appropriate referral and utilization of services, and improve efficiency and effectiveness of service delivery. This model addresses a critical health issue for the aging population where this type of analysis is not widely utilized.

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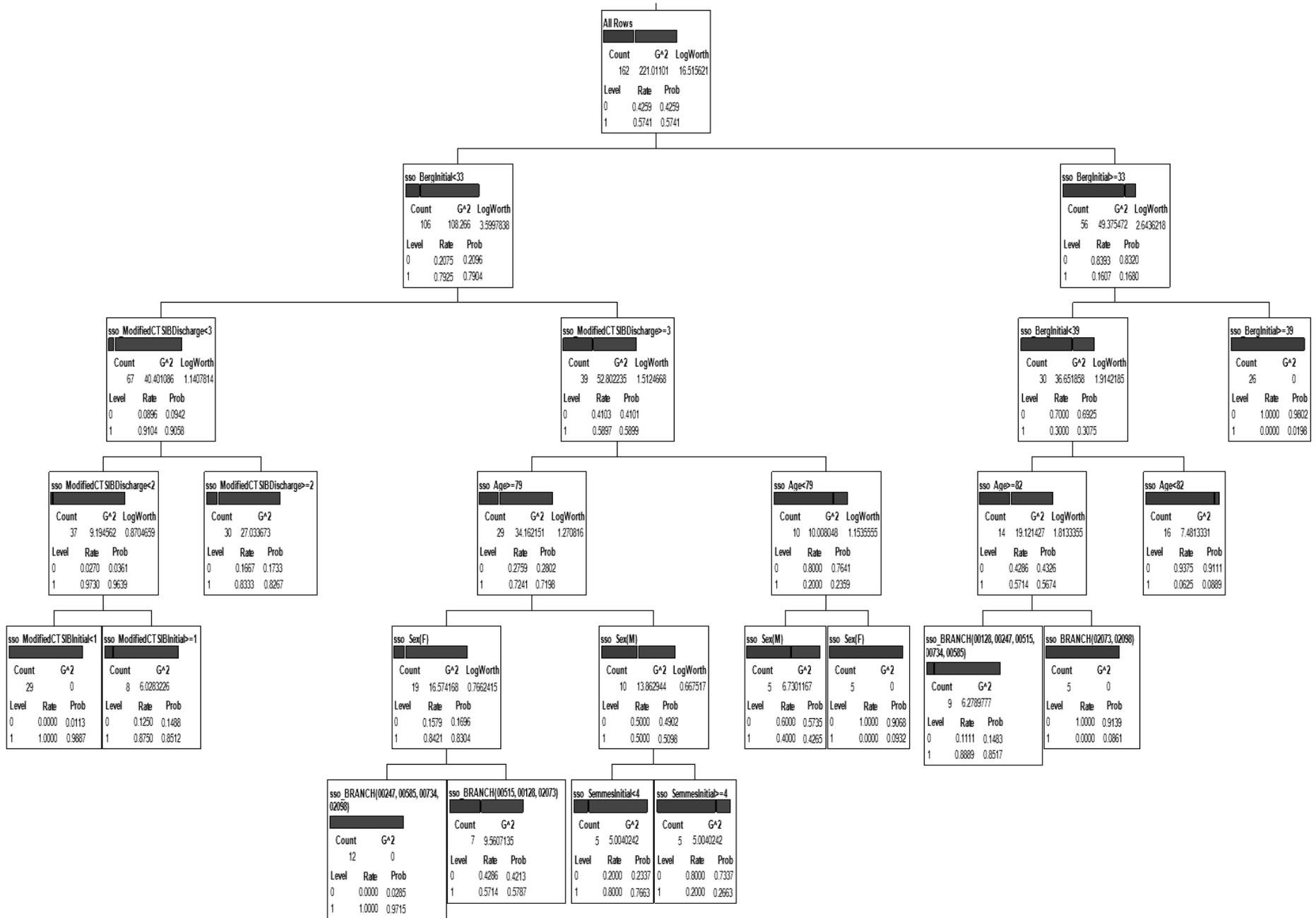


Figure 1. Classification Regression Tree Analysis Model of Falls from Berg Balance Score.