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Are scores on the PPT useful in determination of risk of future falls in individuals with dementia?

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INTRODUCTION

Individuals with dementia or Alzheimer's disease (AD), exhibit both a progressive decline in cognitive function and accumulating difficulty with physical function.¹ As cognitive impairment begins, individuals will initially demonstrate difficulties with short-term memory and with instrumental activities of daily living. As the dementia progresses, individuals will increasingly demonstrate difficulties with long-term memory, communication, and basic activities of daily living.¹

In addition to the progressive decline in function, decreases in postural control are evident in early stages of AD. In a comparison of community living subjects with and without mild AD who were independent in gait, Franssen et al and Petterson et al found those with AD demonstrated significantly lower scores on balance measures.^{2,3} While the balance scores for those with mild AD did not indicate a risk for falls, they did suggest the beginnings of a decline in postural control. Chong et al found individuals with AD [mean Mini Mental State Exam (MMSE) score 19 ± 6] had more difficulty than those without cognitive impairment in maintaining balance under conditions which required suppression of incongruent or distracting visual and somatosensory information and attention to vestibular input.⁴ Similarly, Manckoundia et al found that the addition of a cognitive task, answering questions about a recently viewed videotape, significantly altered quiet standing center of pressure (CoP) sway in those with AD.⁵ Compared to age-matched healthy older adults, those with AD (mean MMSE of 21 ± 2) had significantly greater increases in the total area of sway and the path of the sway as a result of the cognitive task. These increases in sway are indicative of less effective postural control when attention must be divided.

Decreases in postural control place people with dementia at an increased risk for falling. The rate of falls for those with dementia is approximately twice the rate of falls for those without

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dementia.⁶ Tinetti et al followed 336 community-dwelling adults over the age of 75 years for one year and found that 50% of those with cognitive impairment experienced a fall while only 30% of those without cognitive impairment experienced a fall.⁷ In individuals living in nursing homes, van Doorn et al found people with dementia were twice as likely to fall as people without dementia.⁸ Following newly admitted residents over two years they established a rate of falls of 4.05 per person-year in those with dementia compared to a rate of falls of 2.33 per person-year in those without dementia. Risk of injury has also been found to be higher in individuals with dementia compared to individuals without dementia.^{8,9}

The presence of cognitive decline and dementia have, in fact, been identified as independent risk factors for falls and for injurious falls in older adults living in the community.^{7,10} However, within a population of people with dementia, the relationship between degree of cognitive decline and falls is less well understood. In 124 outpatients with probable AD and mean MMSE score of 16.2 ± 5.9 followed over one year for fall occurrence, Horikawa et al found no significant difference in MMSE scores between fallers and non-fallers.¹¹ Similarly, Bassiony et al found no association between fall status and MMSE scores in community dwelling older adults with a mean age of 77 ± 8 years and a mean MMSE score of 15 ± 7 .¹² In people with dementia living in geriatric settings in Sweden, Kallin et al did find a relationship between level of cognitive function and falls, however it was not a linear relationship.¹³ They found those with the highest and lowest levels of cognitive function were at lower risk for falling and those with intermediate levels of cognitive function were at the greatest risk for falling. At this time, knowing degree of cognitive impairment in someone with dementia is not sufficient to understand risk of falling.

Risk for falls in older adults is multifactorial. Known risk factors include older age, previous history of a fall, and decreased function and postural control. Fall incidence increases with increasing age in the general population.¹⁴ Older age has also been found to be independently associated with fall occurrence in people with Alzheimer's disease.¹² Previous occurrence of a fall is a strong predictor of a subsequent fall in older adults without dementia, and has been found to be associated with falls in those with dementia.^{13,15}

Assessment of physical performance is a common way of determining postural control and is used to determine risk of falls in older adults. While there are a number of performance-based measures available to assess postural control and risk of falls in older individuals without cognitive impairment, few have been evaluated for use in individuals with dementia. Given the decline in function and increased risk of falls and fall related injury associated with dementia, a need exists for standardized tools that assess these domains to be validated in people with dementia. To confidently identify individuals with dementia who are at risk for falling, an assessment tool needs to be evaluated for its diagnostic accuracy within this specific population.

One barrier to using assessment tools in people with dementia is the concern that these individuals will not be able to follow the standardized instructions in a manner that would allow for accurate scoring of the assessment tool. In the few studies that have examined functional performance in subjects with dementia, it appears that the extent of cognitive involvement, complexity of testing items, and novelty of testing items influence the ability of subjects to complete the tests and the level of reliability that is established.¹⁶⁻¹⁹

The Physical Performance Test (PPT) is a performance-based measure that has good potential for use in people with dementia. The PPT incorporates multiple physical domains into the assessment including activities of daily living (ADLs), gross motor activities, fine motor control, balance, and walking.²⁰ Because items on the PPT include commonly

performed functional skills, individuals with dementia may be more likely to successfully follow directions and complete the tasks. While other assessment tools (*e.g.* Berg Balance Scale and Dynamic Gait Index) present greater challenges to postural control and are more commonly used clinically, they also include items that are novel and more complex.^{21–22} The concern with using one of these tools for this study population was the potential decreased likelihood that subjects with dementia would be able to successfully complete all testing items.

The validity of the PPT to assess functional performance, measure change, and identify fall risk among older adults has been established.^{23–27} The ability of the PPT to assess ADL function and fall risk gives it the potential to be a very useful tool in the assessment of people with dementia. In the 7-item version of the PPT, the clinician records the time it takes the patient to write a sentence, spoon beans from a bowl into a coffee can (simulated eating), lift a book onto a shelf above shoulder height, put on and remove a jacket, pick up a penny from the floor, and walk fifty feet. One item, turning 360°, is not timed. It is rated either zero or two for continuity of steps and for steadiness.²⁰ Scores for the 7-item test range from 0–28 with higher scores indicating better performance.

Reliability of the PPT has been established in subjects without known cognitive deficits.^{20,28–29} The PPT allows for assessment of older adults with a broad range of functional abilities.³⁰ Subjects less frequently achieve ceiling scores on the PPT when compared to self-report measures.³⁰ Scores on the PPT are associated with significantly different frequencies of medical diagnoses, somatic symptoms, medications taken, and number of co-morbidities.^{23,25,26, 30}

The PPT has also been found to have predictive validity. In community-dwelling older adults, lower scores on the PPT were a significant predictor of death or institutionalization 18–24 months later.³¹ The PPT has also been identified as an independent predictor of recurrent falls in older adults without specified dementia. In a study of 84 frail, community-dwelling veterans, VanSwearingen et al assessed multiple tests for their ability to identify recurrent fallers.²⁴ Recurrent faller status was determined through a structured interview of subjects. Those who reported two or more falls in the previous year were identified as recurrent fallers. Of the 84 subjects, 53 were found to be recurrent fallers. The 7-item PPT was identified as an independent factor in predicting fall risk. A cut-off score of 15 out of a possible 28 resulted in a sensitivity of 79.3% and a specificity of 71% in identifying those who fell repeatedly. Delbaere et al studied multiple intrinsic risk factors in an attempt to construct a risk model to identify frequent fallers.³² A total of 263 older adults with a mean age of 72 years and no diagnosis of dementia were followed for one year and 33.5% of the subjects fell at least once. A cut-off score of <19 for the 7-item PPT or < 25 for the 9-item PPT was found to significantly increase the odds of the person being a frequent faller compared to being a non-faller by four times.

With the differences in postural control and rate of falls in people with dementia compared to older adults without dementia, it is unclear if the PPT will be a good predictor of falls in this population. Given the potential benefits of the PPT for individuals with dementia, it is necessary to establish validity of the PPT in this population. The purpose of the study was to determine the accuracy of the PPT in identifying people with dementia who will experience a fall.

METHODS

Individuals with a diagnosis of dementia were recruited from the greater Portland, OR area. Subjects were included in the study if they had mild to moderate dementia as identified by

scores between 10 and 24 on the MMSE and if they had a care provider available for testing and signing the informed consent form.^{33,34} Subjects were excluded from the study if 1) they had a diagnosis of stroke or Parkinson's disease or other medical condition that would interfere with testing, 2) they required physical assistance for walking, or 3) they did not speak English.

Subjects gave verbal assent and a legal guardian signed an informed consent form approved by the Institutional Review Boards of Pacific University and Rocky Mountain University of Health Professions. A single tester, a physical therapist with previous experience administering the PPT, tested each subject at his or her residence. A questionnaire regarding medical history and information pertinent to inclusion and exclusion criteria was administered to both the subject and the caregiver. As a part of this questionnaire, subject and caregiver pairs were asked to report number of falls that the subject had experienced in the previous six months. The MMSE was then administered to the subject followed by the 7-item PPT. While the tester was blind to the occurrence of future falls, she was not blind to the subject's previous history of a fall.

Following testing, each subject/caregiver pair was instructed in the follow-up procedures. They were given a calendar to post on the refrigerator and instructions to mark on the calendar any falls that occurred during the follow-up period. The definition of a fall was written on the calendar and verbally explained to the subject and caregiver. A fall was defined as "unintentionally coming to rest on the ground, floor or other lower level" and excludes "coming to rest against furniture, wall, or other structure."³⁵ To collect data on fall occurrences and to act as reminder to mark falls on the calendar, a phone call to each residence was made by the primary tester every two weeks. Data on fall occurrences was collected over four-months. This time-frame was chosen in an attempt to be long enough to capture fall occurrences but not so long that progression of the disease process could be a confounding factor. Progression of cognitive decline has been estimated at .24 MMSE points per month, suggesting that after four months subjects in this study would, on average, have an MMSE score that was one point lower.³⁶

During the administration of the PPT, prior to performance, subjects received verbal instructions as well as demonstration of each item. Anticipating that subjects with dementia might have difficulty with short-term memory and with following instructions, testing protocol was modified to include verbal cueing during testing. If a subject appeared to lose focus on a task while performing it, verbal cues were given for redirection. If the subject exceeded the allotted time to complete a task, and it was determined by the examiner to be the result of a distraction, the subject was asked to re-do that item. Subjects also re-did any item if they had difficulty following instructions the first time. Determination of when to allow a second attempt was left to the primary tester's clinical judgment. For example, subjects who stopped performance to begin a conversation or to ask a question were allowed to re-do the item. No item was completed more than two times. Use of assistive device was permitted for all standing activities. In this current study, reliability of the PPT and tester were established and results are presented in Table 1. Description of the procedure to establish reliability is presented elsewhere.³⁷

Data Analysis

A priori power analysis for regression ($\alpha = .05$, three variables, and assumed variance of .30) determined minimal sample size to be 31 subjects.³⁸ There is no power analysis for logistic regression, therefore this formula was used as a close approximation to help estimate sample size. The three variables entered in to the equation were age, history of a fall, and PPT score. The assumed variance of .30 was estimated since falls are multifactorial and it seems unlikely for any one measure to account for a majority of the shared variance. All

statistics were determined using SPSS statistical analysis software version 15 (Copyright © 2006, SPSS Inc., Chicago, Illinois 60606).

Descriptive statistics (mean, standard deviation) were calculated for the variables of age, MMSE score, time since diagnosis of dementia, previous falls (history of no fall or one or more falls in the previous six months), and the number of falls experienced in the follow-up period. A stepwise logistic regression was used to predict the dependent variable, fall status during the four month follow-up period. Fall status was dichotomized as either no fall or at least one fall. Variables entered into the equation included age, previous history of a fall, and PPT score. Age and history of a fall were included as they have been previously identified as risk factors for falls in people with dementia.¹²⁻¹⁵ Criteria for entry into and removal from the regression equation were an alpha of .05 to enter and .10 to remove. Sensitivity and specificity for the predictor variables were then calculated. To determine the cut-off score, a receiver operator characteristic curve (ROC) was plotted to identify a score that represented the best combination of sensitivity and specificity for those variables. Likelihood ratios were then calculated.

RESULTS

Thirty-four subjects with dementia, 19 women and 15 men, participated in the study. Information on their age, MMSE scores, and time since diagnosis are presented in Table 2. Twelve subjects (35%) reported a history of a fall in the previous six months. Twenty-one lived at home, six lived in senior housing, six lived in either assisted living or adult foster care facilities, and one lived in a specialized Alzheimer's unit. Nine subjects (27%) used an assistive device for ambulation; six using a cane occasionally when outdoors or when feeling unsteady and three using a wheeled walker for all ambulation.

All subjects completed the four month follow-up and 12 (35%) reported at least one fall during that period. Of these 12, four reported more than one fall. From the three variables entered into the stepwise logistic regression (previous history of a fall, PPT score, and age), only history of a fall in the previous six months was a significant predictor of a fall in the four-month follow-up period ($p = .044$). A previous fall increased the odds of having a subsequent fall by almost five times [odds ratio 4.76 with 95% CI (1.04, 21.77)]. The addition of neither age nor PPT score significantly changed the predictive ability. Table 3 shows the 2x2 table and calculated sensitivity, specificity, and likelihood ratios for history of a fall.

If PPT score was forced into the logistic regression equation as a lone variable, it was not a significant predictor ($p = .081$). An ROC curve for PPT score was created and the area under curve was .674 with a 95% CI (.478, .870). A cut-off score of 19 yielded the best combination of sensitivity and specificity. Table 4 shows the 2x2 table for PPT score using 19 as the cut-off score. Calculated sensitivity and specificity were 83% and 41% respectively and positive and negative likelihood ratios were 1.41 and .41 respectively.

Of the 13 subjects who were identified as a faller by their PPT score but did not experience a fall in the four month follow-up period (false positives), four had experienced a fall in the previous six months, three others had reported a fall prior to the six month period, with two of them experiencing a hip fracture, and one had a significant change in condition during the follow-up resulting in 24 hour hospice care.

DISCUSSION

The purpose of this study was to determine the accuracy of the PPT in identifying fallers within a population of people with dementia. As a part of this study, we also included other

potential risk factors for fall; age and history of a fall. The results suggest that report of a fall in the previous six months was the strongest predictor of a fall in the subsequent four months. A history of a fall in the previous six months increased the odds of a fall in the subsequent four months by five times. This outcome is supported by other research. Gerdhem et al had similar results in a population of older woman where, compared to performance-based measures, occurrence of a fall in the previous year was a stronger independent predictor of a fall in the subsequent year with an OR of 2.91 and 95% CI (2.09, 4.06).¹⁵ Kallin et al also found, in 2,008 older adults with cognitive impairment living in geriatric settings in Sweden, those with previous history of a fall during their stay at the facility had greater odds of having a fall over a one week period with an OR 2.78 and 95% CI (2.09, 3.69).¹³

While history of a fall was the strongest predictor of a subsequent fall, there were five subjects with no history of a fall in the previous six months who did experience a fall in the four month follow-up period. Of these fallers, two had had a fall prior to the six month period and one had reported experiencing occasional stumbles without a fall. Their PPT scores ranged from 9 to 23, MMSE scores ranged from 15–21, and age ranged from 72–87. None of them used an assistive device. Two of the subjects experienced falls that were not witnessed and therefore the circumstances were not clear. One subject fell outside in the rain, tripping over a parking curb, one fell off the end of the bed while sitting, and one fell two times, once from bumping into the edge of a table and once while carrying a laundry basket. Based on visual inspection of this data it is possible that use of a fall history greater than six months, such as the one year history used by Gerdhem et al, might improve the predictive ability of history of a fall.¹⁵

Over the four month follow-up 35% of the subjects in this study experienced at least one fall. Within this population it took only four months to approach the incidence of falls that occur over the course of one year in similarly-aged community dwelling older adults without cognitive impairment.^{7,39} The apparent higher rate of falls in our group is consistent with the higher rate of falls in people with dementia identified in other studies. The adjusted OR for a fall in those with cognitive impairment, calculated by Tinetti et al, was 5 (95% CI 1.8, 13.7).⁷ Similarly, when Asada et al followed community-dwelling subjects over the course of six months they found the rate of falls to be three times greater in those with dementia.⁹

Our results regarding the predictive ability of the PPT differed from those of VanSwearingen et al and Delbaere et al.^{24,32} In frail older men with unknown cognitive status, VanSwearingen et al found the PPT to be an independent factor for predicting falls. Using a cut-off score of 15 they found sensitivity of 79%, specificity of 71%, a positive likelihood ratio of 2.73, and a negative likelihood ratio of 0.29. Delbaere et al found, in a group of 263 older adults with a mean age of 72 years and no diagnosis of dementia, a cut-off score of <19 for the 7-item PPT or < 25 for the 9-item PPT increased the odds of the person being a frequent faller compared to being a non-faller by four times.

Differences in study design may account for some of the differences in outcomes. In the current study, subjects were followed prospectively for four months. VanSwearingen et al collected fall data retrospectively over six months and Delbaere et al collected fall data prospectively over one year.^{24,32} It is possible that the shorter time-frame used to collect fall occurrences in the current study was not sufficient to capture all potential fall occurrences. Another key difference in the current study was the definition used to identify a faller. The other two studies included only those with two or more falls in the faller group, while we chose to include those with one or more falls in the faller group and did not have a multiple faller category. Lastly, difference in cognitive function between subjects in our study and

subjects in the studies by VanSwearingen et al and Delbaere et al may also have been a contributing factor to the differences in outcomes.^{24,32}

One other potential threat to the validity of the outcomes was the use of self-report to identify fall occurrences. While attempts were made to ensure the accuracy of self reported fall occurrences, it is possible that the data collected was not entirely accurate. Self report/caregiver report of a fall in the previous six months may be inaccurate as a result of either not recalling a fall occurrence or not considering a fall to be an event worth reporting. Strategies to ameliorate this included discussing the definition of a fall, emphasizing that even if no injury occurred it would still be considered a fall, and telling the subject/caregiver pair what month it was six months ago and listing the six months under consideration. For collection of follow-up fall occurrence data subjects were given a verbal and written definition of a fall and were contacted every two weeks to gather fall data. The phone call provided a shorter recall timeframe and acted as a reminder to keep track of falls. While there is no way to know for sure if the fall occurrences reported were accurate, we believe the strategies employed resulted in data that was as precise as possible.

Based on the results of this study, PPT scores by themselves have limited usefulness in predicting falls over the course of four months in individuals with dementia. Contributing factors for falls in people with dementia are numerous and not fully understood.⁶ While components of physical function, such as gait and postural control, are known factors, many non-physical function contributors, such as medication use and the presence of orthostatic hypotension, also contribute to fall risk.⁶ The fact that the PPT does not incorporate these components may help explain why it did not have high diagnostic accuracy in predicting falls. Instead, the results of the PPT might best be used as a piece of the decision making process. The use of likelihood ratios can assist in this process. A clinician can generate a probability for falls based on factors like medication use and history of a fall and then use the results of the PPT to generate a post-test probability. For example if an individual with dementia had a pre-test probability of falling in the next four months of 35% (generated from our incidence data) and scored above 19 (a negative test score) on the PPT, the probability of them falling in the next four months drops to about 18%. If the individual had a positive test result (<19) then the post-test probability of falling in the next four months increases to about 42%. As noted in this example, a negative test result may be more clinically useful in altering our perception of a person's likelihood of falling in the next four months than a positive test score does. However, caution must be taken in interpreting the likelihood ratios. As shown in Table 4, for both the positive and negative likelihood ratios, the 95% CI crossed one. Since the 95% CI indicates the range in which the real likelihood ratio exists there is a possibility that the likelihood ratios are not clinically useful.

Individual items within the PPT may also have contributed to the limitations in its diagnostic accuracy. In administering the PPT within subjects' residence, one item, placing a book on a shelf above shoulder height, was difficult to standardize. The instructions provided by Reuben et al only specify that the shelf be above shoulder height.²⁰ Within each residence it was possible to find a shelf that met this criteria; however, the distance above shoulder height differed. Subjects with higher shelves may require more time to complete the task, which potentially could have artificially lowered scores for that item. Standardizing a height for the shelf, relative to the subject, could improve this problem, however, it would also make it more difficult to find a shelf within an individual's residence that met the criteria.

One other potential factor limiting the diagnostic accuracy of the PPT is its inclusion of two items that do not have an apparent postural control demand to them. The first two items, writing a sentence and simulated eating, are upper extremity tasks completed in a seated position (we chose to have subjects perform the place book on shelf item in standing). It is

therefore possible that some subjects scored lower on the PPT because of poor performance on one of the first two items. The lower score could have inaccurately identified them as a faller. Writing a sentence did, in fact, prove to be a challenge for all 34 subjects. None of the subjects completed the item fast enough to score a 4; ten subjects scored a 3, five scored a 2, thirteen scored a 1, and six scored a 0. Their slower times indicate difficulty with the task of writing, but not necessarily difficulty with postural control. It is possible that the PPT would have greater diagnostic accuracy for falls by eliminating the first two items, or by replacing them with items with greater postural control demands. Brown et al has presented a modified version of the PPT where those two items are replaced by items related to postural control; repeated chair stands (time to rise five times from a 16" chair) and progressive rhomberg (ability to maintain balance with feet together, in semi-tandem, and in full tandem).^{26,27}

In our testing protocol subjects were allowed to use their assistive device for the items done in standing (items 3–7). In the original study by Reuben and Siu, assistive device use was allowed for conditions 6 and 7 (turn 360 and 50' walk).²⁰ It is possible that allowing subjects to use assistive devices for additional items 3–5 (placing book on a shelf, putting on and removing jacket, and picking a penny up from floor) may have altered the time to complete the tasks or the ability of the subjects to successfully complete the tasks. While this could have inflated the scores of the three subjects who used a walker during testing, it most likely only affected one of the subject's scores as the other two scored 0's on these items.

One final potential factor that may have influenced the diagnostic accuracy of the PPT was the smaller sample size. Prior to data collection we calculated a power analysis for regression and estimated that a sample size of 31 subjects would be required. As a part of this equation we made an estimation of a shared variance of .30. This was an estimation based on the assumption that, because falls have multifactorial causes, any one factor would account for only a small amount of the variance associated with falls. The purpose of this calculation was to estimate sample size. It is possible that the estimation of variance was too high, and as a result sample size was underestimated. If this was the case, then any potential association between PPT scores and falls would be missed.³⁸ VanSwearingen et al and Delbaere et al, who both found PPT score to be a factor associated with falls, had larger sample sizes with 84 and 263 subjects respectively.^{24,32}

Based on the results of this study, we could not currently recommend use of the PPT for identifying fallers; however, further research is warranted. It is possible that the PPT is a better indicator of postural control than of fall prediction over a four month period. Of the 13 false positives (Table 4), seven had other strong risk factors for falling, and one had a significant change in condition. It is possible that the PPT was accurately assessing postural control despite the fact that those individuals did not fall.

CONCLUSION

This study was the first to look at the diagnostic accuracy of a performance-based measure of function within a population of people with dementia. While subjects were able complete the PPT, the outcomes were insufficient to draw a conclusion on its diagnostic accuracy for fall risk. Based on the results of this study, report of a fall in the previous six months is the strongest predictor of a fall in the subsequent four months in people with dementia. Neither age nor PPT score were independent factors for predicting falls. Further research is indicated. Considerations for future research on the predictive validity of the PPT in people with dementia should include several factors. For identifying fallers, a larger sample size and longer follow-up time should be implemented. In addition it may be appropriate to use

the modified version suggested by Brown et al.^{26,27} In all instances, previous history of a fall should be a part of the data collected for subjects with dementia.

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Table 1

Reliability of the 7-item PPT

	Reliability	95% CI*
Intra-tester ICC (3,1)	.99	(.98, .99)
Test-retest ICC (3,1)	.90	(.81, .95)

* CI-confidence interval

Table 2

Subject Demographics

	Mean \pm standard deviation	Range
Age (years)	76.6 \pm 9.5	50–93
MMSE* Score (max 30)	18.4 \pm 3.3	10–24
Time since dementia diagnosis	3.8 \pm 3.5 years	1 month–15 years

* MMSE- Mini Mental State Exam

Table 3

Predictive ability of previous history of a fall

Previous 6 months	Four month follow-up	
	fall	no fall
fall	7	5
no fall	5	17
Sensitivity: .58 with 95% CI (.32, .81)		
Specificity: .77 with 95% CI (.57, .90)		
+ Likelihood ratio: 2.57 with 95% CI (1.04, 6.36)		
- Likelihood ratio: .54 with 95% CI (.27, 1.09)		

Table 4

Predictive ability of the PPT

PPT score	Four month follow-up	
	fall	no fall
19	10	13
> 19	2	9
Sensitivity .83 with 95% CI (.55, .95)		
Specificity .41 with 95% CI (.23, .61)		
+ Likelihood ratio 1.41 with 95% CI (.92, 2.17)		
- Likelihood ratio .41 with 95% CI (.10, 1.59)		