

Is dual task performance the most useful factor for fall prediction?

Tomomi Yamada, Fujiko Someya*

Abstract

The aim of this study was to clarify the usefulness of assessing dual task performance for fall prediction. In experiment 1, we prospectively investigated the new fall experiences of 108 participants (50 elderly daycare users and 58 fall prevention class participants) and produced a fall prediction model. The fallers represented the subjects who suffered a new fall experience during the follow up 12-month period, whereas the non-fallers did not fall during this period. The two groups were compared with regard to their age, sex, history of falling, medication related to falling, grip strength, gait speed, step length, dynamic standing balance, the Timed Up and Go (TUG) test score, dt-TUG score, %TUG, and mini-mental state examination score. Multivariate logistic regression analyses were performed to produce a fall prediction model. In experiment 2, we investigated the accuracy of the fall prediction model using 39 newly recruited individuals. In experiment 1, 8 (13.8%) of the fall prevention class participants fell within 12 months. Among the fall prevention class participants, there were significant differences in grip strength, gait speed, step length, TUG, and dt-TUG between the fallers and non-fallers. In stepwise logistic regression analysis, two factors were found to have value for fall prediction; i.e., falling within one year preceding the baseline and TUG. In experiment 2, 12 people were predicted to fall within the 12-month follow-up period; however, only 5 people actually fell. Three of them were predicted to fall, but 2 of them were not. The success ratio of the fall prediction model was 60%. Nine of the 12 people that were predicted to fall did not. Our result showed that TUG was the most important factor for fall prediction; however, dt-TUG was also related to fall prediction in individuals that were not in receipt of care services. Therefore, dual task performance could be a useful reference factor for fall prediction.

Key words

fall, the elderly of living at home, prediction, the physical function, dual task performance

Introduction

Falls can change the quality of life of healthy elderly individuals. In Japan, people aged 65 years or older now represent more than 21%¹⁾ of the population; therefore, the detection of fall risk in the elderly is very important. Measures to protect the elderly against falling have been taken in all parts of Japan. For example, occupational therapists

have intervened in fall prevention in many cases. Nevitt MC et al.²⁾ reported the intrinsic risk factors for falling and divided them into three levels, strong, moderate, and weak. The “strong” risk factors included an age of 80 years or older, being female, mobility impairment, a history of falls, poor performance in an activity-based test of balance, slow gait speed, short step length, poor physical

Division of Health Sciences, Kanazawa University Graduate School of Medical Sciences
* School of Health Sciences, Kanazawa University

performance, reduced muscle strength, cognitive impairment, Parkinson's disease, and medication; however, poor dual task performance was not shown to be an intrinsic risk factor. The incidence of fall is varied among the studies³⁻⁷ and one of the reasons of this variety might be due to the various profiles of subjects in each study⁸⁻¹².

Some studies¹³⁻²¹ have reported a relationship between dual task performance and fall risk. Therefore, an assessment involving complex dual task performance might predict falls better than a physical assessment or a simple cognitive task alone. Dual task studies could provide new interventions for occupational therapists when added to tasks considering physical function, cognitive function, and the environment.

In a previous study, we investigated fall risk using a semi-structured interview, a physical assessment, and dual task performance as a cross-sectional study²². As a result, we suggested that a slow gait speed and a short step length were "strong" risk factors for falling, and it was also suggested that dual task performance is partially related to fall risk. Moreover, physical assessments and dual task performance could not predict the risk of fall in participants that had suffered a stroke or were on medication. Thus, previous studies have not clarified the importance of dual task performance on falls.

In experiment 1, we prospectively investigated the new falling experiences of the 108 individuals we examined in our previous study²² over a 12-month period and assessed the accuracy of fall predictions derived from dual task performance. We subsequently produced a fall prediction model. In experiment 2, we investigated the accuracy of the fall prediction model in 39 newly recruited individuals. The objectives of this study are to clarify the usefulness of assessments of dual task performance for fall prediction.

Method

1. Experiment 1

Participants and Procedures

The study design and data collection were described in our previous report²². The previous

study included 108 individuals of 65 years or older, including 50 elderly daycare users and 58 fall prevention class participants, who were recruited in 2005. Information on fall incidents was collected during a 12-month follow-up period from two sources. Elderly daycare users were asked whether they had fallen in the previous year by their medical staff, and the fall prevention class participants were questioned by phone. The response rate was 95.4%; 45 elderly daycare users and 58 fall prevention class participants participated in the study. The selected subjects were able to walk at home and carry out tasks, even though some of them had dementia, visual or hearing impairments, or partial paralysis.

Age, sex, fall history, medication, Mini-Mental State Examination (MMSE) score, grip strength, gait speed, step length, dynamic standing balance and Timed up & Go test (TUG) score were assessed. For the dual task test, a 2-step forward calculation was performed during the TUG (dt-TUG). It is because that this dual task was reported to affect motor performance in the elderly but not in the young²³. The subjects in the fall prevention class could not undergo the MMSE because the class sponsor prohibited it.

Medication use was classified into two categories: (1) no medication use or medication unrelated to falling and (2) medication related to falling (hypnotics, benzodiazepine, antidepressants, neuroleptics, antihypertensives, vasodilators, NSAID, cardiac drugs, antiepileptic medication, antiparkinson's medication, or chalybeates).

The dt-TUG was assessed using two kinds of evaluation, one was performance time, and the other was whether they "Stopped walking when talking". The ratio obtained by dividing dt-TUG score by TUG score was calculated as follows: $dt-TUG / TUG \times 100 = \%TUG$.

2. Statistical Analysis

We showed the characteristics of the two facilities separately to know the difference of incidence of fall. The subjects' baseline characteristics are shown in table 1. The fallers represented those participants who suffered a new fall experience during the follow up 12-month period, whereas the

non-fallers did not fall within this period. The two groups were compared using the Student t-test for continuous variables: age, grip strength, maximum walking speed, step length, TUG, dt-TUG, %TUG, and MMSE score; the Mann-Whitney U-test was used for comparing ordinal variables: dynamic standing balance; and the Chi-square test was used to compare categorical variables: fall history and medication related to falling.

Secondly, multivariate logistic regression analyses were performed to elucidate the relationships between fall occurrence during the follow-up period and the baseline characteristics. Variables showing statistically significant associations ($p < 0.15$) in this analysis were entered into the subsequent stepwise logistic regression analysis to produce a fall prediction model.

Thirdly, the validity of the stepwise logistic regression model was compared by computing its sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the likelihood ratio (LR) divided by the cutoff score for each parameter at a criterion level of 0.05. Cutoff scores were calculated from a Receiver Operator Characteristic (ROC) curve (Figure.1). The LR combines sensitivity and specificity into a value of prognostic accuracy at an individual level²⁴. The thresholds for prognostic significance were: positive $LR > 2.0$ (LR+) and negative $LR \leq 0.5$ (LR-)²⁵.

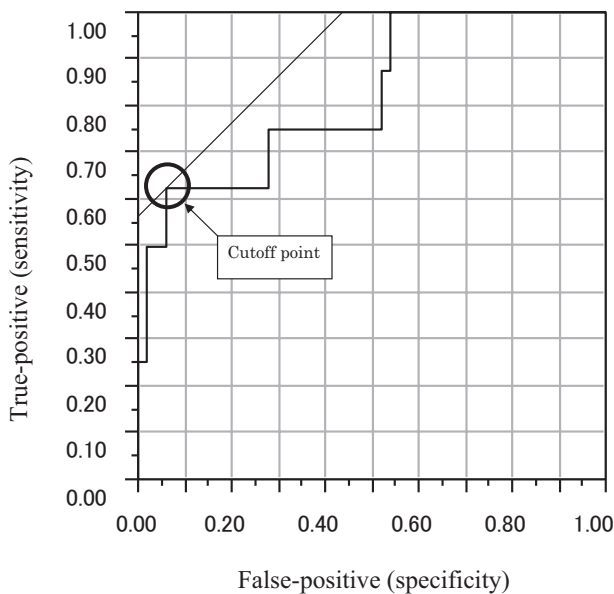


Figure 1. ROC curve area and cutoff point of TUG

All analyses were performed in JMP, version 7.0. Significance was set at $p < 0.05$.

Experiment 2

Participants and Procedures

The participants were recruited through the Nomi Municipal Hospital and a senior citizens' class in Nonoichi. The inclusion criteria were the same as in experiment 1 but participants in receipt of a care service were excluded. The study was approved by the Medical Ethics Committee of Kanazawa University (Ethics judgment number: 140), and the participants gave their informed consent to participate in this study.

Thirty-nine individuals (26 women and 13 men, mean age \pm SD = 75.0 \pm 4.8 years) were enrolled this study between April and July 2008. Two participants (5.2 %) suffer a stroke, and 2 other (5.2 %) underwent total knee arthroplasty. However, they were able to carry out our evaluation tasks.

First, the participants' data was input into the fall prediction model produced in experiment 1. During the next 12 months, information about any new fall experiences was collected by phone between April and July 2009. Then, we calculated the accuracy of the fall prediction model.

Results

Experiment 1

None of the fall prevention class participants died during the follow-up period. All of them were asked about any falls they had suffered, and 8 (13.8%) of these subjects fell during the 12-month study period.

Five of the elderly daycare users dropped out because they were hospitalized or had left the elderly daycare service, and 16 (32.0%) of these subjects fell during the 12-month study period.

Table 1 shows that there were significant differences in grip strength, gait speed, step length, TUG, and dt-TUG between the fallers and non-fallers among the fall prevention class participants. However, there were no significant differences in the any of the parameters among the elderly daycare users. Accordingly, the forward analysis was only applied to the fall prevention class

Table 1. Comparison of baseline characteristics between elderly subjects who did and did not fall during the 12-month study period

	Fall prevention class participants			Elderly daycare users		
	Non-fallers n=50	Fallers n=8	P	Non-fallers n=29	Fallers n=16	P
Age, mean \pm SD	75.1 \pm 5.2	76.1 \pm 7.9	0.629	84.1 \pm 5.2	86.4 \pm 5.7	0.170
Female, n (%)	35 (60.3%)	8 (13.8%)	0.072	23 (51.1%)	13 (28.9%)	0.876
History of falling at the baseline, n (%)	24 (41.4%)	6 (10.3%)	0.156	23 (51.1%)	14 (31.1%)	0.492
Fall within one year preceding the baseline, n (%)	10 (17.2%)	4 (6.9%)	0.066	11 (24.4%)	6 (13.3%)	0.977
Medication related to falls, n (%)	27 (45.6%)	4 (6.9%)	0.833	22 (48.9%)	13 (28.9%)	0.677
Grip strength (kg)	27.04 \pm 5.61	22.22 \pm 3.63	0.029	19.51 \pm 5.37	17.92 \pm 4.22	0.312
Dynamic standing balance (point)	1.58 \pm 0.70	2.00 \pm 1.20	0.164	2.41 \pm 0.98	2.50 \pm 0.90	0.773
Gait speed (m/min)	89.89 \pm 16.30	75.53 \pm 16.21	0.024	55.34 \pm 18.78	53.40 \pm 15.03	0.803
Step length (m)	0.683 \pm 0.099	0.593 \pm 0.092	0.020	0.476 \pm 0.106	0.471 \pm 0.108	0.867
TUG (s)	7.6 \pm 1.2	9.7 \pm 1.8	<0.0001	15.5 \pm 7.9	14.0 \pm 4.8	0.500
dt-TUG (s)	9.2 \pm 1.9	10.7 \pm 2.7	0.048	21.4 \pm 12.5	18.4 \pm 7.6	0.391
%TUG	120.0 \pm 17.2	108.3 \pm 13.2	0.071	138.4 \pm 35.9	131.9 \pm 32.2	0.553
Stop walking when talking, n (%)	4 (6.9%)	0 (0%)	0.407	6 (13.3%)	5 (11.1%)	0.430
MMSE				23.8 \pm 4.6	24.9 \pm 4.6	0.413

Table 2. Risk model for the prediction of falls obtained by multiple logistic regression analysis (N=58)

Variable	χ^2	p	OR	95%CI
Fall experience within one year preceding the baseline, n (%)	2.32	0.1315	4.33	0.80 – 5.40
TUG(s)	12.76	0.0036	3.02	1.57 – 7.26

OR: odds ratio, 95%CI: 95% confidence interval

participants.

In the stepwise logistic regression analysis, two factors were chosen as predictors of falls; i.e., a fall within one year preceding the baseline and TUG. In table 2, the multivariate regression model shows that TUG was significantly associated with new fall events, and the fall prediction model is

described below.

$\log p/(1-p) = 11.099 + 0.733 \times (\text{fall within one year preceding the baseline, Yes} = -1, \text{No} = 1) - 1.104 \times \text{TUG}$
 $p \leq 0.5$: No fall
 $p > 0.5$: Fall
 p: occurrence probability

Table 3. Cutoff scores for falls during the 12-month study period (N=8) versus no falls (N=50)

	Cutoff	Sensitivity	Specificity	PPV	NPV	LR+	LR-	AUC
Fall experience within one year preceding the baseline	yes	50 (4/8)	80 (40/50)	28.7	90.9	2.5	1.6	0.635
Grip strength (kg)	≤ 21.9	62.5 (5/8)	86 (43/50)	41.7	93.5	4.46	2.29	0.748
Gait speed (m/min)	≤ 76.73	62.5 (5/8)	80 (40/50)	33.3	93.0	3.13	2.13	0.723
Step length (m)	≤ 0.556	50 (4/8)	88 (44/50)	40	91.7	4.17	1.76	0.74
TUG (s)	≥ 9.3	62.5 (5/8)	94 (47/50)	62.5	94	10.42	2.51	0.82
dt-TUG (s)	≥ 12.49	50 (4/8)	94 (47/50)	57.1	92.2	8.333	1.88	0.696
%TUG	≥ 112.32	75 (6/8)	68 (34/50)	27.3	94.4	2.34	2.72	0.695

The fall prediction model

Fall experience within one year preceding the baseline and TUG	100	68	33.3	100	3.125	0.888
--	-----	----	------	-----	-------	-------

PPV: positive predictive value, NPV: negative predictive value, LR+: Likelihood Ratio of a positive test result, LR-: Likelihood Ratio of a negative test result, AUC: Area Under the ROC Curve

Table 3 shows each cutoff point, the area under the ROC curve (AUC), and the values associated with the accuracy of fall risk prediction derived from grip strength, gait speed, step length, TUG, dt-TUG, %TUG, and the fall prediction model. Each cutoff point was defined as the point at which the sum of sensitivity and specificity was highest (Figure 1). The cutoff points for TUG and dt-TUG were 9.3 and 12.49 seconds, respectively. While some sensitivity values were as low as 62.5 and 50%, the largest AUC and the highest sensitivity were found in the fall prediction model: 0.888 and 100, respectively.

Experiment 2

The fall prediction model was applied to all participants. All of them provided information about their fall experiences. Twelve individuals had been predicted to fall during the 12-month follow-up period; however, only 5 people actually fell. Among these 5 individuals, three of them had been predicted to fall, but 2 had not been predicted to fall. The success ratio of the fall prediction model was 60%. Nine of the 12 individuals that had been predicted to fall did not fall.

Discussion

Our result showed that TUG was the most important factor for fall prediction; however, dt-TUG was also related to fall prediction in community-dwelling people that were not in receipt of a care service. Therefore, dual task performance could be a useful reference factor for fall prediction.

For elderly daycare users, the number of faller was larger (32%) than those of previous studies (from 10 to 20%) and there were no significant differences between the fallers and non-fallers in any of the factors we examined. These results suggest that fall in elderly daycare users does not occur according to their physical factors examined here but to another unrevealing factor. This result and those of our previous study²²⁾ suggest that individuals who need elderly daycare are always at risk of falling; therefore, fall prediction is pointless for this group.

Changes in gait due to dual task performance

have been reported among older adults²⁶⁾, and a relationship between gait during dual task performance and future falls has been reported¹⁸⁻²⁰⁾. Beauchet et al.¹⁹⁾ suggested that backward counting provoked significant gait changes compared to walking alone, but did not provide any additional predictive information with regard to fall prediction including from simple walking. This result supports our findings.

Beauchet et al.²⁷⁾ reviewed studies about the utility of dual task performance for fall prediction performed from 1997 to 2008. Some studies¹³⁻²¹⁾ suggested that dual task performance was related to fall risk, whereas others²⁸⁻³⁰⁾ suggested the relationship was weak. However, these studies did not involve a standardized method, participant characteristics, etc.; therefore, no consensus on the utility of dual task performance in relation to fall prediction has been reached.

Nordin E et al.³¹⁾ suggested that a shorter step length during dual task performance than during simple walking was related to fall prediction. In the future, we need to study the appropriate usage of dual task performance in the relation to fall prediction.

In experiment 1, we produced a fall prediction model and then investigated the accuracy of the model. As a result, we found that the success ratio of the fall prediction model was 60 % in experiment 2. Previous studies indicated that about 10-20% of elderly people experience a fall within a 12-month period, while 12.8% of all participants fell during the 12-month follow-up period in this study. A meta-analytical method should be used to produce a more accurate fall prediction model in future.

The limitation of our study is that we use a 2-step forward calculation and TUG as the dual task test, while the result evaluating by another type of dual task test on fall is still obscure. A counting task depends on working memory and information processing relates to executive function³²⁻³³⁾. In this study, we should assess physical performance making the most of dt-TUG because of the lack of MMSE in the fall prevention class. Therefore, it will be the future theme of study to assess working memory on fall. Another limitation is that the

living environment of the participants is not evaluated. The fall incidence of the community-dwelling elderly is known to depend on their surroundings, while the fall in the elderly receiving care service depends on their physical disorder³⁴ in conflict with our results. The issue of the variant factors affecting fall among subjects' groups is still remained.

Acknowledgments

We are grateful to all the participants for their co-operation. We also thank the staff of the elderly daycare center in South Kaga, Ishikawa.

References

- 1) Statistics Bureau, Director-General for Policy Planning (Statistical Standards) and Statistical Research and Training Institute (Ministry of Internal Affairs and Communications) <http://www.stat.go.jp/>
- 2) Nevitt MC: Falls in the elderly Risk factors and prevention, In *Gait Disorders of Aging*, Masdeu JC et al eds, Lippencott-Raven, Philadelphia, New York, pp 13-36, 1997
- 3) Tokuda T, Hayashi T, Takahashi T, et al: Research on fall in elderly and the physical characteristics. *Geriatr Med* 26: 999-1008, 1988 (in Japanese)
- 4) Suzuki M, Eguchi K, Endou M, et al: Research on fall experience in the elderly who received a hospital physical check. *Japanese Journal of Public Health* 38: 743-750, 1991 (in Japanese)
- 5) Yasumura S, Shibata H: Falls and fractures in the elderly living in the Touhoku district. *Hirou to Kyuuyou no Kagaku* 8: 19-26, 1993 (in Japanese)
- 6) Yasumura S, Haga H: The factors of fall in the elderly living in a farm area. *Japanese Journal of Public Health* 41: 528-537, 1994 (in Japanese)
- 7) Shinno N, Yasumura S, Haga H, et al: Investigation on fall in the elderly living in a farm area -effects of season and the situation. *Japanese Journal of Public Health* 42: 975-981, 1995 (in Japanese)
- 8) Haga H, Shibata H, Shichita K, et al: Falls in the institutionalized elderly in Japan. *Arch Gerontol Geriatr* 5: 1-9, 1986
- 9) Suzuki M, Eguchi K, Okamura KT, et al: Research on fall experience in the elderly in the nursing home. *Japanese Journal of Public Health* 39: 927-940, 1992 (in Japanese)
- 10) Koga R, Hayashi Y, Inada H, et al: Fall accident in the rehabilitation hospital. *Sogo Rihabiriteshon* 21: 607-610, 1993 (in Japanese)
- 11) Shinno N, Nakamura K: Research on fall in the elderly in the nursing home. *Japanese Journal of Geriatrics* 33: 12-16, 1996 (in Japanese)
- 12) Habu T, Okamoto I, Suganuma H, et al: Fall in the patients with chronic stroke in the rehabilitation ward. *Journal of clinical rehabilitation* 5: 976-979, 1996 (in Japanese)
- 13) Lundin-Olsson L, Nyberg L, Gustafson Y: "Stops walking when talking" as a predictor of falls in elderly people. *Lancet*: 617, 1997
- 14) Lundin-Olsson L, Nyberg L, Gustafson Y: Attention, frailty, and falls: the effect of a manual task on basic mobility. *J Am Geriatr Soc* 46: 758-761, 1998
- 15) Lundin-Olsson L, Nyberg L, Gustafson Y: The Mobility Interaction Fall chart. *Physiother Res Int* 5: 190-201, 2000
- 16) Verghese J, Buschke H, Viola L, et al: Validity of divided attention tasks in predicting falls in older individuals: a preliminary study. *J Am Geriatr Soc* 50: 1572-1576, 2002
- 17) Bootsma-van der Wiel A, Gussekloo J, de Craen AJ, et al: Walking and talking as predictors of falls in the general population: the Leiden 85-Plus Study. *J Am Geriatr Soc* 51: 1466-1471, 2003
- 18) Beauchet O, Dubost V, Allali G, et al: 'Faster counting while walking' as a predictor of falls in older adults. *Age Ageing* 36: 418-423, 2007
- 19) Beauchet O, Allali G, Annweiler C, et al: Does change in gait while counting backward predict the occurrence of a first fall in older adults?. *Gerontology* 54: 217-223, 2008
- 20) Beauchet O, Annweiler C, Allali G, et al: Recurrent falls and dual task-related decrease in walking speed: is there a relationship?. *J Am Geriatr Soc* 56: 1265-1269, 2008
- 21) Faulkner KA, Redfern MS, Cauley JA, et al: Multitasking: association between poorer performance and a history of recurrent falls. *J Am Geriatr Soc* 55: 570-576, 2007
- 22) Yamada T, Someya F: Assessment of the physical function and dual tasking performance on fall. *Journal of Tsuruma Health Science Society, Kanazawa University* 33: 49-56, 2009 (in Japanese)
- 23) Hauer K, Marburger C, Oster P: Motor performance deteriorates with simultaneously performed cognitive tasks in geriatric patients. *Arch Phys Med Rehabil*, 83: 217-223, 2002
- 24) Dawson B, Trapp R: Methods of evidence-based medicine and decision analysis. In: *Basic and clinical biostatistics* 4th ed, McGraw-Hill Companies, New York, pp 303-331, 2004.
- 25) Evidence-Based Medicine Working Group. *Diagnostic Test. User's guides to the medical literature*. 2009 [cites August 15, 2009]; Available from: <http://ebem.org/usersguides/diagnosis.html>
- 26) Shumway-Cook A, Brauer S, Woollacott M: Predicting the probability for falls in community-dwelling older

-
- adults using the Timed Up & Go Test. *Phys Ther.* 80: 896-903, 2000
- 27) Beauchet O, Annweiler C, Dubost V, et al: Stops walking when talking: a predictor of falls in older adults? *Eur J Neurol* 16: 786-795, 2009
- 28) Andersson AG, Kamwendo K, Seiger A, et al: How to identify potential fallers in a stroke unit: validity indexes of four test methods. *J Rehabil Med* 38: 186-191, 2006
- 29) Stalenhoeft PA, Diederiks JP, Knottnerus JA, et al: A risk model for the prediction of recurrent falls in community-dwelling elderly: a prospective cohort study. *J Clin Epidemiol* 55: 1088-1094, 2002
- 30) Hyndman D, Ashburn A; Stops walking when talking as a predictor of falls in people with stroke living in the community. *J Neurol Neurosurg Psychiatry* 75: 994-997, 2004
- 31) Nordin E, Moe-Nilssen R, Ramnemark A, et al: Changes in step-width during dual-task walking predicts falls. *Gait Posture* 32: 92-97, 2010
- 32) Woollacott M, Shumway-Cook A: Attention and the control of posture and gait: a review of an emerging area of research. *Gait Posture* 16: 1-14, 2002
- 33) Beauchet O, Dubost V, Gonthier R, et al: Dual-task-related gait changes in transitionally frail older adults: the type of the walking-associated cognitive task matters. *Gerontology* 51: 48-52, 2005
- 34) Rubenstein LZ, Josephson KR, Robbins AS: Falls in the nursing home. *Ann Intern Med* 121: 442-451, 1994

二重課題は転倒予測にとってもっとも重要か？

山田 ともみ, 染矢 富士子*

要 旨

高齢在宅生活者を対象に、転倒予測における二重課題の評価は重要因子となるかを研究目的とした。今回は、以前評価を行った転倒予防教室参加者58名、デイケア利用者50名に対し、実験1ではその後1年間の転倒有無を追跡調査し、年齢、性別、服薬、歩行速度、歩幅、動的立位バランス、Timed Up&Go (以下TUG)、TUGと加算の二重課題 (以下dt-TUG) を因子として検討し、転倒予測モデルを作成した。実験2では新たに39名の対象者に対して調査し、転倒予測モデルの有用性を検証した。

結果、実験1では転倒予防教室参加者で転倒した者は8名であり、転倒と各項目の分析では、握力、歩行速度、歩幅、TUG、dt-TUGの5項目に有意差がみられた。デイケア利用者は5名の追跡調査ができず、転倒した者は16名であり、転倒と項目の有意な関連がなかった。転倒予測モデルについて転倒予防教室参加者を用い多重ロジスティック回帰分析をした結果、TUGと過去1年間の転倒経験が抽出された。実験2では39名のうち、予測モデルで転倒が予測された者は12名であった。追跡調査で転倒した者は5名で、そのうち3名は予測できたが、2名は予測できなかった。

以上より、転倒予測に有用な因子はTUGであり、dt-TUGは参考程度の因子であった。また、転倒予測については、今回の項目の身体機能と転倒経験だけでは高い抽出率を得るのは困難と示唆された。