Interactive visualization to support fall risk assessment for community-dwelling elderly

Chien-Hua Huang
[1]Department of Industrial Engineering and Management
Yuan-Ze University, Tao-Yuan, Taiwan
[2]Assistive Technology Center,
Fong-Yung Hospital, Tai-Chung, Taiwan
Tel: (+886) 04-25271180-3101, Email: hkwpt2003@yahoo.com.tw

Tien-Lung Sun
Department of Industrial Engineering and Management
Yuan-Ze University, Tao-Yuan, Taiwan
Tel: (+886) 3-463-8800-2525, Email: tsun@saturn.yzu.edu.tw

Abstract. This paper proposes an interactive visualization approach to help domain experts better interpret BBS and 3M TUG scores. The medical domain experts starts visual exploration by examining data points in the scatter plot that fall within the 'grey' area, e.g., data points fall outside the threshold but still within the safe area of the box plot or vice versa. They then interactively include or remove the data points to and from the scatter plot using interactive filter box. If the inclusion of an elderly's data point does not change the direction of the trend line, then this data point is included in the high risk group. On the other hand, if the inclusion of an elderly's data point changes the direction of the trend line, then this elderly is excluded from high risk group. We collected over 350 community elderly's BBS and 3M TUG test scores from a community in enteral Taiwan. When only the thresholds suggested in literature were used, 30 elderly were filtered out into the high risk group. Out of them 12 reported fall experience in the past year. When 95% percentile in the box plot were used, 14 elderly were filtered out and 9 of them reported fall experiences in the past year. With the proposed interactive visualization approach, 18 were filtered out and 12 of them reported fall experiences in the past year. The results showed that visualization supported approach has higher assessment rate than only scale or box plots were used.

Keywords: Interactive visualization, visual exploration, fall risk assessment, elderly

1. INTRODUCTION

Falls are usually the critical factors that lead an elderly from quality life to a less comfortable life style with injury, activity limitations, fear of falling, etc. Finding community dwelling elderly with fall risk possibilities and sending them to hospitals for further evaluation become an important task to maintain the life quality. As comprehensive fall risk assessment is costly in terms of human labor and equipment, a feasible approach is to conduct preliminary fall risk assessment through community service to filter out elderly with possible fall risk and ask them to go to hospital for further evaluation.

Fall risk screening tools are an important element of fall prevention in the community (Barry et al., 2014). Assessment of the physical balance of elderly people in the community can help to identify those who are at risk of falling to allow for follow-up (Lin et al., 2002). However, studies in the past have mentioned that the scale filter is too sensitive, so that too many older adults with no risk of falling are screened (Gates et al., 2008, Yamada et al., 2012). Further, previous studies (Li et al., 2014) have stated that the risk assessment for falls should be suggested from different aspects, allowing the patient to make a thorough decision.

Quick evaluation tools like Berg balance scale (BBS) and 3-meters timed up and go (3M TUG) test can help medical experts conduct preliminary fall risk assessment at community service to filter out elderly with possible fall risk. But they suffer from high sensitivity problems. Elderly with less fall risk possibilities may also be judged as high risk and sent to hospital for secondary stage evaluation. This not only causes inconvenience but also wastes medical resources.

This paper proposes an interactive visualization approach to help domain experts better interpret BBS and 3M TUG scores and make better decision making.

2. METHOD

2.1 Fall Risk Evaluation Tools

The Short-Form Berg balance scale (SFBBS) and the 3-meters timed up and go (3M TUG) test were used to filter out community dwelling elderly with possible fall risks. The SFBBS considers the balance ability whereas the 3M TUG tests the gait functionality.

2.1.1 Berg Balance Scale (BBS)

The Berg Balance Scale (BBS) was originally developed to assess balance performance in geriatric persons or geriatric patients. It has shown high reliability and validity, but it takes more time to complete. To simplify and to improve its utility, short-form BBS (SFBBS) was developed which include 7 best items from original BBS. The SFBBS was found to feature psychometric properties similar to those of the original BBS. Karthikeyan et.al (2012) showed that there is a good test-retest reliability (ICC=0.95) of SFBBS in elder people and conclude that the short form of berg balance scale is a reliable test for balance evaluation in elder population.

For simplicity purpose, we will use BBS to represent the short form BBS in the remaining of this paper.

2.1.2 3-Meter Timed Up and Go

The 3M TUG measures the time it takes a subject to stand up from an armchair, walk a distance of 3m, turn, walk back to the chair, and sit down. It was developed originally as a clinical measure of balance in elderly people and was scored on an ordinal scale of 1 to 5 based on an observer's perception of the performer's risk of falling during the test.

2.2. Visualization of BBS and 3M TUG Score

2.2.1 Tableau

The data visualization tool Tableau (www.tableau.com) was employed to build the visual exploration environment. Tableau is a powerful tool that lets human experts intuitively interact with data and quickly construct graphs by drag and drop.

2.2.2 Scatter Plot

The BBS and 3M TUG scores of all the elderly from a community center were displayed as a scatter plot, as shown in Figure 1. The X-axis is the 3M TUG score and the Y-axis is the BBS score. Each mark in the plot represents an elderly's score measured during the preliminary fall risk assessment at community service.

Two types of information are drawn on the scatter plot to help the visual interpretation process: reference line and box plot. They are explained in following sub-sections.

2.2.3 Reference Lines

The reference lines indicate the threshold suggested in literature to judge high fall risk. Karthikeyan (2012) suggested that community-dwelling elderly who received a short-form BBS score less than 23 should be considered as high fall risk group. Braun (1998) suggested that elderly older than 65 and performed 3M TUG longer than 13.5 second should be classified as high fall risk potentials. Based on these thresholds reported in literature, two reference lines were drawn at the scatter plot at BBS=23 and 3M TUG = 13, shown as the two red lines in Figure 1.

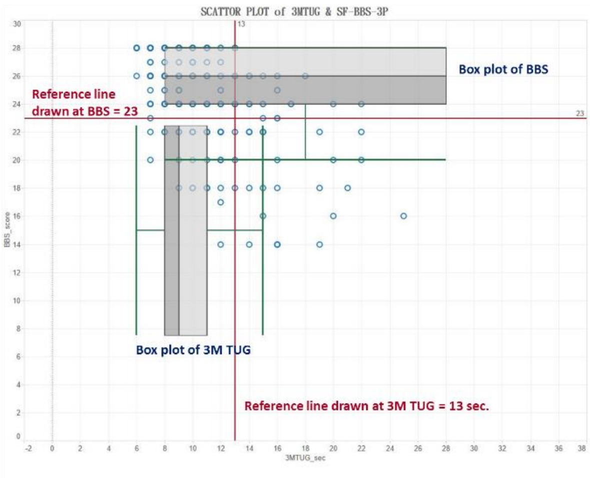

Figure 1. Scatter plot visualization of BBS and 3M TUG score with reference lines and box plots.

2.2.4 Box Plot of Data Values

The box plot displays the distribution of the data points in the scatter plot. The box plots of BBS and 3M TUG scores were displayed in Figure 1. They indicate outlier data points from statistic perspective.

2.3. Interactive Visual Exploration Process

The scatter plot discussed in previous section is not a static picture but a dynamic picture that interacts with the human users. The medical domain experts starts the visual exploration by examining data points in the scatter plot that fall within the ‘grey’ area, e.g., data points fall outside the threshold but still within the safe area of the box plot or vice versa. They then use filtering dialog box to interactively include or remove data points. During the interactive visual exploration process, the trend line of the selected data was automatically calculated and displayed to assist decision making (Figure 2).

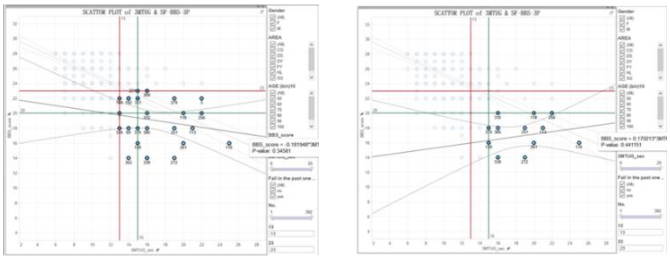

Figure 2. Example of interactive visual exploration process.

2.3.1 Selecting Data Points through Interactive Filtering

The interactive filter dialog box lets domain experts include or remove the data points to and from the scatter plot using conditions such as gender, age, area, and other personal characteristics.

2.3.2 Observing Trend Line of the Selected Data

At any moment during the interactive visual exploration process, the trend line of the currently selected data points was displayed. The trend line is the liner regression model of the data points selected in the scatter plot. If the inclusion of an elderly’s data point does not change the direction of the trend line, then this data point is included in the high risk group. On the other hand, if the inclusion of an elderly’s data point c hanges the direction of the trend line, then this elderly is excluded from high risk group.

3. RESULTS

We conducted a one-year fall risk assessment service for community-dwelling elderly in center Taiwan. The assessment team consists of doctors from geriatrics and rehabilitation departments, physical and occupational therapists, and social workers. The elderly included in this research were older than 65 and can walk independently. They were asked about their fall experience in the past year.

A total of 392 older citizens were evaluated. After excluding those younger than 65 or with incomplete data, 356 subjects were included in this analysis and their fall risk assessment data were collated.

3.1. Fall Risk Evaluation by Thresholds

The data points enclosed at the red rectangle represent elderly evaluated as high fall risk using the thresholds reported in literature, i.e., BBS < 23 and 3M TUG > 13. Out of the 356 elderly examined, 30 were judged as high fall risk by the BBS and 3M TUG thresholds.

3.2. Fall Risk Evaluation by Box Plots

The data points enclosed by the green rectangle represent elderly evaluated as high fall risk when 95% percentile in the box plot were used. A total of 14 out 356 elderly were filtered out with the statistical methods.

3.3. Fall Risk Evaluation by Interactive Visualiza tion

For data lied between the red and green boxes, the interactive visual exploration process presented in Section 2.3 was employed to determine their fall risk. Medical experts interactively include or exclude data to the high fall risk group. A total of 18 data marks was classified as high-risk group after the interactive visual exploration process.

4. DISCUSSION

4.1. Fall Risk Evaluation Results Comparison

Table 1 lists the number of elderly classified as high fall risk by the three methods (N) and the number of elderly who did report fall experiences in the past year (N_0). The accuracy is calculated by N_0/N.

With the first method, which determined elderly of high fall risk using the thresholds recommended in literature, 30 elderly were selected as high fall risk. Out of them, 12 reported fall experience in the past year and the accuracy is 12/30 = 0.4.

With the second method which selects elderly of high fall risk using statistic box plot, 14 elderly lies outside 95% of the box plot and were identified as high fall risk. Out of them 9 reported past fall experiences and the classification accuracy is 9/14=0.64.

With the interactive visual exploration method presented in Section 2.2 and 2.3, domain expert identify 18 elderly as the high fall risk elderly. Out of them 12 reported fall experience in the past year. The accuracy is 12/18=0.66.

It can be seen from Table 1 that fall risk filtering using the BBS and 3M TUG threshold results in least accurate results, which in turn, suggested many healthy elderly to go to hospital for next-stage evaluation. This makes waste of medical resources. Classification with assistance of interactive visual exploration process results highest accuracy.

Table 1: Comparison of fall risk assessment by different methods

Methods	N (N_0)	Accuracy
Using thresholds recommended in literature, i.e., BBS< 23 and 3M TUG > 13 sec	30 (12)	40%
Outside 95% of the box plot	14 (9)	64%
Using interactive visual exploration method presented in this paper	18 (12)	66%

N: Number of elderly classified as high fall risk by that method
N_0: Number of elderly who reported fall experience within past one year

4.2. Advantages and Challenges of Visualization-based Fall Risk Evaluation

Through the presentation of visualized data, users can quickly understand the nature of the information (Macklin et al., 2009). The stimulation through graphical information can also be an incentive for the elderly to increase their engagement (Thai et al., 2015).

In this study, we used graphical data to rapidly filter out the high-risk group for falls in order to understand different fall factors through single or multiple factors in the elderly. It is challenging to integrate clinical information to enhance clinical decision-making and to provide complete patient records (Rantz et al., 2010). However, for medical experts, making the right decisions enables them to provide the right treatments. In the case of BBS, elderly individuals can be assisted through balance training. In the case of BI, elderly individuals can be assisted through a focus on the ability to perform daily activities. In addition, when considering the basic information of the elderly, such as age, we can understand that there are different influencing factors for falls in different age groups, for example, the high-risk group for TUG included elderly individuals aged 80 or above. Medical experts can first obtain a preliminary understanding of the group characteristics, and then bring their clinical experience into the exploration.

5. CONCLUSION

As a result of an aging population, medical expenses due to falls in the elderly has contributed to heavy social burdens. It is therefore necessary to develop a comprehensive assessment method to predict the risk of falls for the elderly in the community. This study used data visualization analysis to present data from fall risk scales in various aspects, to allow medical professionals to screen for a high risk of falls in elderly individuals through community services, and to serve as a reference in making decisions to intervene or prioritize the elderly.

Through the use of data filtering, visualization, and other data analysis techniques to assist in the filtering, analysis, and visualization of the large amount of data, information can be presented in a more effective way. At the first stage, medical professionals can use this graph to communicate with elderly individuals on their current condition when screening and making decisions on whether they are in the high-risk group for falls. Compared to other presentation methods where data and reports are used, graphically presented data allow elderly individuals to understand their positions within the population, and the difference between themselves and others. Medical experts can also more easily inform elderly individuals.

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