Industrial Health 2016, **54**, 354–360

Original Article

Evaluation and simplification of the occupational slip, trip and fall risk-assessment test

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Received October 5, 2015 and accepted February 12, 2016
Published online in J-STAGE March 25, 2016

Abstract: Objective: The purpose of this investigation is to evaluate the efficacy of the occupational slip, trip and fall (STF) risk assessment test developed by the Japan Industrial Safety and Health Association (JISHA). We further intended to simplify the test to improve efficiency.
Methods: A previous cohort study was performed using 540 employees aged ≥50 years who took the JISHA's STF risk assessment test. We conducted multivariate analysis using these previous results as baseline values and answers to questionnaire items or score on physical fitness tests as variables. The screening efficiency of each model was evaluated based on the obtained receiver operating characteristic (ROC) curve.
Results: The area under the ROC obtained in multivariate analysis was 0.79 when using all items. Six of the 25 questionnaire items were selected for stepwise analysis, giving an area under the ROC curve of 0.77.
Conclusion: Based on the results of follow-up performed one year after the initial examination, we successfully determined the usefulness of the STF risk assessment test. Administering a questionnaire alone is sufficient for screening subjects at risk of STF during the subsequent one-year period.

Key words: Slip, Trip, Fall, STF, Cohort study, Risk assessment, Occupational health, Japan

Introduction

Prevention of industrial accidents is a critical issue for companies, and while a number of measures have been taken to reduce the incidence of serious industrial accidents, such as pinching or being caught in machinery or falling from a height, thereby leading to a decrease in such incidents, an increasing trend has been noted in incidence of industrial accidents which might occur in daily activities (daily life accidents), such as slip, trip and fall (STF)[1, 2].

Indeed, in recent years, STFs have accounted for 20% of all industrial accident-related deaths and injuries (requiring rest for 4 days or more), ranking first among causes of industrial accidents in Japan[1]. Due in part to this relatively high incidence of STFs, the number of industrial accident-related deaths and injuries has increased slightly in recent years despite a decreasing trend being observed up to 2005[1, 3]. Similar issues have also been reported in

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a number of developed countries[4–6]. To prevent STF-related injuries, companies are therefore taking measures to improve both physical facilities (e.g. removing potential barriers or adding non-slip walkways) as well as employee training (e.g. providing safety training and thorough instruction to keep the workplace tidy)[7–10].

Assessment of STF risk is one such risk assessment measure, aimed at predicting and preventing future STF risks. Screening tools for assessing STF risks include performance-oriented mobility assessment (POMA) and the slips assessment tool (SAT)[11]. The SAT, which assesses the slipperiness of walkway surfaces, was originally developed by the UK Health and Safety Executive (HSE) to help prevent industrial accidents[12]. POMA is a general test for balance and gait, commonly used in elderly people. On a POMA test, scores of less than 19 points (out of a full 28) are indicative of a very high STF risk.

In Japan, the most commonly used risk assessment tool is the STF risk assessment test developed (and reported in 2009) by the Japan Industrial Safety and Health Association (JISHA). This test involves 5 physical fitness tests (two-step test, stepping while seated, functional reach test, one-leg standing with eyes closed, and one-leg standing with eyes open) and 25 questions on a self-estimated questionnaire. This STF risk assessment test has been reported to be effective in assessing STF risks in workers, demonstrating a correlation between a subject's past experience of STFs and their physical fitness test scores or awareness of safety (evaluable based on questionnaire data)[13]. However, these test items and questions were chosen by referencing study results obtained in an elderly population, and no prospective study has verified the screening accuracy of JISHA's STF risk assessment test. Researchers have pointed out the need for further investigations in order to improve the screening accuracy[13]. Further, some test items—particularly the physical fitness tests—are time-consuming, raising expectations that a more efficient testing method can be developed, geared toward a continuous assessment of STF risks.

Objective

Given the above, we conducted a follow-up study in workers at a company where JISHA's STF risk assessment test had been performed one year prior and retrospectively evaluated the efficiency of the test in screening workers with risks of subsequent STF. In addition, we examined the accuracy of each test item (i.e. physical fitness tests and questionnaire items) in predicting future STF risk.

Subjects and Method

Subjects and setting

Of the 562 employees aged 50 years or older working in the business office of a Japanese manufacturing company (with 1,250 employees), after excluding those in whom physical fitness tests could not be performed due to injuries or disease, the remaining 540 underwent a STF risk assessment test.

Methods

In the present study, subjects underwent JISHA's STF risk assessment test. The test comprises a series of physical

Table 1. List of questions

Q1	Can you walk without bumping into a person in a crowd?
Q2	Do you feel confident of physical strength in comparison with the same age?
Q3	Do you think that your body respond quickly to sudden situation?
Q4	Can you take a step forward immediately when you trip over a small step?
Q5	Can you put on your socks while standing on one leg?
Q6	Can you walk easily with a tandem gait (the toes of the back foot touch the heel of the front foot at each step) on the straight line?
Q7	In your own estimation, how long can you remain standing on one leg with eyes closed?
Q8	On a train, how long can you stand without holding the strap?
Q9	In your own estimation, how long can you remain standing on one leg with eyes open?
Q10	Are you always careful not to be injured? (e.g. holding the handrail on stairs; not holding something in each hand on the move; keeping things tidy and in order)
Q11	Do you take measures such as construction of barrier-free environments or railings in your house?
Q12	Do you run while at work?"
Q13	Do you sometimes not follow correct procedure in order to observe the delivery date.?
Q14	While at work, do you sometimes think that this operation is so dangerous that you are injured if not be careful?
Q15	If a floor gets wet, do you warry about slipping?
Q16	Do you think that the safety is influenced by the luck?
Q17	Do you think that you can prevent injuries with your effort?
Q18	Have you sllipped, tripped and fallen at work in the past year?
Q19	Have you (nealy) got injured at work in the past year?
Q20	Do you take prescription or nonprescription drugs?
Q21	Do you always worry about darkness of the illumination while at work?
Q22	Is it heavy exercise for you to bend a knee and raise a thigh?
Q23	Can you walk while talking with someone?
Q24	Can you talk on the phone while checking a calendar and a schedule book?
Q25	Can you think of an answer to a person's question while listening to him or her talk?

fitness tests and a 25-item questionnaire (Table 1). The five physical fitness tests are a two-step test (measures the widest two-step stride to evaluate walking ability), stepping while seated (measures the number of steps inside and outside lines at 30-cm widths in a seated position per 20 seconds to evaluate agility), functional reach test (measures the maximal distance one can reach forward beyond arm's length while maintaining feet fixed in a standing position to evaluate dynamic balance), one-leg standing with eyes closed (measures the maximal duration of 60 seconds to evaluate static balance without sight), and one-leg standing with eyes open (measures the maximal duration of 90 seconds to evaluate static balance).

In addition, subject background characteristics (age, sex, and type of employment) were obtained from the questionnaire and company's personnel data. One year later, follow-up was performed to inquire about STFs over the one-year period following the test (i.e. "Have you slipped, tripped or fallen at work in the past year?"), and the presence or absence of any STFs was regarded as the outcome.

Statistical analysis

Logistic regression analysis was performed by setting the presence/absence of any STFs during the one-year period following the initial test as an objective variable, while the questionnaire data and physical fitness test scores were treated as explanatory variables, along with age, sex, and type of employment. These variables were included in stepwise analysis with a significance probability of *F* value = 0.3 ($P_{in} = P_{out} = 0.3$), which is the threshold for entry/removal of each variable. The usefulness of each selected variable for screening subjects with future STF risk was evaluated based on the obtained area under an ROC curve. Model 1 included 5 physical fitness test items plus the 25 questionnaire items, Model 2 included only 3 of the 5 physical fitness test items (selected by stepwise analysis) and no questionnaire items, Model 3 included 6 of the 25 questionnaire items (selected by stepwise analysis) and no physical fitness test items, and Model 4 included the initial 5 physical fitness test items as well as the 6 questions selected in Model 3. All four models were then subjected to analysis. All statistical analyses were performed using STATA release 12 (Stata, College Station, TX, USA).

Approval

This study was approved by the Ethics Committee for Medical Care and Research at the University of Occupational and Environmental Health, [city], Japan.

Results

Of the 540 workers (including 23 women; mean age ± standard deviation of 56.9 ± 3.8 years) who underwent a STF risk assessment test, 468 answered the question in the follow-up survey about STFs experienced at work during the previous 1-year period. Of these respondents, 29 (6.2%) had STFs at work during that period (Table 2).

Table 2. Subject baseline characteristics and follow-up results

Variable		(%)
Number of subjects	468	
Age	56.93 ± 3.79	
Height	167.92 ± 6.66	
Weight	65.77 ± 8.98	
Body mass index	23.29 ± 2.54	
Sex		
Male	445	(95.1)
Type of employment		
Daytime worker	343	(73.3)
Shift worker	125	(26.7)
Physical fitness test		
Two-step test (widest two-step stride [cm]/body height [cm])	1.64 ± 0.12	
Stepping while seated (steps/20 sec)	31.6 ± 5.3	
Functional reach (cm)	35.1 ± 4.2	
Duration of one-leg standing with eyes closed (sec)	22.1 ± 21.3	
Duration of one-leg standing with eyes open (sec)	106.6 ± 29.4	
Experience of STF during the subsequent 1-year period: Yes or No		
Yes	29	(6.2)

Model 1: 5 physical fitness test items +25 questions
Model 2: 3 physical fitness test items (after a stepwise analysis)
Model 3: 6 questions (after a stepwise analysis)
Model 4: 6 questions +5 physical fitness test items

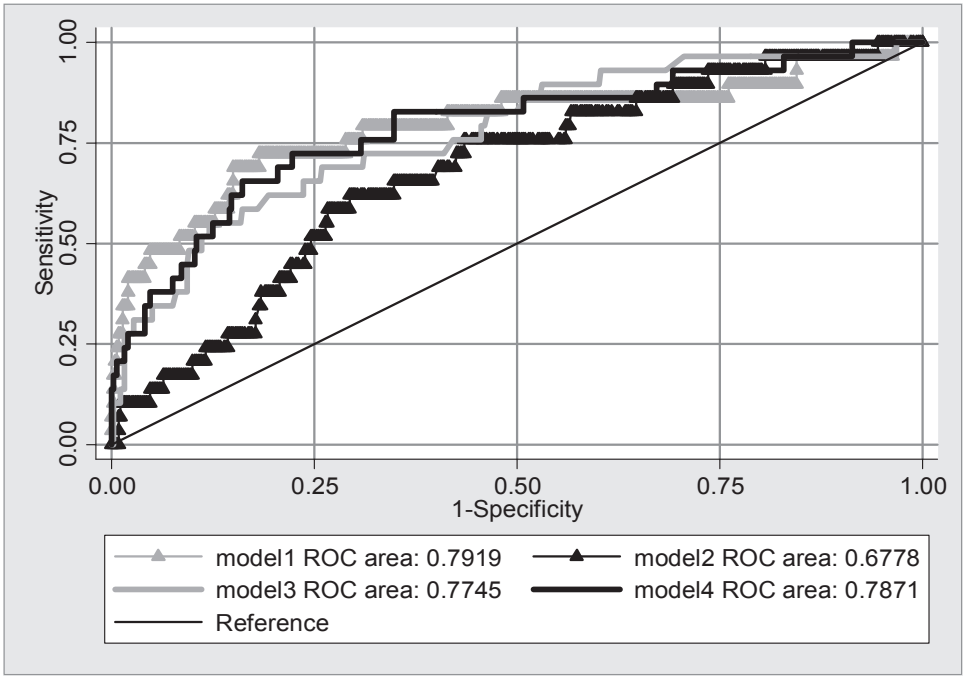

Fig. 1. The screening efficiency of each model.
With STF experienced during the subsequent 1-year period set as the outcome, a multivariate analysis of the test items (i.e. physical fitness tests plus questionnaire) was performed, and an ROC curve was obtained for each model. The ability of the present test to predict subjects with STF risks during the subsequent 1-year period was relatively good, with an area under the ROC curve of 0.79 (Model 1). Physical fitness test items alone provided relatively low screening accuracy (Model 2). When using only 6 of the 25 original questions (selected by stepwise analysis), the screening ability remained (Model 3), and appending physical fitness tests to the questionnaire did not improve efficiency (Model 4).

In Model 1, multivariate analysis was performed for all items (5 physical fitness test items plus 25 questionnaire items) and revealed a significant correlation between an answer of "Yes" to Question 18 ("Have you slipped, tripped or fallen at work in the past year?") in the initial questionnaire and STF during the subsequent 1-year period ($p < 0.001$). The area under an ROC curve of this model was 0.79 (Fig. 1). Of note, on multivariate analysis for the 5 physical fitness test items, no significant correlation was shown between any of these test items and STFs experienced during the subsequent 1-year period (obtained area under the ROC curve = 0.68).

In Model 2, 3 out of the 5 physical fitness test items (functional reach test, one-leg standing with eyes closed, and one-leg standing with eyes open) were selected with a threshold of 0.3 (Table 3), and the area under the ROC curve of this model was 0.68 (Fig. 1), which was the same as that of the 5 physical fitness test items. On multivariate analysis for the 25 questions on the questionnaire, the obtained area under the ROC curve was 0.78.

In Model 3, 6 out of the 25 questions (Questions 1, 5, 11, 12, 18, and 25) were selected with a threshold of 0.3 (Table 3), and the area under the ROC curve was 0.77, which was similar to that obtained using all 25 questions (Fig. 1).

In Model 4, an ROC curve was plotted with the aforementioned 5 physical fitness test items and the 6 questions in Model 3. The obtained area under the ROC curve was 0.79, which was similar to that of Model 3 (Fig. 1).

Discussion

JISHA's STF risk assessment test, which is widely used in workplaces in Japan, was designed to include physical fitness test items and questions for which significant cor-

Table 3. Results of stepwise selection of physical fitness test items and questions

Variable		OR	95% CI		P
Physical fitness test items					
	Duration of one-leg standing with eyes closed (sec)	0.98	0.96	1.01	0.204
	Duration of one-leg standing with eyes open (sec)	0.99	0.98	1.00	0.066
	Functional reach (cm)	0.94	0.86	1.03	0.224
Questions					
Q1	"Can you walk without bumping into a person in a crowd?"	1.34	0.88	2.05	0.178
Q5	"Can you put on your socks while standing on one leg?"	0.77	0.57	1.06	0.108
Q11	"Do you take measures such as construction of barrier-free environments or railings in your house?	0.83	0.58	1.19	0.300
Q12	"Do you run while at work?"	0.62	0.33	1.18	0.146
Q18	"Have you fallen at work in the past year?"	0.28	0.16	0.51	<0.001
Q25	"Can you think of an answer to a person's question while listening to him or her talk?"	0.74	0.45	1.23	0.250

relations with STFs have been reported in preceding studies[13]. However, most previous studies on this matter have been conducted in elderly populations, and to our knowledge, few reports have examined the efficacy of JISHA's STF risk assessment test in healthy workers. To ensure efficient assessment of subjects' STF risk, we evaluated the efficacy of the STF risk assessment test originally developed by JISHA.

The obtained area under the ROC curve of Model 1 (0.79) confirmed that JISHA's test is relatively efficient in predicting STF risk among workers during the subsequent one-year period. We found that past experience of STFs correlated most strongly with STF risk over the following year, which was consistent with previously reported observations in an elderly population[14]. In a model obtained from logistic regression analysis using all of the test items (5 physical fitness tests and 25 questions on a questionnaire), the specificity of the test was determined to be ≤70% when a cut-off value was set so that the sensitivity of the test would be ≥70%; in this setting, the positive predictive value was found to be <15% among subjects enrolled in the present study. Achieving a positive predictive value of ≥50% required reducing the sensitivity of the test to ≤40%.

Although the obtained results are not satisfactory as a test for screening subjects with future STF risk, these values are acceptable for assessing risk of STF that can occur in daily activities in the workplace, with the following conditions taken into consideration: (i) the incidence of STF was lower among workers enrolled in the present study (6.2%) than in elderly (21%) people[15]; (ii) incidence of STF is susceptible to various factors, such as workplace environment, as well as workers' physical strength and safety awareness; and (iii) the JISHA's test is non-invasive.

Based on the above three conditions, we narrowed down the number of test items to improve efficiency. For example, physical fitness test items alone provided relatively low screening accuracy in predicting future risk of STF at work during the subsequent one-year period. In contrast, the questionnaire alone provided relatively good screening accuracy, almost the same as that achieved after isolating the most useful questionnaire items by stepwise analysis. Of note, appending the physical fitness test items again to these selected questions did not improve the screening accuracy to an appreciable extent. Therefore, from an efficacy standpoint, we can conclude that questionnaire data alone in the present follow-up are sufficient for assessing risk of STFs at work during the subsequent one-year period.

In previous studies in elderly or hospitalized patients, decreased physical strength (e.g. muscle weakness or reduced balance capacity) was reported to be closely associated with STFs[16, 17]. For example, Rubenstein claimed that most STFs are associated with identifiable risk factors (e.g. weakness, unsteady gait) in elderly people[17]. JISHA's test was developed in light of concerns that STFs occur frequently in elderly workers whose physical functions were lowered[13]. However, no significant correlation was noted between STF risk and reduction of physical fitness in the present study. The observed difference is primarily because differences in physical fitness test scores tend to be smaller among healthy workers (such as those enrolled in the present study) than among elderly individuals, and secondarily because some questions regarding self-estimated physical abilities (e.g. "In your own estimation, how long can you remain standing on one leg with eyes closed?") may have partially covered what can be assessed by physical fitness tests. Caution should therefore be practiced when using

study results obtained in elderly people to assess STF risk in workers of other age brackets.

From a practical standpoint, questionnaires are non-invasive simple tests, and further statistical selection of questions allows for even more efficient administration. Combining the questionnaire developed by JISHA with other types of questionnaires, such as those obtained in medical check-ups, would save time and money required to assess STF risk. In addition, returning assessment results to participants in a timely manner would reinforce the will to prevent future STFs. Altogether, it took approximately 25 hours for 2 investigators to complete all of the physical fitness tests for 540 subjects in the present study; therefore, if a questionnaire alone is sufficient for the assessment of STF risks, operational efficiency may be improved greatly. Considering that a questionnaire is a subjective index, the questionnaire data should be used in combination with physical fitness test scores, which are regarded as objective indices. Accomplishing this will likely require development of another physical fitness test effective in assessing STF risks in relatively healthy workers.

Conclusion

JISHA's STF risk assessment test was found to be acceptable for screening workers at risk of STF at work during the subsequent one-year period. Administering the questionnaire alone did not reduce the screening efficiency, and appending physical fitness tests to the questionnaire did not improve efficiency. Statistical methods were able to reduce the number of questions listed on the questionnaire while retaining a certain level of screening efficiency, which helped increase the practical efficiency of the test.

Limitations of the Study

Since the present follow-up was performed only at an industrial plant, the generalizability of the obtained results is inconclusive. A subgroup analysis by type of work seems to suggest the generalizability to some extent, but our follow-up did not involve asking workers about the particulars of their work. In addition, no other physical fitness tests (e.g. timed "up & go" test or tandem gait) for which efficacy in assessing STF risk among the elderly has been confirmed were conducted in the present study[18, 19].

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