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Original Article

Falls Characteristics and Falls Risk Factors in Middle- and Old-Aged Adults: A Comparison Between Fallers and Non-Fallers

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ABSTRACT

Background/Purpose: Falls are considered as one of major public health issues in old age. Recently studies found that falls rate has been increasingly reported since middle-age. However, a limited number of studies have investigated falls characteristics and falls risk factors in middle- to old-aged people. This study aimed (1) to compare falls characteristics and falls risk factors between middle- and old-aged groups and (2) to compare falls characteristics and falls risk factors between fallers and non-fallers in each age group.

Methods: A cross-sectional study was conducted with 104 participants (45-80 years). General health information, history of falls and falls risk factors were collected and analyzed.

Results: The middle- and old-aged groups reported high number of falls. All falls risk factors in middle-aged group did not significantly differ between fallers and non-fallers. Physical performance (proprioception, balance) and environmental factors significantly differed between fallers and non-fallers in old-aged group.

Conclusion: The main cause of falls in middle-aged group was slippery surface, while dizziness was the major cause in old-aged group. Cognitive performance, physical performance and fear of falling have been recognized as intrinsic falls risk factors in old-aged group. For middle-aged group, the interaction of limits of stability and functional mobility may be a possible falls risk factor, and these require further studies. Regarding extrinsic falls risk factors, workplace and transportation hazards should be considered in the environmental falls risk assessment for both middle- and old-aged groups.

1. INTRODUCTION

Falls is a major issue in an aging society. Elderly people have reported the frequency of falls at approximately 28 to 35%.[1] Falls can lead to both physical and mental impairments, as well as increased

cost of medication and mortality.[2-4] Therefore, falls are considered as one of the major public health issues in the elderly population.[1] According to the study of Talbot et al., falls directly increased with age, namely, increased from 18% in the young age group (20 to 45 years) to 21% in the middle-aged group (46 to 65 years), and to 35% in the older-aged group (>65 years).[4] Interestingly, the middle-aged group were found to increasingly report rate of falls[4,5] due to developing several risk factors of falls including chronic conditions, medications used, physical activity and physiological changes.[6-9] Identified falls risk factors include physical performance,[10] physical activity levels,[11] fear of falling,[12] cognitive impairment[13] and environmental hazards.[14]

Several recognized falls risk factors have been reported to change with increased age. These include physical performance, physical activity, cognitive function and fear of falling, which were found to deteriorate since middle age.[15-18] A limited number of studies have investigated falls and falls risk factors in people with age ranging from middle-aged to old age groups. Identifying falls and risk factors among middle aged people would assist in understanding falls risk factors which might be related to falls risk and falls occurrences in older-aged people. Therefore, to gain a better understanding for falls characteristics and falls risk factors in the middle-aged group, our aims were: (1) to compare falls characteristics and falls risk factors between two different age groups (middle-aged and old-aged groups), and (2) to compare falls characteristics and fall risk factors between fallers and non-fallers in each age group.

2. METHODS

We employed a cross-sectional design for this study and collected data from participants aged from 45 to 80 years old. Participants were classified in two age groups: 1) middle-aged group (45-59 years old), and 2) old-aged group (60 to 80 years old). Sample size was calculated according to effect size 0.56 (two tailed analysis, power=0.80, and α=0.05) from a related study by Chen and Tang in 2016.[19] The participants totaled 104, consisting of 52 participants per group. We included participants residing in a community, able to walk independently, able to communicate and able to complete the assessment and performance tests. The participants having impairment about vision, speech, hearing or having any signs or symptoms of the musculoskeletal and cardiovascular systems, neuromuscular disorders, and other signs and symptoms that might limit performing physical performance tests in this study were excluded from the study. According to the second aim, each age group was also divided in two subgroups, 1) fallers, and 2) non-fallers. 'Fallers' was defined as persons who have fallen in the previous year; and 'non-fallers' was defined as persons who have not fallen in the previous year.

Assessments consisted of general health data questionnaires, history of falls (self-report, based on information from the participant), and risk factors of falls, as described below.

Cognitive performance: The cognitive performance was assessed using the Mini–Mental State Examination (MMSE) , for which cut-off score was classified as having cognitive impairment considered by education level.[20]

Physical activity: Physical activity level was assessed using the International Physical Activity Questionnaire (IPAQ). The questionnaire comprises seven questions about duration and intensity when participants performed physical activity in the last seven days.[21]

Physical performance: Physical performance consisted of muscle strength, proprioception, and balance.

- Upper body strength and overall strength were assessed using a handgrip dynamometer (Model T.K.K.5401, Grip D, Takei Scientific Instruments Co., Ltd, Niigata, Japan) at the dominant hand.

- Knee extension strength was assessed using a hand-held dynamometer (Model 01165, Lafayette Instrument Company, Lafayette, IN, USA) at 45° knee flexion of the dominant leg.

- Functional lower extremity strength was measured using five times sit to stand test.[22]

- Proprioception was measured using a digital inclinometer (Model ACU001, Acumar single digital inclinometer, Lafayette Instrument Company, Lafayette, IN, USA) at the dominant knee in two angles (40° and 60°).

- Limit of stability in four directions including forward, backward, rightward and leftward was assessed using the Multi-Directional Reach Test (MDRT).[23]

- Functional mobility and balance were assessed using the Timed Up and Go Test (TUG) under different three conditions, performed by TUG, TUG with manual task, and TUG with cognitive task.[24,25]

Fear of falling: Fear of falling was assessed using the Activities-specific Balance Confidence scale (ABC scale), which is a self-report instrument to determine the confidence of performing activities of daily living without loss of balance.[26]

Environment falls risk factors: Environment falls risk factors were assessed using a list of environmental risk factors including walkways, bedrooms, kitchens, bathrooms and stairs.[27]

For each fall risk factor assessment, the researcher

listed alternately between questionnaires and physical performance tests or exerted tests to prevent fatigue. Additionally, falls definition was explained to each participant as "inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects"[1] to optimize understanding.

The statistical software, SPSS (version 20.0 for Windows, IBM, Thailand) was conducted for statistical analyses. The Independent t-test or Mann-Whitney U test was performed in case of continuous data, while Fisher's exact test was used to analyze categorical data.

3. RESULTS

Participant characteristics are shown in Table 1. Significant differences were found between the two groups regarding education level, work status, number of medication conditions, number of prescription medications and number of nonprescription medications (p-value ≤0.05).

Each age group was divided in two subgroups according to the history of falls (faller and non-faller). Number of falls history in the middle age group was significant higher in the faller than in the non-faller subgroups. While in the old-aged subgroup, a significantly lower education level was observed among fallers than non-fallers.

Table 2 shows characteristics of falls between the two groups. No significant differences were found for all of falls characteristics among fallers between two age groups, except the causes of recent falls. Slippery

Table 1. Comparison of participant characteristics between middle-aged and old-aged groups and between fallers and non-fallers in each age group

Characteristics	Total (n=104)			Middle-aged (n=52)			Old-aged (n=52)		
	Middle-aged (n=52)	Old-aged (n=52)	p-value	Fallers (n=34)	Non-fallers (n=18)	p-value	Fallers (n=31)	Non-fallers (n=21)	p-value
Age (year), mean±*SD*	51.06±4.51	69.98±5.77	≤0.001[a]*	50.35±4.28	52.39±4.75	0.171[a]	70.35±6.46	69.43±4.68	0.551[c]
Sex (male: female), (n)	26:26	26:26	1.000[b]	17:17	9:9	1.000[b]	15:16	11:10	1.000[b]
Weight (kg), mean±*SD*	62.95±11.75	61.18±13.51	0.479[c]	61.77±11.82	65.17±11.61	0.326[c]	60.75±14.10	61.82±12.92	0.783[c]
Height (cm), mean±*SD*	161.09±8.10	158.67±7.96	0.118[a]	161.27±8.42	160.75±7.69	0.511[a]	158.26±8.35	159.29±7.49	0.652[c]
BMI (kg/m^2), mean±*SD*	24.26±4.36	24.22±4.53	0.965[c]	23.75±4.48	25.20±4.08	0.259[c]	24.12±4.64	24.36±4.48	0.856[c]
BMI classifications, n (%)			0.808[b]			0.470 [b]			0.428[b]
Underweight (<18.5)	3 (5.8%)	4 (7.7%)		3 (8.8%)	0 (0%)		3 (9.7%)	1 (4.8%)	
Healthy (18.5-22)	18 (34.6%)	16 (30.8%)		13 (38.2%)	5 (27.8%)		9 (29%)	7 (33.3%)	
Overweight (23-24)	13 (25%)	10 (19.2%)		7 (20.6%)	6 (33.3%)		8 (25.8%)	2 (9.5%)	
Obese (≥25)	18 (34.6%)	22 (42.3%)		11 (32.4%)	7 (38.9%)		11 (35.5%)	11 (52.4%)	
Marital Status, n (%)			0.262[b]			0.084[b]			0.455[b]
Single	5 (9.6%)	2 (3.8%)		5 (14.7%)	0 (0%)		2 (6.5%)	0 (0%)	
Married	46 (88.5%)	45 (86.5%)		29 (85.3%)	17 (94.4%)		26 (83.9%)	19 (90.5%)	
Divorced	0 (0%)	1 (1.9%)		0 (0%)	0 (0%)		0 (0%)	1 (4.8%)	
Widowed	1 (1.9%)	4 (7.7%)		0 (0%)	1 (5.6%)		3 (9.7%)	1 (4.8%)	
Education level, n (%)			≤0.001[b]*			0.207[b]			0.026[b]*
No study	1 (1.9%)	2 (3.8%)		1 (2.9%)	0 (0%)		2 (6.5%)	0 (0%)	
Grades 1-3	9 (17.3%)	31 (59.6%)		5 (14.7%)	4 (22.2%)		22 (71%)	9 (42.9%)	
Grades 4-6	10 (19.2%)	5 (9.6%)		9 (26.5%)	1 (5.6%)		1 (3.2%)	4 (19%)	
Grades 7-9	15 (28.8%)	5 (9.6%)		10 (29.4%)	5 (27.8%)		4 (12.9%)	1 (4.8%)	
Grades 10-12	12 (23.1%)	3 (5.8%)		5 (14.7%)	7 (38.9%)		1 (3.1%)	2 (9.5%)	
Bachelor's degree	5 (9.6%)	5 (9.6%)		4 (11.8%)	1 (5.6%)		1 (3.1%)	4 (19%)	
Higher bachelor's degree	0 (0%)	1 (1.9%)		0 (0%)	0 (0%)		0 (0%)	1 (4.8%)	
Work status, n (%)			≤0.001[b]*			0.538[b]			0.778[b]
Unemployed	2 (3.8%)	25 (48.1%)		2 (5.9%)	0 (0%)		14 (45.2%)	11 (52.4%)	
Working	50 (96.2%)	27 (51.9%)		32 (94.1%)	18 (100%)		17 (54.8%)	10 (47.6%)	
Number of medication conditions, mean±*SD*	0.90±1.21	2.44±1.51	≤0.001[a]*	1.03±1.27	0.67±1.09	0.371[a]	2.42±1.71	2.48±1.21	0.894[a]
Number of prescription medications, mean±*SD*	1.08±2.17	2.85±2.30	≤0.001[a]*	1.41±2.48	0.44±1.25	0.104[a]	2.77±2.47	2.95±2.09	0.524[a]
Number of non-prescription medications, mean±*SD*	0.40±0.77	0.37±0.84	0.450[a]	0.47±0.86	0.28±0.58	0.520[a]	0.52±1.00	0.14±0.48	0.132[a]
History of falls (1 yr), n (%)	34 (65.4%)	31 (59.6%)	0.686[b]	34 (100%)	0 (0%)	NA	31 (100%)	0 (0%)	NA

Note: *=Significant difference at p-value ≤0.05. Statistical analysis: [a]=Mann Whitney U test, [b]=Fisher's exact test, [c]=Independent t-test, BMI=Body Mass Index according to Asian BMI classifications, NA=Not assessment

surface was found to be the major cause of falls in middle-age group, whereas, dizzy symptom was the main cause of falls in old-aged group.

Falls risk factors were compared between middle-aged and old-aged groups (Table 3). The middle-age group exhibited higher cognitive performance, physical performance and self-confidence in activities of daily living than those in the old-aged group. However, physical activity level showed no significant difference between the two groups. The environmental falls risk factors in the middle-aged group showed a slightly higher number of home environmental hazards than in the old-aged group.

All falls risk factors in the middle-aged group showed no significant differences between fallers and non-fallers. In the old-aged group, physical performance including proprioception (Absolute Angle Error at 40 and 60°), balance (left side of limit of stability and functional mobility and balance in cognitive task) revealed significant differences between fallers and non-fallers. The results are shown in Table 3.

Table 2. Comparison of falls characteristics among fallers between age groups

Characteristics	Middle-aged (n=34)	Old-aged (n=31)	*p*-value
Number of falls in previous, mean±*SD*	1.10±1.55	1.08±1.234	0.989[a]
Causes of recent falls, n (%)			0.048[b]*
Knee collapses without strength	3 (8.8%)	2 (6.5%)	
Stumbling on objects	2 (5.9%)	9 (29%)	
Dizzy	8 (23.5%)	10 (32.3%)	
Missed a step, slipped downstairs	4 (11.8%)	2 (6.5%)	
Slippery surface	15 (44.1%)	5 (16.1%)	
Other	2 (5.9%)	3 (9.7%)	
Injuries during recent falls, n (%)			0.390[b]
No injury	19 (55.9%)	21 (67.7%)	
Bruise	11 (32.4%)	8 (25.8%)	
Wound	0 (0%)	1 (3.2%)	
Other	4 (11.8%)	1 (3.2%)	
Falls direction of recent falls, n (%)			0.983[b]
Left	7 (20.6%)	8 (25.8%)	
Right	4 (11.8%)	4 (12.9%)	
Forward	9 (26.5%)	8 (25.8%)	
Backward	14 (41.2%)	11 (35.5%)	
Falls location of recent falls, n (%)			0.620[b]
Indoor	17 (50%)	18 (58.1%)	
Outdoor	17 (50%)	13 (41.9%)	

Note: *=Significant difference at *p*-value ≤0.05. Statistical analysis: [a]=Mann Whitney U test, [b]=Fisher's exact test

4. DISCUSSION

The results of this study were consistent with related studies reporting that increased age increases risk factors for chronic diseases[6] and multiple medications used.[7] History of falls in the previous year was reported approximately 60% in both age groups. The incidence of falls in both groups was slightly high compared with those previously reported.[4] One possible explanation could be the methods of taking history of falls used in this study emphasized a clear definition of falls to optimize understanding of falls in all participants. Furthermore, participant characteristics in our study had high physical activity level; however, their physical performance was slightly low. This could be one explanation for the high incidence of falls found in our study.

These results supported that falls incidence could occur in the middle-aged group similar with related studies.[4,11,14] The reason for this result is the transition phase in the middle-aged group regarding health changes included chronic diseases,[6] declining physical performance[28] and declining cognitive performance.[29] These constituted risks for falls; therefore, falls could occur in the future. In the old-aged group, the fallers had lower education level than non-fallers. The result was consistent with a study by Mora et al. indicating that older women who have low education level experienced increased risks of falling.[30] The possible reason could be education level affected awareness of health care and fall prevention strategies.[31] History of falls showed that falling could occur in the middle-aged group as well as in the old-aged. Likewise, a related study by Peeters et al. in 2018 found that the prevalence of falling also increased in the middle-aged group (40 to 64 years); therefore, the middle-aged group should develop strategies to prevent falls.[5] In the present study, causes of falls between the two groups approached significant differences, where most common causes of falls reported in the middle-aged group included slippery surface, dizzy, and missed a step or slipped down stairs; while in the old-aged group, causes of falls included dizzy, stumbling on objects and slippery surface. The causes of falls in the present study were similar to a related study,[4] which commonly found factors in both groups. The directions of falls in the present study exhibited no significant differences between middle-aged and old-aged groups. However, the highest percentage of the directions of the recent falls in both groups was backward (41.52% in the middle-aged and 35.5% in the old-aged groups). Similar to related studies, participants reported they mostly fell backwards.[32] It could be explained by the biomechanical arrangement of the ankle and foot, which provides less capacity for backward deviation compared with forward deviation.[23] In addition, the limit of stability among normal adults is 12° in the anterior-posterior dimension, which accounts for approximately 7° in the anterior and 5° in the posterior dimension.[33] Thus, imbalance could possibly occur in the posterior direction.

The old-aged group showed a lower score of

cognitive performance compared with that of the middle-aged group. However, both groups revealed no cognitive impairment. Declining cognitive performance with increasing age due to the normal aging process would lead to decline in the process comprising speed, memory, language, visuospatial and executive functions,[34] which could impact the awarding of performance in activities of daily living.[13] Additionally, the risk factors of declining cognitive performance include chronic diseases (diabetes, high LDL cholesterol, stroke, high blood pressure), lifestyle, obesity and low level of education.[35] These risk factors supported our findings in that the old-aged group had a high number of medical conditions, obesity (42.3%), and low level of education compared with those of the middle-aged group. In addition to the aging process, the factors previously mentioned might result in the findings of the old-aged group having lower cognitive performance levels compared with those of the middle-aged group in the present study. Another similar study by Jae-Hyun Kima in 2020, investigating the relationship between the history of falls and cognitive function in middle-aged and older people, found that history of falls correlated with cognitive decline, particularly among subjects aged 64 years or less. This study also suggested that cognitive screening should be performed in fall risk screening.[36] Our findings indicated that acuity of proprioception decreased in the old-aged group compared with that of the middle-aged group. These were also consistent with related studies that deterioration of proprioception was associated with balance deficits.[37]

Table 3. Comparison of falls risk factors between middle-aged and old-aged groups and between fallers and non-fallers in each age group

Falls risk factors	Total (n=104)			Middle-aged (n=52)			Old-aged (n=52)		
	Middle-aged (n=52)	Old-aged (n=52)	*p*-value	Fallers (n=34)	Non-fallers (n=18)	*p*-value	Fallers (n=31)	Non-fallers (n=21)	*p*-value
Intrinsic risk factors (mean±*SD*)									
1. Cognitive performance	25.69±2.23	22.94±3.01	≤0.001[a]*	25.79±2.38	25.5±1.95	0.494[a]	22.71±3.00	23.29±3.05	0.464[a]
2. Physical activity									
IPAQ (Total MET)	4279.56±3606.04	3583.41±2918.57	0.371[a]	4123.41±2956.19	4574.5±4680.36	0.722[a]	4078.23±3220.65	2852.98±2285.26	0.259[a]
3. Physical performance									
Upper body strength (kg)	27.51±9.54	23.82±7.70	0.053[a]	27.43±9.26	27.67±10.32	0.885[a]	22.85±7.90	25.24±7.35	0.215[a]
Knee extension strength (N)	318.14±114.75	227.31±87.54	≤0.001[c]*	316.24±126.17	321.72±92.65	0.859[c]	216.29±89.57	243.58±83.91	0.274[c]
Functional lower extremity strength (s)	8.66±2.99	11.63±3.34	≤0.001[a]*	9.05±3.39	7.93±1.91	0.184[a]	12.31±3.59	10.64±2.72	0.103[a]
Proprioception									
AAE at 40°	3.87±1.06	5.32±1.81	≤0.001[a]*	3.83±0.88	3.94±1.37	0.758[c]	4.83±1.45	6.05±2.07	0.041[a]*
AAE at 60°	4.53±1.52	6.06±2.38	0.001[a]*	4.62±1.68	4.37±1.18	0.582[c]	5.40±2.00	7.03±2.60	0.011[a]*
Limit of stability (cm)									
Forward	22.57±5.93	16.43±4.85	≤0.001[a]*	21.81±5.56	24.01±6.51	0.178[a]	15.81±4.88	17.35±4.78	0.268[c]
Backward	10.36±3.38	7.10±2.29	≤0.001[c]*	10.21±3.44	10.64±3.34	0.665[c]	6.83±1.77	7.50±2.89	0.351[c]
Left	18.92±4.69	13.88±3.77	≤0.001[c]*	18.60±4.77	19.54±4.61	0.497[c]	12.99±3.62	15.19±3.69	0.038[c]*
Right	19.53±4.65	14.50±4.41	≤0.001[a]*	19.02±4.80	20.50±4.32	0.408[a]	14.03±4.37	15.20±4.49	0.263[a]
Functional mobility and balance (s)	9.47±1.61	12.59±3.29	≤0.001[c]*	9.38±1.77	9.64±1.30	0.577[c]	13.19±3.54	11.69±2.73	0.106[c]
Functional mobility and balance with manual task (s)	10.01±1.77	13.38±3.25	≤0.001[c]*	9.81±1.89	10.41±1.49	0.248[c]	13.94±3.50	12.57±2.70	0.137[c]
Functional mobility and balance with cognitive task (s)	13.36±3.58	17.09±5.06	≤0.001[a]*	13.27±3.71	13.53±3.42	0.526[a]	18.36±5.22	15.22±4.27	0.027[c]*
4. Fear of falling									
ABC scale (%)	74.73±17.07	65.84±12.85	0.004[a]*	74.10±17.58	75.93±16.49	0.729[a]	64.33±12.52	68.08±13.32	0.232[a]
Extrinsic risk factors									
Environment falls risk factors									
Number of home environmental hazards (mean±*SD*)	5.63±2.58	4.17±2.01	0.002[a]*	5.62±2.88	5.67±1.97	0.697[a]	4.29±1.77	4.00±2.35	0.344[a]
Toilet type, n (%)			0.695[b]			0.571[b]			0.089[b]
Flush toilet	23 (44.2%)	26 (50%)		14 (41.2%)	9 (50%)		12 (38.7%)	14 (66.7%)	
Cesspool	29 (55.8%)	26 (50%)		20 (58.8%)	9 (50%)		19 (61.3%)	7 (33.3%)	

Note: *=Significant difference at *p*-value ≤0.05. Statistical analysis: [a]=Mann Whitney U test, [b]=Fisher's exact test, [c]=Independent t-test. Cognitive performance has maximum score 30 points, Unit of International Physical Activity Questionnaire (IPAQ) is MET-minutes/week, Absolute angle error (AAE), Activities-specific balance confidence (ABC)

These changes might decrease postural stability confidence.[38] In the present study, knee extensor strength and lower extremity functional strength was lower in the old-aged group than in the middle-aged group. Increasing age could affect decline of muscle mass, strength and increased adipose tissue mass.[39] Our results related to one related study in that the old-aged group exhibited low functional mobility and balance.[40] The limit of stability in the old-aged group in this study was lower than that of the middle-aged group in all directions. Our findings were also consistent with those of a related study revealing significant decrease with age especially among people aged 60 years and over.[41] It might be explained in that older people who are afraid of falling could have limitations in balance ability and less balance confidence.[42] In this study, fear of falling found in the old-aged group showed a lower scale than that found in the middle-aged group. It indicated that the old-aged group exhibited increased risk of falling. Similarly, a related study reported that fear of falling in older people related to increased risks of falling.[12] Furthermore, fear of falling in older people could occur due to physical activity deficits, leading to increased fall risks.[43] The environmental falls risk factors in the old-aged group showed fewer home environmental hazards compared with those found in the middle-aged group. It could be explained in that the old-aged in this study demonstrated less confidence in performing activities of daily living than that in the middle-aged group, assessed by the ABC scale. That made older people to better manage and increase awareness of their environmental hazards than those in the middle-aged group. The selection of environmental hazard assessment tools should be based on reasoning and justification by the researcher regarding the home visits and home evaluation.[44]

Interestingly, regarding falls risk factors between fallers and non-fallers, in the old-aged group, fallers showed significantly higher proprioception performance (AAE) than that of non-fallers. However, this might be explained by the possibility that some related factors such as knee pain and education level could have influenced results of the proprioception evaluation. A related study showed that knee pain was associated with proprioception deficit.[45] While education level in the current study was found to constitute lower grades 4 to 6 in older fallers, this might have influenced the understanding of the proprioception test procedure. However, the AAE in both fallers and non-fallers groups was in the reported normal range (0.79 to 7.39).[46] The minimal detectable change of assessing proprioception using a digital inclinometer was reported at 4.43°[47] Therefore, our findings were limited to address the proprioception as a falls risk factors. In addition, fallers in the old-aged group showed decreased balance performance compared with those in the non-fallers group. This corresponded to a related study reporting that fallers showed significantly lower limits of stability, assessed by MDRT, than non-fallers in all directions.[48] However, our findings revealed significant lower limits of stability in left direction among fallers than non-fallers. This might relate to the non-dominant function because most of our participants were right-handed dominant. Moreover, functional mobility and balance with cognitive function was lower among fallers than non-fallers. This result agreed with a related study reporting that the TUG with cognitive task was significantly associated with a history of falls.[49] Additionally, increasing age was associated with declined sensory systems and decreased ability to adjust and maintain balance, and these could result in changed gait performance and increased falls risk.[50] However, no significant differences were found in falls risk factors between fallers and non-fallers in the middle-aged group. Our findings showed lower limits of stability with higher functional mobility among fallers than non-fallers. These reflected imbalance characteristics between stability performance and mobility-task performance which could possibly relate to increased number of falls in the middle-aged group. Concerning the environmental fall risk factors, no significant differences were observed in the number of environmental home hazards between fallers and non-fallers in both middle-aged and old-aged groups. It might also be explained by the assessment list of environmental risk factors used in this study that only focused on the home environment. Due to the fact that approximately 90% of the middle-aged group and 50% of the old-aged group were still working, environmental hazards in the workplace, job characteristics and transportation should be considered. Although, no significant difference was found in the toilet type among fallers and non-fallers, approaching significant difference was found in old-aged group. The data of this study showed trend that falls may relate to using the cesspool toilet in both middle-aged and old-aged groups. According to the results, our study suggested that toilet type should be also considered as another environmental home hazard for falls risk assessment in Asian countries including Thailand.

First limitation was the possibility that there could be potential risk factors related to ageing process changes such as vision and hearing impairments, and these impairments were determined as exclusion criterion in this study. Findings of the study should be interpreted with this consideration. Second, the environmental fall risk factors did not cover the workplace and transportation that should be considered in future studies. Another limitation was ankle proprioception could possibly influence balance control.[50] Further studies should consider assessing ankle proprioception in falls risk assessment.

5. CONCLUSION

The main causes of falls could be different in different age groups. Slippery surface was found to be a major

cause of falls in middle-aged group, while cause of falls in older group in our study was dizziness. Age-related intrinsic falls risk factors including cognitive performance, physical performance and fear of falling were observed to decline in the old-aged compared with those in the middle-aged group, and these factors have been recognized to constitute potential falls risk factors in the old-aged group. It should be noted that associations between limits of stability and functional mobility may be another falls risk factor specifically for the middle-aged group, and these require additional studies. Falls prevention and management recommended for the middle-aged group should focus on balancing of stability and mobility abilities. Additionally, workplace and transportation hazards should be considered in the environmental falls risk assessment for both middle-aged and old-aged groups.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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REFERENCES

1. World Health Organization. WHO global report on falls prevention in older age. 2008. Accessed on 17 May 2019 at: https://apps.who.int/iris/handle/10665/43811.
2. Masud T, Morris RO. Epidemiology of falls. *Age Ageing.* 2001;**30**(suppl 4):3-7.
3. Terroso M, Rosa N, Torres Marques A, Simoes R. Physical consequences of falls in the elderly: a literature review from 1995 to 2010. *Eur Rev Aging Phys Act.* 2014;**11**(1):51-9.
4. Talbot LA, Musiol RJ, Witham EK, Metter EJ. Falls in young, middle-aged and older community dwelling adults: perceived cause, environmental factors and injury. *BMC Public Health.* 2005;**5**(1):86.
5. Peeters G, van Schoor NM, Cooper R, Tooth L, Kenny RA. Should prevention of falls start earlier? Co-ordinated analyses of harmonised data on falls in middle-aged adults across four population-based cohort studies. *PLOS ONE.* 2018;**13**(8):e0201989.
6. Freid VM, Bernstein AB, Bush MA. Multiple chronic conditions among adults aged 45 and over: trends over the past 10 years. *NCHS data brief.* 2012(100):1-8.
7. Qato DM, Alexander GC, Conti RM, Johnson M, Schumm P, Lindau ST. Use of prescription and over-the-counter medications and dietary supplements among older adults in the United States. *JAMA.* 2008;**300**(24):2867-78.
8. Watson KB, Carlson SA, Gunn JP, Galuska DA, O'Connor A, Greenlund KJ, et al. Physical Inactivity Among Adults Aged 50 Years and Older - United States, 2014. *MMWR Morb Mortal Wkly Rep.* 2016;**65**(36):954-8.
9. Borah D, Wadhwa S, Singh U, Yadav S, Bhattacharjee M, Sukumaran V. Age related changes in postural stability. *Indian J Physiol Pharmacol.* 2007;**51**:395-404.
10. Moreland JD, Richardson JA, Goldsmith CH, Clase CM. Muscle weakness and falls in older adults: a systematic review and meta-analysis. *J Am Geriatr Soc.* 2004;**52**(7):1121-9.
11. Mertz KJ, Lee D-C, Sui X, Powell KE, Blair SN. Falls among adults: the association of cardiorespiratory fitness and physical activity with walking-related falls. *Am J Prev Med.* 2010;**39**(1):15-24.
12. Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, de Rooij SE. Fear of falling: measurement strategy, prevalence, risk factors and consequences among older persons. *Age Ageing.* 2008;**37**(1):19-24.
13. Fischer BL, Gleason CE, Gangnon RE, Janczewski J, Shea T, Mahoney JE. Declining cognition and falls: role of risky performance of everyday mobility activities. *Physical therapy.* 2014;**94**(3):355-62.
14. Timsina LR, Willetts JL, Brennan MJ, Marucci-Wellman H, Lombardi DA, Courtney TK, et al. Circumstances of fall-related injuries by age and gender among community-dwelling adults in the United States. *PloS one.* 2017;**12**(5):e0176561.
15. Low Choy NL, Brauer SG, Nitz JC. Age-related changes in strength and somatosensation during midlife: rationale for targeted preventive intervention programs. *Ann NY Acad Sci.* 2007;**1114**:180-93.
16. Teh CH, Lim KK, Chan YY, Lim KH, Azahadi O, Hamizatul Akmar AH, et al. The prevalence of physical activity and its associated factors among Malaysian adults: findings from the National Health and Morbidity Survey 2011. *Public Health.* 2014;**128**(5):416-23.
17. Wilson M-MG, Miller DK, Andresen EM, Malmstrom TK, Miller JP, Wolinsky FD. Fear of falling and related activity restriction among middle-aged African Americans. *J Gerontol A Biol Sci.* 2005;**60**(3):355-60.
18. Aartsen MJ, Smits CHM, van Tilburg T, Knipscheer KCPM, Deeg DJH. Activity in older adults: cause or consequence of cognitive functioning? a longitudinal study on everyday activities and cognitive performance in older adults. *J Gerontol B Psychol Sci Soc Sci.* 2002;**57**(2):P153-62.
19. Chen HY, Tang PF. Factors contributing to single- and dual-task timed "up & go" test performance in middle-aged and older adults who are active and dwell in the community. *Phys Ther.* 2016;**96**(3):284-92.
20. Prasat Neurological Institute. Clinical Practice Guidelines : Dementia. 2014. Accessed on 29 April 2019 at: http://doh.hpc.go.th/data/academic/57dementia.pdf.
21. Rattanawiwatpong P, Khunphasee A, Pongurgsorn C, Intarakamhang P. Validity and Reliability of the Thai Version of Short Format International Physical Activity Questionnaire (IPAQ). *J Thai Rehabil.* 2006.
22. Bohannon RW, Shove ME, Barreca SR, Masters LM, Sigouin CS. Five-Repetition Sit-to-Stand Test Performance by Community-Dwelling Adults: A Preliminary Investigation of Times, Determinants, and Relationship with Self-Reported Physical Performance. *Isokinet Exerc Sci.* 2007;**15**:77-81.
23. Newton RA. Validity of the multi-directional reach test: a practical measure for limits of stability in older adults. *J Gerontol A Biol Sci Med Sci.* 2001;**56**(4):M248-52.
24. 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.* 2000;**80**(9):896-903.
25. Rakyoo C, Hiransinsoonthorn B, Nuang-nieo A, R B. Comparison of time spent during Timed Up and Go Test with naming or arithmetic calculation in Thai elderly. *Thai journal of physical therapy.* 2013;**35**:109-18.
26. Nanthapaiboon K, Wannapake J, Viriyatarakij N, Boonsinsukh R. Thai Translation and Cross-cultural adaptation of the Activities-specific Balance Confidence (ABC) Scale. *The 1st National*

Conference Research and Innovation. 2017.

27. Suttanon P, Piriyaprasarth P, Krootnark K, Aranyavalai T. Effectiveness of falls prevention intervention programme in community-dwelling older people in Thailand: Randomized controlled trial. *Hong Kong Physiother J.* 2018;**38**(1):1-11.
28. Hall KS, Cohen HJ, Pieper CF, Fillenbaum GG, Kraus WE, Huffman KM, et al. Physical Performance Across the Adult Life Span: Correlates With Age and Physical Activity. *J Gerontol A Biol Sci Med Sci.* 2017;**72**(4):572-8.
29. Humes LE. Age-Related changes in cognitive and sensory processing: focus on middle-aged adults. *Am J Audiol.* 2015;**24**(2):94-7.
30. Alfonso Mora ML, Bejarano Marín X, Sánchez Vera MA, García Muñoz LP, Soto León IA. Association between the fall risk, age and educational level in active adult and older women. *Revista Salud Uninorte.* 2017;**33**:306-14.
31. Li YH, Song GX, Yu Y, Zhou DD, Zhang HW. Study on Age and Education Level and Their Relationship with Fall-Related Injuries in Shanghai, China. *Biomed Environ Sci.* 2013;**26**(2):79-86.
32. Vlaeyen E, Deschodt M, Debard G, Dejaeger E, Boonen S, Goedemé T, et al. Fall incidents unraveled: a series of 26 video-based real-life fall events in three frail older persons. *BMC Geriatrics.* 2013;**13**(1):103.
33. Chaudhry H, Findley T, Quigley KS, Bukiet B, Ji Z, Sims T, et al. Measures of postural stability. *J Rehabil Res Dev.* 2004;**41**(5):713-20.
34. Harada CN, Natelson Love MC, Triebel KL. Normal cognitive aging. *Clin Geriatr Med.* 2013;**29**(4):737-52.
35. Anstey KJ, Low LF. Normal cognitive changes in aging. *Aust Fam Physician.* 2004;**33**(10):783-7.
36. Kim J-H. Fall experience and cognitive function in middle aged and elderly population. *Medicine.* 2020;**99**(18).
37. Ribeiro F, Oliveira J. Aging effects on joint proprioception: the role of physical activity in proprioception preservation. *Eur Rev Aging Phys Act.* 2007;**4**(2):71-6.
38. Hurley MV, Rees J, Newham DJ. Quadriceps function, proprioceptive acuity and functional performance in healthy young, middle-aged and elderly subjects. *Age Ageing.* 1998;**27**(1):55-62.
39. Candow DG, Chilibeck PD. Differences in size, strength, and power of upper and lower body muscle groups in young and older men. *The Journals of Gerontology: Series A.* 2005;**60**(2):148-56.
40. Visser M, Goodpaster BH, Kritchevsky SB, Newman AB, Nevitt M, Rubin SM, et al. Muscle mass, muscle strength, and muscle fat infiltration as predictors of incident mobility limitations in well-functioning older persons. *J Gerontol A Biol Sci.* 2005;**60**(3):324-33.
41. Tantisuwat A, Chamonchant D, Boonyong S. Multi-directional reach test: an investigation of the limits of stability of people aged between 20-79 years. *J Phys Ther Sci.* 2014;**26**(6):877-80.
42. Binda SM, Culham EG, Brouwer B. Balance, muscle strength, and fear of falling in older adults. *Exp Aging Res.* 2003;**29**(2):205-19.
43. Jefferis BJ, Iliffe S, Kendrick D, Kerse N, Trost S, Lennon LT, et al. How are falls and fear of falling associated with objectively measured physical activity in a cohort of community-dwelling older men? *BMC Geriatrics.* 2014;**14**(1):114.
44. Romli MH, Mackenzie L, Lovarini M, Tan MP, Clemson L. The Clinimetric Properties of instruments measuring home hazards for older people at risk of falling: a systematic review. *Eval Health Prof.* 2018;**41**(1):82-128.
45. Felson DT, Gross KD, Nevitt MC, Yang M, Lane NE, Torner JC, et al. The effects of impaired joint position sense on the development and progression of pain and structural damage in knee osteoarthritis. *Arthritis Rheum.* 2009;**61**(8):1070-6.
46. Kumar A. Joint proprioception in normal and osteoarthritic knees. *J Yoga Phys Ther.* 2012;**2**(4).
47. Suner-Keklik S, Cobanoglu G, Kafa N, Ugurlu M, Atalay Guzel N. The Validity and reliability of knee proprioception measurement performed with inclinometer in different positions. *J Sport Rehabil.* 2017;**26**:1-18.
48. Taweetanalarp S, Tantisuwat A. Multi-directional reach test between elderly fallers and non-fallers. *Thai journal of Physical Therapy.* 2019;**42**:34-42.
49. Tomas-Carus P, Biehl-Printes C, Pereira C, Veiga G, Costa A, Collado-Mateo D. Dual task performance and history of falls in community-dwelling older adults. *Exp Gerontol.* 2019;**120**:35-9.
50. Osoba MY, Rao AK, Agrawal SK, Lalwani AK. Balance and gait in the elderly: A contemporary review. *Laryngoscope Investig Otolaryngol.* 2019;**4**(1):143-53.