69.7%.

4. Discussion

This is the first study using a stepping performance device that integrates temporal and spatial measurements to identify elderly individuals at a risk for falling. Quick step execution (5, 8) and step accuracy (4, 12) are important skills that can serve to alter the support base, preserve stability, and prevent a fall. Our step-tracking device that uses an infrared laser sensor can conveniently assess these components of stepping performance. Previously, a similar portable device that included a dance mat step-timing device was used to easily assess stepping performance parameters (21). Since our new device can also assess stepping performance step speed, length and accuracy, it may be useful for determining fall risk.

Similar to previous studies (5-7), the present study showed participants with a history of falls had significantly longer stepping reaction times than those with no history of falls. The stepping-response score we developed that integrates temporal and spatial measurements can discriminate between participants with and without a history of falls with good sensitivity using a logistic regression and discriminant analysis. Avoiding falls in real-life situations requires fast and appropriate step responses, and the speed and accuracy of responses can be indicated by the step speed and accuracy measurements used in the present study. In the results of the present study, there was no significant difference in step accuracy measurement, probably because of the comparatively easy stepping performance tasks. However, formulating a stepping-response score

that integrates temporal and spatial measurements was the most reasonable index (preliminary regression analysis) among the candidate indexes (e.g. the model: age and reaction time) and could successfully identify individuals at risk of falling. This may be because step accuracy measurement was related to the risk of falling as an internal factor in our stepping performance task. We will need to investigate this more thoroughly in a future study. Although previous rapid step reaction tests used only step speed as a fall risk indicator for elderly individuals (8, 22), the prevention of falls may require the assessment of multiple aspects of step responses. The stepping-response score in this study is the first index that assesses the risk of falls from the perspective of step speed and accuracy. Moreover, stepping-response score was mildly correlated with motor and cognitive functions (results not shown). Therefore, this stepping-response score is a novel index that assesses fall risk from a new perspective.

The new step-tracking device developed is fairly inexpensive and portable in comparison to other step performance assessment tools. These characteristics enable its use at clinical sites. Furthermore, our device does not require specialized personnel, and the difficulty of the stepping task can be adjusted according to the subjects undergoing assessment. For example, we could ask participants to step in a direction contrary to that indicated by the arrow on the computer monitor. Therefore, the device has high utility and can be used in clinical settings or in homes of elderly individuals as both an assessment tool and a training device. Recent intervention studies have indicated that abilities relating to voluntary stepping can be improved by training (23, 24). Elderly individuals are also able to improve their balance under dual task (DT)

conditions after specific DT balance training (25, 26). In a previous study, we reported that a rhythmic stepping exercise under cognitive conditions like the task of present study improved DT function (26). This exercise has potential as a means of public health promotion, as it can be performed within a small indoor space. Our device can also serve as a training aid and can be used to facilitate effective exercise at community and clinical sites. A prospective cohort study is needed to further evaluate the relationship between falling incidents and stepping-response score. We hope that our device is not only useful for fall assessment but also opens avenues for developments in cognitive-locomotion science.

There are several potential limitations in present study. First, we retrospectively investigated the risk of falls, based on participants' experience of falls within the year preceding the study. Therefore, the accuracy of our device in predicting future falls among elderly individuals was not measured. Examination of the validity of the predictions made using measurements from this device requires a prospective investigation of occurrence of falls. The second limitation is that all participants in the present study were robust elderly individuals with high functional capacity. A previous study reported that DT performance was a reliable predictor of falls in a robust elderly population (27). Therefore, our results may apply only to robust elderly individuals. We need to investigate the stepping performance in frail elderly individuals to prevent falls among all community-dwelling elderly individuals.

5. Conclusions

The present study indicates that our new stepping performance device that uses LRF can be an effective clinical tool to identify high risk elderly individuals and the measurements obtained using this device reflect multilateral parameters, such as motor and cognitive functions. The new index we developed that integrates temporal and spatial measurements can successfully discriminate between participants who are at a high and low risk of falling.

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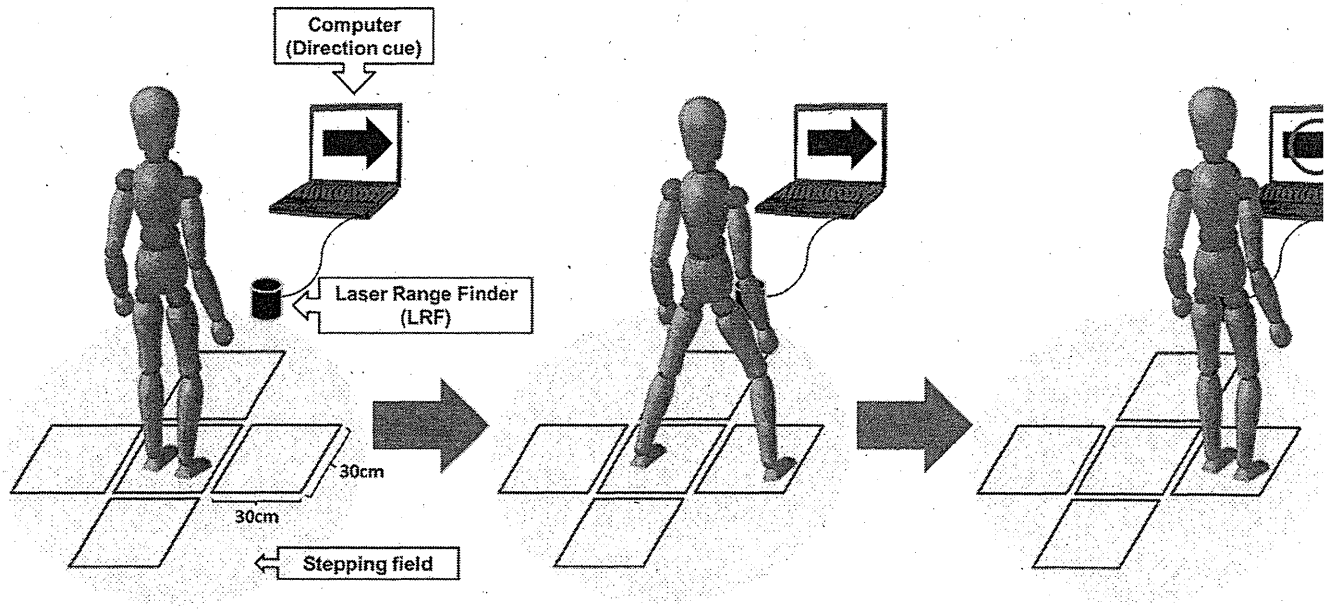

Figure 1. Schematic representation of the step-tracking device and the stepping performance task.

The circle represents the stepping field in which the infrared laser sensor can detect the motion of both legs. Participants initially stood upright in the center square of five 30 cm × 30 cm squares arranged in a plus shape. Participants were instructed to quickly step with one leg, followed by the other leg into 1 of the 4 squares arranged around the starting position when provided with a visual cue indicating which direction to step.

Table 1. Characteristics of community-dwelling participants aged 65 and older with and without a history of falls.

	F (n = 41)	NF (n = 111)	*p*-value
Age (y)	75.4 ± 4.6	73.5 ± 4.6	0.025*
Gender (% men)	26.8	44.1	0.062
Height (cm)	152.0 ± 8.6	155.1 ± 8.5	0.053
Weight (kg)	55.0 ± 9.4	54.8 ± 11.5	0.927
RDST	9.08 ± 2.25	9.63 ± 2.53	0.237
Verbal fluency task	12.8 ± 3.0	13.4 ± 3.9	0.357
WT (s)	8.06 ± 1.48	7.22 ± 1.04	< 0.001**
TUG (s)	7.05 ± 1.09	6.45 ± 1.34	0.012*
5CS (s)	9.66 ± 3.07	8.26 ± 1.89	0.010*

Note: F = faller group; NF = non-faller group; RDST = rapid dementia screening test; WT = 10-m walking test; TUG = timed up and go test; 5CS = 5-chair stand test

*$p < 0.05$. **$p < 0.01$.

Table 2. Comparison of the stepping performance parameters measured in elderly community-dwelling participants.

	F (n = 41)	NF (n = 111)	*p*-value
Reaction time (s)	0.85 ± 0.17	0.78 ± 0.11	0.013*
Stepping time (s)	1.65 ± 0.30	1.55 ± 0.18	0.004**
Step length (cm)	27.0 ± 4.2	27.4 ± 4.2	0.831
Correctly executed steps (%)	96.8 ± 7.6	98.3 ± 3.6	0.256
Stepping-response score	0.76 ± 0.80	1.19 ± 0.54	< 0.001**

Note: F = faller group; NF = non-faller group

*$p < 0.05$. **$p < 0.01$.

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Relationship between depression and risk of malnutrition among community-dwelling young-old and old-old elderly people

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Objectives: This study explores the association between nutritional status and depression among healthy community-dwelling young-old (aged 65–74) and old-old elderly (aged 75 and older).
Method: A cross-sectional design was implemented. A total of 274 community-dwelling older individuals (142 young-old; 132 old-old) were assessed using the Geriatric Depression Scale (GDS), Mini-Nutritional Assessment Short-Form (MNA-SF) and Life-Space Assessment. Logistic regression analysis was used to determine if depression was independently associated with risk of malnutrition, stratified by age (young-old vs. old-old).
Results: In the logistic regression model for young-old, being at risk of malnutrition (MNA-SF (≦11) was strongly associated with depression (GDS (≧5;) (likelihood ratio $v=6.26$; 95% confidence interval [CI]: 1.91–20.49). In contrast, in the old-old group, the model was not statistically significant.
Conclusion: Depression and nutritional status were strongly correlated in young-old but not in old-old community-dwelling elderly. This study reveals that not only the factors correlated with but also the symptoms of depression may vary among different age stratifications of the elderly.

Keywords: depression; nutritional status; young-old

Introduction

In an ageing population, depression is a serious public health issue due to its societal burden and association with various factors. The total cost of depression in Japan in 2005 was estimated to be 2.0 trillion yen (USD 1 = JPY 78: October 2012; Sado et al., 2011), which includes all direct, morbidity and mortality costs. Further, studies in a variety of settings have shown that depression is strongly associated with low function and poor quality of life, increase in the use of health services, late-life suicide tendency and excess mortality (Callahan, Hui, Nienaber, Musick, & Tierney, 1994; Cuijpers & Smit, 2002; Geerlings, Beekman, Deeg, Twisk, & van Tilburg, 2002; Koenig, Shelp, Goli, Cohen, & Blazer, 1989; Nyunt, Lim, Yap, & Ng, 2012; Turvey et al., 2002; van der Weele, Gussekloo, de Waal, de Craen, & van der Mast, 2009; Wada et al., 2005). A systematic review of 34 community-based studies reported that the prevalence of depression in the elderly is as high as 35% (Beekman, Copeland, & Prince, 1999; Woo et al., 1994). In terms of the type of depression, major depression is relatively rare and minor depression more common (Beekman et al., 1999). In addition, clinicians often fail to diagnose and treat depression in the elderly, and elderly individuals are reluctant to report depressive symptoms (Georgotas, Cooper, Kim, & Hapworth, 1983; Lyness et al., 1995; Webber et al., 2005). Therefore, depression in the elderly has often been unrecognized, and it is important to clarify the components of depression to improve the sensitivity of screening methods.

Many variables, including gender, marital status, cognitive status, activities of daily living and independent activities of daily living limitations and social engagement, are associated with increased depression (Anstey, von Sanden, Sargent-Cox, & Luszcz, 2007; Glass, Mendes de Leon, Bassuk, & Berkman, 2006). Meanwhile, weight loss and loss of appetite are the main factors that mediate the relationship between depression and nutritional status (Rubenstein, Harker, Salvà, Guigoz, & Vellas, 2001). Recently, multiple studies have indicated an association between depression and nutritional status in various settings such as outpatient clinics and institutions and in the community (Cabrera, Mesas, Garcia, & de Andrade, 2007; Kaburagi et al., 2011; Smoliner et al., 2009; Wilson, Vaswani, Liu, Morley, & Miller, 1998). In these settings, depression is an independent predictor of nutritional health and a major cause of weight loss (Chen, Chang, Chyun, & McCorkle, 2005; Morley & Kraenzle, 1994; Thompson & Morris, 1991). Conversely, better diet quality is beneficial for preventing and improving depressive symptoms (Akbaraly et al., 2009; Lin & Su, 2007). The relationship between depression and nutritional status is interactive and further investigation is still needed. In this regard, the ageing society needs to be considered. The word 'elderly' is very broad, encompassing all individuals aged older than 60 or 65 years. Age may alter the

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relationship among the various variables associated with depression. For example, the young-old (age 65–74 years) and old-old (age 75 years and above) have different predispositions regarding various aspects of both depression and nutritional status (Kaburagi et al., 2011; Kondo, Kazama, Suzuki, & Yamagata, 2008). Older elderly are more likely to experience frailty, physical illness, bereavement and loneliness, which are risk factors contributing to depression (Blazer, 2002; Bruce, 2002). Investigating age-group differences may help in clarifying the correlation between depression and nutritional status and in developing precise, age-stratified interventions.

The purpose of this study was to analyse the association between depression and nutritional status in different age groups of non-functionally impaired, community-dwelling elderly.

Methods

Participants

Study participants were recruited through advertisements in the local press and at local healthcare events from April 2011 to June 2012. A total of 274 community-dwelling older individuals volunteered in the study. The inclusion criteria were an age of 65 years or older, living in the community and being able to walk independently with or without a cane. The exclusion criteria ensured that none of the participants had any indications of the following health problems: (a) symptomatic cardiovascular disease, (b) neurological and orthopaedic disorders, (c) peripheral neuropathy of the lower extremities and (d) severe arthritis.

This study was approved by the Ethical Review Board of Kyoto University Graduate School of Medicine, Kyoto, Japan.

Variables

The following variables were collected using a questionnaire.

Depression was screened for by the 15-item Geriatric Depression Scale (GDS; Yesavage, 1988), a validated and reliable self-report scale that detects depression in elderly people. Scores range from 0 to 15. We used a cut-off of 4/5, which is a recommended indicator of depression in Japanese populations (Murata, Kondo, Hirai, Ichida, & Ojima, 2008; Yamazaki, Nakano, Saito, & Yasumura, 2012).

Nutritional status was assessed with the Mini-Nutritional Assessment Short-Form (MNA-SF; Rubenstein et al., 2001). MNA-SF includes six items dealing with loss of appetite, weight loss, mobility, stress or illness, dementia or depression and body mass index (BMI). Scores range from 0 to 14. A score of 12 or above indicates satisfactory nutritional status, a score of 8 to 11 implies risk of malnutrition and a score less than 7 suggest malnourishment.

Life-space mobility was assessed by the Life-Space Assessment (LSA; Baker, Bodner, & Allman, 2003), a questionnaire that measures the spatial extent of individuals in a given month. The LSA takes into account the frequency of travel to different life-space levels (bedroom, driveway, within neighbourhood, outside neighbourhood but within town and out of town), and whether personal or technical assistance was required to get to those levels. The composite scores range from 0 to 120.

Statistical analysis

Statistical analysis was carried out with the software package SPSS 20.0 (SPSS Inc., Chicago, IL). Relationships between MNA-SF items and depression were evaluated with chi-squared tests. Multivariate analysis was performed to examine the association between depression and risk of malnutrition. Step-up logistic regression analysis was used to determine if depression (GDS ≥ 5) was independently associated with risk of malnutrition (MNA-SF ≤ 11). In Model I, all the participants were analysed. Model II contained only young-old participants and Model III only old-old participants. Demographic factors (age, gender and BMI) and LSA were adjusted in each model. An acceptable level of statistical significance was considered to be a p-value of < 0.05.

Results

Participant characteristics are presented in Table 1. The mean age was 74.33 (SD 4.72) years, and 185 participants (67.5%) were female. Classifying participants by age, 142 were young-old (51.8%) and 132 participants were old-old (48.2%). Fifty-nine participants (21.5%) were depressed. Seventy-seven (28.1%) were at risk of malnutrition (including one participant determined to be malnourished), and the others were well nourished. Old-old participants had a higher risk of malnutrition than young-old ones, but no significant differences were found for depression. The nutritional characteristics of the participants are presented in Table 2. Among the young-old, there was a trend that depressed participants were more likely to have a loss of appetite within the past three months than the non-depressed participants, but this difference was not statistically significant ($p = 0.075$). There was no trend towards significance in the old-old group ($p = 0.502$).

In the logistic regression model for young-old (Model II), being at risk of malnutrition (MNA-SF ≤ 11) was strongly associated with depression (GDS ≥ 5; likelihood ratio $= 6.74$; 95% confidence interval [CI]: 2.11–21.51) independent from the control variables, while this association was not found in Models I and III (Table 3).

Table 1. Participant characteristics according to age.

	All participants ($n=274$)		Young-old (age 65–75; $n=142$)		Old-old (age ≥ 75; $n=132$)		
	Mean	SD	Mean	SD	Mean	SD	*p*-Value
Age (years)	74.33	4.72	70.61	2.33	78.34	3.07	<0.001**
Female (%)	67.5		66.2		68.9		0.699
BMI	22.44	3.26	22.65	3.21	22.23	3.31	0.287
LSA (range 0–120)	87.83	21.08	89.91	20.62	85.59	21.41	0.107
MNA-SF score (range 0–14)	12.32	1.56	12.44	1.50	12.20	1.61	0.253
At risk of malnutrition (%) (MNA-SF score ≤ 11)[a]	28.1		21.8		34.8		0.022*
GDS score (range 0–15)	2.71	2.74	2.55	2.70	2.89	2.78	0.228
Depression (%) (GDS score (≧5)	21.5		19.7		23.5		0.466

Notes: *p*-Values were determined by Mann–Whitney *U*-test or chi-squared test.
[a]Includes one participant classified as malnourished in the young-old group.
*$p < 0.05$ and **$p < 0.01$.

Table 2. Nutritional characteristics, measured by MNA-SF, of young-old and old-old participants with and without depression.

	With depression (GDS ≥ 5) *n* (%)				Without depression (GDS < 5) *n* (%)				
MNA-SF items (ranking)[a]	0	1	2	3	0	1	2	3	*p*-Value
Young-old (n = 142)									
Loss of appetite	1 (3.6)	3 (10.7)	24 (85.7)	–	0 (0)	5 (4.4)	109 (95.6)	–	0.075
Weight loss	0 (0)	3 (10.7)	6 (21.4)	19 (67.9)	0 (0)	6 (5.3)	13 (11.4)	95 (83.3)	0.108
Mobility	0 (0)	–	28 (100)	–	0 (0)	–	114 (100)	–	–
Stress or acute illness	6 (21.4)	–	22 (78.6)	–	7 (6.1)	–	107 (93.9)	–	0.022*
Neuropsychological status	2 (7.1)	1 (3.6)	25 (89.3)	–	0 (0)	0 (0)	114 (100)	–	0.007**
BMI	4 (14.3)	6 (21.4)	7 (25.0)	11 (39.3)	11 (9.6)	16 (14.0)	45 (39.5)	42 (36.8)	1.000
Old-old (n = 132)									
Loss of appetite	0 (0)	4 (12.9)	27 (87.1)	–	0 (0)	9 (8.9)	92 (91.1)	–	0.502
Weight loss	0 (0)	3 (9.7)	6 (19.4)	22 (71.0)	3 (3.0)	6 (5.9)	12 (11.9)	80 (79.2)	0.338
Mobility	0 (0)	–	31 (100)	–	0 (0)	–	101 (100)	–	–
Stress or acute illness	6 (19.4)	–	25 (80.6)	–	8 (7.9)	–	93 (92.1)		0.075
Neuropsychological status	1 (3.2)	1 (3.2)	29 (93.5)	–	0 (0)	2 (2.0)	99 (98.0)	–	0.235
BMI	3 (9.7)	8 (25.8)	6 (19.4)	14 (40.6)	17 (16.8)	21 (20.8)	22 (21.8)	41 (40.6)	0.681

Notes: Chi-squared test: loss of appetite and neuropsychological status, 0–1 vs. 2; weight loss and BMI, 0–2 vs. 3 and; stress or acute illness, 0 vs. 2.
[a]Higher scores indicate better function.
*$p < 0.05$ and **$p < 0.01$.

Discussion

This study found a correlation between GDS and MNA-SF for young-old individuals, but not for old-old individuals or for the two groups combined. Multiple studies conclude that depression and malnutrition are related, but that the influence of age on the variables differs. Previous studies reported that depression is an independent predictor of malnutrition or nutritional risk even after adjusting for social and educational factors in young-old elderly adults, but not old-old elderly adults (Cabrera et al., 2007; Callen & Wells, 2005). These differences could arise because depressive symptoms in the elderly have different clinical features along the age spectrum from young-old to old-old (Mehta et al., 2008). For example, old-old elderly may suffer from a higher prevalence of disability or medical illnesses (Chou & Chi, 2007). Having a chronic disease is a variable that independently influences depression (Schoevers et al., 2000). The relationship between depression and malnutrition needs to be further examined, with physical, mental and social status taken into consideration.

Various studies have reported a positive relationship between depression and nutritional status, and

Table 3. Step-up logistic regression model of variables associated with depression (GDS ≥ 5).

	All participants (Model I) ($n = 274$)		Young-old (Model II) (Age 65–75; $n = 142$)		Old-old (Model III) (Age ≥ 75; $n = 132$)	
	Likelihood ratio (95% CI)	p-Value	Likelihood ratio (95% CI)	p-Value	Likelihood ratio (95% CI)	p-Value
Risk of malnutrition (MNA-SF ≤ 11)	–	NS	6.738** (2.111–21.510)	0.001	–	NS
Age (years)	–	NS	–	NS	–	NS
Gender (male 0; female 1)	–	NS	–	NS	–	NS
BMI	–	NS	1.201* (1.033–1.395)	0.017	–	NS
LSA	0.985* (0.971–0.999)	0.031	–	NS	–	NS

Notes: NS, not selected.
*$p < 0.05$ and **$p < 0.01$.

they often associate depression with loss of appetite or weight loss (Akbaraly et al., 2009; Davison & Kaplan, 2012). However, the rates of depressed participants in this study with loss of appetite or weight loss were 13.6% and 30.5% in the young-old and old-old, respectively, and were relatively low. Only the relationship between depression and loss of appetite in young-old elderly showed a trend towards significance, and other relationships (between depression and weight loss in young-old and between depression and loss of appetite or weight loss in old-old) did not. Callen and Wells (2005) reported that in old-old elderly, depression is not a predictor of weight loss or low BMI when adjusting for social, physical and economic factors, a finding which is in agreement with our results. The relationship between depression and loss of appetite may have been the principal reason behind the result obtained in this multivariate analysis, that is, the positive relationship between depression and malnutrition.

Our study has several limitations. The cross-sectional design prevents us from making causal inferences. We also did not assess socioeconomic and educational status and social support; the possibility of these being confounding factors cannot be denied. Despite these limitations, this study reveals that the factors correlated with depression could vary among different age groups of elderly and suggests that depression and nutritional status are correlated more strongly in young-old than old-old elderly. Future studies should focus on clarifying the causal relationship, consider the age of subjects and assess nutritional status, social status, etc., for better understanding of depression.

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