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Mechanography assessment of fall risk in older adults: the Vietnam Osteoporosis Study

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Abstract

Background Jumping mechanography is a technology for quantitatively assessing muscular function and balance in older adults. This study sought to define the association between jumping mechanography parameters and fall risk in Vietnamese individuals.

Methods The study involved 375 women and 244 men aged 50 years and older, who were recruited from the general population in Ho Chi Minh City (Vietnam). The individuals had been followed for 2 years. At baseline, Esslinger Fitness index (EFI), jumping power, force, velocity of lower limbs, and the ability to maintain balance were measured by a Leonardo Mechanograph Ground Reaction Force system (Novotec Medical, Pforxheim, Germany). The incidence of falls during the follow-up period was ascertained from self-report. Logistic regression analysis was used to analyse the association between jumping mechanography parameters and fall risk.

Results The average age of participants at baseline was 56.7 years (SD 5.85). During the 2 year follow-up, 92 falls were reported, making the incidence of fall at ~15% [95% confidence interval (CI), 12.1 to 18.2]. The incidence of fall increased with advancing age, and women had a higher incidence than men (17.6% vs. 10.7%; $P = 0.024$). In univariate analysis, maximal velocity [odds ratio (OR) 0.65; 95% CI, 0.52 to 0.82], maximal force (OR 0.83; 95% CI, 0.65 to 1.04), and maximal power (OR 0.68; 95% CI, 0.52 to 0.88) were each significantly associated with fall risk. EFI was not significantly associated with fall risk (OR 1.09; 95% CI, 0.86 to 1.39). However, in a multiple logistic regression model, greater maximum velocity was associated with lower odds of fall (OR 0.38; 95% CI, 0.16 to 0.92).

Conclusions These data suggest that jumping mechanography is a useful tool for assessing fall risk in older adults of Vietnamese background.

Keywords Jumping mechanography; Fall; Jumping power; Jumping velocity; Vietnam Osteoporosis Study

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Introduction

In older adults, fall remains an important public health problem globally. According to the World Health Organization, there are 646 000 fatal falls annually, making it the second leading cause of unintentional injury deaths, only after road traffic injuries.[1] Even those who survive after a fall may still suffer from a fracture, especially hip fracture, subdural hematoma, soft tissue injuries, or activity restriction. These injuries are associated with reduced life expectancy, and they cost more than $50 billion in 2015 alone.[2] With the rapid aging of the population worldwide, the number of falls and their associated costs represent a substantial burden to the public health system.

The propensity to fall is determined by multiple factors. One major risk factor is the decline in muscle function. In older adults, low muscle mass and reduced muscle strength are associated with increased risks of fall and fracture.[3–5] A number of functional performance tests for predicting falls have been developed. Among them, the Five Times Sit-to-Stand test, which records the time required to complete the test, is significantly associated with recurrent falls in the elderly.[6,7] Those who are unable to complete the Five-Time Sit-to-Stand are at greater risk of fall, with odds ratio being 4.2 in 3 years.[8] Taken together, these studies suggest that functional performance assessments can be used to estimate the probability of fall in older adults.

Jumping mechanography has emerged as a promising technology for functional performance assessment. The Leonardo Mechanograph® Ground Reaction Force Plate (GRFP) is such a technology that has recently been developed to assess muscle functions, including muscle power and fitness index. Muscle power is a valuable measure for identifying age-related physical impairments and strongly correlates with physical capability, mobility, and the risk of falling.[9,10] Furthermore, Esslinger Fitness Index (EFI), a measure of relative jumping power, has been shown to be associated with higher risk of falling among older women.[11] Taken together, these studies suggest that mechanography is an attractive technology for fall risk assessment.

Asians have a lower prevalence of fall than their Caucasian counterparts,[12–14] and the habit of squatting among Asian people (i.e. 'Asian squat') and better balance have been postulated as a protective factor for fall. Although fall is recognized as a public health burden in Vietnam, prevalence of and risk factors for falls have not been systematically studied.[12,13] We hypothesize that in Vietnamese older adults, muscle weakness and reduced ability to maintain balance are associated with increased risk of falls. The present study was designed to test the hypothesis by pursuing the following specific aims: (i) to estimate the incidence of falls in Vietnamese older adults and (ii) to define the association between mechanography parameters and falls.

Study design and methods

Study design

This study was part of the Vietnam Osteoporosis Study (VOS) project that was initiated in mid-2015. The rationale, protocol, and procedure of the study have been described elsewhere.[15] VOS is designed as a longitudinal cohort study, in which approximately 4200 individuals were randomly sampled from Ho Chi Minh City, Vietnam. The baseline data collection was conducted between 2015 and 2017. The study's procedure and protocol were approved by the Ethics Committee of the Hospital 115, Ho Chi Minh City. All participants gave written informed consent. Participants could withdraw from the study at any time without giving reasons.

The inclusion criteria of VOS were men and women aged 18 years and older, who agreed to participate in the study. However, for the current study, only individuals aged 50 years and older were included. The following exclusion criteria were applied: inability to stand or walk without aids or unable to stand in one leg; fell in the previous 12 months; and individuals who were completely paralyzed and who cannot give informed consent.

The determination of sample size for this study was based on the test of hypothesis concerning odds ratio as described by Woodward.[16] The following assumptions were made in the calculation: (i) incidence of falls is 12%[17]; (ii) odds ratio of fall risk associated with a risk factor is 0.5; and (iii) relative precision (e.g. the lower limit of the confidence interval (CI) is less than the estimated odds ratio) is 50%. At the significance level of 5%, we estimated a sample size of at least 210 individuals in each gender is required to achieve a power of 80%.

Measurements

Height and body weight were measured by an electronic portable, wall-mounted stadiometer (Seca Model 769; Seca Corp, CA, USA) without shoes, hats, ornaments, or heavy layers of clothing. Body mass index was calculated as weight (kg) divided by the square of height (kg/m^2).

Assessment of neuromuscular performance

The assessment of muscle function and balance was done by a Leonardo Mechanograph® GRFP (Novotec Medical, Pforzheim, Germany) with the manufacturer's software Version 4.3, whose protocol of measurements have been described elsewhere.[18,19] Briefly, the GRFP has a length of 66 cm, width of 66 cm, and height of 7 cm. It has eight sensors (four in each side), with each sensor recording force at a sampling frequency of 800 Hz (i.e. 800 measurements per second for each force sensor). Each sensor can detect a maximum of 1500 N. The detection of force is based on the change in deformation of the detector that is proportional to the applied force and is calculated by the manufacturer's software programme.

Two measurements were used in this study: Single Two Legs Jump and one leg stand–eyes open. Participants in light clothing and without shoes were asked to stand on the platform, and each foot was placed on one plate. Participants were instructed to jump as high as possible with freely moving arms.[19] Participants were instructed to jump using both feet and to land both feet on the platform. After an initial practice jump, each participant performed three jumps, and the recordings of the highest jumping height were obtained for further analysis. Five main parameters obtained from this test are maximal jump height (H_{max}), maximal jump power

(P_{max}), maximal jump force (F_{max}), maximal jump velocity (V_{max}), and EFI. EFI is defined as the percentage between maximum power per body mass when jumping and the normal value of the sex-matched age group. Operationally, EFI was derived as EFI = P_m/P_t, where P_m is the maximum jump power relative to body weight, and P_t is the sex-specific 'normal' value: P_t = 66.17–0.57*age for men and P_t = 49.14 − 0.43*age for women.

The one leg stand–eyes open test is designed to assess balance and fall risk. In this test, participants were instructed to stand as still as possible in an upright position with both arms hanging free, eyes open, and a foot on each side of the platform for 10 s.[20] During the test, the Leonardo Mechanography system records the position of the centre of pressure on the platform. The main parameters of this test include path length and sway area of each leg. The direction and extent of postural sway are described by these variables.

Falls

Falls were ascertained by self-report during the follow-up period, after the baseline mechanographical tests. The duration of follow-up was about 2 years for all individuals. Fall was defined as an unexpected event that results in a person coming to lie inadvertently on the floor or other lower level.[1]

Data analysis

The incidence of falls was estimated as the number of falls over the follow-up period with the number of participants at baseline as denominator. The 95% CI of fall incidence was estimated using the binomial distribution.

We employed the multiple logistic regression model to analyse the association between fall and mechanography parameters. In this analysis, fall was treated as the outcome while age, sex, Single Two Legs Jump, and balance test (e.g. EFI, P_{max}, H_{max}, F_{max}, V_{max}, path length, and sway area] as independent variables. A P value < 0.05 was considered statistically significant. All analyses were performed using the R statistical environments.[21]

Results

During the 2 year follow-up, 92 participants reported to have fallen at least once, making the 2 year incidence proportion of 14.9% (95% CI, 12.1 to 18.2). Women had a higher incidence of falls than men (17.6% vs. 10.7%; P = 0.024). The risk of falls increased with advancing age. Among those 60 years of age or younger, 13% had fallen over the follow-up period, and this proportion was increased to 23.8% among those aged 70 years and older (*Figure* 1). Using the criteria of body mass index $>$ 25, approximately 29.3% of fallers (n = 27) and 31.1% (n = 164) of non-fallers were classified as 'obese'.

In women, fallers had significantly lower baseline P_{max} and V_{max} than non-fallers. However, in men, there were no significant differences between jumping mechanography parameters and fall (*Table* 1).

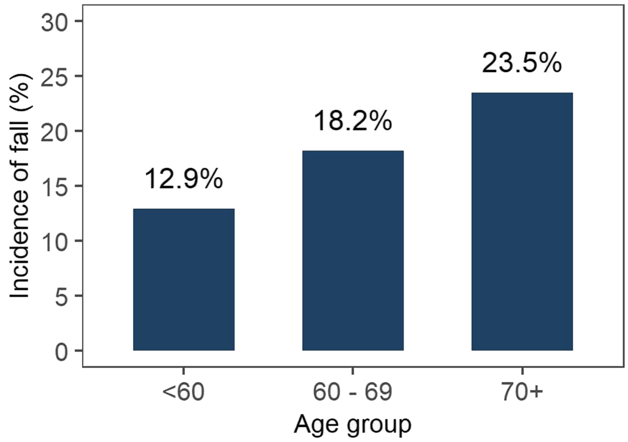

Figure 1 The incidence of fall by age group.

Age and jumping mechanography

Advancing age was associated with reduced EFI, P_{max}, F_{max}, and V_{max}. For example, compared with those aged 50 years, the P_{max} among those aged 70+ was reduced by 50% (*Figure* 2). The reduction of muscle strength was greater in fallers than in non-fallers (*Figure* 2).

In univariate analysis, age, V_{max}, and P_{max} were individually associated with fall risk. However, in multivariable model, only V_{max} was significantly associated with fall risk. Each unit increase in V_{max} was associated with a 62% decrease in the odds of falling (odds ratio, 0.38; 95% CI, 0.16 to 0.92) (*Table* 2). A dose–response relationship was observed between incidence of fall and maximum velocity when jumping (*Figure* 3); the incidence of fall significantly decreased as the tertiles of maximum velocity increased.

Discussion

Despite the recognition that fall and its consequence of injuries represent a major public health problem worldwide, research on fall in developing countries—where the population is rapidly aging—is still lacking. The present study is, to our knowledge, the first prospective documentation of fall risk factors in Vietnam. We have shown that the annual incidence of falls was approximately 15% in men and women aged 50 years and older, and that jumping mechanography could help identify individuals at high risk fall. These findings merit further elaboration.

Our finding of fall incidence is higher than previous findings from Asian cohorts.[22,23] In Thailand and Singapore,

Table 1 Baseline characteristics of the enrolled 619 participants by fall status

Parameter	Men			Women		
	Non-fallers (n = 218)	Fallers (n = 26)	P value	Non-fallers (n = 309)	Fallers (n = 66)	P value
Age (years)	56.8 (6.18)	55.7 (4.73)	0.320	**56.5 (5.45)**	**58.8 (6.65)**	**0.008**
Height (cm)	163 (5.86)	162 (5.61)	0.788	**153 (5.10)**	**151 (5.19)**	**0.016**
Weight (kg)	62.8 (9.30)	64.9 (9.60)	0.299	55.0 (7.95)	54.0 (8.10)	0.343
BMI (kg/m^2)	23.7 (3.14)	24.6 (3.61)	0.217	23.4 (3.08)	23.5 (2.96)	0.909
Smoking (%)	79 (36.2%)	12 (46.2%)	0.439	1 (0.32%)	2 (3.03%)	0.081
Alcohol (%)	87 (39.9%)	12 (46.2%)	0.688	9 (2.91%)	4 (6.06%)	0.257
EFI (%)	81.1 (20.2)	79.3 (21.0)	0.688	112 (28.7)	114 (28.7)	0.702
V_{max} (m/s)	1.92 (0.32)	1.92 (0.39)	0.707	**1.55 (0.25)**	**1.41 (0.28)**	**0.001**
F_{max} (kN)	1.48 (0.27)	1.55 (0.29)	0.197	1.18 (0.20)	1.14 (0.20)	0.092
P_{max} (kW)	2.14 (0.55)	2.24 (0.65)	0.452	**1.37 (0.33)**	**1.20 (0.37)**	**0.001**
Left path length (cm)	79.0 (20.6)	72.3 (17.9)	0.084	62.7 (15.0)	65.9 (18.0)	0.185
Right path length (cm)	74.5 (18.5)	67.9 (15.5)	0.053	61.2 (15.6)	65.0 (19.3)	0.136
Left sway area (cm^2)	0.43 (0.23)	0.45 (0.19)	0.716	0.32 (0.19)	0.34 (0.18)	0.319
Right sway area (cm^2)	0.40 (0.22)	0.36 (0.18)	0.287	0.31 (0.19)	0.35 (0.23)	0.197

Values in each group are shown in mean and standard deviation (in parenthesis). P values were derived from the t-test for independent samples.
BMI, body mass index; EFI, Esslinger Fitness index.

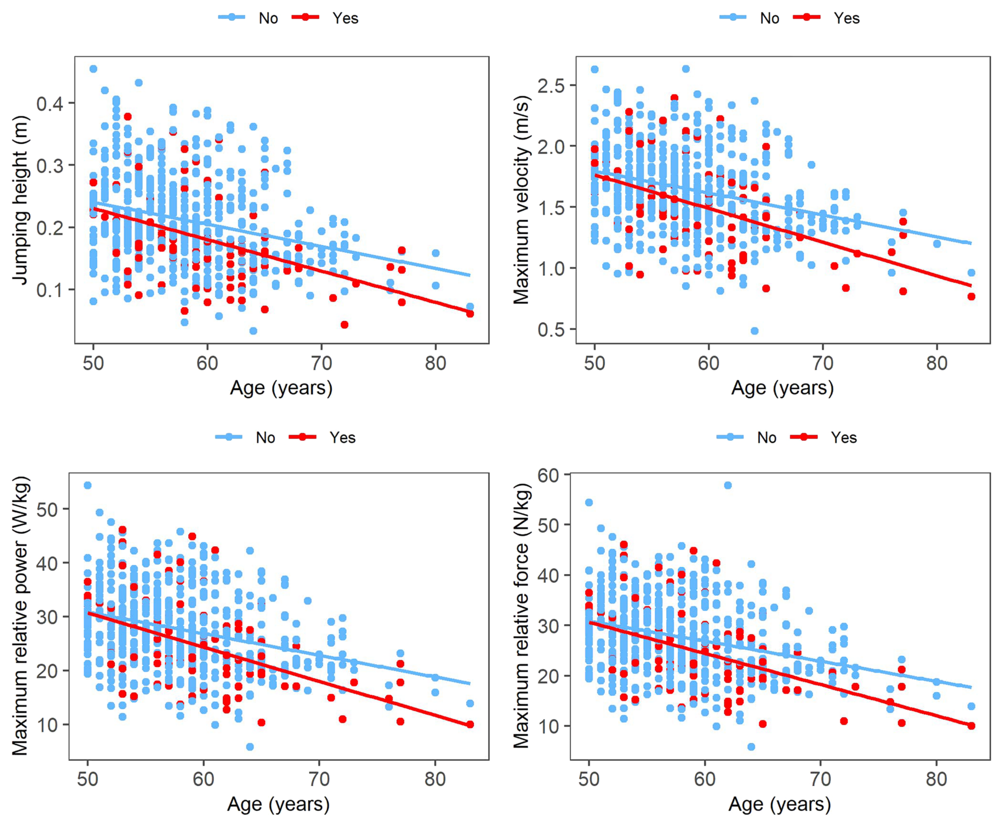

Figure 2 Relationship between age and jumping height (top panel) and maximum force (lower panel) stratified by fall status.

falls occurred in between 7.5% and ~10% per year among the elderly population.[22,24] However, our observed incidence was lower than those reported in Malaysia and the Philippines.[23] A study in community dwellers in the United States found that 12% of individuals reported falling in the previous 12 months.[25] In Australia, the incidence of falls among mid-age women has been reported at ~30% per year.[26,27] The low incidence of falls in our study is probably attributable to the relatively young age of participants who are generally healthy. However, taken together, it appears that fall in Asian populations is lower than that in Caucasian populations.

Table 2 Predictors of fall risk: result of multiple logistic regression analysis

Parameter	Univariate analysis		Multivariable analysis	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Age	1.25 (1.01, 1.54)	**0.04**	1.07 (0.84, 1.36)	0.54
BMI	1.08 (0.87, 1.35)	0.45	1.03 (0.75, 1.42)	0.84
V_{max}	0.65 (0.52, 0.82)	**0.0002**	0.38 (0.16, 0.92)	**0.03**
F_{max}	0.83 (0.65, 1.04)	0.12	0.64 (0.37, 1.12)	0.12
P_{max}	0.68 (0.52, 0.88)	**0.004**	2.59 (0.73, 9.14)	0.14
EFI	1.16 (0.93, 1.44)	0.17	1.09 (0.86, 1.39)	0.44

Values shown are odds ratio and 95% confidence limit obtained from the logistic regression analysis.
BMI, body mass index; Esslinger Fitness index.

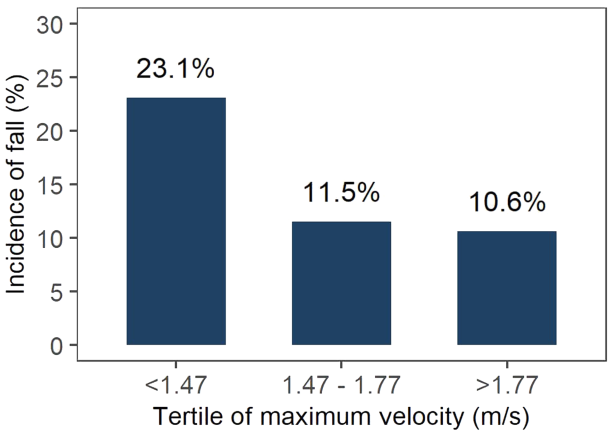

Figure 3 Incidence of fall according to maximum velocity tertile in the entire study population.

Our results showed that jumping mechanography parameters such as maximal jump velocity, maximal jump force, and maximal jump power decreased with advancing age, and the decrease was greater in fallers than non-fallers, suggesting that these parameters may be useful for fall risk assessment. Indeed, increased maximal jump velocity and maximal jump power were associated with reduced fall risk. These results are also congruent with previous findings that muscle function (e.g. gait speed and chair rise time) among fallers were lower than non-fallers.[5,28,29] Lower extremity muscle function was also decreased by about 1–4% per year of advancing age, and the age-related differences were more pronounced for jumping mechanography parameters than other tests.[9] The decrease in muscle mass was in parallel with the decrease of muscle strength,[30,31] and that could explain why muscle related parameters are important fall predictors. Our finding of the association between maximal jump velocity and fall is agreeable with the finding from the Hertfordshire Cohort Study where lower limb peak muscle strength and decrease of jumping velocity were correlated with a greater risk of fall in the elderly.[32]

Esslinger Fitness index is an index reflecting the maximal jump power per body mass normalized to age and gender. In a previous study,[11] women who reported to have fallen had lower values of EFI and lower maximal power.[11,33] In this study, we found no statistically significant association between baseline EFI and subsequent fall risk. The main difference between our study and the previous study[11] is in the study design: our study was a prospective, whereas the previous study was cross-sectional. The difference in findings in relation to EFI could also be due to the different coefficients of normalization between study populations.

The present findings must be interpreted within context of strengths and potential weaknesses. This prospective study was based on a well-characterized cohort in which individuals were randomly recruited from the general population. Nevertheless, the participants in this study were sampled from an urban population; as a result, the study's finding may not be generalizable to the rural populations. Because participants in this sample were volunteers who are normally healthier than their counterparts in the general population, this means that the present results could have been biased. The relatively low frequency of falls is probably an indication of such a selection bias. However, the large magnitude of association between mechanography parameters and fall was strong such that it could rule out the impact of potential biases.

Fall is recognized as a serious public health problem in the general population, but accurate prediction of fall remains a challenge. The implication of this study's findings is that jumping mechanography may be used as a tool for fall risk assessment in older adults. A major advantage of this method is that the muscle function parameters can be measured simply and quickly.[34–36] Muscle power is a function of force and velocity during jumping. Velocity is an important factor reflecting the muscular reflexion when performing a momentary movement. It can be argued that velocity is more relevant to fall prediction given that fall is a sudden event. Our observed association between velocity and fall suggests that interventions aimed at improving rapid muscle reflexes can help reduce fall risk. Some studies have found that chair rise test or gait speed test was associated with fall risk in elderly,[37,38] but these tests can also be quantified by movement velocity, underlining the importance of muscle power and velocity in fall risk assessment in clinical practice.

In conclusion, we found that the incidence of falls in this sample of Vietnamese individuals is comparable with Caucasian populations and that the risk of falls was associated with muscle power, suggesting that jumping mechanography can have a role in the clinical assessment of fall risk.

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Conflicts of interest

Duy K. Hoang, Nhan M. Le, Uyen P Vo-Thi, Huy G. Nguyen, Lan T Ho-Pham, and Tuan V. Nguyen declare that they have no conflict of interest.

Author contribution

DKH, LTHP, and TVN designed and conducted the study; DKH and HGN analysed the data; DKH, NML, and UPVT interpreted the data; DKH, LTHP, and TVN prepared the manuscript and are responsible for the final content. All authors read and approved the final manuscript.

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