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The influence of gait speed on the stability of walking among the elderly

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ABSTRACT

Walking speed is a basic factor to consider when walking exercises are prescribed as part of a training programme. Although associations between walking speed, step length and falling risk have been identified, the relationship between spontaneous walking pattern and falling risk remains unclear. The present study, therefore, examined the stability of spontaneous walking at normal, fast and slow speed among elderly (67.5 ± 3.23) and young (21.4 ± 1.31) individuals. In all, 55 participants undertook a test that involved walking on a plantar pressure platform. Foot-ground contact data were used to calculate walking speed, step length, pressure impulse along the plantar-impulse principal axis and pressure record of time series along the plantar-impulse principal axis. A forward dynamics method was used to calculate acceleration, velocity and displacement of the centre of mass in the vertical direction. The results showed that when the elderly walked at different speeds, their average step length was smaller than that observed among the young ($p = 0.000$), whereas their anterior/posterior variability and lateral variability had no significant difference. When walking was performed at normal or slow speed, no significant between-group difference in cadence was found. When walking at a fast speed, the elderly increased their stride length moderately and their cadence greatly ($p = 0.012$). In summary, the present study found no correlation between fast walking speed and instability among the elderly, which indicates that healthy elderly individuals might safely perform fast-speed walking exercises.

1. Introduction

Falling risk increases as individuals age. Senescence causes not only muscle atrophy but also neurological decline [1–3]. Muscle atrophy leads to shortened step length and lowered foot lift during walking, whereas neurological decline leads to slower action times and impaired coordination [4,5]. Eventually, with age, walking speed and stability decrease and the incidence of falls increases.

Previous studies suggested that fast walking speed and short step length increase stability and reduce the incidence of falling [6,7]. Compared with the young, the elderly typically walk at a lower speed and display a shorter step length [4]. A low walking speed has a negative effect on stability, whereas a short step length has a positive effect [8]. Therefore, the optimum walking speed and step length that individuals should choose when they exercise is an important issue to address. Among young individuals, as their walking speed increases, both their stride length and cadence increase [9–11]. This study aims to explore whether this pattern is also observed among the elderly.

Although some elements of walking are innate, it is a motor skill that is acquired and improved by training and exercise [12,13]. Walking exercise can prevent falls. When walking is included in a training programme, the intensity of the walking prescribed is important, and walking speed can be used as an intensity index. Fast speed walking is beneficial for preventing bone loss [14]. We hypothesized that a fast walking speed among healthy elderly individuals would not cause instability.

The purpose of this study was to investigate the risks associated with performing walking exercises at different speeds among elderly individuals, such that the results could be used to develop an exercise prescription.

2. Methods

In this study, foot-ground contact (FGC) refers to the instantaneous pressure between the foot and its support surface, which is

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measured by a plantar pressure system. FGC data, such as the time course of the interaction were used to calculate gait parameters, such as vertical ground reaction force (VGRF), cadence, step length and walking speed, and to calculate pressure impulse and its time series. To explore the relationship between gait parameter changes and falling risk at different walking speeds in the elderly, this study analyzed parameters such as walking speed, step length and VGRF, pressure impulse along the plantar-impulse principal axis (PIPA), pressure record time series along the PIPA, anterior/posterior variability, lateral variability, and lateral symmetry.

2.1. Test equipment

Plantar pressure system: Zebris FDM System Gait Analysis (Long platform); platform: 56 (width) × 608(length) cm; sensor intensity: 1 sensor/cm^2; sampling rate: 100 Hz.; software: WinFDM V1.2.2 (Zebris Medical GmbH, Isny, Germany). Unit moment plantar pressure measurements were exported as txt files for this study.

2.2. Test participants and requirements

Participants included 30 undergraduate students (16 men, mean age 21.1 ± 1.31 years, height 1.72 ± 0.06 m, weight 61.8 ± 8.30 kg; 14 women, mean age 21.7 ± 1.30 years, height 1.61 ± 0.06 m, weight 51.2 ± 7.60 kg) and 25 elderly individuals (15 men, mean age 68.1 ± 3.31 years, height 1.69 ± 0.08 m, weight 63.8 ± 8.30 kg; 10 women, mean age 66.5 ± 3.10 years, height 1.59 ± 0.07 m, weight 50.2 ± 6.60 kg). A questionnaire was given to the candidates to exclude those with a history of lower limb ligament injury, and then the participants' annual medical reports were reviewed to screen out those with neural and/or musculoskeletal disease or trauma.

When the participants performed walking tests at different speeds, no metronome or moving reference was used to intervene with their speed value. Participants were told to walk in their usual way. A laboratory assistant who had been trained numerous times demonstrated all three walking speeds (normal, fast and slow) to the participants. Values for speed, step length and cadence for the three speed values were the following, respectively: normal: 1.47 ± 0.08 m/s, 135 ± 0.3 cm, 130 ± 0.3 steps/min; fast: 1.72 ± 0.08 m/s, 151 ± 0.3 cm, 138 ± 0.2 steps/min; slow: 1.25 ± 0.08 m/s, 123 ± 0.6 cm, 122 ± 0.4 steps/min.

Participants started the gait test bare-footed (their feet were sterilized with 75% alcohol) in a standing posture. They walked two or three steps before walking onto the platform. If the participant's first step on the platform was considered incomplete, or if the participant walked off the platform or if the steps were apparently non-successive (e.g. a pause), then the participant retook the test. Only data that included six complete successive footprints from each participant were recorded and then analyzed.

2.3. Calculation of the pressure impulse along the PIPA

Pressure impulse was defined as the integral of the force from the FGC interaction (recorded by pressure sensor) over action time. See Appendices 1–3.

2.4. Pressure record time series along the PIPA

The initial action moment of the FGC was recorded and a time series distribution of the initial contact with the ground (ICG) was generated. Additionally, the terminal action moment of the FGC was recorded and a time series distribution of the terminal contact with the ground (TCG) was generated. See Appendix 4.

2.5. Definitions

The following definitions are derived from the WinFDM software:

1) Anterior/posterior variability: the standard deviation of the intersection point on the frontal axis.
2) Lateral variability: the standard deviation of the intersection point on the transverse axis.
3) Lateral symmetry: the left/right shift of the intersection point; 'zero position' is equivalent to the best symmetry.

2.6. Ethical statement

This study received approval from the Ethical Committee of Fujian Normal University. The participants provided fully informed consent to participate in this study by signing a written consent form.

Table 1
Basic gait parameters of young and elderly participants (mean ± SD).

Gait parameter		Young (n = 30)			Elderly (n = 25)		
		Normal	Fast	Slow	Normal	Fast	Slow
Step length, cm	Left	68.69 ± 5.29 ◇	80.04 ± 5.18 ◇	62.53 ± 4.37 ◇	57.93 ± 6.06	67.45 ± 6.97	53.82 ± 6.04
	Right	68.93 ± 5.31 ◇	79.88 ± 5.06 ◇	62.63 ± 4.16 ◇	57.69 ± 5.83	66.95 ± 6.48	53.98 ± 5.88
Step time, s	Left	0.52 ± 0.03	0.46 ± 0.03 ◆	0.57 ± 0.04	0.54 ± 0.04	0.44 ± 0.04	0.58 ± 0.04
	Right	0.52 ± 0.03	0.46 ± 0.03 ◆	0.57 ± 0.05	0.53 ± 0.04	0.44 ± 0.04	0.58 ± 0.04
Stance phase, %	Left	61.95 ± 1.47	60.31 ± 1.62	63.53 ± 1.51	62.69 ± 1.40	60.83 ± 2.10	64.01 ± 1.41
	Right	61.89 ± 1.26 ◆	59.61 ± 1.26 ◆	63.41 ± 1.23 ◆	63.23 ± 2.21	60.71 ± 1.93	64.36 ± 2.21
Swing phase, %	Left	38.05 ± 1.47	39.69 ± 1.62	36.47 ± 1.51	37.31 ± 1.40	39.17 ± 2.10	35.99 ± 1.41
	Right	38.11 ± 1.26 ◆	40.39 ± 1.26 ◆	36.59 ± 1.23 ◆	36.77 ± 2.21	39.29 ± 1.93	35.64 ± 2.21
Double support, %		23.95 ± 2.46 ◇	20.24 ± 2.30 ◆	26.99 ± 2.38	26.26 ± 3.26	21.99 ± 3.45	28.45 ± 3.26
Stride length, cm		137.80 ± 10.21 ◇	160.11 ± 9.79 ◇	125.12 ± 8.37 ◇	115.79 ± 11.73	134.60 ± 13.19	107.98 ± 11.77
Stride time, s		1.04 ± 0.05	0.92 ± 0.05 ◆	1.14 ± 0.09	1.06 ± 0.07	0.88 ± 0.07	1.16 ± 0.07
Cadence, steps/min		115.36 ± 6.02	130.96 ± 7.66 ◆	106.08 ± 7.82	113.90 ± 7.05	137.79 ± 10.98	104.56 ± 8.46
Velocity, m/s		1.33 ± 0.15 ◇	1.75 ± 0.15 ◇	1.11 ± 0.14 ◇	1.10 ± 0.13	1.54 ± 0.17	0.94 ± 0.15
Anterior/posterior variability, mm		3.17 ± 3.28	3.17 ± 1.21	3.53 ± 1.68	3.48 ± 2.96	3.32 ± 2.91	3.32 ± 1.18
Lateral variability, mm		3.20 ± 2.01	2.80 ± 1.16	4.00 ± 2.23	4.56 ± 2.06	3.56 ± 2.47	5.08 ± 2.41
Lateral symmetry, mm		−3.97 ± 4.16	−3.73 ± 4.21	−2.10 ± 4.65 ◆	−4.92 ± 5.22	−5.44 ± 4.29	−6.16 ± 7.55

◇ $p < 0.01$.
◆ $p < 0.05$.
The *t* test uses the two-tailed distribution, two-sample unequal variance (heteroscedastic).