Examination of factors affecting gait properties in healthy older adults: Focusing on knee extension strength, visual acuity, and knee joint pain

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Original Article

Title:

Examination of factors affecting gait properties in healthy elderly people

- focusing on knee extension strength, visual acuity, and knee joint pain –

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***Background & Purpose*:** Gait properties change with age due to a decrease in leg strength and visual acuity or knee joint disorders. Gait changes commonly result from these combined factors. This study aimed to examine the effects of knee extension strength, visual acuity, and knee joint pain on gait change for 181 healthy female *older adults* (age: 76.1 +/- 5.7 years).

***Methods*:** Walking speed, cadence, stance time, swing time, double support time, step length, step width, walking angle and toe angle were selected as gait parameters. Knee extension strength was measured by isometric knee extension strength, and decreased visual acuity and knee joint pain were evaluated by subjective judgment whether or not such factors created a hindrance during walking.

***Results*:** Among *older adults* without vision problems and knee joint pain that affected walking, those with superior knee extension strength had significantly greater values of walking speed and step length than those with inferior knee extension strength (p < 0.05).

Persons with visual acuity problem had more cadence and shorter stance time. In addition, persons with pain in both knees showed slower walking speed and longer stance time and double support time.

***Conclusion*:** A decrease of knee extension strength and visual acuity, and knee joint pain are factors affecting gait in the female *older adults*. Decreased knee extension strength and knee joint pain mainly affect respective distance and time parameters of the gait.

Keywords: Gait; Human locomotion; *Older adults*

Introduction

Walking is an important element for various daily living activities. Gait properties that can assess walking quantitatively may be a simple measure for evaluating overall human health.[1] In old age, various physical functions including leg strength, joints, and visual acuity, decrease and greatly affect gait. It was reported that a gait change with age also relates to falls.[2-4] In addition, gait has been used as an indicator for predicting the risk of disease and death in older adults.[3]

As concrete parameters of gait properties, generally, stance time, swing time, step length, and step width including walking speed and cadence, have been used.[5,6] The following changes have been reported to occur in walking with aging: a decrease in walking speed,[5,7] an increase in single leg support time and a decrease in double leg support time during total contact time,[8] and shortness of step length.[9]

The main factors related to gait change in old age include leg muscle function,[10-12] vision function,[13,14] and knee joint function.[15,16] Among others, there are many reports concerning the effect of a decrease in leg strength on gait.[10-12]

Visual information is important for stable walking, and a decrease of visual function (e. g. low visual acuity) produces disadvantage in achievement of daily living activities.[17] In the case of older adults, it was reported that a decrease in visual acuity increases the risk of falls.[18-20] Elliott et al.[21] confirmed that walking speed and cadence decreased when young healthy persons with

simulated cataracts walked in dim light, and Moe-Nilssen et al.[22] reported that a sudden reduction from normal to marginal lighting while walking induced gait change.

Additionally, leg joints play an important role in gait as walking is a movement that primarily requires use of the lower limbs. In old age, knee joint function decreases, and patients with knee osteoarthritis have slower walking speed, and slower cadence, or shorter step length, and longer stance time.[23,24] Kaufman et al.[25] confirmed that compared with healthy subjects, knee osteoarthritis patients walk with a lower knee extension moment to reduce knee strain. Generally, *older adults* have suppressed joint function. About 25% of *older adults* aged 55 or over, including knee osteoarthritis patients, complain of knee joint pain.[26,27] Knee joint pain greatly affects walking.[28]

In this way, it is considered that vision problems and knee joint pain, in addition to decreased leg strength are important factors affecting gait.

In old age, it is commonly the case that many physical functions decrease simultaneously. In short, *older adults* generally have some problems (e. g. decrease of leg strength and vision function, and knee joint pain) which affect gait. When examining *older adults* with vision problems and knee joint pain in addition to leg strength as subjects, it is difficult to identify the specific factor that affects a gait change. Not only leg strength, but also vision problem or knee joint pain may be involved in gait change.

This study aimed to examine the effects of knee extension strength, visual acuity, and knee joint pain on gait change in *older adults* by considering synergies among these factors.

Materials and Methods

Subjects

The subjects that participated in this study were 181 healthy, community-dwelling female <mark>older adults</mark>. Table 1 shows their age and physical characteristics. All subjects participated in health class or social educational activities that were hosted by municipal governments. In addition, their ADL score was very high (Ministry of Education, Culture, Sports, Science & Technology). Hence, they were judged to have high independence in daily activities because many of them engaged in leisure activity and work. Before the measurements, the purpose and procedure of this study were explained in detail and informed consent was obtained from all subjects. In addition, this study was approved by the Ethics Committee on Human Experimentation of Faculty of Education, Kanazawa University (Ref. No. 19-17).

*** Table 1 near here ***

Testing Protocol

 Gait Property

Gait properties were measured by a gait analysis system Walk Way MG-1000 (Anima, Japan) referenced to a Demura and Demura's [6] method. The MG-1000 with plate sensors can determine time, dimensions and the distance of the foot or feet when the foot touched its surface and can measure

grounding/non-grounding on the bearing surface as an on/off signal. Data were recorded into a personal computer at 100 Hz. Subjects walked 12m road (wooden floor) with above sensors with voluntary maximum speed. The analysis interval was from 4m to 8m.

Factors

   Leg strength:(The effect of knee extension strength

   Knee extension strength was selected for assessing leg strength.[29] During measurement of isometric knee extension strength, the subjects were seated upright in a rigid chair with knees flexed an angle of 90° and with the lower legs strapped in a pad just above the ankle, attached by a backward rigid bar to a tension meter attachment (T.K.K.1269f; Takei Scientific Instruments Co. Ltd., Japan). In addition, the subjects folded their arms on their chest. The subject was asked to extend the knee as far as possible and to maintain it for 3 seconds. Each of the subjects' legs was measured twice at intervals of greater than thirty seconds. It was difficult to adequately judge whether knee extension strength of older adults is superior or inferior because there were little data on their knee extension strength measured with the same method. Hence, superior and inferior groups in knee extension strength were made up among subjects measured in this study. In short, based on mean value (Mean) and standard deviation (SD), subjects were divided into three groups with different knee extension strength (Inferior group: Inferior < Mean-1SD, Middle group: Mean-1SD < Middle < Mean+1SD, Superior group: Mean+1SD < Superior)

Visual acuity: The effect of subjective visual acuity problems

In old age, a decrease in visual function greatly affects gait. Persons who were selected in this study for visual acuity found it difficult to read characters or see people's faces, and felt hindered in their gait. Many of ==older adults== interfere with walking due to narrow visual field even if having normal eyesight. Hence, in this study, it was judged that there is an adequate method to ask whether ==older adults== feel totally trouble in actual walking. Incidentally, such index about visual acuity has been used also in fall risk survey.[30]

Knee joint pain: The effect of subjective knee joint pain

Having knee joints with orthopedic disorders affect walking.[23,24] It was also assumed that subjective knee pain affects walking.[28] Referring Sugiura and Demura's[1] method, Persons with knee joint pain were divided into those who had pain in one knee joint or those who had pain in both knee joints.

Parameters

Gait variability (Temporal and spatial parameters)

The following 9 gait parameters were selected in reference to previous studies:[6] walking speed, cadence, stance time, swing time, double support time, step length, step width, walking angle, and toe angle.

Walking speed: walking distance per second (cm/sec).

Cadence: the number of steps per minute (steps/min).

Stance time: the duration that the body is supported by one or both feet, that
is, the phase in which one foot or both feet contact the floor.

Swing time: the duration that one foot swings, that is, one foot leaves the
floor. This time agrees with a single support time (sec).

Double support time: the duration in which both feet contact the floor (sec).

Step length: the distance between anterior-posterior patterns (one step
length).

Step width: the distance between both feet (cm).

Walking angle: the angle between the direction of movement and bilateral
pattern line (°).

Toe angle: the angle between the direction of movement and the foot axis
(°).

Data Analysis

Older adults usually have a decrease in knee extension strength and vision
problems or else knee joint pain simultaneously. The effect of the other factors
was controlled to examine the unique effect of each factor.

The effect of knee extension strength on gait (F1)

To examine effect of leg strength on gait, mean differences of gait
parameters among three groups with different knee extension strength
(inferior, middle, and superior, divided by mean and SD) for subjects without
a visual acuity problem and knee joint pain were tested using one-way
analysis of variance (ANOVA).

The effect of subjective visual acuity problem on gait (F2)

To examine effect of the visual acuity problem on gait, mean differences in gait parameters between groups with/without visual acuity problems for subjects without knee joint pain were tested using a t-test.

The effect of subjective knee joint pain on gait (F3)

To examine effect of knee joint pain on gait, mean differences of gait parameters between groups with/without knee joint pain for subjects without visual acuity problem were tested using one-way analysis of variance (ANOVA).

In addition, if significant differences were found in age, height, weight, and knee extension strength, gait parameters were tested using analysis of covariance. A Tukey's HSD (Honestly Significant Difference) method was selected for multiple comparisons. The probability level of 0.05 was indicative of statistical significance.

Results

The effect of knee extension strength on gait (F1)

Table 2 shows the basic statistics and results of one-way analysis of variance (ANOVA) for gait parameters among three groups with different knee extension strength (inferior, middle, and superior, divided by mean and SD) for subjects without visual acuity problem and knee joint pain. Walking speed and

step length was significantly larger in the superior group than in the middle and inferior groups.

*** Table 2 near here ***

The effect of subjective visual acuity problems on gait (F2)

Table 3 shows the basic statistics and results of the t-test for gait parameters between those with and without visual acuity problems for subjects without knee joint pain. Persons with visual acuity problems as compared with those without them showed a larger value in cadence and a less value in stance time.

*** Table 3 near here ***

The effect of subjective knee joint pain on gait (F3)

Table 4 shows the basic statistics and results of one-way ANOVA for gait parameters among the three groups with different knee joint pain (one knee, both knee, and none) for subjects without visual acuity problems. Because significant differences were found in body mass and knee extension strength analysis of covariance was used. Walking speed is faster in persons with pain in both knees as compared with persons without knee pain. Persons with pain in both knees as compared with persons with pain in one knee or no pain showed a larger value in stance time and double support time.

*** Table 4 near here ***

Discussion

The effect of knee extension strength on gait

In examining for <mark>older women</mark> without visual acuity problems and knee joint pain, those with superior knee extension strength had significantly larger values in walking speed and step length than those with inferior knee extension strength. It has been reported that gait properties in <mark>older adults</mark> include a decrease in step length and an increase in double support time and step width.[32,33] Patla[34] reported that these gait properties in <mark>older adults</mark>, which differ from younger people, may contribute to increased walking stability.

A decrease in leg strength is closely related to a decrease in walking speed and is considered to be a main cause of gait change with age.[35,36] Ferrandez et al.[37] reported that if walking speed is the same, gait movements in <mark>older adults</mark> will not be largely different from those of young adults. From the above, similarly to results of previous studies,[10-12] it is judged that knee extension strength contributes closely to a decrease in walking speed and step length.

The effect of subjective visual acuity problem on gait

It was reported that fall risk in <mark>older adults</mark> increases with a decrease in visual acuity.[18,38,39] However, there are also reports that there was no relationship between visual acuity and the fall risk when considering factors such as age.[3,40]

On the other hand, walking speed decreased when young persons with simulated cataract walked in dim light.[21] Furthermore, a sudden change from normal to marginal lighting induces gait change, but gait characteristics are nearly normalized due to the adaptation to darkness during the first 90 seconds, suggesting that the darkness itself does not cause the gait changes.[22] Also in this study, cadence was more and stance time was shorter due to visual acuity problem. However, the above will be necessary to examine carefully because ==older women== with visual acuity problems as compared with ==older women== without them showed faster walking speed and wider step length, although significance was not found. In addition, the following may affect also the present result; there was no task in which subjects recognize an obstacle in which visual acuity is affected due to using a flat walkway in this study.

The effect of subjective knee joint pain on gait

Al-Zahrani and Bakheit[23] and Bejek et al.[24] reported that osteoarthiris patients show a decrease in walking speed and step length, and an increase in stance time. In addition, an increase in step width is found as one of the features of abnormal gait in people with disorders.[33] Gehlsen and Whaley[41] reported that ==older adults== with fall history have significantly larger step width than those without it. Hence, step width may be an efficient means of judging abnormal gait.

Moreover, Bejek et al.[24] reported that osteoarthritis patients, when walking with fast speed compared to slow speed, show a more prominent gait change due

to the effects of pain.

In this study, *older women* with pain in both knees showed slow walking speed and long stance time and double support time. This gait changes are similar to those reported by Bejek et al.[24] In addition, it is considered to be one of characteristics in persons with subjective knees joint pain because the above parameters are mainly ones regarding time.

Conclusion

This study examined the effects of knee extension strength, subjective visual acuity and subjective knee joint pain on gait change in *older adults*.

Older adults with superior knee extension strength can walk at a faster speed and with longer step length than *older adults* with inferior knee extension strength. Persons with visual acuity problems had more cadence and shorter stance time. In addition, persons with pain in both knees showed slower walking speed and longer stance time and double support time.

In conclusion, a decrease of knee extension strength and visual acuity, and knee joint pain are factors affecting gait in the female *older adults*. Decreased knee extension strength and knee joint pain mainly affect respective distance and time parameters of the gait.

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Table 1. Characteristics of subjects (Female: 181)

n = 181		Mean	SD	Max	Min
Age	(years)	76.1	5.70	93.0	62.0
Height	(cm)	147.2	5.68	161.4	129.0
Weight	(kg)	49.8	7.90	70.9	31.0
Knee extension strength	(kg)	6.8	2.00	13.5	1.9
Prevalence of visual acuity problems	(%)	With: 38 (21%)		Without: 143 (79%)	
Prevalence of knee pain	(%)	One: 62 (34%), Both: 37 (20%), None: 82 (45%)			

With/Without: Persons with/without visual acuity problem,

One/Both/None: Persons with one-/both-/no knee pain

Table 2. The basic statistics and results of ANOVA for gait parameters among three groups with different knee extension strength groups

Knee extension strength		Inf (n=8)		Mid (n=46)		Sup (n=8)		ANOVA			Post Hoc
(Mean +/- 1SD)		Mean	SD	Mean	SD	Mean	SD	F	p		Tukey's HSD
Knee ext strength	(kg)	4.21	0.48	7.06	1.13	11.0	1.58	77.5	0.00	*	Inf < Mid < Sup
Age	(years)	80.1	6.49	75.1	6.66	77.2	6.72	2.30	0.11		
Height	(cm)	145.0	4.98	146.3	6.21	147.6	3.37	0.45	0.64		
Weight	(kg)	48.6	7.92	46.7	7.34	48.9	8.06	0.47	0.63		
Walking speed	(cm/sec)	160.2	35.66	165.7	31.2	202.7	24.80	5.85	0.01	*	Inf, Mid < Sup
Cadence	(steps/min)	167.3	19.36	160.5	19.2	173.5	19.82	1.95	0.15		
Stance time		0.42	0.06	0.43	0.06	0.39	0.05	2.04	0.14		
Swing time	(sec)	0.31	0.03	0.33	0.03	0.32	0.03	1.61	0.21		
Double support time		0.05	0.02	0.06	0.02	0.04	0.01	2.35	0.10		
Step length	(cm)	57.3	9.22	61.9	9.23	70.4	7.54	5.04	0.01	*	Inf, Mid < Sup
Step width		7.97	2.76	7.02	2.76	7.26	2.09	0.48	0.62		
Walking angle	(°)	8.18	2.94	6.70	3.08	5.96	1.90	1.40	0.26		
Toe angle		2.82	4.42	3.09	3.09	4.19	3.17	0.49	0.62		

Low: < Mean-1SD, Mid: Mean-1SD < Mid < Mean+1SD, High: > Mean+1SD,

Knee ext strength: Knee extension strength,   *: p < 0.05

Table 3. The basic statistics and results of t-test for gait parameters between groups with and
without vision acuity problems

Can you see well? (newspaper, people's faces, etc.)		Yes (n=19)		No (n=64)		t-test		
		Mean	SD	Mean	SD	t	p	
Age	(years)	77.6	4.73	76.1	6.78	0.92	0.36	
Height	(cm)	146.3	6.40	146.3	5.71	-0.03	0.97	
Weight	(kg)	47.4	8.62	47.2	7.44	0.06	0.95	
Knee extension strength	(kg)	6.8	1.72	7.2	2.11	-0.72	0.48	
Walking speed	(cm/sec)	155.2	30.55	170.1	33.39	-1.74	0.09	
Cadence	(steps/min)	152.8	17.61	163.3	19.60	-2.10	0.04	*
Stance time		0.44	0.07	0.42	0.06	2.41	0.02	*
Swing time	(sec)	0.34	0.03	0.33	0.03	1.09	0.28	
Double support time		0.07	0.03	0.05	0.02	2.10	0.04	
Step length	(cm)	60.6	8.24	62.4	9.59	-0.75	0.46	
Step width		8.07	2.83	7.19	2.66	1.25	0.22	
Walking angle	(°)	7.78	3.09	6.80	2.96	1.25	0.22	
Toe angle		2.89	4.33	3.21	3.28	-0.35	0.73	

*: $p < 0.05$

Table 4. The basic statistics and results of ANOVA for gait parameters among the three groups with knee joint pain

Knee joint pain		One (n=48)		Both (n=31)		None (n=64)		ANOVA			ANCOVA			Post Hoc
		Mean	SD	Mean	SD	Mean	SD	F	p		F	p		Tukey's HSD
Age	(years)	75.6	4.75	77.0	5.85	76.1	5.93	0.55	0.58					
Height	(cm)	148.8	5.52	147.1	6.09	146.3	5.70	2.77	0.07					
Weight	(kg)	52.2	7.88	51.8	6.90	46.5	9.45	7.73	0.00	*	covariate			
Knee ext strength	(kg)	6.8	2.04	6.2	2.14	7.2	2.11	2.36	0.10					
Walking speed	(cm/sec)	166.7	28.4	151.8	38.6	170.1	33.4	3.32	0.04	*	3.50	0.03	*	Both < None
Cadence	(steps/min)	163.3	24.7	152.9	24.3	163.3	22.7	2.58	0.08		2.45	0.09		
Stance time		0.43	0.06	0.48	0.09	0.42	0.06	5.69	0.00	*	5.26	0.01	*	Both > None, One
Swing time	(sec)	0.32	0.04	0.34	0.46	0.33	0.03	1.21	0.30		1.28	0.28		
Double support time		0.06	0.02	0.07	0.04	0.05	0.02	6.36	0.00	*	5.24	0.01	*	Both > None, One
Step length	(cm)	61.5	7.77	59.1	9.72	62.4	9.59	1.43	0.24		1.86	0.16		
Step width		7.02	2.62	8.14	2.82	7.19	2.66	1.80	0.17		1.70	0.19		
Walking angle	(°)	6.92	2.79	8.23	3.60	6.80	2.96	2.50	0.09		2.41	0.09		
Toe angle		2.67	4.02	3.55	4.02	3.21	3.28	0.58	0.56		0.74	0.48		

One: Persons with one knee pain on knee joints, Both: Persons with both knee pain on knee joints,

None: Persons without knee pain on knee joints, Knee ext strenght: Knee extension strength