Analysis of Walking Characteristics of Aged Persons

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Abstract: The present study focused on walking movements as the main movements of daily life; investigation was made with the objective of clarifying especially the walking characteristics of aged persons and reasons for their falls. Subjects were 10 healthy elderly women, ages 65 to 75 years. Quantitative analysis was made of their walking characteristics using MMpro3D. As analysis results, it was made clear that elderly women showed walking characteristics that were small in terms of forward inclination of trunk, leg elevations, knee extensions, bending movements, and arm swings in the forward direction. It was confirmed that these walking characteristics are one factor in falls.

Also Analysis results showed that, compared with age 60s group, the age 70s group had even further reductions in forward inclinations of trunk, leg elevations, lower limb movements, and arms swinging in the forward direction; thus, changes in walking characteristics with increasing age were confirmed.

These characteristics must be reflected within clothing design, to improve the fit and functionality of clothes for lower body that are source of falling.

Key word : Aged Persons, Walking, Falling, Three-dimensional movement analysis

1. Introduction

Today, with an ultra-aging society forming in Japan, essential issues are the creation of environmental facilities, infrastructure, support systems, etc., to promote the independence of aged persons, as well as the formation of environments in which the health of aged persons can be maintained. As a key part of aging society-related policies, lifestyle infrastructure is going forward, with vigorous activities regarding residential creation for aged persons, and barrier-free facilities and transport provided by public transportation organizations, on roads, etc.[1)] Still, in their daily lives, aged persons with their reduced physical capabilities face many unforeseeable risk factors, and there has been an increase in persons who become bed-ridden or otherwise handicapped by falls, not to mention increasing transportation accident injuries and deaths.[2)] Especially notable as fall-related external risk factors are the wearing of non-fitting clothing and non-flexible clothing. Looking at the circumstances when aged persons fall down, there are many cases which lost balance during an ordinary daily activity such as standing, sitting, walking, and so on.[3)] For physical capabilities are reduced , inappropriately fitting clothes causes aged person's fall . In regards to clothing, then, an understanding of the movement characteristics of aged persons is significant in

determining risk factors, and in designing safety clothing for the aged.

Thus, in the present study focused on walking movements as the main movements of daily life; the investigation was made with the objective of clarifying especially the walking characteristics of aged persons and the reasons for their falls. Via three-dimensional movement analyses, quantitative analysis was made of the walking characteristics of aged persons. The present study, as it can be utilized in clothing design, enables the design of safe clothing that can support aged persons in their daily lives.

2. Methods

2.1 Test conditions

Subjects were 10 healthy women ages 65-75 residing in the greater Tokyo metropolitan area. Measurement points were eight items, Cervicale, Acromion, Back waist point, Trochanter, Knee joint, Lateral malleolus, Olecranon, Ulnar styloid. (Fig. 1).

Flooring of 0.5 m width and 5 m length was placed within a 67 m^2 testing room having sufficient walking space. Flooring material used was composite Type 1 flooring having natural wood as its main material. Subjects performed walking repeatedly five times. Instructions given to subjects regarding walking speed were as follows: “Please walk normally, not fast, and not slow.”

Walking movements were filmed with two video cameras, and analyses were performed. Used as test clothing was clothing that closely fit the women’s bodies, and walking was performed in bare feet.

2.2 Measurements, Analytical processing

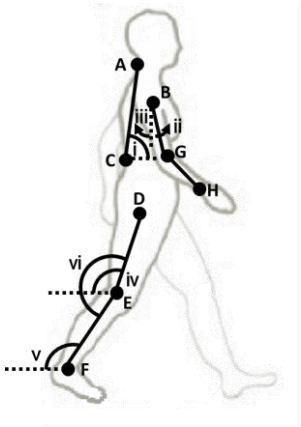
Software used was MMpro-3D and MMpro-3DAnaly (products of Futec, Inc.). 3-D images were created from the filmed video images made with the two cameras, and measurement data was extracted.

2.3 Analysis methods

2.3.1 Analysis categories

From measurement data, 15 categories were extracted: during one walk cycle, walking speeds, step lengths, time periods when both legs were supported, maximum lateral malleolus heights during free-leg periods, upper-limb movement ranges (forward-back, forward direction, back direction), and angles of trunk, thigh, lower leg, and knee joint when heels were touching the ground and when tiptoes were off the ground. Measurement angles for each portion location were as shown in Fig. 1. Differences of angles when heels were touching the ground and when tiptoes were off the ground were determined by calculating, respectively, body-trunk displacement angles, thigh displacement angles, lower-leg displacement angles, and knee-joint displacement angles; analyses were thus performed for a total of 19 categories. Regarding walking speeds, using cervicale position

coordinate data—inasmuch as the cervical point is considered to be stable during movements—, the speed at each respective measurement time was calculated via numerical differentiation, and the average of said data was determined as the walking speed. Times when both legs were supported were expressed as a percentage within one walk cycle of the times when both legs were supported. Regarding the categories stated above, the mean value of each subject's measurement data for three and a times was used as each test subject's variable, and the t-test was used to make comparisons between the two respective age-by-decade groups, namely, the four women in their 60s, and the six women in their 70s. Further calculated was the rate of variability from the age 60s group to the age 70s group, to investigate in even more detail changes in gait due to increased age.



A	Cervicale	i	Trunk angle
B	Acromion	ii	Fore upper-limb movable area
C	Back waist point	iii	Rear upper-limb movable area
D	Trochanter	ii + iii	Upper limb movable area
E	Knee joint	iv	Thigh angle
F	Lateral malleolus	v	Lower leg angle
G	Olecranon	vi	Knee joint angle
H	Ulnar styloid		

Fig. 1 Measurement Points and Measurement Angles

3. Results and Considerations

3.1 Walking characteristics of aged persons

Table 1 shows the mean values for each variable. Yanagawa has reported[4] that body-trunk angles during a single walking-step cycle for young persons is practically vertical, between 86.6° to 92.9°. In the present research on aged persons, however, as shown in Table 1, trunk angles when heels were touching the ground and when tiptoes were off the ground were, respectively, 80.9° and 83.6°, and thus were small. Since there is little angular displacement, it was thus made clear that usually there is forward inclination of the body trunk due to bending of the spine. Further, Shimane and Okada have reported[5] the following for young persons during walking: a knee joint angular displacement average of 60.5°, a heel height average of 235 mm, and an arm movement range average of 60°. However, as shown in Table 1, for our subject aged persons, the following were all small: knee joint angular displacement of 33.6°, maximum lateral malleolus during free-leg periods of 181.9°, forward-direction upper limb movement range of 5.7°, and upper-limit range of motion of 30.5°. These are thought to be because, due to stiffening of the four limbs and the musculoskeletal

frame, etc., with increasing age, aged persons show walking characteristics such that there is reduced knee-joint movement range, smaller bending and extension of the knees, and smaller arm elevations. It was suggested that these walking characteristics are one factor in falls.

Table 1 Mean Values for Each Variable

Variables		Aged Persons(n=10)	
		Average	SD
Walking speed (m/min)		61.5	9.2
Step length (㎜)		553.2	39.1
Both-leg support times (%)		26.9%	0.04
Max. lateral malleolus height in swing phase (mm)		181.9	12.0
Trunk angle (°)			
	With heels on ground	80.9	3.9
	With tiptoes off ground	83.6	2.3
	Displacement	2.6	4.0
Thigh angle (°)			
	With heels on ground	67.7	5.0
	With tiptoes off ground	95.5	5.6
	Displacement	27.8	8.4
Lower leg angle (°)			
	With heels on ground	74.7	5.0
	With tiptoes off ground	141.3	4.0
	Displacement	66.6	4.2
Knee joint angle (°)			
	With heels on ground	168.4	8.0
	With tiptoes off ground	134.8	5.3
	Displacement	33.6	11.6
Upper-limb movable area(°)			
	Forward-direction	5.7	6.2
	Back-direction	24.8	8.2
	Range of movement	30.5	10.1

3.2 Age group comparisons

Table 2 shows a comparison of mean values for each variable for aged subjects in their 60s and 70s, respectively. Significant differences (p<0.05) were confirmed for three categories: walking speed, step length, and trunk angle when tiptoes were off the ground. Among categories where variability rates from women in their 60s to women in their 70s were ±10% or above, a category that increased was time periods when both legs were supported, and categories that decreased were walking speeds, body-trunk angular displacements, thigh angular displacements, forward-direction upper-limb movements, and upper-limb ranges of motion (ROMs). The increase in both-leg support

times was due to the shorter step lengths, and it is thought that as a result of shorter step lengths, walking speeds had become remarkably slower. Moreover, because of the reduction in various joint displacements and of ROMs, with increasing age, there is the forward inclination of the body trunk peculiar to aged persons, as well as the walking characteristics of smaller knee bends and extensions and smaller leg elevations. The following remarkable changes were also clarified: steps became shorter, the trunk inclined forward, there was reduced forward swinging of the arms, and lower limb movements decreased. Reduced ranges of motion could mean reduced reaction levels vis-à-vis obstacles with even slight uneven portions; this is thought to be a major factor in the falls of aged persons.

Table 2 Comparison by Age of Average Values

Variables		Ages 60-69 (n=4)		Ages 70-79 (n=6)		Variability rates of mean values	t-test
		Average	SD	Average	SD		
Walking speed (m/min)		69.6	6.8	56.0	6.0	-20%	*
Step length (㎜)		582.0	39.2	534.0	27.0	-8%	*
Both-leg support times (%)		25%	0.1	27.9%	0.0	10%	
Max. lateral malleolus height in swing phase (mm)		186.0	10.5	179.2	13.0	-4%	
Trunk angle (°)							
	With heels on ground	81.2	3.8	80.8	4.3	0%	
	With tiptoes off	85.3	1.8	82.4	1.9	-3%	*
	Displacement	4.1	4.3	1.7	3.8	-60%	
Thigh angle (°)							
	With heels on ground	64.1	4.8	70.1	3.8	9%	
	With tiptoes off	98.0	3.1	93.8	6.5	-4%	
	Displacement	33.9	7.7	23.8	6.5	-30%	
Lower leg angle (°)							
	With heels on ground	73.2	6.4	75.7	4.2	3%	
	With tiptoes off	142.4	3.5	140.6	4.4	-1%	
	Displacement	69.2	4.8	64.9	2.8	-6%	
Knee joint angle (°)							
	With heels on ground	168.4	8.5	168.4	8.4	0%	
	With tiptoes off	135.8	3.7	134.1	6.4	-1%	
	Displacement	32.5	10.1	34.3	13.5	5%	
Upper-limb movable area (°)							
	Forward-direction	9.6	5.5	3.0	5.4	-68%	
	Back-direction	24.0	8.5	25.3	8.7	6%	
	Range of movement	33.6	7.7	28.4	11.6	-16%	

4. Conclusion

Walking movement analysis of 10 aged women was performed, and from the variables for 19 categories obtained from measurement data, walking characteristics of aged persons were successfully extracted.

The categories used in the analysis were, during one walk cycle, walking speeds, step lengths, time periods when both legs were supported, maximum lateral malleolus heights during free-leg periods, upper-limb movement ranges (forward-back, forward direction, back direction), and, when heels were touching the ground and when tiptoes were off the ground, body-trunk angle, thigh angle, lower-leg angle, and knee-joint angle. Further, for the respective differences in angles between when heels were touching the ground and when tiptoes were off the ground, these were determined as body-trunk angular displacements, thigh angular displacements, lower-leg angular displacements, and knee-joint angular displacements. The results were as described hereafter.

1) Walking characteristics of the aged persons were clarified as follows: both when heels were touching the ground and when tiptoes were off the ground, as trunk angles were small and angles of displacement were also small, due to spine curvature, ordinarily there is forward inclination of the trunk.

2) Since knee-joint angular displacement, lateral malleolus heights during free-leg periods, and forward-direction upper arm movement ranges were all small, walking characteristics were clarified in that knee bendings and extensions, and leg elevations, are small. It was suggested that these walking characteristics are one factor in falls.

3) For each age group of women in their 60s and women in their 70s, respectively, measurements were made, and comparisons were made of the differences in mean values of angular displacements for each of the following: walking speeds, step lengths, time periods when both legs were supported, maximum lateral malleolus heights during free-leg periods, upper-limb movement ranges (forward-back, forward direction, back direction), and angles of trunk, pelvis, thigh, lower leg, and knee joint when heels were touching the ground and when tiptoes were off the ground. Significant differences ($p<0.05$) were confirmed for three categories, namely, walking speed, step length, and trunk angle when tiptoes were off the ground.

4) Among categories where variability rates from women in their 60s to women in their 70s were ±10% or above, a category that increased was time periods when both legs were supported, and categories that decreased were walking speeds, body-trunk angular displacements, thigh angular displacements, forward-direction upper-limb movements, and upper-limb ROMs.

5) It was made clear that with increasing age, in addition to the walking characteristics peculiar to aged persons, the following become remarkable: steps become shorter, the trunk inclines forward, there is reduced forward swinging of the arms, and lower limb movements decrease.

The present study clarified movement factors that could be a cause of falls of aged persons. Based on a consideration of these research results, into the future, we aim at the design of clothing for the lower-body that has a high range of motion and that can bolster physical balance capabilities.

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5. Reference Documents

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