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A kinematic analysis during stair climbing in frail elderly subjects

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Introduction

With aging and frailty, the deterioration of the ability to climb stairs constitutes a major source of disability and a factor contributing to the loss of autonomy. The aim of this study was to investigate the kinematic characteristics of stair climbing in frail elderly.

Methods

Fifteen frail elderly subjects and fifteen young adult controls were recruited for this experiment. The frailty was defined as $\geq 3/5$ on the Korean version of the FRAIL (K-FRAIL) scale. The all subjects underwent three-dimensional motion analysis (VICON MX-T10 Motion Analysis System) during stair ascent with laboratory three steps staircase. The kinematic and the spatiotemporal parameters were compared between groups using the independent t-test.

Results

In the sagittal plane, the frail elderly group presented greater anterior pelvic tilt angles than the young adult group during stair climbing ($p < 0.05$). Compared to the young adult group, the frail elderly group demonstrated greater hip flexion angle at initial contact, less maximal hip extension angle in the stance phase, and greater maximal hip flexion angle during swing phase ($p < 0.05$). The frail elderly group also demonstrated smaller knee flexion and ankle dorsiflexion angles than the young adult group at initial contact ($p < 0.05$). In the coronal plane, the frail elderly group demonstrated less maximal pelvic upward obliquity and greater maximal knee varus angles than the young adult group during stair climbing ($p < 0.05$). In the transverse plane, the frail elderly group presented greater maximal hip internal rotation and external rotation angles than the young adult group during stair climbing ($p < 0.05$) (Table 1). Spatiotemporal characteristics of frail elderly group showed decreased cadence and velocity, and increased stride time and stance time ratio compared to young adult group ($p < 0.05$) (Table 2).

Conclusion

The Results showed that frail elderly subjects had the different kinematic alterations in the pelvis, hip, knee, and ankle compared to young adults during stair climbing. This study provides data for use in basic research into safe gait on stairs for frail elderly people.

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Table 1. Comparison of kinematic variables between frail elderly subjects and young adults in stair climbing

	Frail elderly (N=15)	Young adult (N=15)	p value
(unit: degree)			
Pelvis			
Maximum pelvic tilt during stair climbing	27.15±4.79	19.05±4.16	<0.001
Mean pelvic tilt during stair climbing	22.92±4.87	16.69±3.95	0.001
Maximum pelvic upward obliquity during stair climbing	4.90±2.82	7.59±2.36	0.009
Maximum pelvic downward obliquity during stair climbing	-7.34±3.30	-7.82±1.79	0.626
Maximum pelvic internal rotation during stair climbing	7.52±3.50	7.23±3.16	0.812
Maximum pelvic external rotation during stair climbing	-7.03±4.78	-7.05±4.29	0.991
Hip			
Hip flexion angle at initial contact	66.80±5.58	59.87±5.95	0.003
Maximum hip extension angle during stance phase	-20.00±6.79	-14.34±5.62	0.019
Maximum hip flexion angle during swing phase	79.98±6.16	65.60±6.56	<0.001
Maximum hip internal rotation during stair climbing	19.84±7.72	13.95±5.61	0.024
Maximum hip external rotation during stair climbing	-31.75±15.54	-14.96±6.40	0.001
Maximum hip adduction angle during stair climbing	10.06±3.43	10.06±3.43	0.297
Maximum hip abduction angle during stair climbing	-7.36±2.81	-8.16±3.10	0.462
Knee			
Knee flexion angle at initial contact	53.69±10.82	60.82±6.99	0.041
Maximum knee extension angle during stance phase	14.13±5.20	16.95±4.49	0.122
Maximum knee extension angle during loading response	59.44±8.06	62.41±4.02	0.216
Maximum knee flexion angle during swing phase	98.20±9.21	95.74±5.92	0.391
Maximum knee varus angle during stair climbing	35.58±10.80	22.66±5.62	<0.001
Ankle			
Dorsiflexion angle at initial contact	3.81±6.07	11.44±5.11	0.001
Maximum dorsiflexion angle during stance phase	17.00±3.31	18.61±2.80	0.161
Maximum plantarflexion angle at push off	-23.28±8.66	-17.85±5.18	0.050
Maximum dorsiflexion angle during swing phase	18.18±4.05	18.37±4.98	0.909

Positive values indicate pelvic anterior tilt, pelvic upward obliquity, pelvic internal rotation, hip flexion, hip adduction, hip internal rotation, knee flexion, knee varus and ankle dorsiflexion, while negative values indicate pelvic external rotation, hip extension, hip abduction, hip external rotation and ankle plantarflexion.

Table 2. Comparison of spatiotemporal variables between frail elderly subjects and young adults in stair climbing

	Frail elderly (N=15)	Young adult (N=15)	p value
Cadence (steps/min)	56.60±14.76	77.38±9.42	<0.001
Stride Time (s)	2.28±0.70	1.57±0.21	0.002
Step Time (s)	1.77±1.11	1.47±0.46	0.341
Stance Time (%)	73.27±5.35	63.83±3.42	<0.001
Swing Time (%)	26.73±2.35	36.17±3.42	<0.001
Single Support (%)	16.20±2.03	17.38±2.81	0.199
Double Support (%)	67.59±4.05	65.24±5.63	0.199
Gait Velocity (meter/s)	0.32±0.08	0.43±0.05	<0.001