INFLUENCE OF STAIR DIMENSIONS AND SUBJECT HEIGHT ON ANGULAR DISPLACEMENT OF THE TRUNK DURING STAIRCLIMBING

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Stairclimbing has been touted (Edwards, 1983) as an easy and effective way to build physical activity into one's daily routine, for staircases are readily available and they require the climber to move against a natural resistance force (ie, gravity). Gravity, however, may destabilize the climber and lead to a potentially injurious fall if the centre of mass, and the line of gravity, fall outside the climber's base of support. To maintain balance when stairclimbing, individuals will alter the orientation of the trunk segment and, hence, the location of the majority of the body's mass.

Krebs et al. (1992) studied the trunk flexion/extension patterns of subjects while climbing over a 33" sloped staircase at a pace of 80 steps/min. Maximum trunk flexion values while ascending stairs were double that recorded during stair descent, and six times that recorded during gait. Furthermore, when ascending stairs, subjects positioned their trunks such that they were roughly parallel with the slope of the staircase. Unfortunately, the heterogeneity of the subject sample used (ie, 5 males, 6 females; age range 27.0 to 88.0 years; 152.4 to 179.0 cm in height) limits the interpretation of these results. The purpose of this preliminary investigation, therefore, was to systematically examine sagittal plane angular displacement (ie, flexion/extension) of the trunk segment during stair ascent and stair descent as influenced by internal (ie, subject height) and external constraints (ie, stair dimensions).

METHODS AND PROCEDURES

Six healthy, physically active young-adult females with a mean age of 21.8 ($\pm$ 2.6) years participated as subjects and were classified by their height into the short, medium or tall stature group (Table 1). Those in the medium stature group approximated the mean for young-adult Canadian females (CAHPER, 1980), while those termed short or tall in height were one standard deviation below or above the mean, respectively.

Each subject completed ten trials of free-speed stair ascent and stair descent over staircases categorized as steep (45°), moderate (33°), or shallow

Table 1 Description of the Subject Sample

Subject	Group	Age (yr)	Height (cm)	Mass (kg)
1	Short	26	157.5	56.8
2	Short	19	157.5	56.8
3	Medium	23	165.1	59.7
4	Medium	19	165.1	67.3
5	Tall	22	171.5	61.8
6	Tall	22	170.8	61.4

Table 2 Dimensions of the Testing Staircases

Staircase	Step Height (cm)	Tread Depth (cm)	Slope (°)
Steep	20.32	20.32	45
Moderate	20.32	30.48	33
Shallow	12.70	41.91	16

(16°) in slope (Table 2). With a camera positioned perpendicular to the climbers' plane of progression, one trial per stepping condition was captured on film at a rate of 50 Hz. Data were digitized for one complete gait cycle (right heel strike to right heel strike) per trial. The trunk was defined, by linking reflective markers located on the right lateral aspect of the shoulder (glenohumeral axis) and hip (greater trochanter of the femur) joints, as a single, rigid segment.

Maximum and minimum trunk flexion/extension and range of motion (ROM) values in the XY (sagittal plane) were the dependent variables of interest. The neutral position (0") of the trunk segment was defined as 90" counterclockwise from the positive X axis. The data were analyzed using a mixed between-within repeated measures MANOVA procedure.

RESULTS AND DISCUSSION

For the task of stair ascent, significant differences ($p \leq .03$) in trunk ROM between groups (but not staircase climbed) were noted (Table 3). For

Table 3 Mean and Standard Deviation for Maximum and Minimum Trunk Flexion Values and Trunk Range of Motion Observed During Stair Ascent[ab]

Group[c]	Maximum Angle (°)	Minimum Angle (°)	ROM (°)
Short	18.2 (2.9)	8.2 (3.2)	10.0 (0.4)*
Medium	12.6 (5.1)	3.7 (5.1)	8.9 (0.8)'
Tall	13.6 (3.0)	6.1 (3.1)	7.5 (1.7)**

[a] Positive values represent flexion, negative values extension.
[b] *, ** denotes differences between groups ($p \leq .03$).
[c] Means based on six observations per group.

the task of stair descent (Table 4), significant differences for trunk ROM between groups ($F(2,9)=22.8$, $p \leq .01$) and between stepping conditions ($F(2,9)=9.61$, $p \leq .01$) were observed, as was an interaction effect ($F(4,9)=5.61$, $p \leq .02$). Although trends were apparent, differences in the maximum or minimum trunk flexion/extension angles observed between groups or by staircase climbed, during stair ascent or stair descent, were not significant.

The results support the premise that trunk segment orientation is varied depending upon the stature of the climber, the dimensions of the staircase being climbed, and the task (ie, ascent or descent) being performed. During stair ascent, the trunk was continuously flexed. Shorter subjects, moreover, displayed a greater magnitude of trunk flexion than did their taller counterparts.

Krebs et al. (1992) observation that the trunk will parallel the slope of the stairs during ascent was not observed in this study. Differences in the methodology used may account for the observed differences. Krebs and others (1992) employed an older subject group and asked them to climb at a relatively rapid (ie, 80 steps/min) pace. These age and pace differences 'may have led the subjects to employ a forward lean strategy, one which reduces the length of the hip flexor lever arm thereby allowing energy to be conserved. Such a strategy may not have been required by our younger subject sample under a less energy demanding, free-speed pace.

All subjects displayed greatest trunk ROM values when descending the steepest flight (ie, 45° slope) of stairs. These values may reflect a higher degree of instability for the climbers under this condition. With greater instability, increased fluctuation in trunk ROM values would be expected as the climber adjusted to the demands of the task.

Table 4 **Mean (and Standard Deviation) Trunk Flexion/ Extension and Trunk Range of Motion Values Observed During Stair Descent[ab]**

Group/ Stair[c]	Maximum Angle (°)	Minimum Angle (°)	ROM (°)
Short*			
Steep'	7.7 (4.7)	-2.7 (2.0)	10.4 (2.6)
Moderate	6.5 (3.9)	-2.1 (3.4)	8.6 (0.5)
Shallow	4.8 (3.2)	-1.9 (3.8)	6.7 (0.6)
Medium**			
Steep	0.8 (0.9)	-3.6 (0.5)	4.4 (0.5)
Moderate''	-0.7 (2.8)	-4.5 (2.5)	3.8 (0.2)
Shallow	-0.4 (3.7)	-6.2 (3.0)	5.8 (0.7)
Tall**			
Steep	7.9 (2.6)	-0.7 (1.7)	8.6 (0.8)
Moderate	0.1 (2.1)	-3.7 (2.6)	3.7 (0.5)
Shallow''	1.8 (0.9)	-3.2 (1.4)	5.0 (0.5)

[a] Positive values represent flexion, negative values extension.

[b] *, ** denotes differences between groups ($p \leq .01$); +, ++ denotes differences between stairs ($p \leq .01$) for trunk ROM only.

[c] Means based on two observations per group per stepping condition.

CONCLUSION

The magnitude of trunk flexion/extension during stair ascent/descent appears to be related to the stature of the climber, the dimensions of the stairs being climbed, and perhaps the stepping rate employed. Future studies (ie, biomechanical, physiological) of stairclimbing should acknowledge the role of these variables in constraining the movement of the climber.

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