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Getting up from the floor. Determinants and techniques among healthy older adults

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Determinants of floor-to-stand (FTS) performance and strategies used for FTS have been investigated little. This study explores the relationship of age, lower-extremity strength, and balance with FTS time and documents strategies used for FTS. It was a cross sectional, descriptive study. The study location was a community or university laboratory with carpeted floor. Participants were 52 healthy volunteers (14 men, 38 women), aged 50–90 years. Lower extremity strength was characterized by the time to complete 5 sit-to-stand (STS) cycles. Balance was measured using timed single limb stance (SLS). Three trials for FTS transfers were videotaped and timed. Observational analysis of videotaped FTS trials ($n = 156$) was used to identify FTS strategies. Mean FTS time (4.1 ± 1.1 sec) was related to age ($r = .39$, $p < .005$), STS time ($r = .64$, $p < .001$), and SLS time ($r = -.36$ & $-.42$, $p < .005$). Three stages were observed during FTS: initiation, weight transfer, and transition to upright. Movement strategies identified were: asymmetrical side sitting to half kneeling pivot ($n = 26$), quadruped push-up ($n = 18$), and symmetrical sit-up/roll over feet ($n = 8$). FTS performance may be enhanced by training that addresses impairments in lower extremity strength and balance. Movement strategies used successfully by the participants in this study might be beneficial to older adults having difficulty with the task.

INTRODUCTION

The ability to rise from the floor is a motor skill that is learned early in life, and allows involvement in a wide variety of functional activities. Getting up and down from the floor is a frequent and easily performed activity for most children and young adults (Van Sant 1998a, 1998b). The usual activities of mid-life reduce the frequency, and perhaps the opportunity, for practice of the task of getting up and down from the floor (Green and Williams, 1992). Rising from the floor becomes challenging for many older adults, especially those with musculoskeletal and neuromuscular impairments (Bohannon, Leary, and Cooper, 1995). Concern about being unable to get up from the floor after a fall may lead older adults to avoid activities perceived as having a high risk of resulting in a fall (Myers et al, 1996). This concern appears to be well founded: more than 40% of community living elders who experience non-injurious falls are unable to rise from the floor without assistance (Tinetti, Liu, and

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Claus, 1993). Remaining on the floor for long periods of time can result in dehydration, pressure sores, delirium, joint and muscle dysfunction, incontinence, and ultimately renal failure (Campbell et al, 1990; Mallison and Green, 1985; Nevitt, Cummings, and Hudes, 1991). Given the physical demands of the floor-to-stand (FTS) maneuver, it is not surprising that so many older adults have difficulty with this important mobility task (Didier et al, 1993; Tinetti et al, 1993).

In rehabilitation, clinicians often work with medically and physically frail older adults who have difficulty with transitional activities such as getting out of bed, getting up from a low seat or toilet, and getting up from the floor. While transfers to and from beds and chairs are routinely addressed by clinicians, the ability to rise from the floor is not, even for patients with histories of previous falls (Simpson and Salkin, 1993). Elderly patients themselves may be reluctant to practice a task that is both physically challenging and emotionally charged (Simpson and Mandelstam, 1995). Instruction in how to get up from the floor may be important in assisting older individuals to gain greater functional independence, as well as facilitating their activity by reducing their concern of being stranded on the floor following a fall; however the strategies typically used by older adults are not well described. Knowledge of how healthy elders typically approach this motor task can provide a foundation for directing therapists in their provision of such instruction.

Published studies of how people perform the FTS maneuver are limited in number. Van Sant (1988a, 1988b) described typical strategies used by children and young adults in approaching this motor task. She identified a developmental hierarchy that progresses from asymmetrical toward symmetrical movement patterns with maturation of motor control in children. Green and Williams (1992) described similar patterns among middle-aged adults, noting that sedentary individuals tend to use asymmetrical patterns more frequently than routinely active persons. They suggested that habitual activity may be an important determinant of efficiency of righting responses in the supine to stand movement task. Several investigators who examined FTS performance in adults with neuromuscular impairment (Unrau, Hanrahan, and Pitetti, 1994) or musculoskeletal restriction (King and Van Sant, 1995) reported greater FTS time as well as increased variability in movement strategies used. Van Sant (1990, 1991) suggested that older adults demonstrate greater variability and more asymmetry in movement strategies used in rising from the floor, possibly as a result of age-related changes in the musculoskeletal system and body composition. Thomas, Williams, and Lundy-Ekman (1998) reported that asymmetrical movement strategies were most frequently used by the oldest participants in a sample of 33 healthy community living older adults between 65–88 years of age. Time for FTS increased with age and was moderately associated with hip and knee extension strength and with hip flexion and dorsiflexion range of motion. Alexander et al (1995; Alexander, ulbrich, Raheja, & Channer, 1997) reported that frail elders required more time and reported greater difficulty when rising from supine than did healthy elders and younger control participants. Ulbrich, Rheja, and Alexander (2000) found that, compared to older adults who were not impaired, older adults with musculoskeletal impairment took three times as long to stand and used more intermediate positions for the FTS maneuver. While there are similarities in the descriptions of the movement strategies used by older adults among these studies, there is little agreement about possible factors that influence choice of movement strategy and the determinants of the ability to rise.

The present study had 2 goals: 1) to explore relationships between the FTS performance and age, functional lower extremity strength, and balance, and 2) to describe movement strategies used by healthy older adults when getting up from the floor. We anticipated that the faster FTS completion would be associated with lesser age and greater lower extremity strength and balance. We expected to observe considerable variation in the strategies of the participants in the study and that the observed strategies used would be different than those previously described for young adults.

METHODS

The study was approved by the Institutional Review Board at the University of Connecticut. All participants signed an informed consent document prior to testing.

Participants

Healthy and independent community-living volunteers ($n = 52$, mean age 64.6 ± 9.5 years) between the ages of 50 and 90 years were recruited to participate. There was relatively equal distribution of participants across decades of age within the sample. Thirty-eight participants (73%) were female. Potential participants were asked by the investigators (physical therapists with >10 years clinical experience in geriatrics) whether they had any musculoskeletal, neuromuscular, or cardiopulmonary impairments likely to interfere with their ability to safely rise from the floor. If they responded negatively and had no observable abnormalities, they were included (no formal screening was performed). All participants were able to rise from the floor without assistance.

PROCEDURE

Each participant was tested in a single session lasting 20 to 30 minutes. Functional lower extremity muscle strength was characterized using the time (measured in seconds using a stop watch) required to complete 5 maximum speed sit-to-stand (STS) cycles from a standard armless chair (Bohannon, 1995; Guralnik et al, 1994). Although requiring more than just strength, the STS test is well established as a measure of lower extremity strength (Bohannon, 1998). Timed single limb stance (SLS) with eyes open (measured in seconds using a stop watch) was used to measure balance (Bohannon, 1994). Maximum time of 2 trials (up to 30 seconds) was recorded for both the right and left extremities. Performance on both of these physical tasks was recorded prior to, and again following the FTS task. Three trials of FTS were timed (using a stop watch) and videotaped. Participants were instructed to rise as quickly as possible when prompted by the investigator. They were told to use the movement strategy that was most comfortable for them. All participants began the task in supine with upper and lower extremities in extension, lying on a low pile carpet over a wood, linoleum, or cement floor. The videocamera used to record participants' movement was positioned perpendicular to each participant's right side. It was fixed to a tripod about 2.0 meters from and 1.5 meters above each participant.

Analysis

Descriptive statistics were compiled to provide an overview of participant characteristics and performance on physical measures. Intraclass correlation coefficients (ICC 3,1) were calculated to assess inter-trial reliability for each of the three timed measures (STS, SLS, FTS). Following this, mean values for each measure (based on two trials of STS, the two best trials of SLS, and all three trials of FTS) were calculated for each participant, and used in subsequent analysis. Pearson product moment correlation coefficients were calculated to explore relationships among the variables (STS time, SLS time, and FTS time). Stepwise regression analysis provided information about key determinants for the FTS task.

Qualitative descriptions of patterns used during FTS were developed by review of videotapes using a video cassette recorder with slow and stop action capability. The two investigators simultaneously reviewed and discussed videotaped performance of the three trials for the first ten participants recorded. Based on this review, the investigators identified three essential components of FTS (initiation, transitional weight transfer, and rising to upright) and defined coding criterion for specific upper extremity, trunk, and lower extremity movement strategies used by participants. Next, investigators independently reviewed videotaped trials of the remaining participants, using the agreed upon descriptors to classify movement strategies

Table 1
Participants' performance on timed measures

Timed measure	Time (seconds) Mean ± *SD*	Range
Sit-to-stand (5 cycles)	8.0 ± 2.0	4.2–13.0
Single-limb-stance		
Right	24.2 ± 8.3	2.1–30.0
Left	24.2 ± 8.5	2.8–30.0
Floor-to-stand	4.1 ± 1.1	1.8–7.2

during the three components of FTS. Agreement beyond that expected by chance as to movement strategies used during each participant's trials was assessed by calculation of a kappa or weighted kappa statistic (Kramer and Feinstein, 1981). A sub-sample of videotaped trials was classified a second time after a hiatus of several months to provide evidence of intra-rater reliability. Finally, investigators grouped the upper extremity, trunk, and lower extremity movements into three distinct strategies (side-sit to half kneel pivot, quadruped push-up, and sit-up and roll over) used by older adults during FTS.

RESULTS

The performance measures are summarized in Table 1. Intertrial reliability coefficients (ICC 3,1) for timed measures were .83 for STS trials, .82 for FTS trials, .81 for SLS on the right lower extremity, and .83 for SLS on the left lower extremity.

Relationships among study variables are summarized in Table 2. Age, STS time, and SLS time all correlated significantly with the time required to complete FTS task (Table 2). The highest correlation was between STS time and FTS time ($r = .64$). Stepwise multiple regression demonstrated that a combination of STS time and age provided the best explanation of FTS time ($R = .68$, $p < .001$). Together they explained 47% of the variance ($R^2 = .47$) in FTS time. The regression equation was: FTS time = −.31 + .30 STS time + .03 age.

Stages of FTS Task

Observation of the videotaped trials ($n = 156$) identified three distinct stages of the FTS task: Initiation, Transitional Weight Transfer, and Going to Upright Posture. These stages, and the rising strategies most frequently observed during each, are depicted in Figure 1.

During the first observed stage of the FTS task (Initiation), participants brought their center of mass through an interim base of support toward their feet. Trunk motions observed during initiation included a symmetrical sit up (48%), a partial sit up into a diagonal roll (22%) or an immediate roll into sidelying (30%). Whether moving by sitting up or by rolling, most participants bore weight on one elbow or hand (67%) and reached diagonally across their body toward the weight bearing side (56%). Most also demonstrated an asymmetrical pattern of lower extremity movement (76%).

Table 2
Pearson correlation coefficient (*p* value) matrix for quantitative variables

Stance	Age	Sit-to-stand	Left stance	Right
Sit-to-stand	.39 (.005)			
Left single stance	−.68 (.001)	−.34 (.05)		
Right single stance	−.53 (.001)	−.22 (.124)	.74 (.001)	
Floor-to-stand	.48 (.001)	.64 (.001)	−.42 (.005)	−36 (.005)

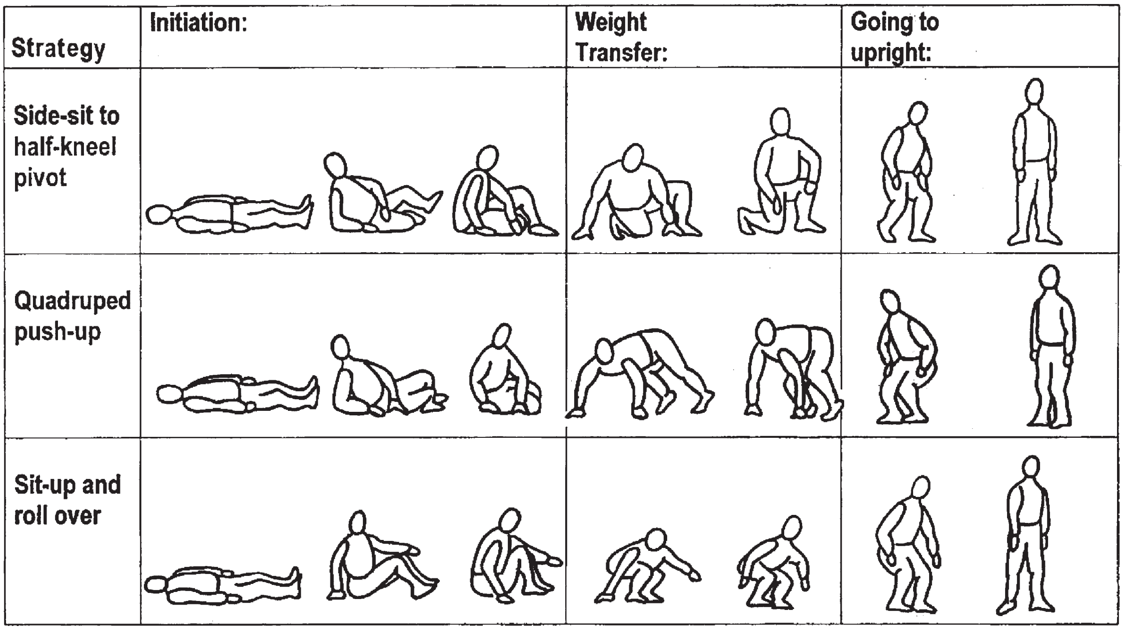

Fig. 1 Three typical movement strategies demonstrated in each stage of the supine-to-standing task. The most frequently observed strategy was side-sitting to half-kneel-pivot ($n = 26$), followed by side-sitting to quadruped/plantigrade push-up ($n = 18$), and symmetrical sit up and roll over ($n = 8$).

During the second stage of the FTS task (Transitional Weight Transfer), participants "loaded" their feet in preparation for standing. To accomplish this, many participants moved through a sidelying (29%) and/or sidesitting (55%) into a quadruped (19%) and/or half kneeling position (46%). Some moved through long sitting (33%) to assume a squatting position (20%). Most (85%) maintained weight-bearing contact with one or both upper extremities during the transitional weight transfer stage.

In the third stage of the FTS task (Going to Upright Posture), participants moved into an upright, standing position. Most (77%) maintained a wide base of support during this stage, taking a step to bring feet together after they were fully upright. Almost a third of participants (29%) began this stage with bilateral upper extremity support. Many (60%), especially those who moved upright from a half-kneeling position, demonstrated a period of unilateral stance. Most participants (60%) were standing perpendicular to their starting position as they completed the motor task. The frequency and consistency of movement strategies observed as participants moved through each of these stages is summarized in Table 3.

Strategies

Participants rising from supine to standing combined individual movements across initiation, transitional weight bearing and going upright stages of the motor task into one of three distinct rising strategies: 26 participants (50%) demonstrated an asymmetrical side sitting to half-kneel pivot, 18 participants (35%) demonstrated a quadruped push up strategy, and 8 participants (15%) demonstrated a symmetrical sit up and roll over strategy. These strategies are depicted, by stage of the movement task, in Figure 1.

The majority of those using the asymmetrical side sitting to half kneel pivot initiated the motor task of rising from supine with a flexion and rotation of the head and neck. This was accompanied by a diagonal reach across the body with one (unweighted) upper

Table 3
Movement strategies observed in adults, ages 50–90 years, when rising from the floor

Stage		Movement strategy	Frequency*	Percent	Consistency**
Initiation		Trunk motions: symmetrical sit-up (more than 45°)	75	48.1	1.00
		Partial sit-up (30°–45°) leading to diagonal reach/roll	34	21.8	.78
		Immediate roll toward sidelying (less than 30°)	47	30.1	.92
	UE:	Moves without UE weight-bearing support	51	32.7	1.00
		Relies on UE weight-bearing support	105	67.3	.80
		Reaches diagonally across trunk during sit-up or roll	87	55.8	.75
	LE	Sit-up with hip flexion/knee extension	58	37.2	.85
		Sit up with lower extremities primarily in extension	5	3.2	1.00
		Roll with symmetrical hip and knee flexion	26	24.4	.94
		Sit-up or roll with asymmetrical hip and knee flexion	119	76.3	.97
Transitional Weight Transfer		Through sidelying	45	28.8	.85
		Through sidesitting	85	54.5	.93
		Immediately into three point (hand/forward foot/pelvis)	35	22.4	.65
		Through half-kneeling position	72	46.2	.86
		Through quadruped	30	19.2	.79
		Into squat position	32	20.5	.89
		Jumps with hands on floor	14	9.0	1.00
		Posterior squat thrust	20	12.8	.78
		Into long sitting or semi-long sitting position	51	32.7	.86
		Pushes on thigh for support	55	35.3	1.00
		Through 2-point floor contact (one hand/one leg)	3	1.9	1.00
		Relies on one or both upper extremities for support	133	85.3	***
Going to Upright		Uses narrow base of support	36	23.1	.56
		Uses wide base of support	120	76.9	.56
		Uses mass extension pattern of lower extremities	29	18.6	.77
		Begins with both UE in contact with floor	45	28.8	1.00
		Maintains two feet on floor	37	23.7	1.00
		Uses UE to push off from floor	27	17.3	.62
		Demonstrates a period of unilateral support	94	60.3	.89
Direction of Movement		Ended facing the same direction as starting position	30	19.2	.87
		Ended facing the opposite direction from starting position	33	21.2	***
		Ended facing perpendicular to starting position	93	59.6	.94

* three trials were filmed and observed for each of 52 participants, for a total of 156 trails.
** all values were calculated using the Kappa statistic, except for Direction of Movement which was calculated using weighted Kappa.
***unable to calculate due to distribution.

extremity, moving the upper trunk over the other (weighted) elbow into an asymmetrical sidesitting position. Most simultaneously flexed the lower extremity on the weight bearing side into a tightly "tucked under" position while moving the unweighted lower extremity up and across the midline until the foot could placed on the floor. Once this asymmetric side-sit position was reached, participants shifted their weight from the bottom pelvis and lower limb onto the opposite foot, and then actively pivoted their pelvis up and away from the floor while weight bearing through the upper extremities. The trunk moved into a more erect position as weight was shifted onto the forward foot, until a half-kneeling position was attained. Most of the participants using this strategy then placed a hand on the forward knee in preparation for the next phase of the task. To begin to move toward upright stance, participants leaned slightly forward while extending hips and knees. Many pushed downward on their forward knee as they began to rise. The base of support during this stage was typically quite wide; the base of support was narrowed by taking a step to bring the feet closer together once upward motion was complete.

Those who used the quadruped push up strategy also initiated movement with a diagonal reach, but flexed both lower extremities into a tight tuck in order to prepare to assume a quadruped or plantigrade position rather than a half-kneeling position. During weight transfer, the pelvis was again pivoted over the knees into a quadruped position, or over the feet into a plantigrade position. Participants then either pushed backward to load their feet, or hopped forward (as in a reverse squat thrust) to narrow their base of support and position their feet under their trunk. Just prior to moving toward upright, participants leaned slightly backward to unweight the upper extremities while completely loading the feet. This was followed by rapid extension of the head, neck, trunk, and lower extremity to complete the upright phase of the movement. Once upright, many participants took a quick step to narrow their base of support and achieve a stable standing position.

Those that used the sit-up and roll over strategy initiated the task of rising by performing a symmetrical "sit-up," accompanied by symmetrical flexion of both lower extremities to position the feet as closely to the pelvis as possible. Most of these participants reached as far forward as possible with one upper extremity, simultaneously propelling themselves forward by pushing forcefully against the floor with the other (weight bearing) upper extremity. The resulting forward momentum enabled them to roll up and over their feet into a crouched "squatting" position. They then unfolded into an upright position, careful to maintain their center of mass over their new, narrower base of support; the feet. Participants using this strategy often had to take a step or two once upright to gain postural control of the forward momentum generated by the forward/upward progression of their center of mass.

Table 4
Comparison of floor-to-stand times and task determinants in three studies of healthy older adults

	Current study	Ulbrich et al*	Thomas et al
Number of participants	52	24	33
Age (years):			
Mean	64.6 + 9.5	73 + 6	74.6 + 6.5
Range	50 − 90	66 − 87	65 − 88
Time to rise/(seconds):			
Mean	4.1 + 1.1	5.5	5.7 + 1.97
Range	1.8 − 7.2	2.3 − 10.4	2.6 − 9.6
Correlation: Age	$r = .48$, $p < .05$	not reported	$r = .59$, $p < .001$

*Subsample of healthy community living elders.

DISCUSSION

The mean time to rise from supine for participants in this study was more than 1 second faster than reported in previous studies (see Table 4 Alexander, Ulbrich, Raheja, and Channer, 1997; Thomas, Williams, and Lundy-Ekman, 1998; Ulbrich, Rheja, and Alexander, 2000). This may be explained, in part, by differences in ages of participants across studies: our sample includes adults between 50 and 90 years, while the other studies include adults over 65 years. The relationship between age and time to rise, however, was consistent and strong across studies. Another reason for the faster FTS time in our study was our instruction to subjects to "rise as quickly as possible."

Postural control, as measured by single limb support, was not as strongly correlated to time to rise as anticipated, and was not an important predictor of time to rise from the floor in regression analysis. This is potentially explained by differences in the nature of postural control across tasks. Single limb support requires maintenance of the center of mass over a small, fixed base of support. Rising from a chair and rising from the floor require dynamic postural adjustments as the center of mass moves over a changing base of support.

While the time required to rise from the floor increased with age, our regression analysis suggest that functional lower extremity strength is an important determinant of the ability to rise from the floor. This finding is consistent with investigations of other functional tasks in later life. Beissner, Collins, and Holmes (2000) found that lower extremity range of motion (standardized $\beta = .53$), lower extremity muscle strength (standardized $\beta = .32$), and age (standardized $\beta = -.26$), predicted physical performance test scores for older adults living in senior housing and in institutional settings. Samson et al (2000) reported that decreasing strength contributes significantly to decline in function (measured by timed up and go and by modified Cooper test) across the lifespan, especially for older women. In the presence of limited knee flexion, is a potential contributor to the ability to rise from the floor (Samson et al, 2000). Thomas, Williams, and Lundy-Ekman (1998) also identified range of motion at the hip and knee as an important influence on the efficacy of the floor to stand transition.

Healthy older adults use a variety of motor strategies to rise from the floor. In addition to taking more time to rise from supine, observation of videotaped trials suggested that older participants passed through more intermediate positions as they moved through each stage of the movement task identified in our analysis (initiation, weight transfer, and going upright). As age increases, older adults may approach the task of rising from the floor by dividing the task into discrete sub-components, using a greater variety of movement strategies than younger adults (Van Sant, 1998a; Green and Williams, 1992). The movement strategies used to rise from the floor we observed in this study were similar to those reported by Van Sant (1998a), Green and Williams (1992), Thomas, Williams, and Lundy-Ekman (1998), and Ulbrich, Rheja, and Alexander (2000). These previous studies grouped movement strategy by body segment (upper extremity, axial, lower extremity); we have instead described combinations of strategies used as participants moved through three distinct stages of the rising from the floor motor task. Familiarity with the stages of the floor to stand task and the movement strategies used by healthy elders when rising from the floor may guide rehabilitation professionals when working with older adults with musculoskeletal and neuromuscular impairments, as well as those who are fearful of falling. While it may be best to allow elderly individuals to determine for themselves the strategies that they find most advantageous, there will be some who need coaching. Knowing what works for others provides the treating therapist with options that the otherwise unable individual can employ.

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