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Original Article

The effect of advanced age and stool modification on reaching distance in sitting

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Abstract. [Purpose] Reaching is an important functional ability. We investigated the effect of advanced age and stool modification on sitting reach distance. [Participants and Methods] Twenty-four participants (twelve older adults 70 ± 4 years and twelve young adults 29 ± 4 years) reached forward and laterally while sitting on an adjustable stool with 0°, 10° forward, 10° backward, 10° right or 10° left inclination of the seat, with and without footrest and front, back or side leg support. [Results] The outcome of this exploratory study revealed that young adults reached farther than older adults across all the directions of reach and seat conditions. While the inclined seat was utilized, both young and older adults reached farthest in the forward direction. Additional leg supports allowed to reach further; however, older adults were not able to reach in the forward direction as far as young adults. When reaching in the lateral direction, leg support had minimal effect on the reach distance. [Conclusion] Age affects the sitting functional reach ability. Future research should focus on investigating the efficiency of interventions to enhance performance of functional tasks in sitting older adults.

Key words: Older adults, Reaching, Sitting

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INTRODUCTION

Ability to reach plays a crucial role in performance of various activities of daily living. However, as people age, their physical abilities naturally undergo changes that can impact capacity to effectively reach for objects within arm's length thus, limiting functional interaction with the environment needed to maintain independence[1, 2)]. Moreover, as people age, they tend to spend more time sitting[3, 4)] so, they must adapt to the need to perform functional activities from the sitting position.

Reaching from a sitting position could involve extending the arm to grasp an object or perform a task in the forward or lateral direction[5, 6)]. The ability to reach in both directions while seated is critical in the performance of many tasks, such as writing, using a computer, turning pages of a book, reaching for a glass of water, and retrieving items from the side table or floor.

For older adults, reaching from a sitting position becomes a vital functional ability, as it enables them to perform various tasks independently, such as reaching for items on a shelf, getting dressed, or cooking meals. However, with advancing age, older adults may experience changes in their physical abilities that can impact their sitting balance and upper extremity strength. For instance, older adults experience declines in muscle strength, joint flexibility, and proprioception, which can negatively affect their ability to maintain postural control during task performance[7)].

Assessing an individual's ability to reach from a sitting position can be an important component of the clinical evaluation of sitting balance and functional ability[8)]. Certain measures have been established to assess dynamic sitting balance. One of such measures is functional reach test[9)], which involves forward reach and lateral reach while sitting on a flat surface[6)].

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Moreover, the configuration of a seat, which refers to the shape[10], size[11] and the positioning of various components such as seat surface[12], inclination[13], footrest, and additional supports[14] has been found to significantly affect the level of support a body receives when seated. Varying seat configurations can enhance support needed to perform activities beyond arm's length including daily home routine, work, and leisure activities. Thus, inclining a seat posteriorly (backward) at 5° was helpful in preventing children with cerebral palsy from sliding forward on the seat[15] while an anterior (forward) inclination of the seat at the same angle resulted in a reduction in lumbar flexion and increase upper extremity efficiency in sitting children[16]. Sitting on a forward-inclined seat at 10° was found to be effective in maintaining a neutral alignment of the spine[17]. Moreover, forward reach distance was enhanced when patients with spinal cord injury performed reaching from a tilted seat when compared to reaching from a standard chair[18].

However, it is important to understand how the ability to reach forward or to the side is influenced by seat configuration in older adults performing a functional reach task. Thus, our aim was to assess how age and modifications of a stool influence reach distance in the forward and lateral directions. We hypothesized that older adults would reach in the forward and lateral direction not as far as young adults. We also hypothesized that availability of additional leg support would enhance reach distance. Based on differences in the biomechanical configuration of the body in the frontal and sagittal plane, we hypothesized that participants would reach farther in the forward direction than in the lateral direction.

PARTICIPANTS AND METHODS

A convenient sample of twelve older adults (5 males, 7 females, mean age 70 ± 4 years, mean height 162 ± 10 cm and mean weight 70.6 ± 11.5 kg) and twelve young adults (6 males, 6 females, mean age 29 ± 4 years, mean height 164 ± 6 cm, mean weight 63.7 ± 14.6 kg) participated in the study. Older adults were recruited from the community using fliers and through an existing participant database. Young adults were recruited from the university students using fliers. Prospective participants who replied to the flyers were screened by a physical therapist. The inclusion criteria were normal or corrected to normal vision, ability to perform reaching in sitting, and ability to follow instructions. The exclusion criteria were a history of any neurological or musculoskeletal disorders, any kind of pain, and taking any medications that might affect balance. All participants were right side dominant. The study was approved by the University of Illinois Chicago Institutional Review Board and all the participants provided a written informed consent.

During the experiments, a wooden stool measuring 65.5 cm in height and with a sitting base of 41 by 41 cm was utilized. The stool was specifically designed to enable the manipulation of sitting positions using adjustable parts that were firmly attached to it. To create a 10° inclination of the seat in forward, backward, right, or left direction, a plywood wedge was placed on the seat of the stool and oriented accordingly. The stool had two height-adjustable and removable supports allowing to provide anterior, posterior, right, and left leg supports as well as a height-adjustable and detachable footrest. The leg supports were designed as wooden bars placed on the distal one-third of the participants leg in the front, back or on the right or left side accordingly (Fig. 1).

During the experiment, participants were instructed to sit on a stool with no back support, positioning their sacrum 1 cm away from the back edge of the seat, maintaining a straight back and forward-facing head. A ruler positioned on the dominant side of the participant, at the height of their acromion, was used to measure the functional reach distance.

Participants were required to make a fist around a vertically held pencil which was utilized as a pointer and reach forward or laterally as far as they could while their other arm was placed on their side. Participants were instructed to lift their

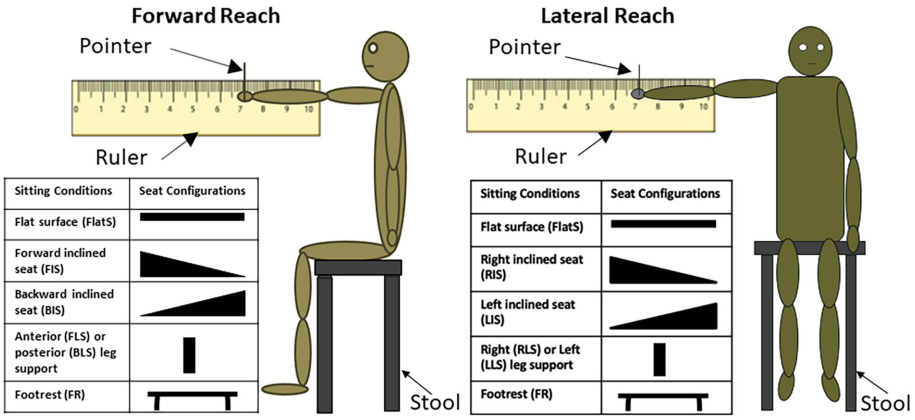

Fig. 1. Schematic of the experimental set up. The participants were seated on a stool. A plywood wedge placed on the seat created a 10° inclination of the seat in the forward, backward, right, or left direction. Wooden parts attached to the stool provided anterior, posterior, right, or left leg supports. A ruler was used to measure reach distance.

dominant arm forward or laterally to approximately 90° and the pencil's position on the ruler was recorded as point A. Then the participants were asked to lean in the desired direction as much as possible while remaining seated, and the pencil's new location was recorded as position B. Reaching distance was defined as the difference between position A and position B[9], and participants performed all reach trials with full vision. Each task was repeated three times, and the mean reach distance was calculated[6]. For safety, the participants were provided with a harness (NeuroCom International, Clackamas, OR, USA) loosely attached to the ceiling.

First participants were required to reach forward or laterally while sitting on the flat surface with their legs hanging freely without footrest or leg support (FlatS) and their other arm by their side (Fig. 1). Then participants performed forward reach when they sat on either a forward inclined seat (FIS) or a backward inclined seat (BIS)[19]. Moreover, participants performed forward reach when sitting with an anterior (FLS) or posterior (BLS) leg support[5, 20], and the footrest was available in both conditions. Next, the lateral reaches were performed when sitting on the right (RIS) and left (LIS) inclined seat, and when right (RLS) and left (LLS) leg support was available. Finally, participants performed forward and lateral reach while sitting with their legs on the footrest (FR). The experimenter ensured that all participants maintained a vertical trunk while seated. The order of experimental conditions was randomized across participants.

Kolmogorov-Smirnov and Shapiro–Wilk test showed that our data was normally distributed. Three-way ANOVAs were employed to investigate the difference in the reach distance. First ANOVA had independent factors 1) age (young adults, older adults), 2) direction of reach (forward, lateral), and 3) seat inclination (forward, backward, no inclination). The second ANOVA had independent factors 1) age (young adults, older adults), 2) direction of reach (forward, lateral), and 3) leg support (front, back, or side leg support). SPSS software (IBM, Armonk, NY, USA) was used. Statistical significance was set at $p<0.05$.

RESULTS

Three-way ANOVA revealed that there was a significant difference in the reach distance attained within the forward and lateral reach directions between young and older adults in the FIS, BIS, RIS and LIS experimental conditions (F (2, 9)=5.255, p=0.002. Pairwise comparison with Bonferroni adjustment revealed that this difference was significant in the FIS (27.2 ± 0.4 cm and 21.8 ± 0.1 cm), p=0.006, BIS (28.9 ± 1.2 cm and 22.8 ± 0.4 cm), p=0.007, RIS (17.8 ± 1.0 cm and 12.7 ± 1.1 cm), p=0.000, and LIS (18.5 ± 1.4 cm and 16.4 ± 2.2 cm), p=0.008, conditions for young and older adults respectively (Table 1).

Young and older adults performed reaching tasks in the forward and lateral directions using different leg supports (FLS, BLS, RLS, LLS, FR, FlatS). The result of three-way ANOVA showed that young adults reached in both forward and lateral directions significantly farther than older adults when the leg support was available, F (2,9)=12.486, p<0.001. Table 2 shows reach distance achieved by young and older adults while seating on a flat surface with and without leg support.

DISCUSSION

We conducted the study to evaluate the effect of age in performance of reaching task in the forward and lateral direction while sitting on a stool when the seat inclination and availability of leg supports were manipulated. The results of the study demonstrated that older adults achieved a smaller reach distance compared to young adults in all experimental conditions. Thus, the first hypothesis that older adults would reach in the forward and lateral direction not as far as young adults was supported. Moreover, when additional leg support and footrest were available, both older and young adults increased the reach distance. Thus, the second hypothesis that provision of additional leg support would enhance reach distance was supported. Finally, in all experimental conditions, both young and older adults reached farther in the forward direction compared to the lateral direction. Thus, the third hypothesis that participants would reach farther in the forward direction than in the lateral direction was also supported.

Young adults attained a farther forward and lateral reach distance compared to older adults in all experimental conditions. There are several factors that could play a role in the observed decrease in the reach distance in older adults. Among them

Table 1. Reach distance (mean ± SE) measured while seating on inclined seat

Direction	Condition	Reach distance (cm)	
		Old adults	Young adults
Forward	FIS	21.80 ± 0.10	27.20 ± 0.40*
	BIS	22.80 ± 0.40	28.90 ± 1.20*
Lateral	RIS	12.70 ± 1.10	17.80 ± 1.00*
	LIS	16.40 ± 2.20	18.50 ± 1.40*

Statistical significance at *p<0.013.
FIS: forward inclined seat; BIS: backward inclined seat; RIS: right inclined seat; LIS: left inclined seat conditions; SE: standard error.

Table 2. Reach distance (mean ± SE) measured while seating on a flat surface with and without leg support

Direction	Condition	Reach distance (cm)	
		Old adults	Young adults
Forward	FLS	31.10 ± 1.80	36.40 ± 1.10*
	BLS	30.10 ± 2.10	37.90 ± 1.30*
	FR	27.90 ± 1.80	35.50 ± 1.00*
	FlatS	22.40 ± 0.90	26.20 ± 1.40
Lateral	RLS	13.50 ± 0.40	17.80 ± 0.80*
	LLS	15.10 ± 0.50	20.00 ± 1.10*
	FR	13.30 ± 0.50	18.40 ± 0.80*
	FlatS	16.80 ± 0.50	18.80 ± 0.70

Statistical significance at *p<0.008.
FLS: front leg support; BLS: back leg support; FR: footrest only; FlatS: no leg support; RLS: right leg support; LLS: left leg support conditions; SE: standard error.

is a reduced ability of older adults to generate muscle strength and power[21, 22]. Indeed, young adults generally have greater muscle strength and power compared to older adults. Moreover, muscles involved in reaching, such as the upper body, back, and shoulder muscles, tend to be stronger in younger individuals[23, 24] which allow young adults to generate more force and exert better control during reaching movements, resulting in a greater reach distance[25, 26]. Another potential contributing factor to the observed decrease in reaching distance in sitting older adults relates to the age-related declines in joint flexibility and range of motion commonly reported in people of advanced age. Indeed, it is described in the literature that older adults exhibit increased joint stiffness, reduced muscle elasticity[27] which contributes to the decline in the flexibility, range of motion and joint mobility, particularly in the shoulders and spine[28]: all these could impact the older adults' ability to reach forward or to the side. Moreover, it is reported that older adults commonly exhibit reduced ability to control balance[29]. Furthermore, decreased sensory feedback and alterations in proprioception, that are frequently seen in older adults, may lead to the implementation of a cautious approach during the performance of a task that potentially could compromise balance[30]. It is quite possible that older adults in our study utilized such a cautious approach and as a result demonstrated shorter reach distances as compared to younger counterparts.

Furthermore, certain biomechanical constraints could be linked to the reported difference in the reach distance between young and older adults. It has been established that spinal mobility decreases with age[31]. This reduced mobility could limit the ability of older adults to flex their spine as required while performing the reaching task. Moreover, adequate muscle strength is required to perform activities of daily living[32] including reaching, but age-related decline in muscle strength[33] known as sarcopenia could impact forward or lateral reach distance attained by older adults. Muscles involved in reaching, such as the shoulder abductors and flexors, play a crucial role in generating the force required for reaching movements. Reduced muscle strength in older adults can affect their ability to generate sufficient force[34], which may lead to decreased reach distance compared to younger adults. Additionally, the physiological and biological processes related to the aging have been found to increase reaction time in older adults[35]. Reaction time refers to the time it takes an individual to start a movement after a command is initiated[36]. Slower reaction times in older adults may delay the initiation of reaching movements, potentially compromising their ability to reach as far as young adults. Moreover, sensorimotor integration (that involves the coordination and processing of sensory information to plan and execute movements accurately) is affected by the advanced age[37]. This also can potentially affect the coordination and timing of reaching movement.

When sitting on an inclined seat, young adults were able to reach significantly farther than older adults: by 5.3 cm in the FIS, 5.7 cm in the BIS and 4.6 cm in RIS conditions. We believe that this outcome relates to the fact that advanced age is associated with higher postural instability[38] and effective postural control declines with age[7]: these could hamper the ability of older adults sitting on an inclined surface to reach further. Furthermore, fear of falling could also be a contributory factor that has the potential to impact the performance of older adults. Fear of falling is often associated with diminished balance control[39], reduced mobility[40] and compromised postural stability[41]. The concern of losing stability and suffering injury when dealing with challenging postural conditions, such as those posed by the need to reach forward or to the side while seated on the inclined seat, can compel older adults not to reach further. Among the inclined seat conditions, older adults reached forward farthest while sitting on the backward inclined seat. We believe this might be because BIS condition enabled the packing of the pelvis such that the margin of perceived safety in this sitting condition felt higher than the other inclined seat conditions[42]. Moreover, when sitting on the right inclined seat, lateral reaching distance achieved by older adults was significantly smaller than younger adults. We believe this could be because the direction of inclination of the seat in the direction of reach further shifts the center of mass towards the stability limits which could increase the probability of a fall in the right direction. Since advanced age is associated with the decline in postural stability[7], it is quite likely that older adults might have selected to tradeoff shorter reaching distance for keeping the body stability and avoiding falling over.

The use of additional leg support as compared to no leg support brought about an increase in the reach distance attained by older adults. Thus, older adults reached 8.7 cm further in the FLS, 7.7 cm in BLS, and 6.5 cm in FR condition than in the no leg support condition (FlatS). This finding is in line with the outcome of our previous study where the use of additional leg support increased the reach distance attained by young adults[5].

Providing additional support, in the form of a body contact with a support surface, was found to enhance postural control in older adults in sitting and standing[43, 44]. Additional somatosensory information obtained from a contact surface has been found to improve postural control in standing young adults[45]. The use of additional leg support to the lower limbs of older adults is particularly important in improving their functional reach performance by mitigating the age-related decline in postural control and muscle strength. The enhanced stability provided by the leg support allowed older adults to better maintain their balance and distribute their body weight effectively, creating a firm base from which they could initiate and execute reaching movement. The provision of additional support to the lower limbs may help counteract the tendency for older adults to adopt cautious or restricted movement patterns due to fear of instability or falling.

The outcome of this exploratory study also revealed that both young and older adults reached farther in the forward direction than the lateral direction. This could be because the human body is designed in a way that certain movements are more efficient or easier to perform in specific directions. The joint structure of the body plays a crucial role in determining the range of motion in different directions. In the anterior direction, joints such as the shoulder, elbow, and wrist allow for flexion, which is the bending of a joint to bring two body parts closer together. This flexion movement allows for reaching forward with relative ease, as the joints allowed to facilitate this motion[46]. On the other hand, in the lateral direction, joints like the shoulder and hip are primarily designed for abduction, which is the movement away from the body's midline. While abduction is essential for various activities, it may not be as efficient for reaching objects laterally, as it requires moving the arm away from the body's center, which can be more challenging and less natural compared to anterior extension. Thus, there is a higher degree of anterior trunk flexion (73−40°) than lateral flexion (28−14°), and these values decrease with age[47].

The outcome of the study suggests that seating on a stool with an inclined seat or using additional leg support while performing reaching tasks in clinical settings can help patients reach farther. Thus, clinicians can implement modified stools while providing an intervention focused on retraining sitting balance and enhancing reaching distance in older adults and individuals with impaired balance control.

There are several limitations in the current study that we would like to mention. First, the sample size was relatively small and only healthy young and older adults were enrolled. Second, while the participants were required to maintain a straight back and forward-facing head during performance of reaching tasks, the trunk range of motion, strength, and spinal alignment that potentially can influence reach distance in a seated position were not assessed in the current study. Future studies involving more participants, including older adults with balance deficits, and measurements of the motion of the trunk and spinal alignment as well as recording electrical activity of the muscles would be needed to study the effect of stool modification on reaching distance in sitting.

In conclusion, age played a significant role in the reaching ability in all the studied sitting positions. The provision of additional leg support significantly enhanced the reaching ability in older adults. Biomechanical constraints of the body played a key role in the reach distance attained allowing to reach more in the forward direction. The findings from this study provide information for future research focused on enhancement of performance of functional tasks in the sitting position in older adults.

Conflict of interest

The authors report there are no competing interests to declare

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