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Effects of task context during standing reach on postural control in young and older adults: A pilot study

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ABSTRACT

Reaching is an important component of daily activities with goals to interact and acquire objects in the environment. The task context of reaching, as determined by the behavioral goal and the properties of the object, can influence the control of posture and movements. This study examined age differences in postural stability during a forward reach under two task contexts, grasping versus pointing to a target. Young and older participants living in the community performed the tasks from the standing position. They reached forward, grasped or pointed to a target, and then returned to an upright posture as fast as possible. Postural stability was analyzed using the center of pressure (COP) during two phases of the task: the reaching movement phase and the returning movement phase. In the grasping context, the COP path deviations were significantly larger in older compare to young participants during both the reach and the return movement phases. In addition, during the return movement phase, only older participants showed a context-dependent increase in COP path deviations after grasping compared to pointing. The results highlight the impact of task context on postural stability during standing reach in young and older adults. Interventions for older adults with balance problems should consider incorporating activities that involve the interaction with objects of various properties in the environment. Future studies are necessary to investigate the factors underlying the person-environment interplay of postural control and the adaptation of anticipatory postural control associated with object interaction during functional tasks in older adults.

1. Introduction

Reaching is an important component of functional activities as the arms are used 8–9 h a day [1]. When the arm and trunk are coordinated to carry out reaching movements from standing, postural stability is essential to accomplish the task. Movements can disturb stability because of joint reaction forces and changes in posture [2]. Therefore, anticipatory postural adjustments are required to stabilize the posture before the perturbations associated with movements occur [2,3]. Subsequently, sensory feedback signaling imbalance triggers compensatory postural responses to restore stability [2,3].

Age-related changes in the physiological systems are known to cause deficits in postural control [4–6], leading to increased risk of falls [7], heightened morbidity, mortality, and cost of care [8]. A prospective study of community-dwelling older adults reported that 17.3% of falls occurred during reaching or leaning [9]. Another prospective study of older adults with a history of falls found that reaching or leaning accounted for about 5% of falls with moderate or severe injuries [10]. Moreover, 29.2% of injurious falls happened while people were engaged in diverse daily activities, such as cleaning, opening or closing doors [10]. While the major causes of falls included slip, trip, and leg weakness, the causes of more than 40% of falls remained unspecific or attributed to a loss of balance [10]. These results underline the need to further investigate the mechanisms of postural instability during daily activities. Because up to 95% of daily activities carried out by older adults involve movements of the arms and trunk [11], examination of age-related changes in postural control during reaching and learning may provide new insights into strategies for fall prevention.

Reaching tasks are primarily goal-oriented and require the individual to interact with objects in the environment. The central nervous system controls movements and posture based on the internal representation of the context, particularly the properties of

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objects and the predicted disturbances associated with interacting with objects [12]. The characteristics of a reaching target have been shown to alter postural response in a feedforward manner [13,14]. Wing et al. [15] instructed young adults to grasp a handle, and pull or push against a load. They found that the increase in the grasp force and ground reaction torques preceded any detectable change in the load force [15]. The results indicated that grasp and postural adjustments were pre-planned in anticipation of the perturbations induced by moving the load [15]. In a study by Mallau et al. [16], young and older adults grasped and lifted an object in standing. It was shown that center of pressure (COP) velocities and sway paths before and after grasping were similar between age groups [16]. Nevertheless, older adults applied significantly larger grasp force compared to young adults, reflecting a strategy to prioritize postural stability over grasping in older but not young adults [16]. To date it remains unclear whether the anticipatory postural control to reduce the perturbations associated with object intervention is affected by age. When standing subjects were exposed to predictable external perturbations, delayed and smaller anticipatory postural responses and subsequently, larger compensatory muscle activities to restore balance were found in older adults compared to young adults [17]. These results suggested that the effectiveness of anticipatory postural control is reduced with age [17]. In this connection, the ability to anticipate perturbations associated with object interaction at the end of reaching is likely altered with age. Based on the evidence of age-related declines in anticipatory postural control, older but not young adults may be less stable during reaching and grasping as compared to reaching only.

This study was a pilot study to investigate age differences in postural stability during standing reach between two task contexts, reaching and grasping versus reaching and pointing. To this end, participants grasped or pointed to a target at the end of a forward reach, and then returned to an upright position. It was expected that grasping would induce larger disturbances compared to pointing. The hypothesis was that the task context would influence postural stability in older adults but not young adults.

2. Method

2.1. Participants

Eight young adults (23.6 $\pm$ 3.0 years, 5 females and 3 males) and 10 older adults aged 65 years and over (74.1 $\pm$ 4.8 years, 6 females and 4 males) participated in the study. Young participants were recruited via emails and flyers at the University of Michigan. Older participants were recruited through advertisements and flyers. All participants were right-handed as assessed by the Edinburgh Handedness Inventory. Other inclusion criteria included the ability to walk without an assistive device, follow instructions in English, and not participating in competitive sport activities. Exclusion criteria included a history of diabetes, vestibular, ophthalmologic, neurological or debilitating musculoskeletal conditions, cognitive deficits as determined by the Mini-Cog test, binocular visual acuity at normal contrast less than 20/50, and impaired proprioception at the 1st metatarsophalangeal joint. The University of Michigan Institutional Review Board approved all procedures. Participants gave their written consent prior to data collection.

2.2. Procedure

Body weight, height, and foot length were measured. Participants stood barefoot with heels separated by 10% of body height. Foot positioning remained consistent throughout trials. The reach target was a cylinder (3.5 cm in diameter, 14 cm in height) placed at the height of xiphoid process and in front of participants in the mid-sagittal plane. Maximum reach distance was determined by instructing the participants to reach and point forward as far as possible without taking a step. The distance between the right acromion process at the start position and the distal end of third finger at the end position was the maximum reach distance. The task context was varied by the goals of reaching, i.e. grasping versus pointing to a target. For the pointing task, the target distance was 90% of maximum reach distance and measured from the right acromion process. For the grasping task, the target was at a distance of 90% of maximum reach distance subtracted by the length between the distal end of third finger and the middle of third metacarpal. With this adjustment, the reach distance was comparable between the pointing and grasping tasks.

The tasks required forward bending of the trunk as the arm reached towards the target (Fig. 1B). For the grasping task, participants grasped the cylinder by flexing all four fingers and the thumb to form a ring around the target. They reached to the target, grasped without removing it from the stand, and returned to upright. For the pointing task, participants reached forward, pointed to a yellow square (2.5 cm $\times$ 2.5 cm) on the cylinder with their index finger, and returned to upright.

Participants initiated the tasks at a self-chosen time with their right arm after a verbal “Go” command. They kept the feet in place while performing the task as fast and as many times as possible in a 20 s trial. Data from one 20 s trial for each task context were recorded. Participants rested for 2 min after completing each trial. The order of the tasks (grasp versus point) was randomized across participants.

2.3. Data collection

A motion capture system (MotionSTAR, Ascension Technology. Burlington, VT) recorded 3D kinematics of the reaching arm from a sensor placed on the radial styloid. A force platform (AccuSway, Advanced Mechanical Technology, Inc., Watertown, MA) recorded ground reaction forces and moments. The platform was zeroed after every trial and every rest break to prevent drift. The signals from the force plate were filtered by a built-in, primary 200 Hz low-pass, two-pole filter. The COP data were obtained using the Balance Clinic software (Advanced Mechanical Technology, Inc., Watertown, MA). Grasp force was measured using a strain gauge based force transducer embedded inside the target, which comprised of two polyetherimide half cylinders [18]. The strain gauge was a bonded foil compression load cell, with a measuring range of 0–1112 N, zero balance $\pm$5%, repeatability rating $\pm$0.1 of full scale, and hysteresis of 0.2% (Button mount model, Omega, Stamford, CT). It measured forces from multiple directions applied from all fingers during a whole hand grasp. The recording device for grasp force was calibrated before data collection. All data were collected at 100 Hz simultaneously using custom-written LabVIEW programs (National Instruments Corporation, Austin, TX).

2.4. Data processing

Arm movements, COP, and grasp force data were processed using custom-written Matlab programs (Matlab Version 7.5, MathWorks, Natick, MA). A zero-lag, 4th-order Butterworth filter (6 Hz cutoff) was applied. A 5% of peak velocity was the threshold to identify onsets/offsets of COP AP displacement and arm movements. Onsets and offsets of grasp force were determined using a threshold of 5% of maximum grasp force.

Arm movements and COP variables were analyzed in two phases of the task: (1) reach movement phase was the time when the movement was made towards the target, and (2) return movement phase was the time when participants returned to upright after grasping or pointing to the target (Fig. 1). The first repetition of reaching and returning movement from each trial was