

# Effect of Aging on Anticipatory Postural Adjustment and Reaction Times in the Pre-Crossing Phase of Obstacle Negotiation

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## Abstract

**Background:** Obstacle crossing is the common reason of falling in older adults. Anticipatory postural adjustments phase (APAP) and reaction time phase (RTP) are two important factors in falling prediction. According to previous studies, these parameters increase in older adults at high risk falling. This study explored the effect of aging on APAP and RTP in obstacle negotiation. **Method:** Nineteen older adults (mean age:  $66.73 \pm 3.38$  years) and twelve young adults (mean age:  $26.5 \pm 4.37$  years), participated in this study. Participants take part in gait initiation task from a starting position on a force platform under two conditions, unobstructed and obstructed (obstacle placed at 1 m from the initial position). RTP and APAP were measured and Timed “Up” & “Go” test (TUG) as a functional test, recorded for all participants. **Results:** There was no significant difference between healthy young and older adults in RTP and APAP in the unobstructed and obstructed conditions. TUG test was the most sensitive indicator of falling between two groups. **Conclusion:** Information processing capacity for motor planning and proper strategy selection in pre crossing phase of obstacle negotiation did not have significant difference in healthy old and young groups. Maybe in respect to select healthy older adults without any neurological disorders and cognitive impairments, low attention demand of well learned walking and obstacle negotiation tasks, lead to perform both postural task more automatically and without any significant difference detection.

## Keywords

Obstacle Negotiation, Fall, Anticipatory Postural Adjustment Phase, Aging, Reaction Time Phase

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## 1. Introduction

About 35% - 53% of all falling in older adults is trip related. It necessitates more detailed studies to create more efficient intervention protocols to reduce this rate. Many older adults fall in transition phase, including gait initiation and termination [1]-[5]. Gait initiation (GI), as a voluntary destabilizing behavior, is a sensitive indicator of the dynamic postural stability dysfunction. It provides insight into postural control; and biomechanical changes that are related to aging and recognize falling risk in older adults [6]-[10]. Central nervous system (CNS) counteracts with environmental instability, with two types of strategies, compensatory and anticipatory postural adjustments (APAs). Compensatory strategies counteract real perturbation and APAs trigger before real perturbation to minimize it [3] [4]. GI requires APAs to effect on center of pressure (COP) trajectory by shifting it toward the supporting side, so that the leg can be raised [10]-[12]. GI when obstacle crossing, because of motor planning for obstacle clearance, needs more cognitive resources than steady state walking [1]. Some studies stated that, cognitive demands can disrupt balance and walking patterns, increasing the risk of falling [13]. Obstacle crossing, because of necessary motor planning for proper foot placement and visual inputs dependency, from pre-crossing phase is attention demand [1] [14] [15]. Obstacle negotiation, stress available cognitive resources and also aging is related to cognitive resources reduction [1] [16] [17]. APAs is affected by aging, and because of relation with CNS, it is an important factor to study dynamic balance [3] [4]. Rapid execution of stepping is another important factor in fall avoidance that aging declines speed of it because of changing in sensory motor systems. This ability in older adults decreases compared with young adults; consequently more time to initiate and execute a step can be a predictor of falling [13]. Therefore, rapid reaction time and shorter APAs time may be the key components of successful obstacle crossing to prevent falling [13] [18]. Previous works have studied reaction phase and anticipatory postural adjustments phase duration in pre-crossing phase of obstacle negotiation stated that, high risk falling participants had significantly longer APAs duration compared with low risk falling older adults [1]. This first study in 2011 reported, maybe high risk and low risk older adults fallers use the same motor planning in smooth walkway, but; because of additional attention cost by obstacle crossing, in obstructed walkway they had longer APAs duration in obstacle crossing [1]. Risk of falling has been evaluated in this study, but authors found no comparison study between healthy older and young adults concerning the effect of aging on APAs and reaction phase in GI with or without obstacle negotiation. In this study, we evaluate the effect of aging on these two important factors of GI in both smooth walkway and obstructed walkway (Table 1).

## 2. Method

Nineteen older adults (age:  $66.73 \pm 3.38$  year, height:  $162 \pm 0.6$  cm, weight:  $69.47 \pm 9.87$  Kg) and twelve young adults (age:  $26.5 \pm 4.37$  year, height:  $163 \pm 0.7$  cm, weight:  $54.83 \pm 5.20$  Kg) participated in this study. Inclusion criteria in the study were as follows: participants had to be 20 years or older, and be able to initiate gait and walk independently, live independently in the community, be able to understand auditory cue to initiate gait, score more than 24 in Mini-Mental State Examination, and no depression and anxiety, according to HADS-anxiety and HADS-depression scores. Subjects were excluded if they had neurological or musculoskeletal disorders or significant auditory and visual impairments. All subjects signed an informed consent form approved by the ethics committee at Tehran University of medical science.

### 2.1. Protocol

All tests were assessed by the same rater, in the same laboratory environment. For all conditions of tests, mean

**Table 1.** Abbreviations list.

Abbreviation	Full meaning
APAP	Anticipatory postural adjustments phase
ROC	Receiver operating characteristic
RTP	Reaction time phase
GI	Gait initiation
A	Area

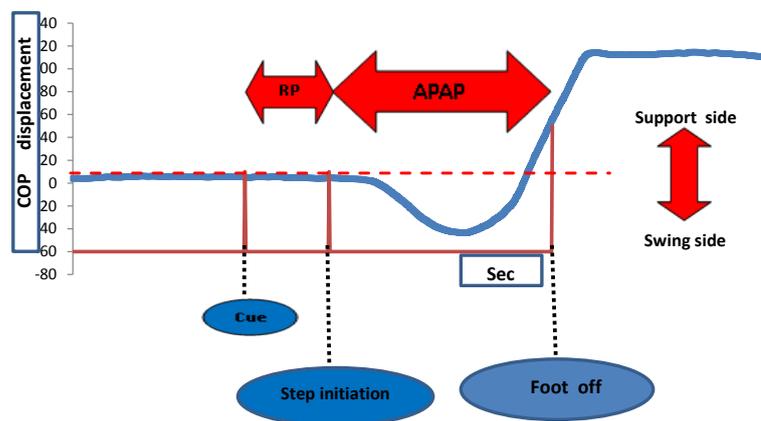
value of two repetitions with a time interval of 15 min, used as the final data for analyzing. The participants initially stood upright on the force platform and were instructed to load their weight equally on both right and left legs. The initial position of foot contact with platform was  $10^\circ$  abduction in every foot, and heels separated mediolaterally by about 6 cm, symmetrically related to the middle line of recording surface of the instrument [1]. Participants were instructed to make gaze at the black point center of a white circle with 2.5 cm radius in the red background that accommodates to every persons' eye level. This point was at the cross point between the line perpendicular on the line between two eyes and opposite wall [19]. They were allowed to see the floor and obstacle after the auditory cue. Auditory cue adjusted 2000 msec after onset of the force plate recording. This time was used to calculate initial COP position identified as mean amplitude in the 1500 ms period, prior to the onset of the auditory cue. The participants were instructed to initiate gait with self selected leg after auditory cue. The participants instructed to initiate gait with self selected leg as quickly as possible after auditory cue. In obstacle crossing, after gait initiation they should cross over obstacle. We defined the location of obstacle in 1m from the initial position because it is a length that older adults could not step over in the first step and would instead initiate anticipatory motor planning, which demands attention during gait initiation on the force platform. It has been reported that the average first-step length during gait initiation is 52.5 cm in healthy older adults with mean age of 73 years [1]. Previous studies stated that, walking speed of older adults in free velocity condition and in a range of 66 - 84, is 100 cm every second and we know usual gait speed declines with age and that those  $\geq 70$  years old show significant reductions in usual gait speed compared to those between 40 and 59 years old [20] [21]. Accordingly, all participants were under 70 years and consequently the speed of gait in all participants in our study was in a same range. If an obstacle were placed closer to initial standing point, anticipatory motor planning during GI would require little attention, because participants would know that they could cross the obstacle by the first step. Researchers let them check the location of the obstacle before the trial and instructed them to step over the obstacle. Step's numbers to the obstacle crossing was arbitrarily prescribed. The obstacle would tip with a small external force, so the risk of accidental falling by tripping was minimal. The obstacle was wooden and white (91.0 cm wide  $\times$  2.4 cm high  $\times$  1.0 cm deep). The walkway floor was brown. The contrast between obstacle and floor was sufficient to see the obstacle easily. Tests were performed in two conditions for both groups. Normal gait initiation on smooth walk way and Normal gait initiation on obstructed walkway with an obstacle placed 1m from initial position. Tests were randomly performed. Before data collection, participants performed one trial to familiarize themselves with equipment and gait initiation tasks. All persons participated in Timed "Up" and "Go" test (TUG), the only functional test in this study before other measurements. In this test, all participants were instructed to stand up from a standard chair with seat height of 40 cm, and walk a distance of 3m at a normal pace and turn, then walk back to the chair and finally sit down. The time between the moment of "go" and the moment when participant's back touched the chair backrest, measured in second. Data after first

## 2.2. Data Collection and Statistics

COP data were obtained, using Bertec Columbus, Ohio, USA, force platform, sampling rate: 1000 Hz, sensitivity: 10, height: 15.2 cm, size: 90  $\times$  90 cm, and low-pass filter at 3 Hz. The analysis of GI data extracted specific temporal events, using a program written in Excel [1]. The following timing events calculated from the COP trajectory. First, step initiation was defined as the first mediolateral deviation of the COP toward the swing leg (COP excursion  $>3 SD$  away from the initial COP position defined as the mean amplitude in the 1500 ms period prior to the onset of the auditory cue), and second, foot-off was defined as the end of the mediolateral shift of the COP toward the stance leg (absolute COP slope  $<100$  mm/s, two samples in a row) [1] [3]. The reaction phase was calculated as the time from cue to step initiation. The APA phase was calculated as the time from step initiation to foot-off **Figure 1**. In both groups (young, old), we used paired sample *t-test* separately to compare reaction time phase (RTP) and anticipatory postural adjustments phase (APAP) in smooth walkway and obstacle crossing. Then we used independent paired *t-test* to evaluate RTP, APAP and TUG test differences between young and old groups in two conditions. Statistical significance defined as a probability of  $p < 0.05$ . To evaluate the sensitivity and specificity of these parameters to differentiate between two groups, we used receiver operating characteristic (ROC) for analyzing.

## 3. Results

There were no dangerous unsuccessful crossings or obstacle contacts recorded in this study. **Table 2**, depicts



**Figure 1.** Mediolateral Center of pressure trajectory in gait initiation. The following timing events are marked in this figure: onset of the auditory cue (cue), the first mediolateral deviation of the center of pressure (COP) toward the swing side (step initiation), and the end of the mediolateral shift of the COP toward the stance leg (foot-off); RP: Reaction phase; APAP: Anticipatory postural adjustment phase.

**Table 2.** Comparative data in different conditions between two groups.

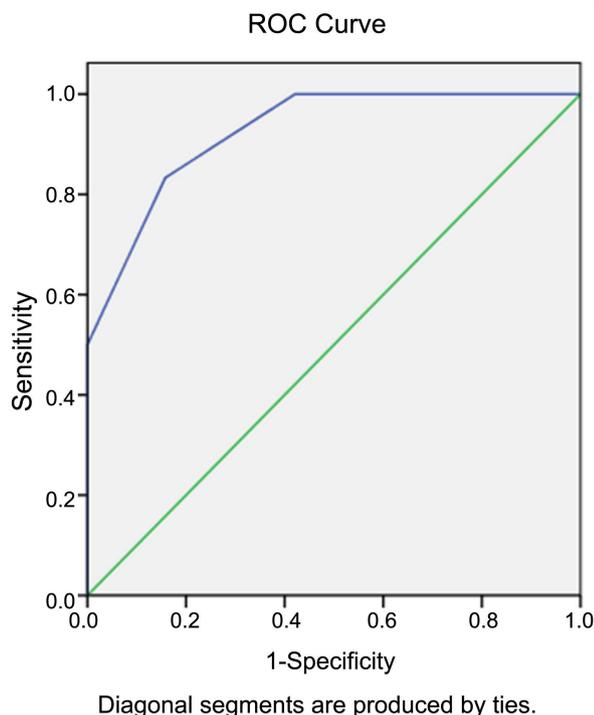
	Unobstructed		Obstructed	
	Young	Old	Young	Old
RTP, s	0.39 (0.08)	0.42 (0.07)	0.40 (0.06)	0.43 (0.10)
APAP, s	0.48 (0.06)	0.49 (0.10)	0.50 (0.10)	0.52 (0.11)

RTP, s: Reaction time phase (second); APA, s: Anticipatory postural adjustment (second).

two dependent variables for young and old participants in the individual task condition (**Table 2**). In paired *t-test* in healthy old group, the difference between reaction time in two conditions (smooth walkway and obstructed way) was not significant ( $p = 0.74$ ). There was no statistical difference between anticipatory postural phase in this two conditions ( $p = 0.27$ ). Same analysis of paired *t-test* in healthy young group explored that, the difference between reaction time in two conditions was not significant ( $p = 0.84$ ) and also there was no statistical difference between anticipatory postural phase in these two conditions ( $p = 0.39$ ). Independent paired *t-test* was used to evaluate difference of these two dependent variables and TUG test between two groups. The reaction time phase on smooth walkway ( $p = 0.30$ ), and RTP on obstructed walkway ( $p = 0.37$ ) had no significantly difference between groups. In other part, APAs comparison between two groups explored, this parameter on smooth walkway ( $p = 0.81$ ) and on obstructed walkway ( $p = 0.61$ ) had no significantly difference between two groups. Only the time of TUG test had statistically significant difference between two groups ( $p = 0.00$ ). The area for RTP on smooth walkway ( $A = 0.64$ ), RTP on obstructed walkway ( $A = 0.55$ ), APAP on smooth walkway ( $A = 0.53$ ), APAP on obstructed way ( $A = 0.56$ ) and the most sensitive indicator, TUG functional test ( $A = 0.94$ ), calculated in receiver operating characteristic analysis (**Figure 2**).

#### 4. Discussion

There was no significant difference between young and old groups in the reaction or APA phases in smooth walkway. This indicates that all young and old groups' participants use the same motor program with same information processing speed in normal gait initiation task. In information processing model, we have three main compartments; stimulus identification, response selection and response programming. In stimulus identification, central nervous system knows what happens in environment, in the second step decide about what response to make and later part is organization and initiation of action [20]. On the other hand, in our study because of inclusion criteria, we choose only healthy older adults without any neurological and physiological disorders, thus; all information processing stages in pre crossing phase of old participants had same efficiency as young partici-



**Figure 2.** Receiver operating characteristic analysis for TUG functional test.

pants. In the other part, we had no significant difference between two groups in RTP or APA phases under obstructed walkway when crossing obstacle. The pre crossing phase of obstacle negotiation is a visually dependent process and this additional visual related processing factor, affect as a cognitive load on information processing process when obstacle crossing [1] [14] [15]. Greany and coworkers stated delayed saccade-foot lift in elderly community dwellers having high risk of falling that is probably related to the greater time of central processing to plan precise foot placement [22]. Uemura and colleagues stated that maybe central cognitive processing delay is responsible for long duration planning of anticipatory strategies in high risk falling older adults [1]. Accordingly, they had insufficiency to select proper strategy in response selection or in response programming of information processing. Some researchers reported altered selected postural synergies (*i.e.*, weak response of gluteus medius on the stepping side, antagonist muscles co-contraction), that is related to cognitive load of motor planning for obstacle negotiation [1]. Despite these researches, we found no statistical significant difference between healthy young and older adults in two pre crossing obstacle negotiation parameters (RTP and APAP), in respect to select healthy older adults, the speed of central information processing in pre crossing phase of obstacle negotiation had the same efficiency in both groups. RTP and APAP in both conditions, were longer than young adults (**Table 1**), but the difference didn't reach a significant level. Learning influence on stages of information processing especially pattern recognition of stimulus identification stage. It sounds that obstacle negotiation is a well learned condition in healthy older adults, that make closed two groups in processing speed. In another perspective, maybe with more participants, we had detected these differences.

The TUG, is a simple, quick and valid clinical performance-based measure of lower extremity function, mobility and fall risk used a lot in elderly populations evaluation [23]. Recently researchers stated that, in community-dwelling older people, TUG performance is influenced by several factors including cognitive function and health status [5]. Our evaluation according to calculated area under TUG functional test curve, explored TUG functional test had the most sensitivity to differentiate between two healthy young and older groups as a fall predictor ( $A = 0.92$ ). This indicated, the main difference between two groups was in mobility characteristics, such as; range of motion in joints and amount of force transferred from one leg to another, but; the capability of central information processing to select proper strategies was closed in two groups may be related to insufficient cognitive load to create more difficult postural task and in the other hand, our postural task was well learned in

both groups.

## 5. Conclusions

This study is the first study comparing two important fall predictors of pre crossing phase of obstacle negotiation in gait initiation (RTP and APAP) between healthy young and healthy old participants. It reported no statistical significant difference between two groups. This stated enough central capability of information processing for motor planning and strategy selection. Maybe, well learned postural task and healthy status of our old participants, have closed the performance of two groups. Functional TUG test performance identified as the most sensitive fall predictor in this study.

It is suggested to evaluate these parameters using dual task paradigm to impose more cognitive overload in gait initiation task with and without obstacle crossing in future studies.

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## Conflict of Interest Statement

The authors declare no known conflicts of interest.

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