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Vision and agility training in community dwelling older adults: Incorporating visual training into programs for fall prevention

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Abstract

This study aimed to examine the effect of visual training on obstacle course performance of independent community dwelling older adults. Agility is the ability to rapidly alter ongoing motor patterns, an important aspect of mobility which is required in obstacle avoidance. However, visual information is also a critical factor in successful obstacle avoidance. We compared obstacle course performance of a group that trained in visually driven body movements and agility drills, to a group that trained only in agility drills. We also included a control group that followed the American College of Sports Medicine exercise recommendations for older adults. Significant gains in fitness, mobility and power were observed across all training groups. Obstacle course performance results revealed that visual training had the greatest improvement on obstacle course performance (22%) following a 12 week training program. These results suggest that visual training may be an important consideration for fall prevention programs.

Keywords

Mobility; Balance; Older adults; Fall prevention; Visual training; Wii; Obstacle course

1. Introduction

A number of independent factors predict falls in older adults: age (>65 years), arthritis, impairment in activities of daily living, depression, diabetes and hypertension to name a few [1]. Other significant factors such as decreased processing of visual stimuli [1,2] limitations to cognitive processing [3], and slow reaction time [4] also contribute to falling incidents. Guidelines provided by the American College of Sports Medicine (ACSM) and American/British Geriatrics Societies recommend aerobic activity, muscle-strengthening, flexibility and balance exercises for older adults [5,6]. However, such recommendations do not address the complex nature of falling and miss key components necessary to improve mobility (the ability to independently and safely move oneself from place to place [7]) in older adults.

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Conflict of interest statement
The authors declare that there are no conflicts of interest.

When performing activities of daily living (ADLs), such as walking around the home, older adults must negotiate obstacles such as furniture and objects on the ground. These obstacles require older adults to change their walking pattern by stepping over or around them. During obstacle avoidance, an individual is forced to modify ongoing movement patterns using available visual, vestibular and somatosensory information [8,9]. Available response time (ART) is the amount of time available from obstacle detection to collision [10]. In this time period, the central nervous system must process visual information regarding the obstacle's position and characteristics, as well as self motion information such as relative velocity and body position, to determine a modified movement pattern that can be safely adopted [8-10]. Clearly, older adults are at the greatest risk for obstacle collision when ARTs are short, as visual processing time increases and reaction time decreases with age [10,11]. Therefore, it is not surprising that studies have shown that most falls among older adults occur due to obstacles in the walking path [11-14].

Generally, fall prevention and physical activity programs for older adults are insensitive to the importance of visual information in adaptive motor control. Manual resistance training, cardiovascular endurance, and balance exercises are beneficial [15], but are unlikely to improve the neural processes involved in visually guided adaptive locomotion. Agility, referring to the ability to move freely and swiftly, is closely linked to reduction of falls in older adults [16]. Repeatedly training adaptive body responses may improve movement patterns to avoid obstacles. While, visual training may strengthen the central pathways associated with the visual control of adaptive locomotion for obstacle avoidance [8,9,17].

In addition, the use of obstacle courses, instead of the standard Timed-Up-and-Go test (TUG) [20,21], may provide additional information regarding deficits in mobility as they include environmental hazards typically encountered during ADLs [13,18,19]. Obstacle course performance is dependent on the effective integration of sensory input (visual identification of objects) and motor output (adaptive locomotion). It measures the integrity of physiological systems responsible for balance and adaptive locomotion as a whole [18].

The purpose of this study was to investigate the effectiveness of visual and agility training on balance and mobility capabilities of independent community dwelling older adults when implemented in addition to the basic physical activity recommendations for older adults. This study used an obstacle course for the evaluation of mobility performance in independent community dwelling older adults. It was hypothesized that visual training would challenge older adults to frequently modify their movement patterns in response to imminent object collision, and provide better training for obstacle avoidance. To date, there are limited studies addressing visual response training for obstacle avoidance in older adults [22,23].

2. Methods

2.1. Participants

Forty-nine older adults (35 female and 14 male) mean ± SD age 67.5 ± 5.9, participated in the intervention. Of the forty-nine individuals 14 had experienced a fall within the last year with 10 of those falls resulting in serious injury. Prior to inclusion in the study, older adults were asked to complete a health and fall history questionnaire and provide written approval from their health care provider.

Recruited older adults were randomly assigned to one of three experimental training groups: (1) CONTROL, a group following the ACSM exercise recommendations for older adults; (2) AGILITY, a group with additional exposure to agility training; and (3) VISUAL, a group with additional agility training and visual training. Approval was obtained from The

University of Texas at El Paso Institutional Review Board prior to the start of the training study.

2.2. Training protocol

The total involvement in the physical activity program was normalized among the three groups (Table 1). All participants engaged in two 90-min exercise sessions weekly for 12 weeks, to include cardiovascular exercises, muscular strength activities, balance drills, and stretching following the ACSM guidelines [5]. All three groups performed the same set, repetition, intensity and rest time specifications. The only training differences among the groups were the added agility and visual training activities in the AGILITY and VISUAL groups, which replaced extra cardiovascular endurance training performed by the CONTROL group (Table 1).

Cardiovascular endurance exercises included activities on the treadmill, cycle ergometer, and elliptical trainer with a predetermined intensity and duration. All participants exercised on each piece of equipment in each session. Strength training included a variety of body weight, free weight, machine, medicine and Swiss ball, and rubber band exercises targeting all major muscle groups of the upper- and lower-body. Generally, two to four sets of eight to twelve repetitions were completed for each strength training exercise, under the close attention of qualified student trainers. All participants performed the same number of sets and repetitions but the amount of weight lifted was individualized. Balance activities included Swiss ball, wobble disc, and foam roller exercises, as well as practicing various single leg standing and modified yoga positions. Agility training included low and high hurdle activities, as well as agility ladder and cone agility drills.

Visual training (VISUAL group) was conducted using the Nintendo® Wii Fit Plus with Wii Balance Board. The games played involved directing the body's center of pressure while dodging objects presented by the video game. Video games were back projected onto a rear projection screen while participants stood one meter from the screen on the balance board. The visual angle of display was 60°, therefore objects appeared as if coming toward the participant from their center and moving to their periphery.

2.3. Performance assessment

Assessment included fitness and muscular power tests and an obstacle course. The fitness tests followed the procedures proposed by Rikli and Jones [20] to assess functional fitness in older adults. Assessment included hand grip dynamometry (isometric upper-body muscular strength); 30-s chair stand and 30-s arm curl tests (lower- and upper-body muscular endurance); 6-min walk test (cardiovascular fitness); forward reach test (balance), and (8 ft) Timed-Up-and-Go test (motor agility and dynamic balance).

Additional fitness tests were included to assess muscular power. A ramp walk power test [24] assessed participant's lower limb power. Two different ramp sizes were used: a short ramp with a 5.53 m walking distance at 4.1° angle, and a long ramp with a 19.05 m walking distance at 7.9° angle. The two ramps allowed for power assessment for both short and endurance bursts. For assessing upper body muscular power, the Gallon-Jug Shelf-Transfer Test [25] and medicine ball chest-press throw test were used.

An obstacle course was used as an integrated measure of visually guided mobility. The obstacles included rising from a chair, stepping over, ducking under, going around, picking a weight off the ground, going up and down steps, walking along a foam beam, turning 360° around an obstacle and sitting back in a chair at the start position (Fig. 1). Time was recorded using a stopwatch and started on the command "Go" and ended as the participant sat back in the chair. The number of obstacle collisions was recorded during performance on

a topographical figure of the course. Participants performed two obstacle trials and means were calculated. Performance on the obstacle course was based on three dependent variables: completion time (CT), number of obstacle collisions (HITS), and combined CT + HITS. The CT + HITS observed any sacrifices in accuracy for faster time. To convert the number of HITS into a time variable, each HIT in a trial was multiplied by a 2.23 s time penalty and added to CT. The time penalty value was calculated from a time per hit analysis of obstacle course performance of ten healthy older adults (not involved in training).

Participants' performances on all physical tests were assessed Pre-training, Mid-training (6 weeks), and Post-training (12 weeks) using a General Linear Mixed Model Analysis for repeated measures with post hoc Bonferroni corrected pair-wise comparisons: Group (between subjects) and Time (within subjects). The independent variable *Time* represented the three training periods: Pre-, Mid-, and Post-training. Separate analyses were performed for the fitness data, obstacle time data, and obstacle contact data. For obstacle contact data a third independent variable, obstacle course section (*Section*), was used to assess where along the obstacle path HITS occurred. In addition, Pearson product correlations were conducted between participant fitness scores and obstacle course scores.

3. Results

Pre-, Mid-, and Post-training data were collected for forty-five older adults (33 females and 12 male). Four participants dropped out of the intervention due to personal reasons or unrelated health concerns. The forty-five participants who completed the intervention demonstrated a mean ± SD 78.9 ± 17.5% session attendance over the 12 week program.

3.1. Fitness tests

A significant main effect of *Time* $p < .001$ was found for all fitness measures. This main effect indicates significant improvement in strength, power and cardiovascular fitness across all groups for the 12 week intervention (Table 2).

3.2. Obstacle course

A significant main effect of *Time* was found for course time ($p < .001$; $\eta^2 = .560$). Pair-wise comparisons revealed that CT decreased significantly Pre- to Mid-training ($p < .001$), and Mid- to Post-training ($p = .003$). A significant main effect of *Time* was also found for CT + HITS ($p < .0001$; $\eta^2 = .468$). Pair-wise comparisons revealed that CT + HITS decreased significantly Pre- to Mid-training ($p < .001$) but not Mid- to Post-training. No significant effect of Group was found for these variables.

A significant interaction *Time* × *Group* was found for HITS ($p < .001$; $\eta^2 = .212$).

To evaluate this interaction, we split by *Group* to observe the effect of *Time* on HITS in each group. Results revealed that only the VISUAL group had a significant effect of *Time* on their HITS ($p < .001$; $\eta^2 = .614$). Pair-wise comparisons (VISUAL group) revealed decreased HITS occurred between Pre-and Mid-training ($p < .001$). HITS did not significantly decrease between Mid-and Post-training. In addition, a significant main effect of *Section* was found ($p < .001$; $\eta^2 = .315$). Pair-wise comparisons revealed that a significantly greater ($p < .001$) number of HITS were made in sections 2 and 3 of the obstacle course (Fig. 1).

Fig. 2A illustrates CT improvements from Pre- to Mid-training and Mid- to Post-training for all three groups. Fig. 2B illustrates that the VISUAL group had the greatest decrease in HITS followed by the AGILITY group. The CONTROL group actually increased their HITS. Fig. 2C illustrates that the VISUAL group had the greatest overall improvement

(22%) increasing their accuracy in shorter completion times. The AGILITY and CONTROL groups decreased CT + HITS scores by 18% and 11%, respectively.

3.3. Correlation of measures

The obstacle course variables CT and CT + HITS were found to correlate significantly with a number of fitness measures. Most notably the correlation with the TUG and ramp tests were above 80%. These high correlations supports that the obstacle course is a valid comprehensive functional test for mobility, agility, and muscular power (Table 3).

4. Discussion

Muscular strength, cardiovascular endurance, and flexibility only contribute to part of the ability to prevent falls resulting from contacting an obstacle. In order to effectively avoid an obstacle, visual information regarding the object and self motion have a large contribution [8,9]. Thus visual information is a critical aspect to obstacle avoidance and may be an area where new approaches to training can benefit fall prevention. The findings of the current study suggest that visual training improves obstacle avoidance above and beyond gains seen with fitness training alone. Agility training may improve older adults' reflexes and ability to execute rapid body movements enabling effective balance control [15,16]. Visual training may improve visual processing, attention and cognition of visual information pertaining to obstacle avoidance [2,17,22,26].

The Nintendo Wii® was used as a tool to train visual responses to obstacles. Based on previous studies [17,22,23] we hypothesized that the use of virtual reality would enhance the function of visual perception-action systems. Participants trained on games chosen specifically for the visual stimuli provided e.g. time to contact, smooth pursuit, and selective visual attention [9,26,27]. For example, a soccer heading game required individuals to direct their COP to the left or right to head soccer balls kicked toward them. Distracters were presented (e.g. shoes kicked toward the player) so individuals had to be able to select the correct object to avoid as it approached.

Following the 12 week training program, significant improvements in muscular strength, cardiovascular endurance and muscular power were observed for all participants (Table 2). This was expected as all participants engaged in exercises aimed to improve these factors. The most interesting results were observed in the obstacle course, a measure intended to go beyond physical fitness and provide an integrated evaluation of visually guided body control. All groups significantly reduced their course time (CT) over the 12 weeks (Fig. 2A). Mean ± SD post training CTs for each group: CON 23.71 ± 4.38, AGILITY 22.05 ± 4.51, and VISUAL 26.32 ± 6.46. However, a significant reduction in HITS was only observed in the VISUAL group (Fig. 2B), suggesting that visual training provided advantages specific to the ability to avoid obstacles.

There are two possible mechanisms through which visual training may improve obstacle avoidance. One mechanism is that the visual training improves visual processing and visual attention thereby improving ones' ability to detect and react to obstacles in the path. Decreased visual processing and selective attention in older adults are associated with greater obstacle collisions [26]. The second mechanism is that training center of mass (COM) control via direct online visual feedback significantly improves ones' ability to adapt locomotion for obstacle avoidance. However, one argument to the latter is that agility training also trains adaptive locomotion yet similar improvements were not found with agility training in the current study. Further research examining these potential mechanisms is clearly required, including studies examining visual perception, processing and cognition of visual information following Wii training.

Of note is that the majority of improvements observed in the study were seen in the first 6 weeks of the intervention. Reasons for a leveling off in the last 6 weeks could be due to plateaus in performance. Though 14 participants in this study had experienced a fall within the last year and had mobility difficulties, mean data indicates a fairly mobile older adult sample (e.g. TUG < 8 s; Table 2) who may have had limited room for improvement. Further study of older adults with greater mobility difficulties may yield a better indication of the impact of training.

In addition, the different training programs were not found to influence any particular section of the obstacle course. Overall, older adult participants had the greatest difficulty in sections that involved going around obstacles, picking a weight off the ground, going up and down steps (section 2); walking along a foam beam, and turning 360° (section 3). Again, inclusion of older adults with low mobility may provide greater insight into what aspects of mobility each training program affects.

High correlation of CT and CT + HITS with the TUG test, as well as other tests of muscular power and strength (both upper and lower body), support its use as a comprehensive tool for mobility assessment (Table 3). The HITS variable did not have significant correlation with the fitness tests, however; this may reflect the non-fitness nature of this measure. If HITS is related to efficiency in visual information, it could have higher correlation with tests of visual perception (e.g. visual processing speed). A limitation to the current study is that we used the obstacle course to infer improvements of visual perception. Therefore, the next logical step in the evaluation of visual training for fall prevention would be to use tests of visual perception and determine whether visual perception improves with Wii.

The findings of this initial study suggest that visual training improves obstacle avoidance. Further research is clearly required to study the mechanisms that occur with this training. The gains achieved with visual training also need to be teased apart from those of agility training. The Wii® has the potential to serve as a useful training tool for frail and clinical populations in the home and clinic. Training can be done in the safety of a stationary apparatus that can be accessorized with balance bars or harnesses. Though, the Wii® training of this study involved demanding postural tasks, there are a variety of games and levels that are less demanding and could provide flexibility for tailoring training to an individual’s abilities.

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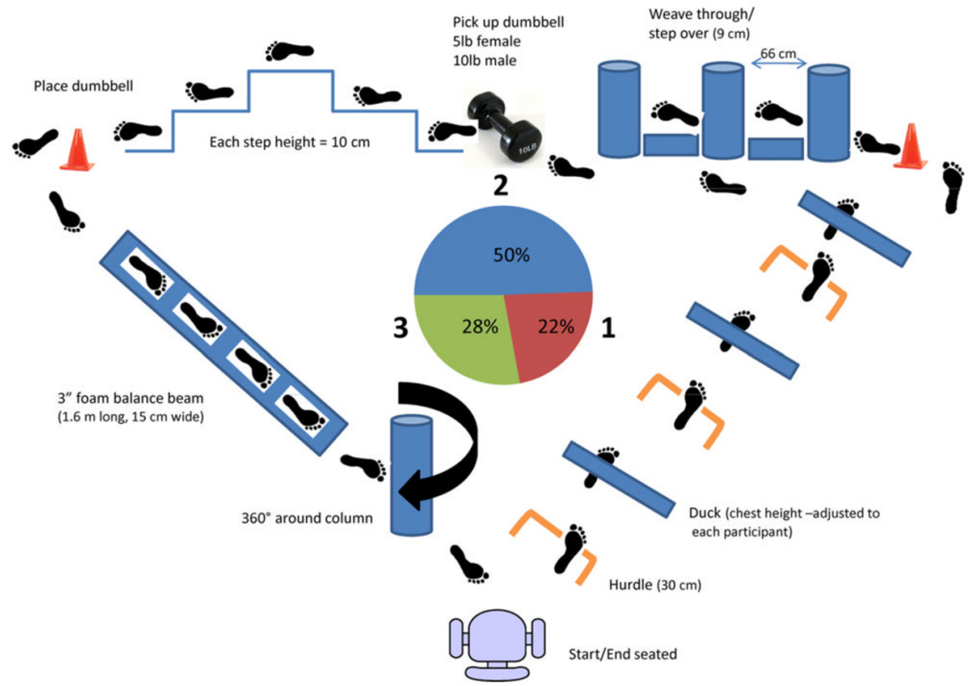

Fig. 1.

Schematic of the obstacle course used for integrated assessment of older adult mobility, balance, agility and visual perception. The obstacle course was divided into three sections. At center a pie chart illustrates the overall mean percentage of HITS scored for each section of the course.

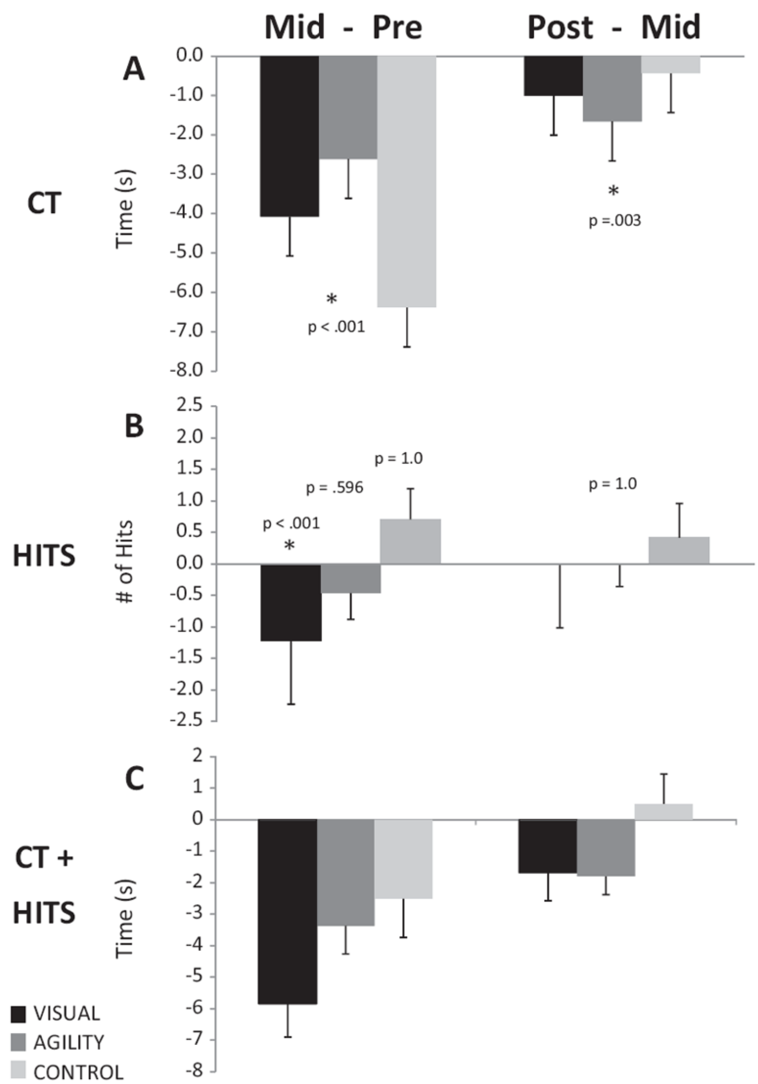

Fig. 2.

Summary of the obstacle course results: all variables are presented as mean + SE difference measures between Pre- and Mid-training, and Pre- and Post-training. (A) Comparison of the course completion time (CT) difference for the three experimental groups. (B) Comparison of the HITS difference for the three experimental groups. (C) Comparison of the combined CT + HITS variable for the three experimental groups. Note that a greater negative indicates a greater reduction in course time (CT) or obstacle collisions (HITS) in the second test.

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Table 1

A simplified representation of a single 90-min exercise session for the CONTROL, AGILITY and VISUAL groups.

CONTROL group		**AGILITY group**		**VISUAL group**	
Focus: exercise program following the ACSM recommendations		**Focus: exercise program with additional agility training**		**Focus: exercise program with additional agility and visual training**	
Activity	**Duration**	**Activity**	**Duration**	**Activity**	**Duration**
Warm-up	5 min	Warm-up	5 min	Warm-up	5 min
Two strength exercises	5 min	Two strength exercises	5 min	Two strength exercises	5 min
Cardiovascular activity	5 min	Cardiovascular activity	5 min	Cardiovascular activity	5 min
Two strength exercises	5 min	Two strength exercises	5 min	Two strength exercises	5 min
Cardiovascular activity	5 min	*Two agility exercises*	5 min	*Two agility exercises*	5 min
Two strength exercises	5 min	Two strength exercises	5 min	Two strength exercises	5 min
Two balance exercises	10 min	Two balance exercises	10 min	Two balance exercises	10 min
Two strength exercises	5 min	Two strength exercises	5 min	Two strength exercises	5 min
One balance exercise	5 min	One balance exercise	5 min	One balance exercise	5 min
Cardiovascular activity	10 min	*Three agility exercises*	10 min	*Three agility exercises*	10 min
Two strength exercises	5 min	Two strength exercises	5 min	Two strength exercises	5 min
Cardiovascular activity	15 min	Cardiovascular activity	15 min	*Visual training*	15 min
Flexibility training	10 min	Flexibility training	10 min	Flexibility training	10 min
Total	90 min	Total	90 min	Total	90 min

Table 2

Summary of fitness tests results (mean ± standard deviation) for the three experimental groups.

Component	Test	CONTROL group			AGILITY group			VISUAL group		
		Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Anthr.	BMI	28.7 ± 6.2	28.6 ± 6.1	28.7 ± 6.1	28.7 ± 5.8	28.7 ± 5.8	28.2 ± 5.7	28.6 ± 5.2	29.5 ± 5.9	28.2 ± 5.0
Strength *	Hand grip (kg)	31.0 ± 8.4	31.7 ± 9.3	32.5 ± 8.5	30.2 ± 8.1	30.4 ± 7.5	31.9 ± 9.1	27.5 ± 8.0	27.9 ± 7.5	27.6 ± 7.5
	Arm curl (#)	18.5 ± 2.1	22.2 ± 3.0	25.9 ± 2.8	19.8 ± 3.3	23.7 ± 3.8	26.0 ± 2.5	19.5 ± 4.6	21.7 ± 5.2	22.9 ± 4.2
	Chair stand (#)	18.7 ± 5.4	21.3 ± 5.9	23.6 ± 6.7	15.6 ± 5.7	18.3 ± 5.7	20.3 ± 5.9	15.3 ± 6.0	17.0 ± 6.2	19.0 ± 6.5
Cardio fitness *	6-min walk (yd)	688 ± 102	687 ± 121	718 ± 121	672 ± 73	686 ± 96	684 ± 108	575 ± 137	552 ± 174	615 ± 131
Power *	Gallon Jug (s)	7.6 ± 0.9	7.2 ± 0.7	6.7 ± 0.5	7.2 ± 0.9	7.2 ± 0.6	7.1 ± 0.4	8.0 ± 1.3	8.1 ± 1.5	7.8 ± 1.2
	Long ramp (s)	9.5 ± 1.8	8.6 ± 1.4	8.3 ± 1.6	9.8 ± 1.8	9.0 ± 1.6	8.2 ± 1.5	11.4 ± 3.7	12.0 ± 7.1	10.3 ± 2.7
	Short ramp (s)	2.7 ± 0.5	2.4 ± 0.5	2.1 ± 0.3	2.4 ± 0.5	2.2 ± 0.4	2.0 ± 0.4	2.7 ± 0.8	2.7 ± 1.1	2.3 ± 0.5
	Medicine Ball Throw (m)	4.4 ± 1.0	4.6 ± 0.7	4.7 ± 0.7	4.7 ± 1.0	4.5 ± 0.9	5.0 ± 1.0	4.3 ± 0.8	4.3 ± 0.9	4.6 ± 0.8
Balance and mobility *	Forw. reach (in.)	18.8 ± 1.8	20.0 ± 1.7	20.3 ± 1.5	18.5 ± 2.4	19.2 ± 2.5	20.0 ± 2.2	18.4 ± 1.6	19.0 ± 1.8	19.6 ± 1.8
	TUG (s)	5.7 ± 1.0	5.0 ± 0.6	5.0 ± 0.6	5.5 ± 0.8	5.3 ± 0.8	5.1 ± 0.6	6.5 ± 2.3	6.3 ± 2.4	5.4 ± 1.1

* Significant time effect ($p < .001$) found for all strength, cardio fitness, power, and balance/mobility measures.

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Table 3

A summary of Pearson product correlation coefficients between obstacle course scores and fitness measures.

N = 45	Forward reach	Gallon Jug	Up and Go	Chair stand	Arm curl	Long ramp	Short ramp	Medicine Ball Throw
CT	−.455**	.632**	.822**	−.760	−.424**	.813**	.700**	.476**
HITS	−.044	.164	.326	−.227	−.200	.310	.241	−.303
HITS + CT	−.450**	.697**	.958**	−.151	−.520**	.950**	.891**	−.712**

** Correlation significant $p < .001$ level (2-tailed).