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CLINICAL REPORT

The Obstacle Course: A Tool for the Assessment of Functional Balance and Mobility In the Elderly

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Abstract—Many conventional methods employed in the assessment of balance and mobility in the elderly are expensive, difficult to administer, rely heavily on complex technology, or provide limited functional information so essential to the planning and implementation of rehabilitation interventions. The author has developed a functionally oriented obstacle course for use in the rehabilitation setting, to aid in the evaluation of elderly subjects with balance and mobility dysfunction. The obstacle course consists of 12 simulated functional tasks. Qualitative and quantitative individual task and overall scores are given for each obstacle course performance. A description of the design and rationale for the obstacle course is presented. For demonstration purposes, nonexperimental obstacle course performance data from a small group of elderly volunteers is included. With further validation studies, the obstacle course has potential to become a useful tool in the evaluation and rehabilitation of balance and mobility disorders, in order to aid in the prevention of falls and fall-related injuries in the elderly.

Key words: *balance, elderly, fall-related injuries, mobility dysfunction.*

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INTRODUCTION

Falls and fall-related injuries pose a serious threat to the health and independence of elderly persons. Hip fracture from falling is associated with significant morbidity, mortality (1,2), and functional limitation (3). This functional limitation may lead to secondary complications and premature institutionalization.

The actual cause of falling in individual cases is multifactored, and involves the interaction of intrinsic and environmental factors, which reduce the effectiveness of the body's balance control mechanism (4–9). The interactive etiology of falls and the difficulty in reproducing realistic environmental conditions in the clinical or research setting, makes evaluation of balance problems and falls problematic.

Numerous methods of evaluating balance and mobility in elderly subjects with and without dysfunction have been proposed. Sophisticated techniques have been developed including computerized motion analysis systems (10), instrumented platforms (11–13), and computerized posturography (14–16). Commonly, these complex technological methods require expensive specialized equipment and extensive training to administer. Many complex methods are impractical in most clinical settings that serve the elderly population.

In contrast, simple methods have been proposed to evaluate balance and mobility in the elderly. These methods include the "get up and go test" (17), the "postural stress test" (18), the "timed balance test"

(19), and Tinetti's "performance-oriented assessment of mobility" (20). These tests do not require significant technology, equipment, or expense and are relatively easy for the clinician to administer. Of these methods, only the last one has been tested extensively in elderly subjects and has been found to have some advantages over a standard neuromuscular examination in identifying mobility problems (21). However, even the Tinetti mobility assessment, which consists of a variety of maneuvers intended to stress physiologic balance, provides a limited amount of functional information.

In our medical center, we have developed an interdisciplinary clinic for veterans with falls and mobility problems (22). Services provided by this clinic include a home visit to evaluate environmental hazards in and around the home. The obstacles included in the obstacle course were selected largely on the basis of environmental challenges most commonly experienced by veterans seen in this clinic. The environmental challenges that patients face in and around the home, especially patients living in rural areas, are difficult to reproduce within the time and physical constraints of most clinical settings, using standard physical examination techniques. Functional balance and mobility deficits may, therefore, go undetected during a routine clinical evaluation.

Short-term response to a hospital-based rehabilitation program, is often difficult to assess. It is often unclear as to how much functional carry over has occurred as the elderly patient returns home to confront real-life environmental obstacles. An ideal (though impractical) solution to this problem would be for clinicians to evaluate every patient at home. A reasonable alternative is an evaluation using simulations of obstacles commonly encountered at home, but based in the clinic.

Obstacle courses have been used by relatively few investigators to evaluate various pediatric and adult clinical conditions (23–27). Attix and Nichols (23) described an obstacle course consisting of bending, pushing and pulling activities, as well as walking around barriers, which they used to evaluate posture and body mechanics among patients receiving treatment for low back pain. Thompson and associates (26) used an obstacle course consisting of negotiating steps, walking on a plank and over objects, and turning in a chair and picking up an object, to test neuromotor function of physically impaired elderly subjects after participation in a conditioning exercise program.

Imms and Eldholm (27) used performance on an obstacle course, which included rising from a chair, walking across a room, and ascending and descending three steps, in a study of gait and mobility in a mixed sample of institutionalized and community-dwelling elderly subjects. The obstacle course described by Imms and Eldholm, like our own, was videotaped, and included timed scores and qualitative scores determined by the number of faults observed by a rater. Performance scores were positively correlated with the walking speed of the subjects and were unrelated to the subjects' age and history of falls. More recently, Brown et al. (28) used timed performance on two functional activities (walking and rising from a chair) and completion of a 12-ft long obstacle course to evaluate the relationship between muscle strength and physical performance in frail elderly subjects. A description of the content of the obstacle course was not included in their report. Few other studies could be found in the literature, in which an obstacle course was used to evaluate balance and mobility problems in community-dwelling elderly persons.

The concept of using realistic environmental situations to evaluate function has also been used in a commercial product. Easy Street Environments® (Habitat, Inc., Scottsdale, AZ), introduced in 1984 by David Guynes Design, Inc. and Health Services Marketing, Ltd., Phoenix, AZ, contains a series of modular units simulating a variety of everyday home, community, and hospital settings (bus stop, restaurant counter, living room, etc.). Each setting includes several realistic obstacles (stairs, chairs, curbs, and so forth). These obstacles have been used to assess and treat patients with a variety of health conditions. Unfortunately, Easy Street Environments often involves significant construction costs and space requirements, and though its use has gained popularity, its efficacy has not been well-documented. Few descriptive reports and no scientific studies using Easy Street Environments could be found in the scientific literature (29–31).

The purpose of this report is to describe a new obstacle course and testing procedure. Preliminary nonexperimental sample performance data from volunteer subjects are presented for demonstration purposes.

METHODS

The Obstacle Course

The Obstacle Course consists of a series of 12 stations where functional tasks or simulations of common functional conditions encountered in and around the home environment are presented. The layout and actual order of presentation of the obstacles is depicted in the schematic diagram shown in **Figure 1**. The obstacle course stations, designed to challenge different physiologic strategies used in balance control and ambulation, are as follows: four stations with different types of floor surfaces, two ramps, two sets of stairs, and four discrete functional tasks (opening a door, rising from a chair, walking around, and stepping over obstacles).

Layout of the Obstacle Course

The configuration of the obstacle course can be customized to fit a variety of clinical areas. Our obstacle course was set up in an existing physical therapy room. A 7.6 m×9.1 m (69 m^2 or 750 ft^2) room dedicated for this purpose, with a vinyl tile floor and an adjacent hallway is ideal. If necessary, the obstacle course can be set up within a smaller area with minor variations in the course configuration of obstacles and the corresponding inter-obstacle distances. However, for reproducibility and comparison purposes, the exact configuration and inter-obstacle distances (listed in **Table 1**) should be maintained.

Stations of the Obstacle Course

1. Four stations involve walking across different types of floor textures, including sand (fine texture, loose support); pine bark chips (coarse texture, loose support); artificial turf to simulate grass (uneven texture, firm support); and deep pile carpeting (uneven texture, medium support). The different flooring surfaces are accomplished by insertion of a 61 cm × 2.44 m plywood flooring panel (**Figure 2**) covered with the material (carpet or turf) or a 61 cm × 2.44 m × 5.1 cm shallow tray (**Figure 3**) filled with the material (pine bark chips, sand), on a walkway. The walkway is placed between commercial parallel bars for maximum safety. Obstacles are interchanged while testing is in progress, unless multiple sets of parallel bars are available. Ideally, at least two sets of parallel bars are desirable.
2. Four stations include two graded surfaces (up and down ramps) and two types of commercial stairs. All subjects ambulate up to the end of the ramp, where it levels off, make a 180° turn and walk down. The ramp is constructed from plywood and covered with a non-skid finishing varnish (**Figure 4**). The grade of the up and down ramp is 20.32 cm rise or drop for each 2.44m in length. The grade conforms to the standard 1:12 rise to length ratio commonly used in the construction of accessible facilities. The ramp is also placed between parallel bars for safety. The parallel bars used are electronically height-adjustable and 3.66 m in length, with at least a 61 cm width between the bars (**Figure 5**). Manually adjusted parallel bars with these dimensions would suffice. The stairs used are the type commonly used in physical therapy departments. The stairs contain 2 varieties of steps; 8 low or shallow type steps (7.6 cm riser height by 25.4 cm tread length by 61 cm wide),

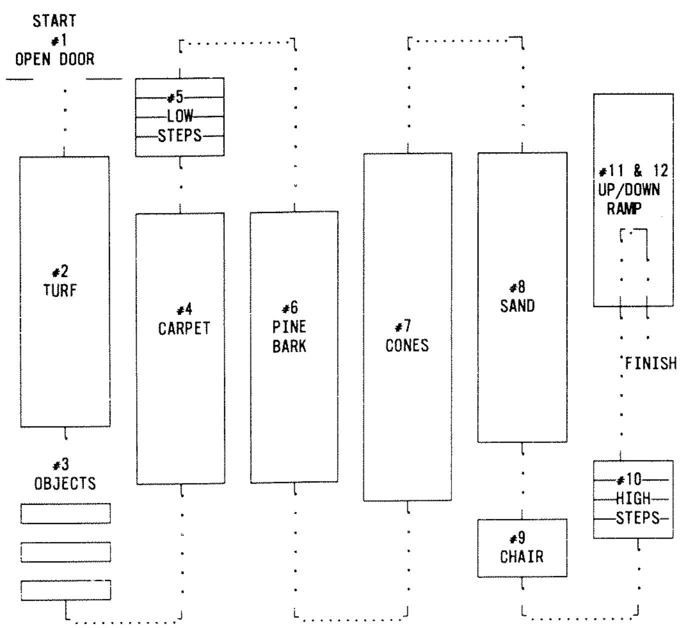

Figure 1.
Schematic representation of the obstacle course layout.

Table 1.
Inter-obstacle and overall distances of the obstacle course (in meters).

From	To	Distance
Door	Turf	8.53 m
Turf	Bolsters	5.21 m
Bolsters	Carpet	5.21 m
Carpet	Low Steps	7.19 m
Low Steps	Pine Bark	7.19 m
Pine Bark	Cones	11.62 m
Cones	Sand	10.85 m
Sand	Chair	11.92 m
Chair	High Steps	8.53 m
High Steps	Up Ramp	6.71 m
Up Ramp	Down Ramp	0.00 m
Start	Finish	106.27 m

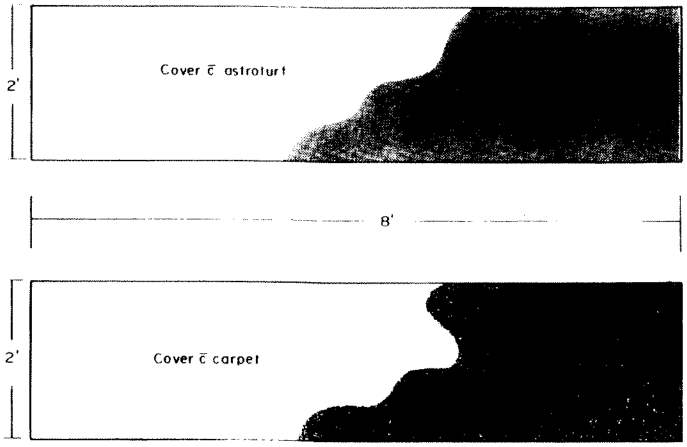

Figure 2.
Plywood flooring panels for the turf and carpet obstacles.

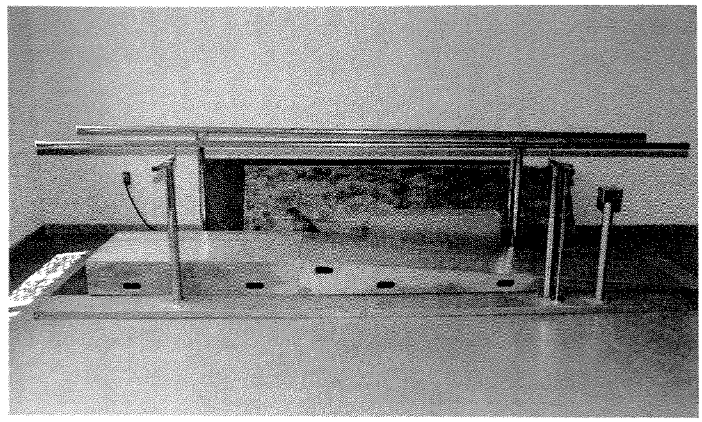

Figure 5.
Parallel bars used in the obstacle course (shown with the ramp inserted).

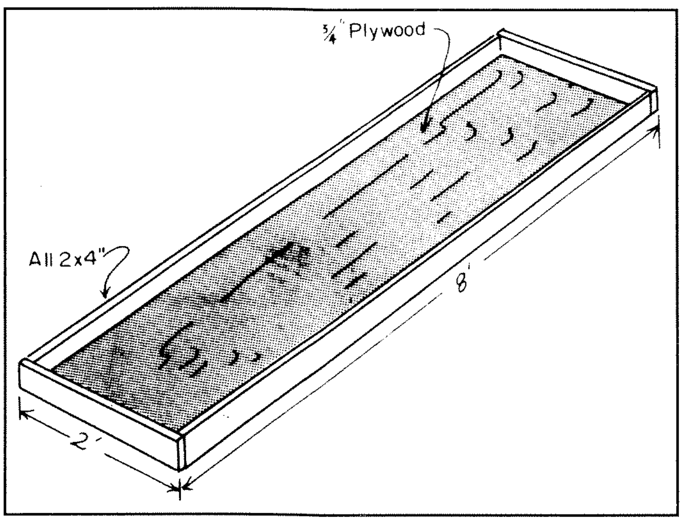

Figure 3.
Shallow wooden tray used for the pine bark and sand obstacles.

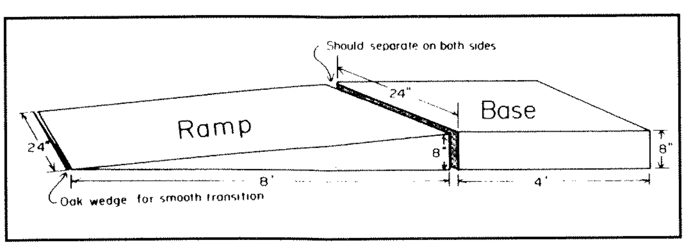

Figure 4.
Plywood ramp.

and 4 standard type steps (15.2 cm riser height by 25.4 cm tread length by 61 cm wide). The 2 sections of steps are separated by a 61 cm wide by 76.2 cm long by 61 cm high level area (**Figure 6**). These stairs are equipped with wooden side railings. The exercise stairs selected for use in the obstacle course are commercially available and extremely common among physical therapy departments. The dimensions (riser height, tread length, and width) of these stairs are standards for building construction in the community. All subjects ascend and descend the shallow stairs and later ascend then descend the standard height stairs.

3. Four discrete functional tasks and maneuvers are also included in the obstacle course. These discrete

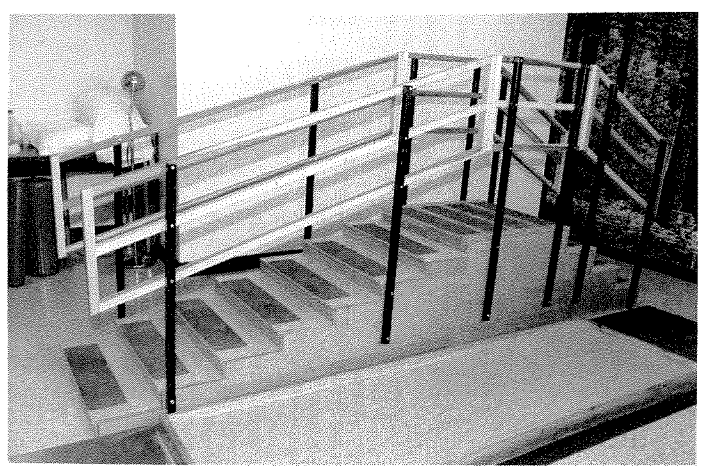

Figure 6.
Exercise stairs used for the low (left) and high (right) step obstacles (shown next to a shallow tray filled with sand).

tasks include opening a closed (2.13 m × 1.07 m) door before proceeding through the doorway; arising from a soft, armless chair (40.6 cm from the floor) if possible, without the use of hands (**Figure 7**); walking through a slalom course between a straight line of 8 plastic cones spaced 61 cm apart; and stepping over 3 parallel cylindrical foam bolsters, 10.2 cm, 15.2 cm, and 20.3 cm in circumference and 61 cm long, placed on the floor 61 cm apart and parallel to each other (**Figure 8**). Subjects were asked to step over bolsters or walk around cones without touching them. The cones used are the type used by our hospital environmental management service to warn passers by of wet floors. The subject follows a weaving path around the cones (**Figure 9**) and is instructed to try to remain inside a 7 x 1.5 m rectangular area delineated by a line of 2.5 cm white tape. The subjects are asked not to touch or cross the taped line, which extends 61 cm around all sides of the line of cones. Walking around the cones and remaining inside the surrounding area requires ten 90° turns (5 right and 5 left) and one 180° turn.

Most of the obstacles used are existing or common structures or equipment in our department (parallel bars, a door, exercise stairs, bolsters, cones, a waiting room chair). Some materials were purchased locally (pine bark chips, sand, 2.7 m × 91.4 cm sections of deep pile and outdoor carpeting). The remainder of the obstacle course components were constructed from plywood (the ramp, the floor boards for the carpet and turf, and wooden trays for the sand and pine bark) in the manual arts therapy wood shop of our medical center. Overall, the total cost of the purchased supplies and wood was under $300. Commercial construction of the wooden components should not add more than another $200 to the total costs.

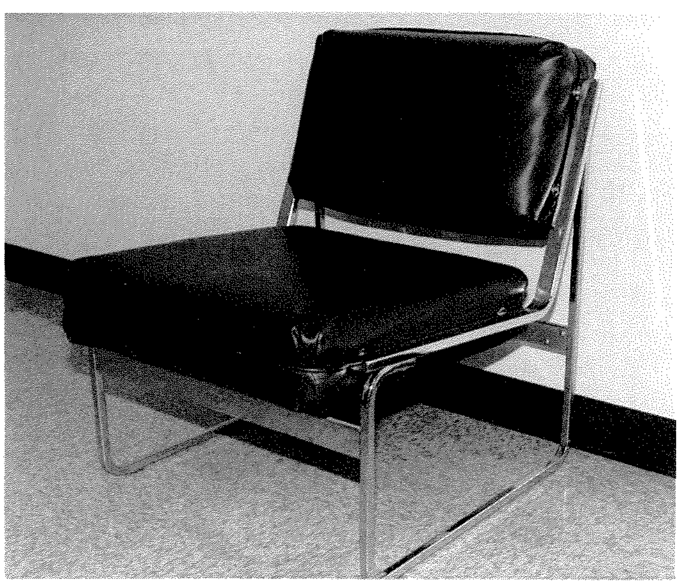

Figure 7.
Chair used in the obstacle course.

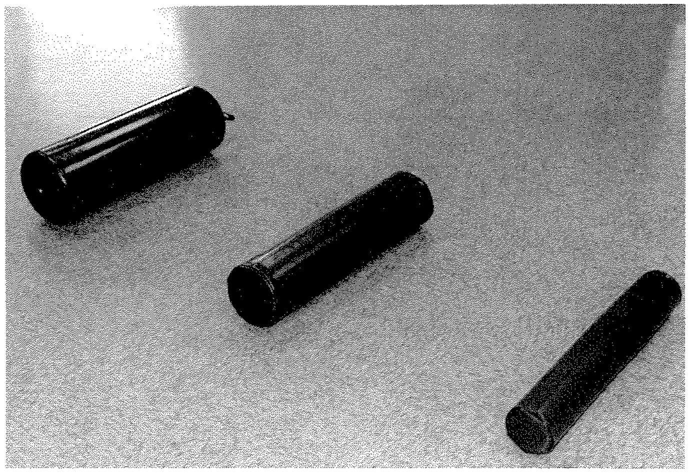

Figure 8.
Three bolsters used for the objects obstacle.

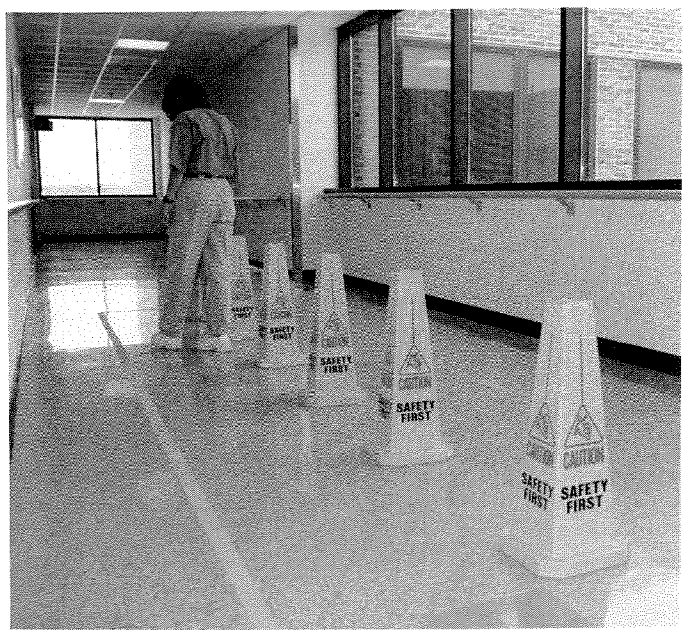

Figure 9.
Cones obstacle: safety cone area surrounded by a taped border.

Physiologic Aspects of the Obstacle Course

Optimal performance on the obstacle course (and on real-life obstacles), is largely dependent upon the integrity of specific physiologic systems. Accordingly, specific types of physiologic impairment should be detected and quantified by the different obstacle course substations. The difficulty that some subjects may experience is reflected in the overall course and individual and substation performance scores.

Flooring Surfaces

Physiologic Mechanisms

Four different flooring surfaces (artificial turf, carpet, pine bark chips, and sand) are presented in approximate order of increasing difficulty. These obstacles introduce different types of sensory input into the subject's physiologic balance control mechanism. The artificial turf, carpet, and sand provide a support base of decreasing firmness for the weight-bearing limb during ambulation. This resultant decreased contact between the foot and the underlying floor, is a function of the thickness (distance) and density of the different floor surfaces. This decrease in direct floor-foot contact results in altered translation of the normal force of body mass and the opposing ground reaction force during normal gait (32). The pine bark chips decrease the floor-foot contact in this same manner. The coarse, uneven texture of the pine bark chips effectively decreases the surface area on which contact can occur.

Pathologic Mechanisms

Subjects may be unable to make compensatory adjustments in physiologic balance control when challenged with the different surfaces (32–35). Individuals with sensory impairment may be unable to detect alterations in floor-foot contact. Subjects with muscle weakness or musculoskeletal abnormalities (hip, knee, ankle or foot arthrosis or deformity) may not be able to make the compensatory motor output adjustments accurately or efficiently (36).

Stairs and Ramps

Physiologic Mechanisms

Foot placement during level walking is a function of the stature and intent of the individual. In contrast, foot placement during stair descent is highly dependent upon the dimensions and conditions of the stairs (37). The key to successful stair ascent or descent is in the transition from free-form movement on a level landing to the highly circumscribed type of foot placement required to go up or down a flight of stairs. Visual scanning, immediately followed by kinesthetic feedback from the initial step(s) taken are critical factors in stair use. The most critical element in stair usage is the ability to use visual and/or kinesthetic information to detect the location of the edge of each step (38). In addition, motor coordination and strength, especially in the hip flexor, hip extensor, knee extensor, and ankle dorsi- and plantar flexor muscles, are important elements in using stairs and ramps. Ramps also require subjects to make accurate compensatory adjustments in their center of mass (COM), according to the gradient.

Pathophysiologic Mechanisms

Elderly subjects with visual impairment and individuals with peripheral sensory impairment may have difficulty with stairs or ramps due to inaccurate or delayed sensory feedback. Subjects with vestibular dysfunction may have difficulty detecting and adjusting to displacements of the COM induced by the ramps (26). Subjects with motor incoordination (such as in hemiparesis, cerebellar and extrapyramidal disorders) would find stair usage problematic due to inaccurate foot placement. Subjects with generalized or lower limb muscle weakness and musculoskeletal deformities may perform on the stairs and ramps with some difficulty, due to reduced biomechanical efficiency while attempting these obstacles (38–40). This would be reflected by lower scores.

Discrete Functional Tasks and Maneuvers

Physiologic Mechanisms

Opening the door requires coordinating shoulder and elbow use and fine motor dexterity with lower limb and trunk motion, integrated into one motor task. Similarly, the other discrete functional task (rising from a chair) involves a coordinated sequential muscle contraction of different muscle groups (knee extensors, hip extensors, ankle plantar flexors, spine extensors) and a simultaneous controlled anterior shift of the COM. Rising from a chair is a very important task in daily function. The chair included in the obstacle course was intended to be challenging to arise from because of its lack of arms and relatively low height—mean chair height in a recent community survey (41) was 43 cm.

Both types of object negotiation maneuvers included in the obstacle course (stepping over bolsters, walking around cones), challenge the ability to incorporate visual input information into the planning and performance of the respective motor task. Accurate visual (depth) perception is a critical component of these tasks, as is successful central integration and processing of the visual information. Lower limb coordination is also important for both tasks. Stepping over bolsters also challenges balance control by effectively increasing the time spent in unilateral support/ stance.

Pathophysiologic Mechanisms

Elderly subjects with visual-perceptual deficits (right cerebral hemisphere dysfunction, cataracts, presbyopia) or conditions that affect higher central nervous system processing (overmedication, depression) and subjects with muscle weakness or neuromuscular incoordination (cerebellar ataxia, spastic hemiplegia, basal ganglia lesions) would be expected to have difficulty with the object negotiation maneuvers (stepping over bolsters, walking around cones) of the obstacle course, resulting in a lower qualitative or quantitative score. Subjects with lower limb weakness will also have difficulty. Rising from a chair can be affected by a variety of neuromuscular, musculoskeletal, and other conditions (42), and has been the subject of much study (41–45).

Energy Expenditure During the Obstacle Course

While walking through the obstacle course along a specified path, a subject will traverse the equivalent of a linear distance of 106 m. Functionally, this distance is equivalent to the amount of walking encountered inside an office building, a large bank, or store in a medium-sized community (46). Some obstacle course stations (stairs, ramp, sand) require greater energy expenditure than when walking on a firm, level surface. The energy requirements of the obstacle course may exceed the endurance capacity of some deconditioned subjects. Many volunteer subjects in the demonstration testing reported increased problems with balance when fatigued. For maximum safety, the subjects are allowed to rest during the obstacle course, if necessary. Identification of subjects with a fatigue component of balance dysfunction may have important implications in planning rehabilitation intervention, since deconditioning is a reversible condition.

Obstacle Course Testing Protocol

All obstacle course testing was conducted in the physical therapy room of the Physical Medicine and Rehabilitation (PM&R) Service during special testing hours. All subjects are read verbal instructions (See Appendix A) and then observe as a staff member walks through the obstacle course. Subjects are not allowed to walk through the course prior to actual testing. This conserves available energy for actual testing, reduces fears associated with facing an unknown situation, and minimizes any direct learning effect from practicing on the course.

All subjects are instructed to complete the course at a pace that is comfortable, but are not informed that the elapsed time will be recorded. Subjects are asked to wear their preferred footwear and encouraged to use their usual assistive devices or walking aids (if any). A transfer safety belt is placed around the subjects' waist during testing and at least one staff member, used as a spotter, is in close proximity. Apparent subject instability and staff member judgment are used to determine how close the spotter needs to be during testing. Care is taken not to distract or impede the subject's progress or provide any physical assistance unless it is requested.

Obstacle Course Scoring System

Performances on the obstacle course are videotaped by a staff member using a camcorder. The camcorder is placed approximately 15 ft away from the subject to minimize distraction and impedance of progress. The camcorder remains stationary for each obstacle and is positioned so that a frontal view of all obstacles is obtained. Most obstacles include a directional change. In these cases, frontal (approaching) and rear (receding) views are obtained. To facilitate this, the videographer must change positions between obstacles. Use of the camcorder's zoom feature will minimize position changes. The zoom feature is also helpful in detecting precise movements used for timing or scoring of some obstacles, such as when the foot of the subject crosses a line or makes contact with an object.

Times generated by the on-screen timer of the camcorder are used to determine all obstacle course time scores. Preliminary comparison of individual station and overall obstacle course time scores, determined by stopwatch to times generated by videotaping with the camcorder's on-screen timer activated, have been found to agree within ± 1 second. Videotapes are reviewed on a videocassette recorder (VCR).

Qualitative scores are determined by the presence or absence of compensatory "reactions" or apparent difficulty with balance and mobility observed during performance of each of the 12 tasks, according to specific criteria. These criteria use judgments by the rater for each task on an ordinal scale, ranging from "unable to complete the task without assistance" [0] to "no observed difficulty or apparent unsteadiness while performing the task" [3]. An overall qualitative score is determined by the sum of the 12 individual qualitative scores (maximum score=36). Each obstacle course performance generated 1 overall and 12 individual quantitative (time) scores, and 1 overall and 12 individual qualitative scores. A sample scoring sheet used by the raters is included in Appendix B.

Preliminary Obstacle Course Testing

Preliminary testing of volunteer subjects was conducted on the obstacle course, in order to estimate possible ranges of performance and to determine if subjects would have a difference in performance (learning effect) upon immediate retest on the course. A convenience sample of 22 subjects (mean age=68.8±5 yrs) with a self-reported history of 1 or more fall(s) within the past year (fallers), and 22 subjects (mean age=73.3±4 yrs) with no history of falls (non-fallers) participated. Volunteers were recruited at our medical center from among staff members, outpatients, and visitors. All subjects were ambulatory without assistive devices.

Two consecutive trials were conducted on a randomly selected subgroup of eight subjects (four fallers and four non-fallers). Consecutive trials were separated by a 15-minute rest period. The rater who scored the videotapes was blinded to the order of the different trials, which was determined at random. The faller/non-faller status of the videotaped subjects was also unknown to the rater. T-tests were used to determine significance of performance differences between faller and non-faller groups. Ordinal qualitative obstacle course scores were treated as continuous variables for the purpose of this analysis.

RESULTS

Inter-rater and Intra-rater Agreement

The data from this preliminary study established inter-rater agreement among three independent raters (one physiatrist and two physical therapists) on the scoring of 10 videotaped obstacle course performances randomly selected from among videotapes of all 44 volunteers. Bivariate correlations between rater pairings (physiatrist vs. therapist #1; physiatrist vs. therapist #2; therapist #1 vs. therapist #2) for the time and quality scores exceeded 0.98 in all cases, with the mean correlation for time 0.999, and for quality 0.988. Similarly high mean correlation was found for intra-rater agreement (0.984 for time; 0.976 for quality) when these same raters reviewed the videotapes again at least 2 weeks after their initial ratings and all ratings were compared.

Obstacle Course Testing and Inter-trial Variability

The subjects in our sample of 44 volunteers were not necessarily a representative group and hence can only be considered preliminary. Mean quantitative and qualitative obstacle course scores for this sample are presented in **Table 2.** Mean obstacle course completion time (and standard deviation) was 274.6 (131.2) seconds for all subjects combined: 181.5 (15.6) seconds for non-fallers and 367.8 (129.8) seconds for fallers. Mean obstacle course overall quality score, out of a maximum of 36, was 30.4 (6.47) for all subjects combined: 34.6 for non-fallers and 26.1 for fallers.

Non-faller subjects completed all individual obstacles significantly faster than faller subjects. For 8 of the 12 obstacles (all except the door, carpet, cones, and up ramp), non-faller times were at least twice as fast as faller times. Non-fallers also had significantly higher qualitative scores for all except two obstacles (stepping over bolsters and walking around cones).

Of the subgroup of eight subjects who had two trials, the mean inter-trial difference in obstacle course completion time was −10 seconds (range=+4 to −19). The coefficient of variation among the trials was 5.2 percent. These data are presented for demonstration purposes only.

DISCUSSION

Prevention or reduction of falls and the injuries they often lead to will ultimately depend on our ability to understand this complex problem. Performance on the obstacle course may help to further our understanding of specific situations that contribute to falling. Reproduction or simulation of at least some of these situations with the obstacle course is a practical way to study mobility impairment and falls.

The possibility of performance enhancement by repeated exposure to the obstacle course during subsequent trials is an important issue. Of the studies mentioned above that utilized an obstacle course, only two reported the number of trials performed. Imms and Eldholm (27) used two trials during testing but did not

Table 2.
Mean obstacle course time (in seconds) and quality scores. Standard deviations in parentheses.

Obstacle	Combined n=44	Non-fallers n=22	Fallers n=22	p value
Time Scores				
Open Door	3.8 (1.6)	2.8 (1.0)	4.7 (1.4)	0.0001
Turf	14.5 (7.5)	9.5 (1.1)	19.5 (8.0)	0.0001
Bolsters	12.3 (8.5)	7.4 (1.1)	17.1 (9.9)	0.0002
Carpet	14.2 (6.6)	9.6 (1.4)	18.8 (6.7)	0.0001
Low Steps	17.5 (10.4)	10.4 (1.4)	24.6 (10.7)	0.0001
Pine Bark	18.8 (11.0)	11.2 (1.0)	26.3 (11.4)	0.0001
Cones	28.7 (12.1)	19.7 (2.6)	37.8 (11.0)	0.0001
Sand	17.8 (10.8)	10.8 (1.1)	24.9 (11.5)	0.0001
Chair	6.1 (5.7)	3.5 (1.1)	9.0 (7.3)	0.0039
High Steps	12.4 (11.1)	6.0 (1.7)	18.8 (12.9)	0.0001
Up Ramp	4.4 (2.1)	3.1 (0.5)	5.8 (2.3)	0.0001
Down Ramp	4.7 (2.4)	3.1 (0.4)	6.3 (2.6)	0.0001
Total Time	274.6 (131.2)	181.5 (15.6)	367.8 (129.8)	0.0001
Quality Scores				
Open Door	2.9 (0.36)	3.0 (0.00)	2.8 (0.50)	0.0001
Turf	2.5 (0.76)	2.9 (0.42)	2.1 (0.83)	0.0001
Bolsters	2.0 (0.86)	2.1 (0.79)	1.9 (0.92)	0.2900
Carpet	2.6 (0.67)	3.0 (0.00)	2.3 (0.85)	0.0020
Low Steps	2.3 (0.86)	2.9 (0.21)	1.8 (0.90)	0.0001
Pine Bark	2.5 (0.72)	2.9 (0.21)	2.1 (0.85)	0.0004
Cones	2.8 (0.54)	2.9 (0.21)	2.6 (0.71)	0.0900
Sand	2.4 (0.79)	3.0 (0.00)	1.9 (0.79)	0.0001
Chair	2.3 (0.73)	2.7 (0.45)	2.0 (0.79)	0.0007
High Steps	2.3 (0.86)	3.0 (0.00)	1.6 (1.66)	0.0001
Up Ramp	2.6 (0.63)	3.0 (0.00)	2.3 (0.79)	0.0011
Down Ramp	2.7 (0.63)	3.0 (0.00)	2.4 (0.79)	0.0022
Total Time	30.4 (6.47)	34.6 (1.17)	26.1 (6.80)	0.0001

Maximum quality score for individual obstacles = 3; maximum total quality score = 36.

report from which trial the final results were obtained. DiPietro (25) used one trial during initial baseline testing. Agreement between our initial trial and immediate retest data was high. Based on this preliminary experience, it appears that a single trial accurately reflects an individual's performance on our obstacle course and that subsequent exposure minimally affects performance. Additional reliability testing with a delayed retest period is planned for a future study.

Some investigators have used various grouped or single physical performance measures to study aspects of balance and mobility in the elderly (20,28,41–44,47–51). However, few recent studies were found that tested or reported performance results on functional motor tasks in an arrangement similar to the obstacle course reported here. The diversity of methods used in the studies of these instruments makes comparison with the obstacle course difficult.

Associations between specific types of impairment and specific patterns of performance deficiency on the obstacle course are being studied with large scale testing. This use of the obstacle course to aid in the identification or diagnosis of functional problems is an important potential application that will be explored further in future investigations.

The author acknowledges that the present array of obstacles uses more numbers and types of obstacles than may ultimately be necessary. An important goal of future investigation will be to determine which obstacles, if any, are duplicative and, therefore, unnecessary. A recent bivariate correlation analysis, published elsewhere (52), of all 12 obstacles for time and quality and the overall scores indicated that the scores are highly intercorrelated, suggesting that the total time and quality scores will be reliable measures of obstacle course performance. The effect of variation in the sequence of obstacles and the inter-obstacle distances also merits further study. This is because some modification may be necessary to facilitate testing at different sites with a variety of space configurations. In the author's experience to date, the effect of changes in obstacle sequence appears to be minimal.

The preliminary work reported in this report gives credence to the use of the obstacle course, which is relatively easy to construct. Subjects could readily follow instructions to complete the course. Scores for time and quality could be obtained reliably. There is variability in the time it takes to complete the obstacle course and variability in the quality of performance among subjects. With three exceptions, the course could be completed within 540 seconds (range=162–613 sec; mean=274±131 sec). Inspection of the preliminary data suggests that differences in performance exist between fallers and non-fallers. This difference appears to be greatest for the time scores.

The obstacle course attempts to provide the main advantages of the low technology balance and mobility evaluation methods (lower cost, relative ease of administration, greater acceptance by elderly subjects with low gadget tolerance), while providing some of the objectivity of the high technology methods. The greatest advantage of the obstacle course is the ability to provide functionally oriented information about dynamic balance and mobility at the person-environment interface, during performance of simulated real-life functional tasks. This emphasis on function is of paramount importance in the geriatric rehabilitation setting. In addition, the obstacle course may have increased acceptance from our target population of veteran subjects, because of their greater familiarity with this concept from their prior military training experience.

A larger study, in progress, is testing a modified version of the obstacle course without parallel bars, which will eliminate the need to interchange obstacles. That study will establish the validity of the obstacle course, and test its use as an evaluation tool and a method to monitor the response of elderly persons with balance and mobility impairment to a rehabilitation intervention. With further development, the obstacle course may be utilized by rehabilitation personnel in clinical and research settings, as a practical method of evaluating patients with balance dysfunction who are at risk for falls and fall-related injury.

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Appendix A

INSTRUCTIONS TO SUBJECTS ON THE OBSTACLE COURSE

GENERAL INSTRUCTIONS TO ALL SUBJECTS:

"This obstacle course is designed for us to get some idea how you get around by using some obstacles that you may come across at home. There are 12 obstacles, all contained in this room except for one which is out in the hallway. I will walk through the course myself first, so you can see what you will be doing. I will also be walking right next to you at all times to remind you what is next." "This is not a race! It is most important that you complete the course safely. We would like you to go at the speed that is most comfortable for you. We are interested in knowing what your 'natural' pace is. Some will take longer than others to finish. Someone will follow us to videotape you so we can see how you did later."

"When you walk through the course, if you have a cane or walker, use it if you want to, but don't use it if you don't need it. Also, when going through the parallel bars and stairs, try not to hold on to the rails unless you need them for support. But, if you feel safer or more comfortable holding on to the rails, it's OK to hold on. Try to complete all parts of the course if you can. However, if there is something that you feel you cannot do safely, just let me know and we can move on to the next part. I will have you wear a safety belt that I can grab to prevent you from falling, if necessary. But, I will not to hang on to you unless I think you are about to fall. Since I need to watch out for your safety, I am not supposed to hold a conversation with you while you are walking through the course."

INVESTIGATOR: Proceed to walk through the course yourself while the subject watches. **[READ THE INSTRUCTIONS BELOW FOR EACH STATION TO THE SUBJECT WHILE WALKING THROUGH.]** After the walk through, ask if there are any questions. If not, start the subject at the first station and read the following.

INVESTIGATOR TO SUBJECT: "Before we begin, please turn to the camera and state your name."
Station #1: **DOOR OPENING**
INVESTIGATOR TO SUBJECT: "Please open the door and walk through the doorway yourself and go toward the parallel bars with the green carpeting. Don't worry about holding the door open for me."
Station #2 **ARTIFICIAL TURF**
INVESTIGATOR TO SUBJECT: "Walk between the bars, across the green carpeting, completely out of the bars, turn around and walk back through the other way. Remember, don't touch the bars unless you need to, but if you want to that's OK."
Station #3 **OBJECTS (BOLSTERS)**
INVESTIGATOR TO SUBJECT: "Now walk over to these three objects lying on the floor and carefully step over them, one at a time. Then turn around and walk back over them the same way."
Station #4 **SHAG CARPET**
INVESTIGATOR TO SUBJECT: "Now back to the same parallel bars and walk over the carpeted surface to the other end. Go completely outside of the bars, turn around, and walk back through all the way. Try not to touch the bars unless you need to, but if you want to hold on, that's OK."
Station #5 **SHALLOW STEPS**
INVESTIGATOR TO SUBJECT: "Now over to this end of the steps. These steps are low, walk up to the top of the steps, turn around and walk back down this same side. Try not to hold on to the rails unless you need to, but if you want to hold on, that's OK."
INVESTIGATOR TO SUBJECT: "ARE YOU OK?" (If yes, continue)
Station #6 **PINE BARK**
INVESTIGATOR TO SUBJECT: "Now back over to the same parallel bars. There are pine bark chips between

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the bars now. Walk across and completely out the other end. Then turn around and come back out this side. Be careful stepping in and out and remember, don't touch the rails unless you have to.
Station #7 CONES [DEMONSTRATE HOW TO WEAVE IN AND OUT OF THE FIRST TWO CONES.]
INVESTIGATOR TO SUBJECT: "Next, let's go outside in the hallway where the yellow cones are. There is a line on the floor around this area. Please try to walk around the cones without touching them and stay inside the lines. If you are using a cane or walker, please try not to cross the lines or touch the cones with it."
Station #8 **SAND**
INVESTIGATOR TO SUBJECT: "Now over to the parallel bars. There is sand between the bars. Walk across to the end of the bars and step out of the sand, but not completely out of the bars. Then turn around and walk back this way and out of the bars. Try not to hold on to the bars unless you need to, but if you want to hold on, that's OK."
Station #9 **CHAIR**
INVESTIGATOR TO SUBJECT: "Now walk over to the chair. Turn with your back to the chair and sit down without using your hands if you don't have to. As soon as you are ready, stand back up again, without using your hands, if you can, but if you need to use your hands, that's OK."
Station #10 **STEEP STEPS**
INVESTIGATOR TO SUBJECT: "Now over to the other end of the stairs. Just like before, walk up the steps to the top, turn around and walk back down this way. Don't hold on unless you need to, but if you want to hold on, that's OK."

"ARE YOU OK?" (If yes, continue) "THIS IS THE LAST OBSTACLE COMING UP."

Station #11 **UP-RAMP** and Station #12 **DOWN RAMP**
INVESTIGATOR TO SUBJECT: "Now over to the parallel bars. There is a ramp between the bars. Walk up the ramp to the level part and turn around. Then walk back down the ramp to where you started. Don't hold on to the bars unless you need to, but if you want to hold on, that's OK. Once you are back down the ramp and outside of the bars, that's the end."

"GOOD JOB!"

Appendix B

OBSTACLE COURSE SCORING SHEET

SUBJECT NAME: ______________________ ID NUMBER: ______________________

DATE: ______________________ REVIEWER: ______________________

1. DOOR OPENING: (Start time = moment hand touches door; Stop at the moment the subject clears the doorway and closing door) TIME = ________

QUALITATIVE:

- Subject refuses or is unable to independently complete this station = 0
- Two or more of the following: unsteady; difficulty opening door; uses both hands for support; cannot clear doorway before the closing door swings back = 1
- Minor difficulty opening door or clearing doorway = 2
- no difficulty opening door or clearing doorway = 3

QUALITATIVE SCORE = ________

2. TURF: (Start time = moment 1st foot touches turf; stop at moment both feet are on the floor and completely outside parallel bars) TIME = ________

QUALITATIVE:

- Subject refuses or is unable to independently complete this station = 0
- Hands actually touch bars/person and/or are used for support; and irregular body motion = 1
- Arm(s) abducted/elevated in "guarding" position but not touching bars/person; or irregular body motion [Not both] = 2
- Arms at sides; no touching of bars/person; smooth motion = 3

QUALITATIVE SCORE = ________

3. OBJECTS (Bolsters): (Start time = moment 1st foot leaves ground to step over 1st object; stop = last foot on ground after stepping over last object) TIME = ________

QUALITATIVE:

- Subject refuses or is unable to independently complete this station = 0
- Touches any object while attempting to step over = 1
- Excessive high stepping (heel elevates beyond the opposite mid-tibia); or circumduction (foot goes around the side of the object rather than over it), but no foot-object contact = 2
- Adequate clearance (heel below opposite mid-tibia); without touching = 3

QUALITATIVE SCORE = ________

4. CARPET: (Start time = moment 1st foot touches carpet; stop when last foot touches floor outside parallel bars) TIME = ________

QUALITATIVE:

- Subject refuses or is unable to independently complete this station = 0
- Hands actually touch bars/person and/or are used for support; and irregular body motion = 1
- Arm(s) abducted/elevated in "guarding" position but not touching bars/person; or irregular body motion [Not both] = 2
- Arms at sides; no touching of bars/person; smooth motion = 3

QUALITATIVE SCORE = ________

5. LOW STEPS: (Start time = moment foot contacts 1st step; end when the trailing foot touches the floor after descending last step) TIME = ________

QUALITATIVE:
- Subject refuses or is unable to independently complete this station = 0
- Two or more of the following: hands grab railing for support; unsteady, or apprehensive, "single stepping" (=trailing foot comes up to same step as lead foot) = 1
- Either hand makes only initial contact with railing without continued support; or irregular motion or "single stepping" = 2
- Hands do not touch rails; alternate stepping (trail foot advances to step beyond lead foot); smooth motion [No errors] = 3

QUALITATIVE SCORE = ________

6. PINE BARK: (Start time = moment 1st foot touches bark; stop = moment the trailing foot touches the floor outside of the parallel bars) TIME = ________

QUALITATIVE:
- Subject refuses or is unable to independently complete this station = 0
- Hands actually touch bars/person and/or are used for support; and irregular body motion = 1
- Arm(s) abducted/elevated in "guarding" position but not touching bars/person; or irregular body motion [Not both] = 2
- Arms at sides; no touching of bars/person; smooth motion = 3

QUALITATIVE SCORE = ________

7. CONES: Start time when 1st foot crosses taped line; stop when trailing foot exits taped line area and touches floor. TIME = ________

QUALITATIVE:
- Subject refuses or is unable to independently complete this station = 0
- Foot or assistive device touches any line; AND touches any cone(s) = 1
- Foot or assistive device touches any line OR cone(s) [Not both] = 2
- Feet and device remain within lines; cones untouched [No errors] = 3

QUALITATIVE SCORE = ________

8. SAND: (Start time = moment 1st foot touches sand; stop at moment both feet are on floor outside of parallel bars) TIME = ________

QUALITATIVE:
- Subject refuses or is unable to independently complete this station = 0
- Hands actually touch bars/person and/or are used for support; and irregular body motion = 1
- Arm(s) abducted/elevated in "guarding" position but not touching bars/person; or irregular body motion [Not both] = 2
- Arms at sides; no touching of bars/person; smooth motion = 3

QUALITATIVE SCORE = ________

9. CHAIR: (Start time = moment descending motion begins; stop when fully erect after standing) TIME = ________

QUALITATIVE:
- Subject refuses or is unable to independently complete this station = 0
- Any use of upper limbs AND hesitation/irregular descending or arising motion [Two errors] = 1
- Any use of upper limbs OR hesitation/irregular motion [Not both] = 2
- Smooth descent and arising; no use of upper limbs [No errors] = 3

QUALITATIVE SCORE = ________

10. STEEP STEPS: (Start time = moment foot contacts 1st step; end when last foot touches floor after descending from last step) TIME = ________

QUALITATIVE:
- Subject refuses or is unable to independently complete this station = 0
- Two or more of the following: hands grab railing for support; unsteady, or apprehensive, "single stepping"(=trailing foot comes up to same step as lead foot) = 1
- Either hand makes only initial contact with railing without continued support; or irregular motion or "single stepping" = 2
- Hands do not touch rails; alternate stepping (trail foot advances to step beyond lead foot); smooth motion [No errors] = 3

QUALITATIVE SCORE = ________

11. UP-RAMP: (Start time = moment 1st foot touches ramp; stop = moment the trailing foot touches the level part of the ramp) TIME = ________

QUALITATIVE:
- Subject refuses or is unable to independently complete this station = 0
- Hands actually touch bar and/or are used for support; and irregular body motion = 1
- Arm(s) abducted/elevated in "guarding" position but not touching parallel bars; or irregular body motion [Not both] = 2
- Arms at sides; no touching of parallel bars; smooth motion = 3

QUALITATIVE SCORE = ________

12. DOWN-RAMP: (Start time = moment 1st foot touches down ramp; stop when the trailing foot touches the floor outside of parallel bars) TIME = ________

QUALITATIVE:
- Subject refuses or is unable to independently complete this station = 0
- Hands actually touch bar and/or are used for support; and irregular body motion = 1
- Arm(s) abducted/elevated in "guarding" position but not touching parallel bars; or irregular body motion [Not both] = 2
- Arms at sides; no touching of parallel bars; smooth motion = 3

QUALITATIVE SCORE = ________

TOTAL RUNNING TIME (From the start of the first station to the end of the last station) in seconds: ________

TOTAL QUANTITATIVE SCORE (Add the sum of the 12 individual qualitative scores above); [Maximum = 36]: ________

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