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## **Objective assessment of balance and muscular fitness in older adults with movement sensor technology**

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### **ABSTRACT**

The United States aging population is expected to grow from 13% in 2011 to 19% in 2030. Interventions that effectively help older adults perform activities of daily living will improve quality of life. Traditional fitness tests for adults >60 years of age rely on timed assessment or the number of repetitions or distance completed to quantify performance. Age-gender norms are used to categorize fitness and measure change after prescribed exercise. However, this type of assessment does not provide objective information about the quality of the performance. Movement sensor technology (MST) that utilizes three-axis accelerometry and a gyroscope provides additional performance measures during recognized standardized tests. The movement sensor is a small portable device that can be attached to (a) the body such as the lower back, (b) a light-weight barbell or wood dowel and/or (c) embedded inside a weighted ball. The physical performance evaluation can be conducted with the usual testing protocol. However, the MST provides additional objective measures. Metrics include the change in force, velocity and power for dynamic movement such as the 30-Second Chair-to-Stand Test and the Standing or Seated Chest Throw Test. The MST quantifies the time an individual remains within zones of stability, minor instability and major instability during the Side-by-Side Stand, Semi-Tandem, Tandem and/or Single-Leg Balance Test. Movement reaction time and time to complete each segment of the Timed-Up-and-Go (TUG) Test is also quantified. Results are sent in near real-time from the movement sensor to an iPad via Bluetooth Smart BLE technology. This provides useful information for the exercise professional and patient to assist with an exercise prescription and follow-up testing.

### **LEARNING OBJECTIVES**

Participants will:

1. Understand the rationale for the assessment of physical function in older adults.
2. Identify a process to objectively measure physical function in cardiac and pulmonary rehabilitation.

### **BACKGROUND**

The United States aging population is expected to grow from 13% in 2011 to 19% in 2030.<sup>1</sup> Interventions that effectively help older adults perform activities of daily living will improve quality of life. Traditional fitness tests for adults >60 years of age rely on timed assessment or the number of repetitions or distance completed to quantify performance.<sup>2-5</sup> Field testing such as this has been conducted in cardiac and pulmonary rehabilitation populations.<sup>6-8</sup>

Age-gender norms are used to categorize fitness<sup>9</sup> and measure change after prescribed exercise. However, this type of assessment does not provide objective information about the quality of the performance.

### **PURPOSE**

To describe how movement sensor technology (MST) that utilizes three-axis accelerometry and a gyroscope can be used in cardiac and pulmonary rehabilitation to provide additional performance measures during recognized standardized tests.

### **METHODS**

The movement sensor is a small portable device that can be attached to (a) the body such as the lower back, (b) a light-weight barbell or wood dowel and/or (c) embedded inside a weighted ball (See Figures 1a-c). The physical performance evaluation is conducted with the usual testing protocol. However, the MST provides additional objective measures. Results are sent in near real-time from the movement sensor to an iPad via Bluetooth Smart BLE technology. This provides useful information for the exercise professional and patient to assist with an exercise prescription and follow-up testing.

Figure 1 (a)



Figure 1 (b)



Figure 1 (c)



### **Lower and Upper Body Muscular Fitness Testing**

Metrics such as force, velocity and power and how it changes during dynamic movement can be quantified with MST in the 30-Second Chair-to-Stand Test and the Standing or Seated Chest Throw Test.

### **Lower Body Muscular Fitness: 30-Second Chair-to-Stand Test (See Figure 2-4)**

In this field test of muscular power and endurance the originators selected 30 seconds of timed performance rather than measuring the time to complete a specific number of repetitions. This enables the patient to attain a score even though the score may be as low as zero in extreme cases.<sup>2,10</sup>

**Patient Instructions:** Do you think it is safe for you to try and stand up from a chair for 30 seconds without using your arms? Please stand up straight as quickly as you can without stopping in between. You can perform the test at a pace that is comfortable for you. After standing up each time, sit down and then stand up again. Keep your arms folded across your chest.

You can stop at any time if necessary. Please watch while I demonstrate. I'll be timing you with a timer. Are you ready? Begin and stop when you hear a dinging sound.

**Test Instructions:** Patient is given the chance to practice standing up from the chair unassisted. During the test the evaluator can stop the patient the arms are used or if there is concern about the patient's safety. In this situation document the number of seconds completed and the presence of imbalance. The test is started by activating the Assess2Perform (A2P) software on an Ipad and begins after a 10-second count down (See Figure 2). Each repetition is displayed and recorded in near real time on the ipad with the metrics included such as force, velocity and power. On completion of the test all repetitions are displayed on a bar graph with a results summary showing the rate of power decrement as each repetition was performed. This provides objective measures of muscular power by analyzing the performance in the early repetitions and muscular endurance in the later repetitions. There is the option to email the results to a personal account.

Figure 2

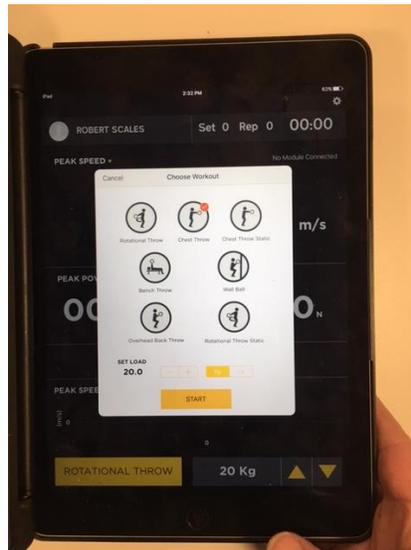


Figure 3

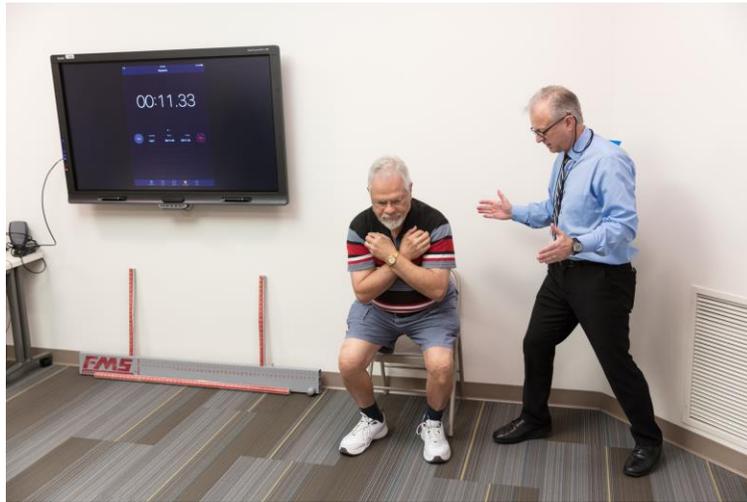
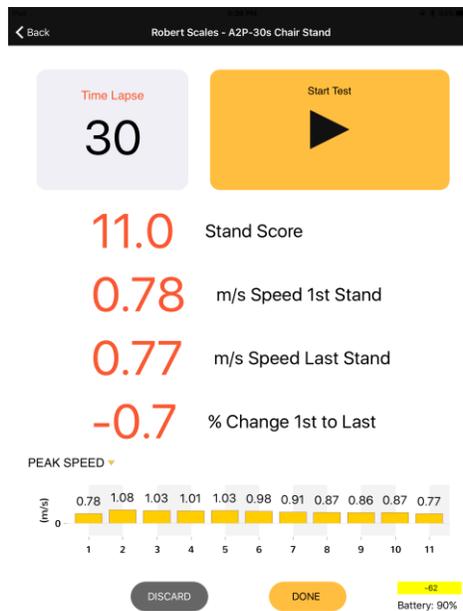


Figure 4



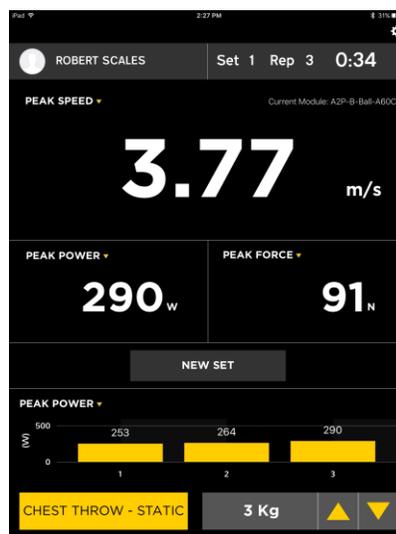
### Upper Body Muscular Fitness: Standing or Seated Chest Throw Test (See Figure 5-6)

**Test Instructions:** In this test of upper body muscular power the patient is instructed to sit back on a standard 17-inch armless chair in an upright position with feet flat on the floor or standing with their back to the wall.<sup>4</sup> Patient holds a weighted ball (2 kg female; 3 kg men) close to the center of their chest with the hands on the side of the ball and elbows out. To throw the ball the arms are extended out and the ball is caught by the evaluator. The patient is instructed to throw forcefully with a flat trajectory. Patient is given a practice throw. The test consists of three throws. The test begins on the first dinging sound by activating the A2P software on the iPad. Between throws the patient is given the ball and asked to sit in the ready position until they hear the next dinging sound. A different sound indicates that all throws have been successfully completed.

Results are displayed in near real time while the test is performed and a summary report is displayed at the end of the test. The best throw is used as the measure of performance.  
Figure 5



Figure 6



### Balance: Four Stage Balance Test

The 4-Stage Balance Test is a component of the Stopping Elderly Accidents, Deaths & Injuries (STeADI) toolkit compiled by the Centers for Disease Control for use by health care providers to identify patients at low, moderate and high risk for falls.<sup>5</sup> The addition of MST quantifies the time an individual remains within zones of stability, minor instability and major instability during the Side-by-Side Stand, Semi-Tandem, Tandem and/or Single-Leg Balance Test. Some patients may be unable to remain balanced for the 10-second timeframe for the tests. However, the progressive demand with each test enables the evaluator to determine the patient's current balance performance status with additional objective metrics of stability that would not otherwise be quantified with the original field test.

**Test Instructions:** Begin with a semi-tandem stand (heel of one foot placed by the big toe of the other foot). Individuals unable to hold this position should try the side-by-side position. Those able to stand in the semi-tandem position should be tested in the full tandem position.

### **Semi-Tandem Stand**

**Patient Instructions:** Now I want you to try to stand with the side of the heel of one foot touching the big toe of the other foot for about 10 seconds. You may put either foot in front, whichever is more comfortable for you. Please watch while I demonstrate.

Stand next to the patient to help him/her into semi-tandem position. Allow patient to hold onto your arms for balance. Begin timing when patient has the feet in position and standing without holding on for support.

### **Side-by-Side Stand**

**Patient Instructions:** I want you to try to stand with your feet together, side by side, for 10 seconds. Please watch while I demonstrate. You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.

Stand next to the patient to help him/her into the side-by-side position. Allow them to hold onto your arms for balance. Begin timing when patient has feet together and stands without holding on for support.

### **Tandem Stand**

**Patient Instructions:** Now I want you to try to stand with the heel of one foot in front of and touching the toes of the other foot for 10 seconds. You may put either foot in front, whichever is more comfortable for you. Please watch while I demonstrate.

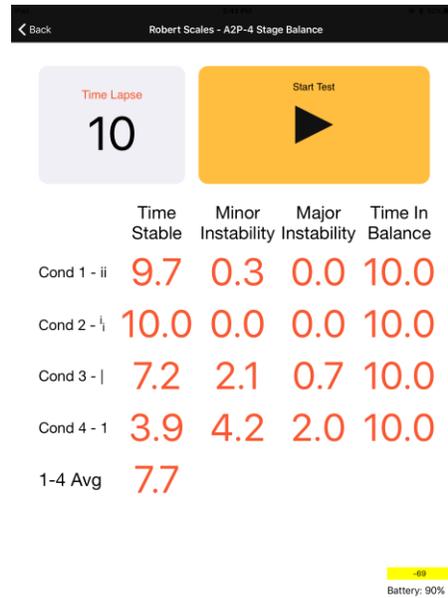
Stand next to the patient to help him or her into the side-by-side position. Allow participant to hold onto your arms for balance. Begin timing when patient has feet together and stands without holding on for support.

### **Single Leg Balance Test (See Figure 7-8)**

Figure 7



Figure 8



### Dynamic Balance: 8-Foot Timed-Up-and-Go (TUG) Test (See Figure 9-10)

**Test Instructions:** The 8-Foot Timed-Up-and-Go (TUG) Test requires the patient to stand up from a 17-inch armless chair and walking 8 feet to and around a cone and return to the chair in The shortest time possible.

The test is a composite measure of muscular power, speed, agility and dynamic balance.<sup>2</sup> MST enables movement reaction time and time to complete each segment of the 8-Foot TUG test to be quantified. Results are sent in near real-time from the Movement sensor to the iPad. This provides useful information for the exercise professional and patient to assist with an exercise prescription and follow-up testing.

Figure 9

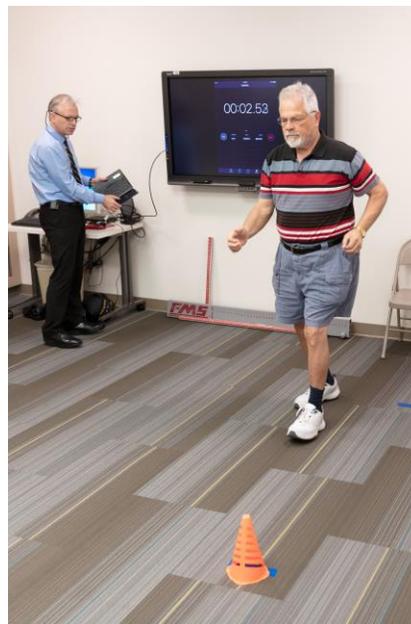
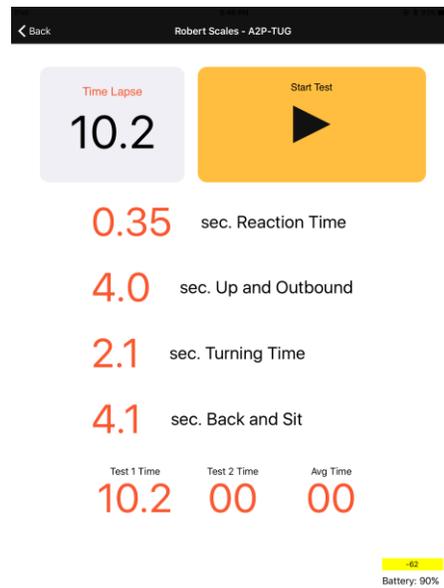


Figure 10



## DISCUSSION

### Rationale for the Assessment of Physical Function in Older Adults

The quantification of balance and muscular fitness are important components of physical function in older and frail adults. Field tests such as the Short Physical Performance Battery<sup>3</sup> showed that performance was a strong predictor disability, nursing home administration, hospitalization and mortality in adults >70 years of age.<sup>3,11</sup> Therefore, interventions that use assessment to strategically design an exercise plan to help older adults perform tasks of daily living may add years to life and life to years.<sup>12</sup>

### Enhancing Field Tests of Physical Function with Movement Sensor Technology

In a laboratory setting, isokinetic dynamometry, force plate platforms, video analysis and pneumatic resistance training equipment are examples of valid and reliable modalities that accurately capture the objective metrics associated with physical function. However, these laboratory-based assessment tools are too expensive and impractical for use in the clinic.

MST is a portable, user friendly and relatively inexpensive way to enhance the patient experience and gather objective metrics associated with the quality of performance in traditional physical function field tests. Validity and reliability studies that compare three-axis accelerometry and gyroscope technology with laboratory testing have shown encouraging results,<sup>13-15</sup> but further research is recommended.

## CONCLUSION

This type technology may provide useful information for cardiac and pulmonary rehabilitation professionals and patients to assist with an exercise prescription and follow-up testing.

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