



EXERCISE TESTING (FUNCTIONAL STATUS) (OUTCOME MEASURES



PHYSIOLOGY MONITORING DURING TESTING



Rating of Perceived Exertion (RPE)	
6	No exertion at all
7	Extremely light
8	Very light
9	Light
10	Somewhat hard
11	Hard (heavy)
12	Very hard
13	Extremely hard
14	Maximal exertion



PHYSIOLOGY MONITORING DURING TESTING

- Heart Rate
 - Before, during and after exercise
- Blood Pressure
 - Before, during (???) and after exercise
- Subject self Report of Perceived Exertion
 - RPE (Rating of Perceived Exertion)
 - Before, during and after exercise
- Dyspnea
 - Before, during and after exercise

ACSM GUIDELINES, 8th edition

PHYSIOLOGY MONITORING DURING TESTING

- O₂ saturation status: Pulse oximeter
 - Before, during and after
- Pain levels/Change in Pain Levels
 - Before, during and after
- Presence of Anginal Pain
 - Each stage

ACSM GUIDELINES, 10th edition

MONITORING HEART RATE



MONITORING BLOOD PRESSURE

- Muntner P, et al. Measurement of Blood Pressure in Humans: A Scientific Statement From the American Heart Association. Hypertension. 2019;73:e35-e66.



MONITORING BLOOD PRESSURE

Table 2. Key Points in Selecting Cuff Sizes for BP Measurement

Arm circumference should be measured at the midpoint of the acromion and olecranon.
BP cuff bladder length should be 75%–100% of the patient's measured arm circumference.
BP cuff bladder width should be at 37%–50% of the patient's arm circumference (a length-to-width ratio of 2:1)
BP cuff should be placed on bare skin.
Shirtsleeves should not be rolled up because this may create a tourniquet effect.
The most frequent error in measuring office BP is "miscuffing," with undercuffing large arms accounting for 84% of the miscuffings. ^{18,19}



MONITORING PATIENT PERCEPTION OF EXERCISE INTENSITY

Rating of Perceived Exertion (RPE)	
6	No exertion at all
7	
8	Extremely light
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Rating of Perceived Exertion (RPE Scale)	
10	Maximal
9	Really, Really, Hard
8	Really Hard
7	
6	Hard
5	Challenging
4	Moderate
3	Easy
2	Really Easy
1	Rest

Borg, GA. Med Sci Sports Exer. 1982;14:377

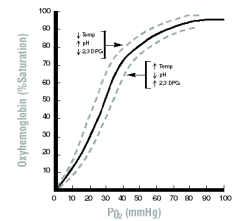
MONITORING DYSPNEA

Shortness of Breath Modified Borg Dyspnea Scale	
0	Nothing at all
0.5	Very, very slight (just noticeable)
1	Very slight
2	Slight
3	Moderate
4	Somewhat Severe
5	Severe
6	
7	Very Severe
8	
9	Very, very severe (almost maximal)
10	Maximal

MONITORING O₂ STATUS



Pulse Oximeter



MONITORING PAIN

- 0 -10 scale recommended for older patients.
- Define location of pain
- "Did yesterday's exercise session cause any pain this morning?"



Submaximal Exercise Testing

SUBMAXIMAL EXERCISE TESTING

- The test protocols **do not** reach the maximum capabilities of the respiratory and cardiovascular systems.
- Safety considerations
- By using Age Predicated HR_{max} we can calculate an estimated VO_{2max} or VO_{2peak}

ESTIMATING MAXIMAL HR

- Estimating Maximal Heart rate (HR_{max}):
 - $HR_{max} = 220 - \text{age}$
 - Urban myth
 - **$HR_{max} = (209 - (0.7 \times \text{age}))$**
 - Tanaka et al. J Am Coll Cardiol. 2001;37(1):153-6. Cited 2481 times
 - $HR_{max} = (205.8 - (0.685 \times \text{age}))$
 - Inbar et al. 1994

SUBMAXIMAL EXERCISE TESTING

- Noonan V, Dean E. Submaximal exercise testing: clinical application and interpretation.
 - *Phys Ther.* 2000;80:782– 807.
- Gappmaier E. The Submaximal Clinical Exercise Tolerance Test (SXTT) to Establish Safe Exercise Prescription Parameters for Patients with Chronic Disease and Disability.
 - *Cardiopulm Phys Ther J.* 2012. 23(2):19.



Incrementally increase treadmill speed and elevation until an endpoint is reached-typically a % of Age Predicted HR_{max} .

EXERCISE TESTING PROTOCOL: Modified Bruce Protocol (Treadmill)

STAGE	SPEED	GRADE	STAGE DURATION	TOTAL DURATION
1	1.7 mph	0 %	3 min	3 min
2	1.7 mph	5 %	3 min	6 min
3	1.7 mph	10 %	3 min	9 min
4	2.5 mph	12 %	3 min	12 min
5	3.4 mph	14 %	3 min	15 min
6	4.2 mph	16 %	3 min	18 min
7	5.0 mph	18 %	3 min	21 min
8	5.5 mph	20 %	3 min	24 min
9	6.0 mph	22%	3 min	27 min

EXERCISE TESTING PROTOCOL: Modified Bruce Protocol (Treadmill)

- At the end of each stage measure and record:
 - Heart rate
 - RPE
 - BP if possible

EXERCISE TESTING PROTOCOL: Modified Bruce Protocol (Treadmill)

- Criteria for ending/stopping the test:
 - Subject achieves age predicted estimated HR_{max} ?
 - Subject achieves a predetermined % of estimated HR_{max} (typically 85%)
 - Test is stopped with the appearance of symptoms (what are those symptoms?)
 - Patient asks to stop

How might we use results from the modified Bruce protocol as an outcome measure/assessment of fitness or function

EXERCISE TESTING PROTOCOL: Modified Bruce Protocol

- Estimating peak VO_2 :
 - Women active or sedentary: VO_{2peak} (ml/kg/min) = $4.38 \times \text{Time (min \& fraction)} - 3.90$
 - Men active or sedentary: VO_{2peak} (ml/kg/min) = $14.76 - (1.379 \times (\text{time})) + (0.451 \times (\text{time}^2)) - (0.012 \times (\text{time}^3))$.

Assume a 45 YoA female who was on the treadmill for 11 min and 41 sec.

$$\begin{aligned} VO_{2max} &= (4.38 \times 11.69) - 3.9 \\ &= [41/60 = 0.69] \\ &= 47.30 \text{ ml/kg min} \end{aligned}$$

Assume a 45 YoA female who was on the treadmill for 5 min and 11 sec.

$$\begin{aligned} VO_{2max} &= (4.38 \times 5.18) - 3.9 \\ &= [11/60 = 0.18] \\ &= 18.08 \text{ ml/kg min} \end{aligned}$$

Female (ml/kg/min)						
Age	Very Poor	Poor	Fair	Good	Excellent	Superior
13-19	<25.0	25.0 - 30.9	31.0 - 34.9	35.0 - 38.9	39.0 - 41.9	>41.9
20-29	<23.6	23.6 - 28.9	29.0 - 32.9	33.0 - 36.9	37.0 - 41.0	>41.0
30-39	<22.8	22.8 - 26.9	27.0 - 31.4	31.5 - 35.6	35.7 - 40.0	>40.0
40-49	<21.0	21.0 - 24.4	24.5 - 28.9	29.0 - 32.8	32.9 - 36.9	>36.9
50-59	<20.2	20.2 - 22.7	22.8 - 26.9	27.0 - 31.4	31.5 - 35.7	>35.7
60+	<17.5	17.5 - 20.1	20.2 - 24.4	24.5 - 30.2	30.3 - 31.4	>31.4

Male (ml/kg/min)						
Age	Very Poor	Poor	Fair	Good	Excellent	Superior
13-19	<35.0	35.0 - 38.3	38.4 - 45.1	45.2 - 50.9	51.0 - 55.9	>55.9
20-29	<33.0	33.0 - 36.4	36.5 - 42.4	42.5 - 46.4	46.5 - 52.4	>52.4
30-39	<31.5	31.5 - 35.4	35.5 - 40.9	41.0 - 44.9	45.0 - 49.4	>49.4
40-49	<30.2	30.2 - 33.5	33.6 - 38.9	39.0 - 43.7	43.8 - 48.0	>48.0
50-59	<26.1	26.1 - 30.9	31.0 - 35.7	35.8 - 40.9	41.0 - 45.3	>45.3
60+	<20.5	20.5 - 26.0	26.1 - 32.2	32.3 - 36.4	36.5 - 44.2	>44.2

EXERCISE TESTING PROTOCOL: Modified Bruce Protocol

- What other information can we derive from this test and how will it change with training?
 - Stage completed
 - Exercise Duration (min & sec)
 - RPE/Dyspnea/HR at a fixed work load i.e. at a given stage
 - Why?

EXERCISE TESTING: Modified Bruce Protocol

- How can we use the results of this test as an outcome measure?
 - Demonstrate need for continued PT service
 - Demonstrate achievement of treatment goals
 - Demonstrate patient progress

EXERCISE TESTING: Rocky Mountain Cancer Rehabilitation Protocol

• Stage	Speed	Grade	Time	• Stage	Speed	Grade	Time
• 0	1.0 mph	0%	1 min	• 11	3.8 mph	8%	1 min
• 1	1.5 mph	0%	1 min	• 12	3.9 mph	9%	1 min
• 2	2.0 mph	0%	1 min	• 13	4.0 mph	10%	1 min
• 3	2.5 mph	0%	1 min	• 14	4.1 mph	11%	1 min
• 4	2.5 mph	2%	1 min	• 15	4.2 mph	12%	1 min
• 5	3.0 mph	2%	1 min	• 16	4.3 mph	13%	1 min
• 6	3.3 mph	3%	1 min	• 17	4.4 mph	14%	1 min
• 7	3.4 mph	4%	1 min	• 18	4.5 mph	15%	1 min
• 8	3.5 mph	5%	1 min	• 19	4.6 mph	16%	1 min
• 9	3.6 mph	6%	1 min	• 20	4.7 mph	17%	1 min
• 10	3.7 mph	7%	1 min				

EXERCISE TESTING: Rocky Mountain Cancer Rehabilitation Protocol

- Test stopped at volitional fatigue (max test!)
- Time, speed & grade recorded
- If subject walking at the end of the test:
 - $VO_{2peak} = (0.1 \times S) + (1.8 \times S \times G) + 3.5$
 - S= speed; G = grade
- If subject running at the end of the test:
 - $VO_{2peak} = (0.2 \times S) + (0.9 \times S \times G) + 3.5$



6-MIN WALK TEST

EXERCISE TESTING: 6-MWT

- 6-minute walk test (6-MWT):
 - is a practical simple test that requires a 100-ft hallway but no exercise equipment or advanced training
 - measures the distance that a patient can quickly walk on a flat, hard surface in a period of 6 minutes
 - is self-paced and assesses patient **functional capacity** and provides limited information about patient physiologic status

Am J Respir Crit Care Med Vol 166. pp 111–117, 2002

EXERCISE TESTING: 6-MWT PROCEDURE

- Use standardized instructions
- Use a 30 m. course (100-ft hallway)
 - Out and back course
- Outcome: Distance walked

– ATS Statement: Guidelines for the Six-Minute Walk Test. Am J Respir Crit Care Med 2002;166:111–117

EXERCISE TESTING: 6-MWT

- 6-MWT Procedure:
 - **Limit your conversation with subject**
 - A practice test is not needed in most clinical settings but should be considered.
 - Only standardized phrases for encouragement should be used during the test.
 - Patient may use O₂ and assistive devices during test but if used, use if, possible at retest
 - Am J Respir Crit Care Med 2002;166:111–117.

PHYSIOLOGY MONITORING DURING 6-MWT

- Blood Pressure: Pre and post exercise
- Heart rate (HR); Pre, during exercise and post exercise
- Respiratory Rate (RR): Pre and post exercise
- Arterial O₂ saturation: Pre, during and post exercise

EXERCISE TESTING: 6-MWT MONITORING

- Rating of perceived exertion (RPE):
During and at end of testing
- Rating of breathlessness: During and at end of testing
- Pain/changes in pain

USING RESULTS FROM THE 6-MWT AS AN OUTCOME MEASURE/ASSESSMENT OF FITNESS OR FUNCTION

EXERCISE TESTING: 6-MWT NOW WHAT?

- Compare to age matched healthy normals:
 - Healthy Females
 - $6\text{-MWD} = (2.11 \times \text{height}_{\text{cm}}) - (2.29 \times \text{weight}_{\text{kg}}) \times (5.78 \times \text{age}) + 667 \text{ m}$
 - Healthy Males:
 - $6\text{-MWD} = (7.57 \times \text{height}_{\text{cm}}) - (5.02 \times \text{age}) - 1.76 \times \text{wt}_{\text{kg}} - 309 \text{ m}$

EXERCISE TESTING: 6-MWT NOW WHAT?

- Compare to age matched healthy normals:
 - Troosters, et al. Eur Respir J 1999; 14: 270-274
 - $6\text{-MWD} = 218 + [(5.14 \times \text{ht}_{\text{cm}}) - (5.32 \times \text{age})] - [(1.80 \times \text{wt}_{\text{kg}}) + (51.31 \times \text{gender})]$
male = 1, female = 0

EXERCISE TESTING: 6-MWT NOW WHAT?

SIX-MINUTE WALK TEST

Table 2. Summary of descriptive meta-analysis of 6-minute walk distances

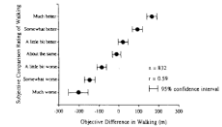
Category, y	Studies/groups (n) ²	Total sample (N)	Meters walked ¹	Homogeneity Q (P)
All ≥60	13/63	4809	499 (480-519)	76.8 (.097)
Men ≥60	10/31	1534	524 (496-553)	33.5 (.299)
Women ≥60	10/30	3212	475 (448-503)	37.3 (.138)
Men 60-69	8/10	582	560 (511-609)	8.0 (.533)
Women 60-69	8/10	1176	505 (460-549)	6.9 (.648)
Men 70-79	9/10	661	530 (482-578)	7.5 (.584)
Women 70-79	8/9	1426	490 (442-538)	7.2 (.516)
Men 80-89	7/8	228	446 (385-507)	4.8 (.689)
Women 80-89	6/7	499	382 (316-449)	4.1 (.662)

²Most studies (see Table 1) contributed to multiple gender/age categories. The data in some studies could not be categorized into groups by gender or age.

¹Mean (95% CI).

EXERCISE TESTING: 6-MWT NOW WHAT?

- Minimal clinically significant difference (MCSD)
 - "... the average individual would judge a difference greater than 54 m (37-71 m) as a noticeable difference in functional status."
 - Redelmeier Am J Respir Crit Care Med. 1997;155:1278.



STRENGTH AND STRENGTH ASSESSMENT



IMPROVED STRENGTH: UTILITY

- Improved functional capacity
- Reduced disability
- Increased bone mass
- Improved gait speed and gait quality
- Improved quality of life
- "script" calls for strengthening
- Guidelines call for resistance exercise

STRENGTH: METHODS OF ASSESSMENTS

- 0-5 scale (MMT)
- 1 rep maximum or 1-RM
 - the maximum amount of weight that one can lift or move with good form



STRENGTH: METHODS OF ASSESSMENTS

- Hand held dynamometer
- Isokinetic machines



ASSESSMENT: STRENGTH

- 1-repetition max or 1RM
 - The maximum weight a person can lift 1 time through a full ROM with good form
 - Warm up
 - Select a weight and ask patient to complete a full ROM with that weight
 - Complete 1 rep, ask RPE
 - Use RPE to assess subject effort

– Shaw et al. J Cardiopul. Rehab. 1995; 15:283

ASSESSMENT: STRENGTH

- 1-repetition max or 1RM
 - Increase weight for next trial (dependent on muscle tested!)
 - 30 sec. between trials & alternate UE with LE
 - When patient can not move a weight through a complete ROM, test is over
 - Previous weight = the 1 RM
 - Problems/challenges?

– Shaw et al. J Cardiopul. Rehab. 1995; 15:283

ASSESSMENT: STRENGTH

- Predicting 1-repetition max or 1RM
 - Predicting 1 RM = weight that can be moved 10 times resulting in fatigue/0.75
 - There is a near linear relationship between the number of reps to fatigue and the percentage of maximum load
 - Select a weight, do an exercise to fatigue, count the reps, use the number of reps to define 1-RM

DEFINITIONS: POWER

- Power: Work accomplished per unit time
 - Peak Cycling Test
 - Stair Climb Test
 - 30 sec. repeated sit to stand



DEFINITIONS: POWER

- Amount of work produced per unit time
- Power = force X velocity
 - Power = body weight X velocity
- Reflects a combination of strength and endurance

POWER TESTS

- Will have a force component and a time component
 - Strong man competition
 - Gait speed (BW X distance/time)
 - TUG, TUDS, 5X/30 sec. repeated sit to stand, inclined board



Power

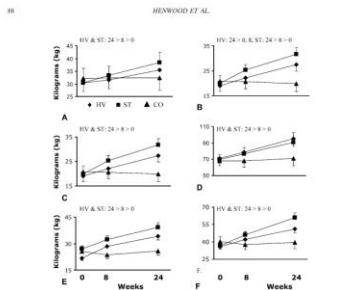


Figure 1. Mean and long-term changes in muscle strength for groups of older adults undertaking high-velocity varied resistance training (HV) or strength training (ST) or resistance control (CO) for biceps brachii (A), quadriceps (B), triceps (C), hip flexors (D), hip abductors (E), and hip extensors (F). Within-group comparisons are presented for each exercise, $p < .05$.

Henwood, TR. J of Gerontology: MEDICAL SCIENCES. 2008;63A:83.

Table 4. Functional Performance at Baseline and Following 8 and 24 Weeks of Resistance Training in Older Adults, Adjusted for Sex

Variable	Group	Baseline (s)	Week 8	Week 24	p Value*		Comparison†
					Time	Group × Time	
Floor rise to standing (s)	HV	3.49 ± 0.29	3.58 ± 0.32	3.54 ± 0.29	.023	.325	
	ST	3.77 ± 0.29	3.81 ± 0.31	3.69 ± 0.28			
	CO	3.68 ± 0.38	3.96 ± 0.38	3.98 ± 0.37			8, 24 > 0
Stair climb (s)	HV	4.89 ± 0.17	4.52 ± 0.19	4.27 ± 0.21	.087	.042	0 > 8
	ST	4.81 ± 0.17	4.64 ± 0.19	4.70 ± 0.21			
	CO	4.85 ± 0.20	5.05 ± 0.21	5.09 ± 0.25			24 > 8
Usual 6 m walk (s)	HV	3.93 ± 0.08	3.78 ± 0.11	4.04 ± 0.08	.435	.064	24 > 8
	ST	3.95 ± 0.08	3.88 ± 0.11	3.81 ± 0.08			
	CO	3.86 ± 0.09	3.95 ± 0.13	4.09 ± 0.09			
Fast 6 m walk (s)	HV	3.15 ± 0.08	2.94 ± 0.08	3.02 ± 0.07	.383	.005	0 > 8
	ST	3.13 ± 0.08	2.91 ± 0.08	2.93 ± 0.07			0 > 8, 24
	CO	3.02 ± 0.08	3.13 ± 0.09	3.19 ± 0.07			
Backward 6 m walk (s)	HV	18.91 ± 1.13	17.66 ± 1.29	15.97 ± 0.97	.498	.284	0 > 8, 24
	ST	17.81 ± 1.14	16.42 ± 1.29	15.83 ± 0.99			0 > 8, 24
	CO	19.12 ± 1.28	17.75 ± 1.45	18.51 ± 1.11			0 > 8, 24
Chair rise (s)	HV	11.77 ± 0.44	10.27 ± 0.41	10.26 ± 0.38	.598	.002	0 > 8, 24
	ST	12.29 ± 0.44	11.38 ± 0.41	10.99 ± 0.39			0 > 8, 24
	CO	12.10 ± 0.49	12.18 ± 0.46	12.58 ± 0.43			
Functional reach (cm)	HV	31.17 ± 1.11	33.93 ± 1.06	33.86 ± 1.11	.927	.017	24 > 0
	ST	29.28 ± 1.11	33.83 ± 1.06	33.93 ± 1.11			8, 24 > 0
	CO	31.89 ± 1.25	30.51 ± 1.19	30.81 ± 1.25			
400 m walk (s)	HV	256.15 ± 4.34	237.57 ± 5.89	236.34 ± 5.56	.513	.100	0, 8 > 24
	ST	245.39 ± 4.35	243.48 ± 5.91	237.34 ± 5.58			
	CO	247.91 ± 4.87	253.79 ± 6.61	244.94 ± 6.24			

Notes: Values shown are adjusted mean ± standard error.
 *Analysis of covariance adjusted for sex.
 †Within-group multiple comparisons for weeks 0, 8, and 24, $p < .05$.
 HV = high-velocity varied resistance training (n = 19); ST = strength training (n = 19); CO = controls (n = 15).
 BW = body weight.

Henwood, TR. J of Gerontology: MEDICAL SCIENCES. 2008;63A:83.

ASSESSMENT: POWER

- Stair Climbing Power Test
 - Determine the time required to climb 10 stairs as quickly and safely as possible.
 - ↑ time suggests ↓ power output
 - Reflects reduced muscle function
 - Power = (vertical height (m)/time) X (Body Weight) X (9.81 N).
 - Power = (1.75 m/time) X (BW) X (9.81)
- Bean JF et al. Arch. Phys. Med. Rehab. 2007;88:604

ASSESSMENT: POWER

- Physical Function ICU test
 - Marching on spot (MOS)
 - Duration, repetitions, cadence (reps/duration)
 - Bilateral Shoulder Flexion
 - From a standing position raise your hands up and down over your head for as long as you can.
 - Duration, repetitions, cadence (reps/duration)
- Skinner, E. et al. Critical Care and Resuscitation. 2009;11:110-115.

Table 2. PFIT results before and after weaning from mechanical ventilation and exer

Test component	Mean result (SD)		Mean difference	95% CI	P
	Before	After			
Marching on the spot					
Steps	37.6 (33.2)	123.8 (129.4)	86.3	15.8–156.8	0.02*
Seconds	34.4 (25)	88.4 (86.5)	56	5.2–102.8	0.03*
Cadence (reps/min)	56.5 (42.4)	80.8 (17.6)	25.4	–1.7–50.3	0.04*
Shoulder flexion					
Reps	15.8 (12.1)	23.8 (16.7)	8	0.5–25.4	0.02*
Seconds	40.3 (38.7)	47.7 (45.8)	5.5	–29.2–44.2	0.16
Cadence (reps/min)	25.4 (12.9)	34.4 (8.6)	7.1	–1.3–17.3	0.08

Reps = repetitions. * Significant difference (P < 0.05).