Fitness tests

Cardiovascular tests

Balke treadmill test

Balke and Ware (1959) devised one of the most commonly used treadmill protocols. During the Balke test:

- The treadmill speed is set at 3.3 miles per hour (5.3 kilometres per hour) and the initially flat gradient rises to 2%.
- Increase the gradient by 1% with each subsequent minute until the client is unable to maintain the intensity of the exercise.

Maximum treadmill time (minutes and fractions of minutes) is directly related to aerobic capacity, and VO2 max can be reliably predicted from the following equation:

WORK IT OUT

VO_2 max (ml·kg-1·min-1) = 1.444(time/60) + 14.99
(Pollock et al, 1976)

For example, a treadmill time of 950 seconds predicts a VO_2 max of 37.9 ml·kg-1·min-1.

[1.444 x (950/60) + 14.99]

The score can be compared with the VO_2 max norms offered in the norms tables.

The gradual and equal increments make the Balke protocol suitable for many adults, including older and/or deconditioned individuals. However, the test may take too long for more fit individuals. It should be stressed that, due to the gradual nature of the test, no separate warm-up is required.

Fitness categories for males based on VO_2 max expressed in ml·kg-1·min-1					
Age (years)	**Low**	**Fair**	**Average**	**Good**	**High**
20-29	≤24	25-33	34-42	43-52	≥53
30-39	≤22	23-30	31-38	39-48	≥49
40-49	≤19	20-26	27-35	36-44	≥45
50-59	≤17	18-24	25-33	34-42	≥43
60-69	≤15	16-22	23-30	31-40	≥41

(Cooper and Storer, 2001)

Fitness categories for females based on VO_2 max expressed in ml·kg-1·min-1					
Age (years)	**Low**	**Fair**	**Average**	**Good**	**High**
20-29	≤23	24-30	31-37	38-48	≥49
30-39	≤19	20-27	28-33	34-44	≥45
40-49	≤16	17-23	24-30	31-41	≥42
50-59	≤14	15-20	21-27	28-37	≥38
60-69	≤12	13-17	18-23	24-34	≥35

(Cooper and Storer, 2001)

Cooper 3-mile walk test

For many individuals, Cooper's 3-mile walk test provides an indication of aerobic fitness without requiring a maximal effort. As a result, the test is suitable for healthy males and females aged 13–70 years who have been actively walking for at least 6 weeks (Cooper and Storer, 2001). If the course is accurately measured, the test can be performed indoors or outdoors. Participants should be instructed to walk 3 miles as fast as possible without running. Time to completion can be used to assess aerobic fitness, as indicated in the table.

Classification of cardiorespiratory fitness based on the Cooper 3-mile walk test (Cooper and Storer, 2001). Values represent time (mins) to complete the 3-mile walk.					
Age (y)	**Very poor**	**Poor**	**Fair**	**Good**	**Excellent**
13-19					
Males	≥45:01	45:00-41:01	41:00-37:31	37:30-33:00	≤32:59
Females	≥47:01	47:00-43:01	43:00-39:31	39:30-35:00	≤34:59
20-29					
Males	≥46:01	46:00-42:01	42:00-38:31	38:30-34:00	≤33:59
Females	≥48:01	48:00-44:01	44:00-40:31	40:30-36:00	≤35:59
30-39					
Males	≥49:01	49:00-44:31	44:30-40:01	40:00-35:00	≤34:59
Females	≥51:01	51:00-46:31	46:30-42:01	42:00-37:30	≤37:29
40-49					
Males	≥52:01	52:00-47:01	47:00-42:01	42:00-36:30	≤36:29
Females	≥54:01	54:00-49:01	49:00-44:01	44:00-39:00	≤38:59
50-59					
Males	≥55:01	55:00-50:01	50:00-45:01	45:00-39:00	≤38:59
Females	≥57:01	57:00-52:01	52:00-47:01	47:00-42:00	≤41:59
60+					
Males	≥60:01	60:00-54:01	54:00-48:01	48:00-41:00	≤40:59
Females	≥63:01	63:00-57:01	57:00-51:01	51:00-45:00	≤44:59

Cooper 1.5-mile run test

Aerobic fitness can be assessed using the 1.5-mile run test first described by Cooper in 1968. The test can provide a valid measure of aerobic capacity, but it requires pacing and a sustained, near-maximal effort. For these reasons, at least six weeks' aerobic training (preferably running) is recommended before attempting the test.

After warming-up, participants should be instructed to complete the 1.5-mile distance as fast as possible. Time is recorded to the nearest second, and a gradual cool-down should follow the test. Interpret test performance using the corresponding table. If the Cooper 1.5-mile run test is performed on a treadmill, the incline should be set at 1% to replicate the energy cost of running outdoors (Jones and Doust, 1996).

Classification of cardiorespiratory fitness based on Cooper 1.5 mile run test (Cooper, 1982). Values represent time (mins) elapsed in completing 1.5 miles						
Age (y)	**Very poor**	**Poor**	**Fair**	**Good**	**Excellent**	**Superior**
13-19						
Males	≥15:31	15:30-12:11	12:10-10:49	10:48-9:41	9:40-8:37	≤8:36
Females	≥18:31	18:30-16:55	16:54-14:31	14:30-12:30	12:29-11:50	≤11:49
20-29						
Males	≥16:01	16:00-14:01	14:00-12:01	12:00-10:46	10:45-9:45	≤9:44
Females	≥19:01	18:31-19:00	15:55-18:30	13:31-15:54	12:30-13:30	≤12:29
30-39						
Males	≥16:31	16:30-14:44	14:45-12:31	12:30-11:01	11:00-10:00	≤9:59
Females	≥19:31	19:01-10:30	16:31-19:00	14:31-16:30	13:00-14:30	≤12:59
40-49						
Males	≥17:31	17:30-15:36	15:35-13:01	13:00-11:31	11:30-10:30	≤10:29
Females	≥20:01	20:00-19:31	19:30-17:31	17:30-15:56	15:55-13:45	≤13:44
50-59						
Males	≥19:01	19:00-17:01	17:00-14:31	14:30-12:31	12:30-11:00	≤10:59
Females	≥20:31	20:30-20:01	20:00-19:00	19:00-16:31	16:30-14:30	≤14:29
60+						
Males	≥20:01	20:00-19:01	19:00-16:16	16:15-14:00	13:59-11:15	≤11:14
Females	≥21:01	21:31-21:00	20:30-19:31	19:30-17:30	17:30-16:30	≤16:29

Queen's College step test

Step tests are useful for assessing cardiorespiratory fitness because they can be administered to individuals or large groups of people without requiring expensive equipment or highly trained personnel. Like most step tests, the Queen's College step test uses recovery heart rate to assess aerobic fitness (McArdle et al, 1972).

The test is conducted in a single 3-minute period and requires a 41.3cm (16.25in) step or platform (which is the same height as many gymnasium bleacher seats). To produce an accurate, repeatable test, a metronome should be set to 88 beats per minute for females or 96 beats per minute for males. These rates will ensure that females perform 22 steps per minute whilst males perform 24 steps per minute if the following four-step cycle is followed: on count 1, step up on to the step with one foot; on count 2, step up with the opposite foot, fully extending both legs and the back; on count 3, return the first foot to the floor; and, on count 4, return the second foot to the floor.

At the end of the test, the participant remains standing and heart rate is recorded for 15 seconds, beginning precisely 5 seconds after the 3-minute stepping period has ended. Convert heart rate to beats per minute by multiplying by 4 and use the following prediction equations to estimate VO2 max (ml·kg-1·min-1): males = 111.33 – (0.42 x heart rate); females = 65.81 – (0.1847 x heart rate).

The predicted VO2 max scores can be used to identify fitness categories using the same tables as the Balke treadmill test. Beware, however, that the error associated with this method is 16% of the actual VO2 max.

The multistage fitness test

Leger and Lambert (1982) first developed a 20-metre shuttle run for the prediction of V02 max. The 'bleep test' is now recognised as one of the most popular and valid tests of aerobic fitness in individuals or groups. The test should be performed on a dry, firm and flat surface with sufficient space for the 20-metre course and for deceleration at each end (around 5-10 metres). During the test, participants move between markers whilst the bleep intervals become progressively shorter. The audio for the multistage fitness test can be obtained via download or audio CD.

Table of Predicted Maximum Oxygen Uptake Values for the Multistage Fitness Test. Department of Physical Education and Sports Science, Loughborough University, 1987.

Level	Shuttle	Predicted VO_2 Max		Level	Shuttle	Predicted VO_2 Max
4	2	26.8		14	2	61.1
4	4	27.6		14	4	61.7
4	6	28.3		14	6	62.2
4	9	29.5		14	8	62.7
				14	10	63.2
5	2	30.2		14	13	64.0
5	4	31.0				
5	6	31.8		15	2	64.6
5	9	32.9		15	4	65.1
				15	6	65.6
6	2	33.6		15	8	66.2
6	4	34.3		15	10	66.7
6	6	35.0		15	13	67.5
6	8	35.7				
6	10	36.4		16	2	68.0
				16	4	68.5
7	2	37.1		16	6	69.0
7	4	37.8		16	8	69.5
7	6	38.5		16	10	69.9
7	8	39.2		16	12	70.5
7	10	39.9		16	14	70.9
8	2	40.5		17	2	71.4
8	4	41.1		17	4	71.9
8	6	41.8		17	6	72.4
8	8	42.4		17	8	72.9
8	11	43.3		17	10	73.4
				17	12	73.9
9	2	43.9		17	14	74.4
9	4	44.5				
9	6	45.2		18	2	74.8

9	8	45.8		18	4	75.3
9	11	46.8		18	6	75.8
				18	8	76.2
10	2	47.4		18	10	76.7
10	4	48.0		18	12	77.2
10	6	48.7		18	15	77.9
10	8	49.3				
10	11	50.2		19	2	78.3
				19	4	78.6
11	2	50.8		19	6	79.2
11	4	51.4		19	8	79.7
11	6	51.9		19	10	80.2
11	8	52.5		19	12	80.6
11	10	53.1		19	15	81.3
11	12	53.7				
				20	2	81.8
12	2	54.3		20	4	82.2
12	4	54.8		20	6	82.6
12	6	55.4		20	8	83.0
12	8	56.0		20	10	83.5
12	10	56.5		20	12	83.9
12	12	57.1		20	14	84.3
				20	16	84.8
13	2	57.6				
13	4	58.2		21	2	85.2
13	6	58.7		21	4	85.6
13	8	59.3		21	6	86.1
13	10	59.8		21	8	86.5
13	13	60.6		21	10	86.9
				21	12	87.4
				21	14	87.8
				21	16	88.2

Velocity at VO_2 max (vVO_2 max)

This concept is based on the work performed by the highly respected French researcher Veronique Billat (1999). She advocates the importance of something called vVO2 max which is the exercise velocity which causes your body to utilise oxygen at its highest possible rate.

This measurement has been a better predictor of ability and performance than VO2 max, as it encompasses elements of movement economy and efficiency (how well the individual moves without wasting effort and oxygen on unnecessary movement).

Training at an intensity equivalent to vVO2 max has been shown to not only increase this variable, but also the ability to tolerate the fatiguing effects of lactic acid and movement economy, both of which are key features in enhanced performance. The next question, therefore, is how to calculate vVO2 max and how to use this in programme design. It should be emphasised that this is a test for intermediate to advanced clients who are clear of any risk factors and who are well-motivated.

Determining vVO2 max is relatively easy to do. The activity mode chosen obviously depends on the client's sport and/or chosen activity. The rowing ergometer will be used in this example. After performing an appropriate warm-up, the timer on the ergometer should be set to 6 minutes and the display to indicate distance travelled in metres. It is then a simple matter of working as hard as possible for this 6-minute time trial. It is tough, and if the client is not used to pacing him/herself over this duration, they may want to have a few attempts to fully optimise performance.

Once the client has completed a good 6 minute effort, use the following calculation. Divide the distance travelled by 6 (metres per minute). For example, if the client rowed 1700 metres in 6 minutes this would be 1700/6 = 283.2. This is the vVO2 max in metres per minute. The test should also produce a maximum heart rate for the client. Based on the above result, exercise intensity can be prescribed. For example: 50% of 283.2 = 141.6 metres per minute.

Muscular strength and endurance tests

Maximum muscle strength (low-speed strength):

- Hand grip dynamometer.
- 1RM protocol.

Hand grip dynamometer:

- Adjust the gripping mechanism so that the second joint of the fingers fits snugly under the handle. The
- dynamometer should be gripped between the fingers and the heel of the hand.
- The hand being tested should be held out in front, free from contact with the body.
- The client should have two or three attempts on each hand with the highest reading from each hand recorded.

One of the major drawbacks in using this test to assess strength is that it is only measuring a small, select group of muscles.

One repetition maximum (1RM) protocol:

Dynamic strength is usually measured as 1RM, which is the maximum weight that can be lifted for one complete repetition of that movement with perfect technique (Heyward, 2002). After familiarising themselves with the equipment, the client is given several chances to achieve a maximal repetition with the resistance being increased incrementally with each trial. A maximum movement is hopefully attained within five trials so that fatigue does not become a confounding factor (Harmann, Garhammer & Pandorf, 2000).

1RM testing protocol (adapted from Earle, 1999):

- Instruct the athlete to warm-up with a light resistance that easily allows 5-10 reps.
- Provide a 1-minute rest period.
- Estimate a warm-up load that will allow the client to complete 3-5 reps by adding:
    - 4-9 kg or 5-10% for upper body exercise.
    - 14-18 kg or 10-20% for lower body exercise.
- Provide a 2-minute rest period.
- Estimate a conservative, near-maximum load that will allow the client to complete 2-3 reps by adding the

same increments as before.

- Provide a 2-4 minute rest period.
- Make a load increase using the same increments as before.
- Instruct the client to attempt a 1RM.
- If successful, allow a 2-4 minute rest period then estimate a new load.
- If unsuccessful allow a 2-4 minute rest period then decrease the load by subtracting:
- 4-9 kg or 5-10% for upper body exercise.
- 14-18 kg or 10-20% for lower body exercise.

Continue increasing or decreasing the load until the client achieves a 1RM with good technique. The weights obtained as 1RM for upper and lower body can then be used as guidance for planning exercise loads and intensity.

Estimated strength test (taken from Sandler, 2005)

The estimated strength test is an alternative to the 1RM test and is suitable for clients who should not be taken to maximum load. These tests rely on a formula to predict maximum strength. Select one exercise for the upper body and one for the lower body. As with the 1RM test, a suitable warm-up using a light weight for 5-10 reps should be performed. Follow the warm-up with a 2-minute rest then select a weight that failure is reached anywhere between 2 and 10 reps. The following formulae can be used to predict maximum strength.

WORK IT OUT

Upper body rep max predictor:

Upper body estimated 1 repetition maximum = Weight used for reps x (1 ÷ (1 – [Reps made x 0.025])).

Lower body rep max predictor:

Lower body estimated 1 repetition maximum = Weight used for reps x (1 ÷ (1 – [Reps made x 0.035])).

Upper body rep max predictor:	Lower body rep max predictor:
Step 1 Reps made x 0.025 = X e.g. 12 reps x 0.025 = 0.3 **Step 2** 1 – X = Y e.g. 1 – 0.3 = 0.7 **Step 3** 1 ÷ Y = Z e.g. 1 ÷ 0.7 = 1.43 **Step 4** Weight used for reps x Z = Estimated 1 repetition maximum. e.g. 50kg x 1.43 = 71.43 kg estimated 1RM	**Step 1** Reps made x 0.035 = A e.g. 12 reps x 0.035 = 0.42 **Step 2** 1 – A = B e.g. 1 – 0.42 = 0.58 **Step 3** 1 ÷ B = C e.g. 1 ÷ 0.58 = 1.72 **Step 4** Weight used for reps x C = Estimated 1 repetition maximum. e.g. 50kg x 1.72 = 86.2 kg estimated 1RM

Back extensors test (taken from McGill, 2002)

This test does not have a set of normative values but simply provides a reference point for comparing future performance.

Back extensor test protocol (adapted from McGill, 2002)

- The client lies in a prone position with the upper body extended over the end of a table or bench. Hips, knees and pelvis should be secured and supported by the table or bench.
- Arms are crossed so the hands rest on the opposite shoulders.
- The client extends at the hips so their body is straight and parallel to the floor, with the lower part of the body (to the hips) secure and supported by the bench and the upper part of the body held in position using the back extensors.
- The test is timed from the moment a client reaches the parallel position, until they cannot hold a fixed position.

Sit up test

This test does not have a set of normative values, but it will provide a reference point to compare to later tests.

Sit-up test protocol

- The client lies on their back with the soles of their feet flat on the floor and knees at 90 degrees.
- Arms are crossed so the hands rest on the opposite shoulders.
- Whilst keeping the feet on the floor and arms crossed, the client performs a technically correct sit-up.
- The client performs as many sit-ups as they can in one minute.
- The PT observes technique and only full repetitions (e.g. the scapula should contact the floor before a repetition can be considered complete) with accurate technique are counted.

Power tests

Vertical jump test

Vertical jump tests can be performed in two distinct ways: the squat jump (SJ) and the countermovement jump (CMJ). Both assess the ability of the musculature of the hips, thighs and lower legs to propel the individual vertically into the air, but unlike the SJ, the CMJ utilises the elasticity in muscles and the stretch-shortening cycle. If the trainer wishes to perform just one variant of the vertical jump test, then the CMJ is probably more appropriate as it more closely replicates the way the body loads then unloads in function.

Countermovement jump (CMJ)

Equipment required:

- A smooth wall with a ceiling higher than the jumper can reach.
- A flat floor with good traction.
- Chalk of a different colour than the wall.
- Measuring tape or ruler.

Procedure:

- The client rubs chalk on the fingertips of their dominant hand.
- The client stands side on to the wall with the shoulder of their dominant hand about 15cm from the wall.
- With their feet flat on the floor, the client reaches as high as they can and makes a chalk mark on the wall.
- The client then performs a maximal countermovement jump. The countermovement requires the client to rapidly flex the hips and knees, bring the torso forward and down and swing the arms behind the body. This is the eccentric loading phase of the stretch-shortening cycle.
- The concentric phase of the jump should instantly follow the eccentric loading phase. The client rapidly extends both hips and knees while simultaneously swinging the arms upward.
- At the apex of the jump, the client should make a second chalk mark with their fingertips.
- The trainer then measures the vertical distance between the two chalk marks

Normative table for vertical jump performance (CMJ)		
Performance % rank	**Female height (cm)**	**Male height (cm)**
91-100 World class	76-81	86-91
81-90	71-75	81-85
71-80	66-70	76-80
61-70	60-65	71-75
51-60	55-59	66-70
41-50	50-54	60-65
31-40	45-49	55-59
21-30	40-44	50-54
11-20	35-39	45-49
1-10	<35	<45

Adapted from Chu (1996)

Note that the normative table (adapted from Chu) is derived from data obtained from competitive athletes. Inappropriate use of this type of table could be very demotivating for the average client, as they are more likely to rank within a very low percentile. Trainers are advised to exercise caution when comparing clients to normative tables of any kind. Test scores are more appropriately used to monitor a client's progress against their own previous performances.

This table (adapted from Newton) shows average vertical jump performances obtained from a variety of population groups.

Vertical jump performance for various populations (CMJ)	
Population group	**Vertical jump height (cm)**
18-34 year old males	41
Recreational male college athletes	61
Competitive male college athletes	64-65
18-34 year old females	20
Recreational female college athletes	38-39
Competitive female college athletes	41-47

Adapted from Chu (1996)

The vertical jump tests are particularly useful for clients who participate in sports or activities that require powerful vertical leaping for successful performance (e.g. basketball, netball, volleyball, high jumping).

Squat jump

The procedure for the squat jump is similar to the CMJ. The only difference is that the jump is initiated from an isometrically held, partial squat position. The trainer should ensure that there is no movement from the client for a period of two seconds once the partial squat position has been adopted. Measurement of the squat jump is recorded in the same way as for the CMJ.

Standing broad jump

Like the vertical jump tests, the standing broad jump can be performed almost anywhere with limited equipment.

Equipment required:

- Flat surface with good traction.
- Tape measure.
- Straight line marked on the floor.

Procedure:

- The client starts with their feet shoulder-width apart and their toes behind the line marked on the floor.
- The client swings their arms behind the body and simultaneously initiates a countermovement from their knees and hips (performs a 1/4 to 1/2 squat).
- The client swings their arms forward and extends their knees and hips to leap explosively forward as far as possible.
- The trainer marks the back heel of the client and measures the distance between this mark and the start line.
- The best score of two to three trials is recorded.

The trainer can also ask the client to conduct a non-countermovement jump by instructing them to adopt a static semisquat position behind the starting line prior to the jump phase. This squat must be held statically for two seconds prior to the jump.

Normative table for standing board jump performance (CMJ)		
Performance % rank	**Female distance (m)**	**Male distance (m)**
91-100 World class	2.94-3.15	3.40-3.75
81-90	2.80-2.94	3.10-3.39
71-80	2.65-2.79	2.95-3.09
61-70	2.50-2.64	2.80-2.94
51-60	2.35-2.49	2.65-2.79
41-50	2.20-2.34	2.50-2.64
31-40	2.05-2.19	2.35-2.49
21-30	1.90-2.04	2.20-2.34
11-20	1.75-1.89	2.05-2.19
1-10	1.60-1.74	1.90-2.04

Adapted from Chu (1996)

Range of motion tests

It is possible to assess the flexibility of individual muscles/muscle groups and their possible impact on joint motion. These assessments allow more focus in the identification of tight or shortened muscles so that subsequent flexibility work can be more specifically targeted to the needs of the individual. The assessments discussed below can provide a useful overview of key musculature. The optimal joint ranges of motion are taken from Kendall et al (1993).

Hamstring muscles

- Client lies in the supine position, arms by their sides.
- Trainer places one hand underneath the client's lumbar vertebrae and the other on the leg being assessed.
- Trainer raises the leg into hip flexion, until the client starts to go into a posterior pelvic tilt.
- This tilt will be felt as the spinous processes pressing onto the trainer's hand.
- Trainer assesses the angle at which this pelvic tilt occurs. Repeat on the other side and compare.

Quadriceps

- Client lies in the prone position.
- Trainer places one or two hands on the client's lower leg (shin), leaving the foot relaxed and the knee on the floor.
- Trainer raises this lower leg into knee flexion, until the 'spongy' end of ROM is reached or until the pelvis rotates anteriorly.
- Trainer assesses the angle at which this occurs. Repeat on the other side and compare.

Iliopsoas

- Client lies in the supine position, arms by their sides.
- Trainer places two hands on the client's 'non-assessed' lower leg (shin), leaving the foot relaxed.
- Trainer raises this lower leg into knee and hip flexion and pushes the knee towards the chest.
- The pelvis is taken into posterior pelvic tilt, so the client has a flat back, and when the hip flexor becomes taut the 'assessed' knee starts to lift.
- Trainer assesses the angle at which this occurs. Repeat on the other side and compare.

Adductor muscles

- Client lies in the supine position, arms slightly out to the sides.
- Trainer places one hand on the client's 'non-assessed' or far side ASIS (anterior superior iliac spine).
- Trainer places other hand on 'assessed' or near leg and pulls this towards them, taking the leg into hip abduction.
- Trainer feels for the point where the ASIS starts to move, indicating a pelvic lateral tilt and that the hip adductors have reached their end of ROM.
- Trainer assesses the angle at which this occurs. Repeat on the other side and compare.

Pectoralis major and latissimus dorsi

- Client lies in the supine position in a posterior pelvic tilt (flat back) with their arms resting above their head.
- Trainer takes hold of the client's wrists and instructs the client to completely relax their arms.
- Trainer raises the arms into shoulder flexion, then allows the arms to gently fall into their passive end ROM.
- Tight pectoral muscles will try to pull the arms into adduction.
- Tight latissimus dorsi muscles will try to pull the arms into extension.
- Trainer assesses for shoulder extension and/or adduction on both sides.

Soleus and gastrocnemius

- Client lies in the supine position in a neutral spine with their arms resting by their sides.
- Trainer takes hold of the sole of the client's foot and asks the client to relax their lower leg.
- Trainer takes the foot into (passive) ankle dorsiflexion to assess gastrocnemius ROM (ideal of 15-20°).
- Trainer can then assess active gastrocnemius ROM by asking the client to pull their toes back (dorsiflexion) unaided.
- Soleus flexibility can be assessed by repeating the tests above with one hand under the back of the knee, taking the knee in flexion.
- Assess the active and passive flexibility of both muscles and on both sides, compare with each other and the norms.

Wall standing shoulder flexion

- Client stands against the wall, feet placed four inches away with back flat and arms by sides.
- Ask the client to raise both arms above their head as far as they can go without letting the lower back lift away from the wall.
- Stop the test when lower back lifts and observe the arms' distance from the wall.
- A positive test,