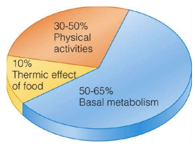
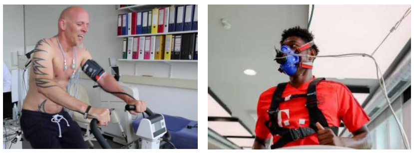
Physical Activity and its Assessment

Physical activity is defined as ***"any bodily movement produced by skeletal muscle that results in energy expenditure"*** (Caspersen et al., 1985).
It includes occupational work, domestic chores, leisure activity, playing sports, and exercise that is planned for fitness, health, or performance purposes, respectively.
Physical is the most variable component of an individual's total daily energy expenditure (consisting of basal metabolic rate, the thermic effect of food and physical activity).
In epidemiology, in clinical assessment and general in fitness assessment a valid and reliable measure of (daily / weekly) physical activity is required to evaluate the association between PA and the risk of chronic disease, for assessing the health status and for monitoring the effectiveness of interventions.



Fitness Assessment versus Performance Diagnostics
Health-Related Fitness versus Performance Related Fitness / Assessment of Physical Activity / Exercise Monitoring

When it comes to fitness (and fitness assessment) we have to distinguish between the concepts of **health-related fitness** aiming to improve, promote, maintain, or restore health (prophylactic & therapeutic aspects) and **performance-related fitness** (**skill-related fitness**) aiming to optimize or maximize performance or adaptation.



The course aims to cover both aspects of fitness assessment

Health Related	Performance Related
Cardio Respiratory Endurance	Aerobic Power / Anaerobic Power
Muscular Strength and Power	Muscular Strength, Power, Muscular Endurance
Muscular Endurance	Speed / Agility / CoD / Reaction Timing
Flexibility / Mobility	Flexibility / Coordination / Technical Skills
Body Composition	Body Composition
Postural Control / Postural Stability	Postural Control / Balance

Measurement of Physical Activity

Method	Measures
Self-Report Questionnaires	Physical Activity Questionnaires / Interview (assessment of occupational and leisure time physical activity habits of a large number of people assessing PA over different time periods; type of activity (leisure, household, transportation, occupation,..); recall based ; cost and time efficient; there is no gold standard concerning validity and reliability; most often used method in epidemiology; many different methods available (Harvard Alumni/Paffenbarger PA Survey, Minnesota Leisure Time PA Questionnaire, Stanford Seven-Day PA Recall Interview, International PA Questionnaire [IPAQ], Global PA Questionnaire [GPAQ]; 3-Day Physical Activity Recall [3-D PAR], CHAMPS PA Questionnaire,….
Behavioral Observation	Direct observation provides detailed information about frequency, duration, and intensity of bouts of activity (where and with whom it occurs) during the period of observation); socially unacceptable for round-the-clock surveillance
Physiological Markers	Heart Rate Monitors, Doubly Labeled Water; Direct or Indirect Calorimetry; Blood Pressure, Body Fat; Blood Lipids; Aerobic Power, Muscular Strength, Muscular Endurance;…
Dietary Intake	Interview or self-report: eg. 24 hrs Dietary Recall, Dietary Record, Dietary History
Motions Sensors	Accelerometers, Pedometers, Stabilometers, Gait assessment, Electronic Motion Sensors,…

Physical Fitness

Physical fitness is an attribute that has a genetic basis but is also sensitive to changes in type and amount of physical activity.
It is important to measure fitness both as an outcome of physical activity and as a moderator or mediator of physical activity's effect on disease morbidity, mortality and risk of injury.
WHO has defined fitness as "***the ability to perform muscular work satisfactorily***". However, this definition does not specify what satisfactorily means, nor does it acknowledge that physical fitness comprises several abilities rather than a single overall ability. Physical fitness is better understood when the specific components that can be measured, and the circumstances under which those components relate to bodily function, health or reduced disease, are defined.

Health-related physical fitness
- Morphological
- Muscular
- Motor
- Cardiorespiratory
- Metabolic

Performance-related physical fitness
- Psychomotor abilities & skills
- Maximal & submaximal cardiorespiratory power
- Muscular strength, power & endurance in limbs and trunk
- Body size; body composition
- Technical skills

ASSESSING THE COMPONENTS OF FITNESS

After having screened and stratified clients,
the next step is usually to **assess their fitness in various areas**.
This gives baseline information that is helpful in designing
the exercise prescription.
It is also useful to **repeat assessments** at regular intervals
to evaluate the clients progress and modify the program.

Measurement of the Components of Health-Related Fitness (*Bouchard et al., 1994*)

Component	Measures
Morphological	Body mass for height Body composition Subcutaneous fat distribution Abdominal visceral fat Bone density Flexibility
Muscular	Power Strength Muscular endurance
Motor	Agility Balance Coordination Speed of movement
Cardiorespiratory	Submaximal exercise capacity Maximal aerobic power Heart functions Lung functions Blood pressure
Metabolic	Glucose tolerance Insulin sensitivity Lipid and lipoprotein metabolism Substrate oxidation characteristics

Measurement of Performance & Skill-related Fitness

Component	Measures
Psychomotor abilities & skills	Speed, agility, lateral movement, change of direction, reaction time, postural control, postural stability, balance, flexibility, range of motion, mobility, coordination, movement economy, anaerobic tests
Maximal and submaximal cardiorespiratory power	Laboratory versus field tests, proper selection and administration of a protocol, testing cardiovascular endurance, VO_2max, VO_2peak, speed at VO_2max, maximal power, ventilatoric thresholds, lactate thresholds, timed field tests, critical speed, critical power, distance field tests, submaximal exercise testing methods, regression equation calculations,
Muscular strength, power and muscular endurance	Laboratory versus field tests, dynamic versus isometric, isokinetic, single vs. multi-joint, force magnitude (peak and mean force), rate of force development, acceleration and velocity parameters, ballistic versus non-ballistic, reactive strength, maximal instantaneous power, dynamometry, force plates, contact and flight time, 1 RM testing, prediction equations, exercise to failure, peak power, anaerobic capacity
Body size, body composition	Anthropometric measurements, height, body mass, body mass index, waist-to-hip ratio, skinfold measurements, girth measurements, hydrodensitometry, bioelectrical impedance, air displacement plethysmography, dual-energy x-ray
Technical skills	Sport-specific procedures based on physical demands and determinants of performance

Laboratory Testing – versus Field Testing

Sacrificing specificity to reduce artefacts is a consideration that should be made test-by-test.

In diagnostic testing (e.g. pre-exercise screening it is frequently necessary to select a mode of exercise that does not necessarily reflect activity profile of a specific sport or discipline).

=> Improved signal acquisition (ECG, pulmonary metabolic measures).

Logistically, it can be difficult to get an athlete or a team of athletes to a testing laboratory. Laboratory tests are often very expensive, thus making them inaccessible for regular use even for clubs with sound financial backing. These inhibitory factors have lead to the design of valid and reliable field tests.

Performance or skill-realted fitness

Assessment should be preceded by a full needs analysis which in turn should be based on a triangulation of the requirements and views of the athlete, coach and scientist. Assessments should be an integral part of an athlete's training and scientific support programs and should be conducted regularly and frequently.
Moreover, assessment should reflect the movement and other demands the sport or activity in which the athlete or client participates.

It is important to understand

- **Mechanics**: Forces, or kinetics involved in a target activity (rate and time of peak force production ⬄ impulse and velocities at it is applied; dynamics of effort ⬄ power; region of force application; regime of muscular work; direction of movement
- **Energetics**: How the energetic systems contribute to target activities (phosphocreatine [PC]; glycolysis; lactate-shuttle mechanism; aerobic mechanisms ⬄ tactical metabolic modelling
- **Coordination**: Which movement skills are involved in the target activity (adaptive ability, balance, combinatory ability, differentiation; reactiveness; rhythm

⇒ Fitness testing planning in performance related sports should consider what event the subject competes in and select the appropriate set of tests.

Laboratory Testing – versus Field Testing

Laboratory Test
- Controlled Environment / Usually small measurement error
- measures specific functions or variables thought to be determinants of athletic performance
- The most accurate measurements by measuring gas exchange and/or blood serum levels utilizing a controlled environment. May not be practical or specific (i.e. cycle ergometers)
- Higher monetary and time costs

Field Test
- Performed under "real world" conditions
- May not be as reliable or accurate as a lab test
- Limited parameters can be monitored
- However, results must also be valid (ecological validity), that is, they must accurately reflect what happens under sport or discipline specific conditions

Testing general and specific qualities

Assessing general physical qualities

Sport-specific assessment

Trainer and coaches frequently demand that the focus has to be on sport-specific methods in assessing athletes.

- However, in both assessment and training, general does not mean non-relevant.
- Assessing general physical qualities can be extremely insightful in determining training needs.
- Important training priorities could be overlooked by only assessing "specific qualities".

Experience and Training Status

For a well trained, experienced athlete,
a technique-intensive test may be appropriate
because it can be very sport specific,
and one can assume that poor technique will not impair performance of the test.

This assumption cannot be made for a client just learning or trying out for a sport.

Example: repeated one leg hops may represent a valid and reliable test
of plyometric strength for an experienced long or triple jump
but not for a novice athlete or non-athlete *(Chu & Vermail, 1983)*

Standardizing the preparation of participant(s) before tests

Test participants should be fully informed of what is expected of them.

Adherence to pre-test behavior which could otherwise affect the results. This might include instructions about nutrition, level of training 48 hours pre-test, the consumption of alcohol and nicotine.

Most physical tests are enhanced by a warm-up and therefore a standard warm up should be performed by the participants. The exact content of the warm-up will depend upon the sport and test, but is likely to be similar to that used before a competition.

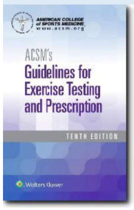
If conducting a series of tests, the sequence in which they are performed can be important, as fatigue from one test can affect the results of another test. Therefore the test sequence and if appropriate, duration of recovery between tests should be standardized and if repeated either on the same individual or another squad member the tests should be carried out identically.

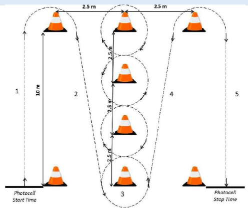
Psychological factors, such as lack of motivation or anxiety can contribute to low exercise performance.

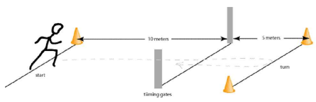
Standardizing the test protocol

Unless a test protocol is closely standardized it will not generate meaningful data that can be compared. For example, there are a number of variations of the sit-up, each of which affect the difficulty of the exercise and consequently the number of repetitions they are likely to achieve. Therefore, the preferred version needs to be selected, carefully administered and the details recorded for future test comparisons.

In tests where a time limit is used to generate a test score the quality of the movement assessed must be standardized and must not be sacrificed in the desire for speed. If conducting a test of speed or agility which requires the use of markers or cones, it is vital that the position of these is recorded precisely.







Enhancing test standardization through familiarization

Familiarization with test procedures can affect the results and it may be necessary for the participant to repeat the test several times (generally 2-4 times for most field tests) before a true measurement can be attained.
For some non-exhaustive tests, a repeat measurement may take place within a matter of minutes, whereas for exhaustive tests several hours or even days may be required to fully recover.

The basis of checking for familiarization is that as fitness improvements are unlikely to occur in a matter of days, any observed improvements in the test score are likely due to increased familiarity.

If a test requires a particular technique or skill, some familiarization/practice should be included in the warm-up preceding the test to ensure that the participant is fully familiar with the test requirements.

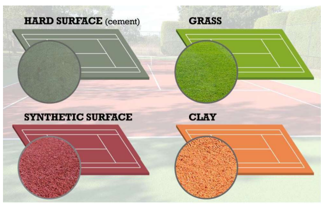
Sequence of Testing

Testing tasks which are highly skillful, such as those which require coordinated movements and an attention, should be conducted before performance tests inducing fatigue in order that the latter do not distort the results.

- Body composition / Anthropometrics
- Flexibility
- Postural control
- Jumping tests
- Agility
- Speed / Acceleration
- Power and Strength
- Local Muscular Endurance
- Anaerobic Capacity
- Aerobic Capacity

Rest periods between tests should be based on the time course for restoration of key metabolic substrates.
Approximately 70% ATP restoration occurs in around 30s, whereas 3–5min of recovery is needed to completely resynthesize ATP.
Approximately 84% of PCr stores are restored in 2 min, 89% in 4 min, and 100% in 8 min.
Therefore, for power tests lasting around 1second (e.g., the power clean and CMJ) and strength and speed tests lasting around 4 seconds (e.g., the 1RM back squat and 30-m sprint), 3–5 min between trials may be required because these depend on intramuscular stores of ATP.
However, for longer lasting tests, for example, repeated sprint tests, which also tax intramuscular stores of PCr, 8 min between repetitions/tests may be warranted.

Environmental factors can have a profound effect on field testing particularly when performed outdoors due to the weather primarily. Consideration should be given to the effect alterations in the weather may have on the testing environment (e.g. slippery/muddy surfaces) and the sports performer (e.g. temperature extremes).
Ideally tests should be performed in very similar conditions enabling comparisons to be drawn.
Therefore the coach / sport scientist should note environmental conditions when recording the test scores.
In some circumstances it may be necessary to cancel tests if the conditions are too adverse to allow uncompromised performance.



Test Criteria

To be effective,
assessments should be **specific** and **valid** and resulting measures should be **reproducible** and **sensitive** to changes in performance.

- Specificity
- Validity
- Reproducibility
- Sensitivity

Reliability refers to how repeatable and consistent a test is.
Ideally if a performer repeated a test under exactly the same conditions with no change in their fitness they should produce identical results.
However, in reality attaining exactly the same results are most unlikely due to slight differences by the performer from one day to the next.
Coaches and performers should be aware that a relatively small change in the test scores may not mean a change in fitness.

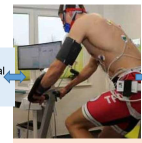
- Specificity
- Validity
- Reproducibility
- Sensitivity

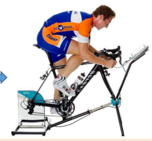
Validity refers to the requirement that a test must assess what it is intending to. For example, whilst completing as many press-ups as possible may be a good measure of muscular endurance, it is not a valid measure of maximal strength.
Likewise, if a test lacks sport specificity it is unlikely to be a valid test for that particular sport. Poor validity may also arise if other factors have the potential to mask what is being assessed.
For example, if assessing sprinting speed in soccer, it would be inappropriate to require the player to dribble a ball, as this would assess dribbling speed not sprinting speed.

Test accuracy is incorporated into the test validity and reliability and covers the accuracy to which measurements can be recorded. For example, a highly skilled coach may be able to hand-time with an accuracy of ± 0.1 seconds, but would not be able to accurately record to ± 0.01 seconds.

Sensitivity: A test must be sufficiently sensitive to detect changes in fitness or else hard earned fitness gains could go undetected, which may severely de-motivate the performer and undermine the credibility of the coach. A test's sensitivity will depend upon its reliability and measurement accuracy.

Reliability and Accuracy





Limitation of many of many ergometers, is the ecological validity, given the cyclist is not using their own bike.

In the field, mobile power meters provide the ability for sport scientists and coaches to measure power and subsequently interpret the competitive characteristics of the various cycling disciplines.

The measurement of power output has become a critical factor in monitoring cycling performance. Many new tools for monitoring power output in cycling both in the lab and field have entered the market, without any assessment on the reliability of these new tools.

For professional cyclists, small differences in performance can determine the difference between finishing on the podium or in the minor placing's, indicating that performance changes as small as 1% in highly-trained cyclists can be meaningful.

(Currell and Jeukendrup 2008)

Therefore the **accuracy and reliability** of devices to measure power is of great importance.

Whether it is laboratory or field based testing the administrator must have good knowledge and understanding of the procedure and protocols to follow. The following two aspect of fitness testing are key:
Validity relates to whether the test actually measures what it sets out to measure.
Reliability is a question of whether the test is accurate. It is important to ensure that the procedure is correctly maintained for ALL individuals.

In order to compare the results from fitness tests normative data tables can be used. This is also known as benchmarking data and is collected from a number of studies to allow you to make a judgement against.
Pre-test - methods of ensuring reliability: Calibration of the equipment – Checking functionality is important. Warm-up – The subject must be ready for strenuous exercise. Fitness test technique practice – A demonstration of the technique can aid reliability.

During the test - methods of ensuring reliability: **Skill level of the administrator** - Tests should be undertaken by experienced testers. Adherence to test protocol – Deviation from the correct procedures will invalidate the results. Constant conditions – Weather and motivation of the performer are just two. Appropriate rest period between tests – Subjects must be able to produce the same level of performance across trials.

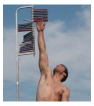
Before selecting appropriate fitness test for a subject the administrator must decide on the suitability and practicality of each test. Factors affect the practicality of testing: Cost – many test require expensive equipment. Time – This depends on the number of subjects to test. Equipment – Will the subjects require a laboratory or is the test mobile? Facilities available – Safety of such areas should be checked.

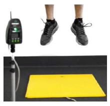
Reliability and Accuracy

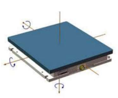
The proper selection of equipment is vital to the ability to accurately measure and track changes in performance. When measuring sprint time, electronic timing systems are recommended but may contain significant errors when an arm or leg passes through a gate before the torso. Dual-photocell and signal processing systems have been developed to overcome these issues and minimize error.

1RM requires technical competence

Recently, linear position transducers have gained in popularity as a means to monitor velocity in strength training exercises. The measurement error of such devices has been shown to be low and both relative and absolute reliability have been shown to be acceptable. Linear position transducers are reliable and valid tools to help monitor and optimize strength training programs.







Several devices are available to measure vertical jump height based on flight time, reach height, or ground reaction forces. It seems that the different flight times derived from the VJ mat may permit the VJ mat to be in closer agreement with VJ heights from the Vertec. Also, the VJ mat may not be an appropriate tool for assessing high VJ performances.

Releability - Standardising Tests

A test must have good reliability in order to produce meaningful results.
To maximise its reliability, as many variables as possible must be standardised.

Factors which can affect the results of a test are:

- the environment,
- the test protocol,
- motivation of the performer,
- their pre-test physical state and
- familiarisation with the test itself

Reliability and Accuracy

Skinfold sites and their associated error used for the determination of body fat percentage

Method	Sites	% Error male	% Error female
7-site formula	Chest, midaxillary, triceps, subscapular, abdomen, suprailiac, thigh	3.5	3.8
3-site formula	Chest, abdomen, thigh (men only); triceps, suprailiac, thigh (women only)	3.5	3.9
3-site formula	Chest, triceps, subscapular (men only); triceps, suprailiac, abdominal (women only)	3.6	3.9

Information attained from the American College of Sports Medicine (1).

The measurement of an athlete's body composition - the most common method used in field-based testing is the determination of body fat percentage via skinfold assessment. The validity of this protocols based on its high correlation (0.798) with the ''gold standard'' laboratory-based protocols of dual-energy x-ray absorptiometry scanning and hydrostatic weighing. Logically, the strength of this correlation and thus its validity is largely based on the **expertise of the investigator (this also affects its reliability)**. Moreover, this correlation is further affected by **methodological issues, such as the number of sites** on the body that are assessed as well as the location of those sites.

Reliability and Accuracy

PERFORMANCE ANALYSIS IN SOCCER: APPLICATIONS OF PLAYER TRACKING TECHNOLOGY

Video-based-motion analysis, semi-automated multiple camera systems and global positioning technology record distance covered by players during matches and data can be analyzed based on players' positions on the pitch, changes in the players' motor activity intensity level, and match period (first or second half).

The analysis of physical loads on soccer players during a match is highly useful for training individualization. It provides a tool for effective planning and for recording the loads on players, which is an indispensable element of modern coaching.

However, the results from different systems such as GPS based athlete tracking devices and semi-automated multiple camera based **systems cannot be used interchangeably**. Indeed, the magnitude of measurement differences between methods suggests that **significant measurement error** is evident.

This is apparent even when the same technologies are used which measure at different sampling rates, such as GPS systems using either 1 Hz or 5 Hz frequencies of measurement.