SECTION 2.

THE SCIENTIFIC BASIS OF STRENGTH AND CONDITIONING

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2.1 INTRODUCTION

As a S&C Trainer, you will develop the skills and understanding to plan, prepare and deliver sessions that focus on:

- Foundation movement skills – an essential introduction to all elements of strength and conditioning and the gateway to sustainable, long-term fitness and well-being
- Energy systems training to improve aerobic and anaerobic endurance
- Strength-based training to develop:
    - Foundation movement competency
    - Strength
    - Muscular endurance
    - Hypertrophy
    - Explosive movements
- Speed (acceleration, deceleration and change of direction).

Foundation movements and the development of a broad work capacity form the platform from which all subsequent strength and conditioning prescriptions should progress (see Figure 1). Once developed, higher intensity and more specific capacities will be built that will lead to actual performance changes in sport.

The process should be a progressive journey that allows development of the highlighted physical qualities. As each physical layer is reached, the next quality can be developed. The emphasis through all layers should be on quality of movement. Trainers should develop a comprehensive movement and skill vocabulary in participants.

For more advanced athletes where sports performance is essential (eg, professional sports people), the needs analysis (see 3.3 Sports/activity needs analysis) and the testing battery (see 4.5.2 Physical testing) will identify physical qualities that must be prioritised. Even advanced athletes may demonstrate foundation movement deficiencies; in addition, they will probably have developed some of the levels of the pyramid to a greater extent than others, depending on their previous training history. In this scenario, the progression through the pyramid layers is not practical. Training should always consider development and maintenance of the foundation movement qualities, but exercise selection to develop the necessary physical qualities higher in the pyramid should involve competent movement patterns that can be overloaded in a safe and effective way.

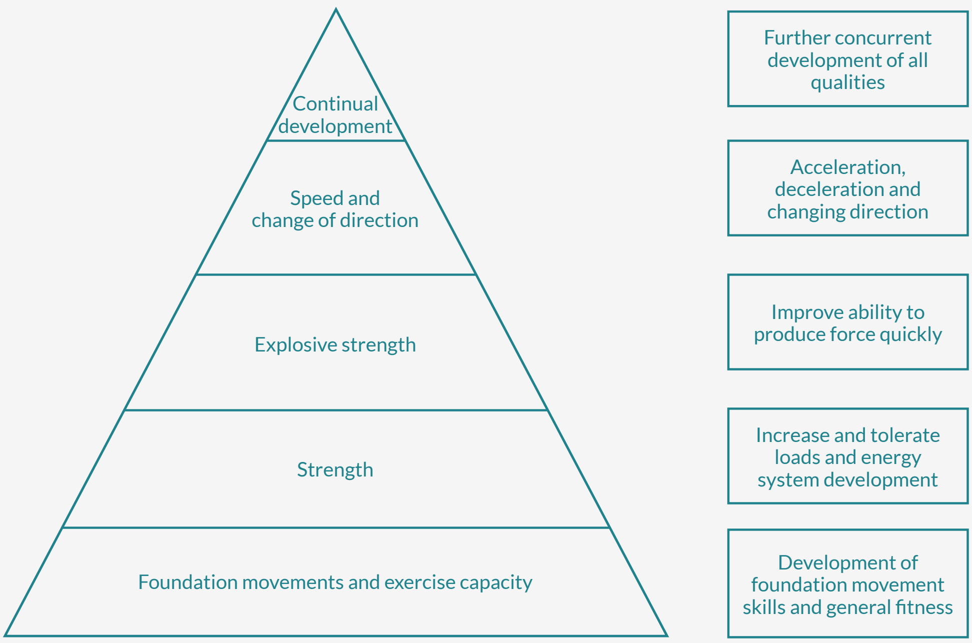


Figure 1. General conceptual model for developing movement

2.2 FOUNDATION MOVEMENT SKILLS

Foundation movement skills form the platform from which all athletic movement is built, and as such should be given priority in programming regardless of the target group.

These movements are physical and technical skills that require effective coaching and application in order to master control, stability and mobility. Failure to do so will prevent progression and may lead to muscle imbalance, injury and reduced performance. Only when participants develop a foundation of movement and technical ability in these movements can a programme be advanced.

The goal should be to develop symmetry throughout the body with the ability to achieve optimal posture and control, specifically through the trunk and limb alignment.

Flexibility, mobility and stability will determine a participant's ability to execute the foundation movements and should therefore be developed through programming and coaching. Sex, age and daily activity will have an influence on individual levels. For example, flexibility and mobility will decrease with age if not maintained in a programme.

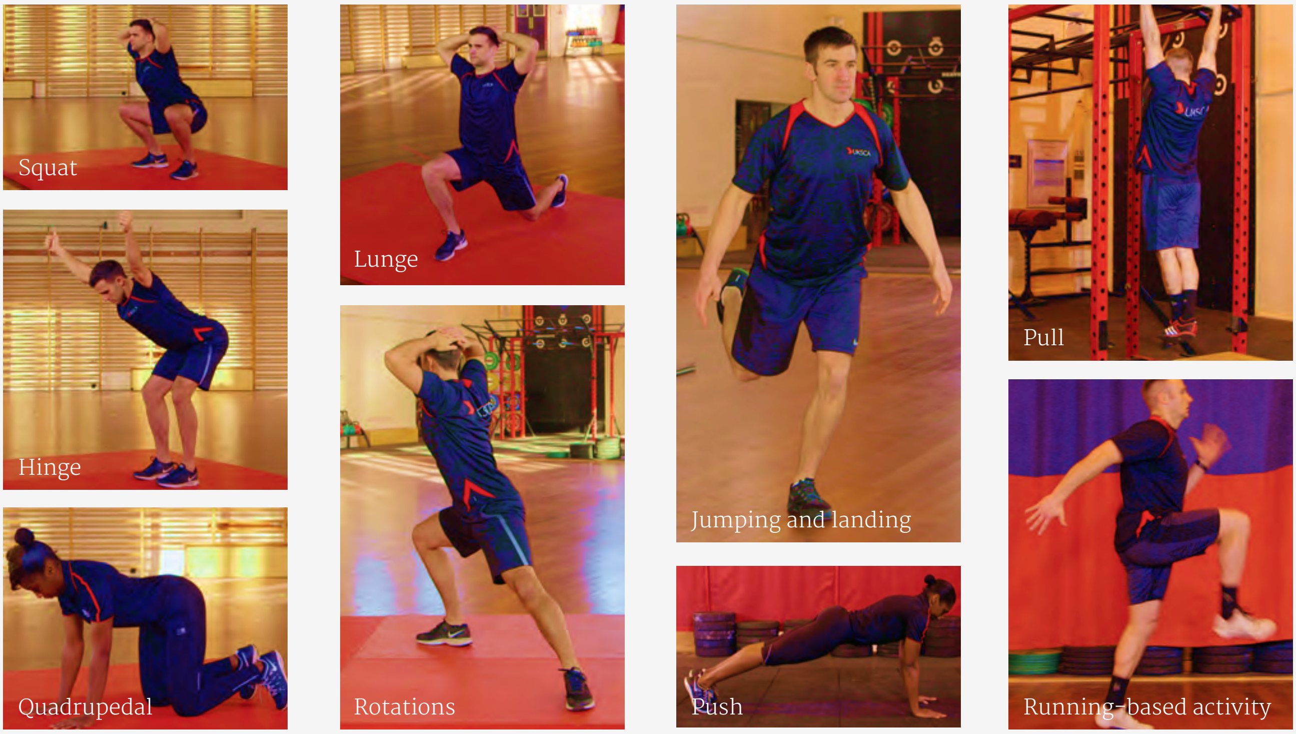


Figure 2. Foundation movements

These categories of movement provide the S&C Trainer with a framework to guide exercise prescription and encourage the development of flexibility, mobility, stability, balance and coordination. The foundation movements include basic athletic actions like running, jumping and throwing, that can be adapted for all abilities to improve the health and function of the neuromuscular and skeletal systems.

The ability to lift and carry a load are also foundation movements that are explored later in this section (see 2.4 Strength-based training).

2.2.1 FLEXIBILITY

This is the ability to move a joint or joints through its/their complete range of motion, which is dictated by the normal extensibility of the surrounding soft tissue and the structure of the joint.

2.2.2 MOBILITY

Mobility is the ability to use available 'range of motion' (ROM) in a controlled and coordinated movement pattern through a range of joint actions. It should be noted that high levels of mobility without high levels of strength could be problematic, contributing to a lack of stability and overall neuromuscular control. In order to protect the joints from injury, development of strength through full ROM is essential.

2.2.3 STABILITY

Stability encompasses both flexibility and mobility, but is more directed at the ability to maintain a desired position at any point of a participant's available ROM. This involves having strength and control and can be developed by the S&C Trainer. Stability of the joint should exhibit the same qualities irrespective of movement planes.

Stability and mobility interplay throughout the main joints of the body, ensuring sound posture and freedom of movement. When an athlete is competent in a foundation movement it is then safe to load the movement as part of a progressive programme. Developing movement competency through all major joint sites at differing speeds and loads is vital for stability through all sporting actions; this loading is explored later in the manual (see Section 5 Guidelines for designing specific S&C sessions). Restriction of movement can lead to imbalances, which in turn can contribute to injury as well as reductions in strength. This decrease in force output can prevent participants from optimising their performance.

2.2.4 BALANCE

Balance is the even distribution and control of load throughout the body. It is developed in a range of scenarios, including static balance and dynamic balance actions, to allow movement in multiple directions at a range of speeds while maintaining effective posture. The ability to balance or regain control of the body will reduce injury and further enhance athletic movement.

2.2.5 COORDINATION

Coordination is the ability to synchronise the component parts of the body in multiple directions. Efficient coordination results in fluid, athletic movement under a range of speeds and loads.

2.2.6 STRENGTH

As a stand-alone quality through the foundation movements, strength should be underpinned by competence in the qualities above. Loading dysfunctional movement will result in both injury and compromised performance. Seek to develop full ROM in large coordination patterns before loading with high intensity actions.

2.2.7 STABILITY AND MOBILITY OF KEY JOINTS

Cervical spine	**STABILITY:** the neck should be able to be stabilised in a neutral position during all other body movements **MOBILITY:** the neck needs to be mobile to allow visual scanning through rotation, flexion and extension patterns without unnecessary compensatory movements of the shoulder girdle or vertebral column
Shoulder girdle	**STABILITY:** the shoulder girdle is the anchor for all upper body push/press and pull activity. Stability of the shoulder girdle is often evaluated by observation of scapular position and movement during pull and push actions **MOBILITY:** the shoulder girdle should move with ease through full range in retraction, protraction, elevation and depression
Shoulder joint	**STABILITY:** the shoulder is by design a very mobile joint with multiple actions. Stability should be developed by strength-based training in full-range actions in unilateral, bilateral and contralateral movements. Function of shoulder joints will be enhanced by stability and mobility of the shoulder girdle and thoracic spine **MOBILITY:** the shoulder should move with ease through full ranges in multiple actions
Thoracic spine	**STABILITY:** the thoracic spine needs to be able to stabilise to brace against external forces at any given point in normal range of motion **MOBILITY:** the thoracic spine has approximately 35–45° of rotation; promoting movement in this portion of the spine will help to ensure it does not come from the lumbar region. The thoracic spine is naturally in a position of flexion and, for many participants, issues with thoracic mobility will relate to an inability to reduce relative flexion ('extend' the thoracic spine). An inability to reduce flexion from a 'neutral' 40° to +/- 15° will be problematic for overhead movements[19]
Lumbar spine	**STABILITY:** the lumbar spine has approximately 5–10° of rotation (approximately 1–2° per vertebrae); thus excessive rotational movement should be avoided in this region. Stability and integrity of the lumbar spine will be optimally maintained through healthy function of the shoulder joint, shoulder girdle, thoracic spine and hips **MOBILITY:** the lumbar spine still needs to be able to flex and extend when required
Hips	**STABILITY:** the hip is by nature a very mobile joint with multiple actions. Stability should be developed by strength-based training in full-range actions in bilateral, unilateral and contralateral movements **MOBILITY:** the hips move in all three planes of motion; thus keeping this area mobile is essential for optimal movement and the reduction of injury risk at the lumbar spine, knee and ankle joints
Knee	**STABILITY:** stability at the knee will ensure proper alignment with the hip and ankle joints as well as influencing control around the knee joint, thus decreasing the likelihood of injury **MOBILITY:** the knee should be mobile through full ranges of motion
Ankle	**STABILITY:** the ankle must be able to hold optimal positions and aid stiffness for effective ground contacts in running and jumping activities. These abilities can be developed through full ROM plantar- and dorsiflexion actions and reduction of eversion and inversion actions during ground contacts **MOBILITY:** the ankle should be mobile through full ranges of motion to ensure efficient movement and reduce the risk of injury.

Table 1. Detail of stability and mobility of key joints

2.2.8 MOVEMENT PROGRESSION AND REGRESSION

Time spent developing the foundation movements at the beginning of the coaching journey leads to greater potential for long-term gains. Trainers should be able to assess movement qualities with a 'coaching eye' and apply progressions and regressions where appropriate.

- Bilateral movement to unilateral movement:eg, 'squat jump and stick' into 'horizontal progressions'
- Simple movements to complex movements: eg, 'thoracic clams' to 'rotating medicine ball throws'
- Slow movements to fast movements: eg, 'jump position' to 'full extention' to 'counter movement jump'
- Static movements to dynamic movements: eg, 'pouncing cat' to 'cat walk'
- Unloaded movements to loaded movements: eg, 'bodyweight squat' to 'barbell back squat'.

(See Section 6 Technical models: Foundation movements and Section 7 Technical models: Strength-based training)

The syllabus of foundation movement skills provides the S&C Trainer with a valuable framework with which to introduce and develop confidence and competence in the exercise and training environment.

Participants can be monitored, progressed and regressed appropriately through effective coaching and using screening tools (see 4.5.2 Physical testing) to evaluate individual technique against the guidelines laid out in the technical model.

SECTION 2. THE SCIENTIFIC BASIS OF STRENGTH AND CONDITIONING

2.3 ENERGY SYSTEMS TRAINING (EST)

The term 'energy systems training' (EST) is used in preference to terms like cardiovascular (CV) training in order to include a broader range of training objectives and conditioning protocols. These range from low intensity steady-state activity, to improving the aerobic energy system of an inexperienced participant, to repeating sprint intervals to develop the ATP-PC energy system of a competitive athlete. The ATP-PC system consists of adenosine triphosphate (ATP) and phosphocreatine (PC). This energy system provides immediate energy through the breakdown of these stored high energy phosphates.

There are a number of strategies that the S&C Trainer can apply in the context of improving energy systems fitness and these will be determined by the participant's needs. The process of assessing and programming for energy systems fitness will begin at the stage of the initial consultation to establish medical history, risk factors and exercise preferences (see 4.3 Initial consultation and analysis and 5.1 Risk stratification).

The scope of practice of the S&C Trainer encompasses a wide range of ages, abilities and training histories, and the objectives of energy systems training for different individuals might range from implementing and monitoring minimum levels of moderate to vigorous physical activity (MVPA), to developing high-intensity interval training (HIIT) based on the demands of a specific sport. These levels will be determined with initial consultations and the status of the individual participant, (see 4.4 Participant/athlete needs analysis and 3.3 Sports/activity needs analysis).

In all cases, it is important that there is discussion, explanation and agreement between the participant and the S&C Trainer in order to establish the purpose of the training, to determine the appropriate mode of assessment and to agree the structure of the resulting programme.

As a trainer, you will be required to assess and train participants in the context of submaximal ('moderate to vigorous'[1] physical activity) energy systems training, as well as maximal or near-maximal exercise ('vigorous to very vigorous'or high intensity activity), thereby meeting the needs of a range of abilities and objectives.

It is worth noting, in Figure 3, that the Chief Medical Officer's (CMO) guidelines for vigorous and very vigorous exercise contain a misleading generalisation about the increasing intensity of exercise, namely that increased heart rate, respiratory rate and energy consumption always accompany an increase in intensity. It is expected that the S&C Trainer can see past this simplification and recognise that intensity in anaerobic (ATP-PC) activities such as short sprints and strength training is independent of heart rate. Much lower heart rate rises will be seen compared to continuous or interval-based training dominated by aerobic/anaerobic glycolysis energy systems.

2.3.1 LOW INTENSITY EXERCISE ENDURANCE (LIEE)

Although it is termed 'low-intensity', this level of training actually falls under the UK Chief Medical Officer's 2019 guidelines for moderate to vigorous activity, being characterised by the following:

- Notably accelerates heart rate and breathing
- Example activities include walking, running, cycling – where intensity can be easily varied
- Moderate – can talk comfortably; vigorous – difficulty talking without pausing.

LIEE is commonly represented by a continuous bout of exercise at a relatively constant pace, or 'steady state'. Training sessions of this nature are therefore referred to as 'low-intensity steady state' (LISS). If using a heart rate monitor, LISS training would be in or around the range of 50-60% of maximum heart rate (this can be estimated for participants new to training by using the formula 220-age to establish maximum heart rate).

The S&C Trainer can use LISS principles to establish baseline measures for a participant's energy systems fitness at the start of a training programme if there are concerns about their participation in a maximal effort assessment, or if the participant would prefer a submaximal evaluation. If participants are new to structured, coach-led training, the LISS session presents a good opportunity to build confidence and establish a rapport with the participant. In addition, it helps to develop training skills such as equipment operations, technique and awareness of training intensity through use of perceived rate of exertion (RPE) scales and monitoring heart rate.

Using a treadmill, stationary bike, rower or other EST equipment (see 3.4.4 Equipment considerations), the trainer can establish an individual's appropriate LISS training intensity by using the talk test, recording rate of RPE and by monitoring heart rate (recommended, but not essential). LISS principles can also be applied to any outdoor running trial, provided the same route is used for comparative assessments.

The observation should last 20 minutes and be preceded by a comprehensive induction to ensure effective use of the equipment and the assessment protocol. The participant should be capable of operating the adjustable settings for optimal body position, use the console to monitor intensity and understand correct technique. The S&C Trainer needs to explain the use of the RPE scale as shown on the following page (using the Borg scale or Modified Borg scale according to personal preference) and use this frequently during the 20 minute observation to ensure the intensity remains within LISS objectives ie, within the 'moderate' to 'somewhat hard' range. The participant should be encouraged to control the pace themselves, with the trainer recording the corresponding speed/intensity displayed on the console with each RPE reading.

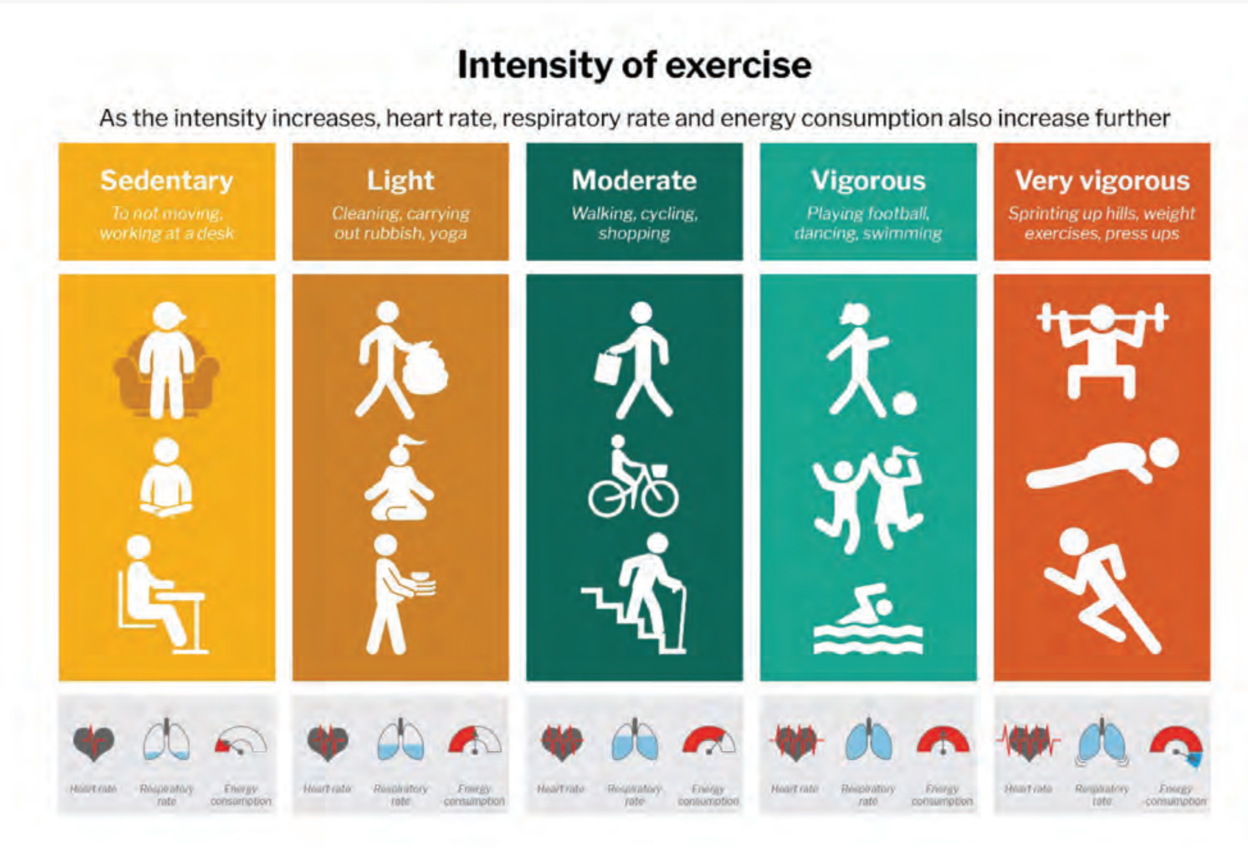


Figure 3. CMO guidelines for intensity of exercise

RPE

BORG SCALE	
6	At rest
7	Very, very light
8	
9	Very light
10	Somewhat easy
11	Moderate
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

MODIFIED BORG SCALE	
0	At rest
1	Very light
2	Somewhat easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very hard
8	
9	
10	Very, very hard (maximal)

Table 2. Rate of perceived exertion (RPE)

Following the LISS assessment, the trainer and participant will have the necessary information – specific to the mode of assessment (eg, walk, run, cycle, row) – to prescribe an appropriate training programme.

The LISS equipment-based assessment for energy systems fitness is useful in as much as it provides a simple, sub-maximal baseline measure for the participant, and it can help to develop confidence and engagement in the exercise environment.

Given that the CMO guidelines for physical activity are 75 – 150 minutes per week[6] (see Figure 4), the trainer should consider how equipment-based EST sessions will link with other physical activity and the participant's strength-based training to create a holistic programme of health and well-being.

2.3.2 HIGH INTENSITY EXERCISE ENDURANCE (HIEE)

High intensity interval training (HIIT) has had a surge in popularity and there are well-documented benefits, but more is not necessarily better than other levels of training, particularly when working with participants for whom endurance activities (distance running, triathlons, cycling) are a primary training objective, or when working with participants who might find moderate intensity training more enjoyable and sustainable in the long term.

In the case of competitive and recreational endurance sports participants, it is widely recognised that the majority of the volume of endurance training will occur at lower intensities, with the guideline being the application of an 80:20 ratio.

Figure 4. CMO guidelines for physical activity

It is important that the S&C Trainer takes a measured approach to the prescription of training for the participant, ensuring that their needs, preferences and ability are the leading factors in the selection of EST protocols, rather than just following general trends in training.

2.3.3 LOWER VERSUS HIGHER INTENSITY TRAINING

This information shows some of the thinking around lower versus higher intensity training - specifically for endurance athletes (ie, fairly steady state action for > 30 mins). Based on Table 3 below, 80% of training would occur in zones 1 and 2, and 20% in 2-5, with the dividing line being blood lactate concentrations of +/- 2mmol/L.[24]

INTENSITY ZONE	Vo_2 (% MAX)	HEART RATE (% MAX)	LACTATE (MMOL/L)	DURATION WITHIN ZONE
1	45 - 65	55 - 75	0.8 – 1.5	1 – 6 h
2	66 - 80	75 - 85	1.5 – 2.5	1 – 3 h
3	81 - 87	85 - 90	2.5 - 4	50 – 90 min
4	88 - 93	90 -95	4 - 6	30 – 60 min
5	94 - 100	95 - 100	6 - 10	15 – 30 min

Suggested volume of lower versus higher intensity training for endurance athletes	
80%	20%

Table 3. Lower versus higher intensity training for endurance athletes

Endurance capacity is determined by three key variables which are outlined in Figure 5:

1 **Maximal oxygen uptake (VO_2Max)** – the maximal volume of oxygen that the body can deliver to the working muscles per minute

2 **Lactate threshold** – the intensity of exercise at which lactate begins to accumulate in the blood at a faster rate than it can be removed. In any progressive exercise test, two breakpoints in the lactate curve can be identified. The first is the lactate threshold (LT) which is when blood lactate accumulates to a level 1mM above resting levels or 2.5mmol/L – see zone 2 in Table 3. The second, which occurs at a fixed lactate concentration of 4mM, is termed the onset of blood lactate accumulation (OBLA) – see zone 3 in Table 3. The percent of VO_2max that can be maintained in an endurance event or race is closely linked to the oxygen uptake at the LT

3 **Movement economy** – the aerobic energy cost required to perform a submaximal task, providing information about an individual's aerobic efficiency while exercising.

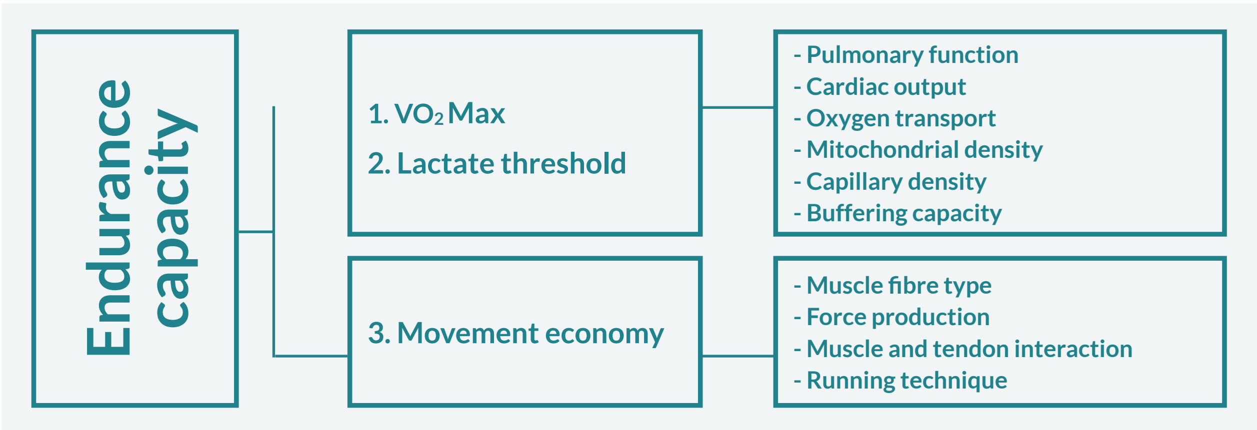


Figure 5. Key variables affecting endurance capacity[28]

From the CMO Guidelines 2019:

'This report recognises an emerging evidence base for the health benefits of performing very vigorous intensity activity performed in short bouts interspersed with periods of rest or recovery (high intensity interval exercise, HIIT). The available evidence demonstrates that high intensity interval exercise has clinically meaningful effects on fitness, body weight and insulin resistance and can be as or more effective than moderate to vigorous physical activity (MVPA)'[6]

TRAINING VARIABLE	ATP-PC	ANAEROBIC GLYCOLYSIS	ANAEROBIC/AEROBIC GLYCOLYSIS	AEROBIC GLYCOLYSIS/FAT OXIDATION
Mode of exercise	Short sprint intervals	Short intervals	Long intervals	Continuous/long intervals
Intensity (% of max effort*)	90-100	75-90	30-75	20-30
Exercise time	2-6 secs	15-30 secs	1-3 mins	>3 mins
Work:rest ratio	1:12-1:2	1:3-1:5	1:1-1:2	1:0.5-1.1

Table 4. General guidelines for training energy systems

*Max effort would be maximum sprint speed in running-based activity, or maximum power output in activities such as cycling or rowing

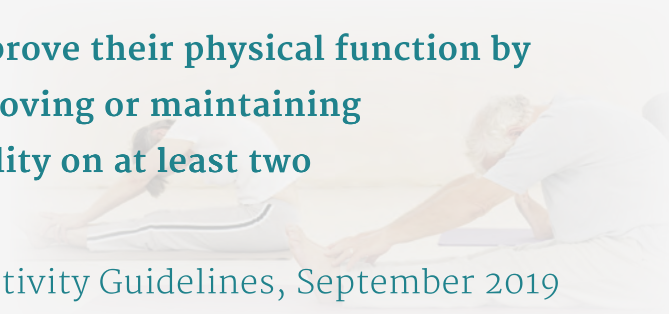
Table 4 represents very broad guidelines for trainers looking to positively impact specific energy systems, but it can often be difficult to decide which is the most appropriate way, particularly in terms of what is the best intensity. Intensity is often prescribed as a percentage of maximum heart rate, which works for training the aerobic energy systems, but does not accurately predict appropriate intensity for training anaerobic systems. Hence Table 4 looks at a percentage of maximum running speed (or maximum power output in other activities such as rowing and cycling) to train ATP-PC and anaerobic glycolysis. ATP-PC development is at or near maximal velocity and anaerobic glycolysis is at a fast but sub-maximal velocity. The key for these two systems is the recovery. Near maximal recovery for ATP-PC allows near maximal velocity with each training repetition; in contrast, extended, but partial recovery, taxes the anaerobic glycolytic system, forcing athletes to cope with an increase in acidosis.

2.4 STRENGTH-BASED TRAINING

Strength is the ability to produce force, both in magnitude and direction, against an external resistance. It is essential that all participants, irrespective of age and sex, develop this skill

Strength-based training uses both bodyweight and external resistance, with the desired outcome of developing strength (or the ability to produce force) and changes in musculoskeletal capacity. Commonly, resistance will be an external load such as barbells, dumbbells and kettlebells, but bands and 'soft' resistance, such as sandbags, medicine balls and bodyweight, can also be utilised. A foundation level of strength will underpin a wide range of physical qualities and efficient athletic movement; it will also contribute to a reduction in injury. The type of strength training is categorised by the muscular contraction utilised through the chosen exercises. Muscular contractions or actions can be eccentric (muscle lengthening), concentric (muscle shortening) and isometric (no change in muscle length). Once competent in foundation movements, the S&C Trainer should be aiming to progress participants through well-rounded programming that develops all contraction types as well as targeting specific outcomes through exercise and task selection.

There is a significant body of evidence that suggests that maintaining or even developing strength qualities throughout life should be the primary focus of any exercise programme to provide the best chance of a healthy ageing process.



> **'Older adults should maintain or improve their physical function by undertaking activities aimed at improving or maintaining muscle strength, balance and flexibility on at least two days per week'[6]**
>
> UK Chief Medical Officers' Physical Activity Guidelines, September 2019

Optimal strength training relies heavily on underlying mobility, control and full range of motion. As it is a technical skill, time should be allocated for its development. Consideration should be given to individuals based on their ability to coordinate their body and their underlying natural strength. It is common to see a range of genetic strength qualities in participants and no two people will react in the same way to similar exposures to training.

The following sections discuss and explain the components of strength-based training:

- Muscular endurance
- Hypertrophy
- Maximum strength
- Rate of force development (RFD)
- Explosive strength
- Strength endurance

NB: The order of strength qualities above reflects the typical programming progression for participants new to strength and conditioning (see 5.2 Guidelines for designing a strength-based session).

2.4.1 MUSCULAR ENDURANCE

Muscular endurance is the ability to produce submaximal forces for extended periods of time

Loads lifted when training muscular endurance are substantially lower than other training modalities and incomplete recovery is vital, promoting submaximal contractions for extended periods. Muscular endurance involves the body's ability to tolerate fatigue caused by anaerobic glycolysis, utilise lactate as an energy source and promote the use of the cardiovascular system to aid recovery from anaerobic exercise bouts.

Training targeted towards improved muscle endurance aims to develop a foundational work capacity and can be further subdivided into:

- General anatomical adaptation (GAA)
- Technical development
- Muscle hypertrophy.

General anatomical adaptation is the process of 'getting ready to train' and prepares the participant for structured strength training.[3] The key focus should be on the use of large muscle groups through the foundation movements, typically in higher repetition ranges and lower loads than strength training. It can occur alongside the process of technical development with new participants as they develop basic movement competency in a range of total body, coordinated lifts. This process is an opportunity for trainers to correct issues with posture, coordination and imbalances while building a base work capacity.

Training may also increase a participant's lean muscle mass and connective tissue through muscle hypertrophy (see 2.4.2 Hypertrophy), but this should be considered a 'by product' of muscular endurance training and not the main aim. Trainers should be aware that increasing lean muscle mass alone will not necessarily lead to strength gains and they should seek to develop a hypertrophy that will benefit the participant in later training. Trainers should therefore not select exercises that isolate muscle groups (due to their low functionality and issues with coordinating complex movements).

2.4.2 HYPERTROPHY

Hypertrophy involves an increase in mass of muscle and connective tissue thickness

As an effect of training, hypertrophy is a double-edged sword: for some participants increasing muscle mass alone is an incentive to train, whereas for others, misconceptions about 'gaining size' or 'muscle bulk' are a barrier. It is important that the S&C Trainer has a good understanding of the factors related to hypertrophy in order to effectively advise participants to achieve their training objectives. As discussed, many of the benefits of strength-based training (eg, mobility, coordination, balance) can be achieved without significant increase in muscle mass because of neural adaptations (development of motor neuron pathways that enhance an athlete's brain-body coordination during functional movements).

Muscle cross-sectional area (CSA) is proportional to maximum force-producing capabilities[5] and it is likely that hypertrophy-focused training will be an integral part of an effective strength-based programme. This training objective is usually integrated in a GAA plan, following a period of movement competency and technical development for new participants. This notion of using hypertrophy training as a foundation for further performance or 'functional' objectives is distinct from the goal of increasing hypertrophy for purely subjective, aesthetic reasons, as the latter can be achieved to some extent without necessarily improving overall athleticism.

Evaluation of the effectiveness of a hypertrophy programme is challenging for a S&C Trainer in the absence of accurate monitoring of changes to body composition to determine if the gains in size are indeed an increase in lean body mass. It is advisable for the trainer to seek support from appropriately qualified professionals who can provide approved assessments of body composition.

A simple strategy to implement - alongside tracking changes to body mass, body composition and circumferential measurements - is to monitor load lifted relative to bodyweight and/or jump height/distance and then set goals that aim for strength.

2.4.3 MAXIMUM STRENGTH

Maximum strength can be defined as: The force that a muscle or group of muscles exerts in a single maximal contraction against an external load

Typically, traditional strength training uses higher loads than muscle endurance, which utilises increases in volume. It requires longer rest periods to allow the body to recover sufficiently and repeat tasks at a high intensity. Because of the higher loads involved, it is common for multi-joint compound lifts to be used, although strength training can extend to smaller assistance movements, particularly when muscle imbalances are being prevented.

For the vast majority of sports, the ability to generate large forces in a relatively short period of time (ie, high rates of force development, RFD) is an essential fitness quality for successful participation. Strength, or the ability to generate large forces, is central to large RFD capabilities[27] and participants demonstrating superior strength levels are generally more successful in sports activities that include running, jumping, punching, throwing, kicking and changes of direction.[12] Additionally, cross-sectional studies report that stronger people are more likely to perform at a higher level in their chosen sport when compared to their weaker counterparts.[10]

From a participant's perspective, strength is an essential foundational physical quality for both successful performance/participation and injury reduction. Programming to consistently develop strength in all three contraction types (ie, eccentric - muscle lengthening; concentric - muscle shortening; isometric – no change in muscle length) should be considered important. Sport-specific examples to support this rationale are provided below:

Eccentric: a high level of eccentric (muscle lengthening) strength is important to be able to effectively decelerate (eg, landing phase in jumps and rebound activities, deceleration before a change of direction). When playing a sport, the ability to decelerate as quickly as possible will enable the participant to create space and potentially create a goal-scoring opportunity, to evade an opponent to prevent collisions and potential injury and/or to be better able to defend an opponent and prevent a goal-scoring opportunity in the opposition. In a recent study looking at acceleration and deceleration profiles of elite female soccer players, it was reported that players performed a total of 430 (± 125) decelerations during a match, with the mean distance ranging from 1 to 4m and a mean time between efforts of 11-16 seconds.[17]

Concentric: In any dynamic movement there are two phases evident – concentric and eccentric – with the maximal load that can be overcome being limited by an individual's concentric (muscle shortening) strength capacity. Therefore, for any dynamic sports movement (eg, lineout or maul in rugby union) the ability to generate concentric force is crucial.

In ballistic activities which are performed with maximal intent, concentric strength is the major determining factor in the velocity of release (throwing) or take-off (jumping). The greater the velocity of release or take-off, the more successful the throwing or jumping action will be.

Isometric: Trunk control, defined as the 'capacity of the body to maintain or resume a relative position (static) or trajectory (dynamic) of the trunk after perturbation',[30] is a necessary strength quality for many sports activities and exercise techniques. Appropriate coordinated co-contraction of the trunk flexors and extensors is a basic requirement to

provide stability of the spine; a lack of strength in these muscles means that the trunk may be caused to buckle rather than keep a strong isometric shape during sports performance or in training.
A common theme of many of the technical models (see Section 6 Technical models: Foundation movements and Section 7 Technical models: Strength-based training), is the maintenance of a neutral lumbar curve – poor postural shapes often preclude a participant from loading the exercise for strength gains (eg, squatting movements, stiff legged deadlift). Isometric strength of the trunk musculature can be achieved through progressive loading of multi-muscle, multi-joint weightlifting movements,[4] such as overhead squats or pulls from floor, which will ultimately lead to a greater ability to load these exercises for strength gain.

The trunk is a vulnerable area in relation to injury/pain, but can also be associated with predicted risk of knee, ligament and ACL (anterior cruciate ligament) injuries in athletic populations (see 4.4.7 Sex considerations for S&C).

2.4.4 RATE OF FORCE DEVELOPMENT (RFD)

Rate of force development can be defined as: The ability to produce large forces quickly

Depending on the external load, either force output (ie, high loads) or velocity (ie, light loads) will be prioritised.

NB: In muscle there is an inverse relationship between the force it can generate and the velocity with which it contracts.

RFD might be prioritised according to high loads moved quickly (ie, 'strength-speed') or relatively lighter loads moved even faster (ie, 'speed-strength'). It is important for the S&C Trainer to recognise that the scope of RFD activities within a S&C Trainer qualification is limited and that further professional development is needed to develop the knowledge, understanding and application of available training methods and exercises to target RFD. Building on the scope of practice, the S&C Trainer should look to develop competency, using and coaching weightlifting movements and their derivatives.

Sports usually involve technical elements that require participants to produce high rates of force development over a continuum of loaded conditions – the ability to express high forces over the full range of concentric contraction velocities is key to successful performance. For example, in rugby union, rucks, mauls and scrums will require players to overcome a 'heavy resistance' (ie, player's own body weight, plus an opponent's body weight).
In contrast, the ability to overcome a lighter load (ie, throwing the rugby ball) will also be required numerous times during training and competition.

2.4.5 EXPLOSIVE STRENGTH

Explosive movement such as jumps and throws are performed with maximal intent

They are performed once there is sufficient underlying strength, movement and coordination given their highly technical nature. Quality of the work should be the key consideration here, rather than the total volume, and work to rest ratios will reflect this, eg, complete rest is required. These highly technical, coordinated movements correlate highly with athletic movements such as running, jumping, changing direction etc.

A range of training methods can assist a trainer's programme for explosive training and include:

- Jumps
- Throws (eg, medicine ball)
- Sprinting
- Pushing/dragging (eg, prowler and sleds).

2.4.6 STRENGTH ENDURANCE

Strength endurance is: The ability to produce high forces in a fatigued state

Force production will always be a balance between strength and endurance. Less fatigue (longer rest between sets) will lead to the ability to produce greater forces. However, in some sports, large forces are required to be produced despite short recoveries.

Muscular endurance and **strength endurance** are often confused. The exercise prescription and the physiological adaptations to a muscular endurance programme are very different to those for strength endurance. Muscular endurance training uses relatively lower loads to increase the ability to do work over an extended period. Strength endurance uses higher loads with the aim of developing a capacity to repeat near-maximal efforts.

For most sports, both muscular endurance and strength endurance are relevant to both performance and injury risk. For example, volleyball is a sport characterised by repeated explosive jump efforts (see Figure 6), interspersed with brief rest periods over the match duration (60-90 minutes).[18,25] Consequently, volleyball players need high levels of strength endurance to be able to maintain maximal jump efforts throughout the match. Although this is relevant to all players, positional differences exist and there are some players, specifically middle/central players, where well-developed strength endurance capacities may have a greater impact.

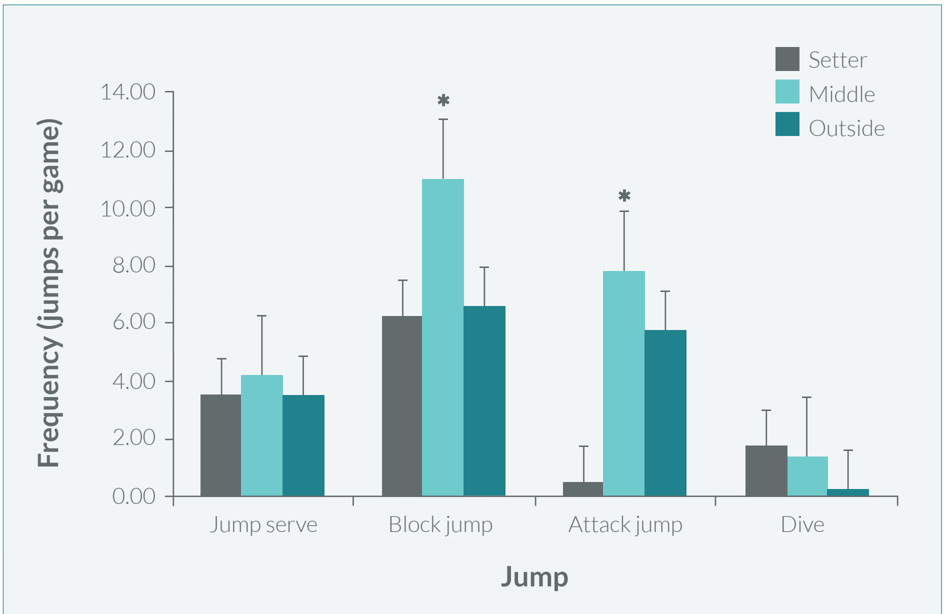


Figure 6. Time-motion analysis of different positions in elite men's volleyball

2.4.7 THE PHYSIOLOGY OF DEVELOPING STRENGTH

ANATOMICAL (OR MORPHOLOGICAL) CHANGES	NEURAL CHANGES
Changes in muscle fibre type, specifically a hypertrophy of fibres	Increased recruitment of the motor unit
Changes in cross-sectional area of the muscle which contributes to a greater ability to generate force	Increased firing frequency (rate coding)
Changes in the architecture of the muscle (pennation)	More intra and intermuscular coordination
Associated increases in tendon strength and stability	
Improved joint stability and ligament strengthening	

Table 5. The anatomical and neural adaptations to strength training

The main physiological mechanisms underpinning strength qualities are changes in the size and structure of the muscle (ie, hypertrophy, muscle architecture), together with modifications in the nervous system. For participants new to strength training, the relatively quick gains (ie, first few weeks) observed at the start of a strength training programme have previously been attributed to predominantly neural adaptations, but it should be noted that increases in protein synthesis have been shown to occur within hours following a resistance training session.[7,8] Hence, significant increases in muscle cross-sectional area (CSA) can also be evident within 2–4 weeks of starting a training programme, particularly in individuals who respond positively to strength training protocols.

HYPERTROPHIC RESPONSES

The cross-sectional area (CSA) of a muscle is directly proportional to its maximum force-producing capabilities.[5] All fibre types (ie, fast and slow twitch motor units) will hypertrophy (see 2.4.2 Hypertrophy) in response to strength/hypertrophy training protocols, but the CSA of type II (fast twitch) motor units is particularly important because of their ability to generate high forces and high rates of force development (RFD),[5,9] which is key to sports performance.

In addition to increases in CSA, sarcomeres (the most basic units that make up skeletal muscle) can be added in series, causing an increase in muscle length. Eccentric training methods (>100% of 1-repetition maximum (1RM)) have been shown to initiate a greater degree of hypertrophy and addition of sarcomeres in series when compared to traditional heavy resistance training.[1,5,21]

A longer muscle fibre will have a greater velocity of shortening and will promote increases in rate of force development during dynamic movements.

An increase in muscle CSA is the result of an increase in the volume of multiple, individual fibres. This is understood to be the result of two main factors:

- An increase in the amounts of myofibrillar contractile proteins, actin and myosin and the total number of sarcomeres in parallel, thereby increasing the cross-sectional area (CSA) of the muscle fibre.[23]
- An increase in volume and/or proliferation of non-contractile elements such as the sarcoplasm and organelles found therein, particularly those relating to energy production, such as mitochondria,[14] glycogen stores and the metabolites of anaerobic glycolysis.

In the centre of Figure 7 are the training stimulus effects required to elicit a hypertrophic effect. The magnitude of these effects will be determined to a large extent by the participant's genetics and the quality of their nutrition and recovery.

Based on these principles, and in the absence of any performance objectives, it is possible to have a hypertrophic effect on muscles with a range of strategies. The more deconditioned or inexperienced the participant, the more likely they are to respond positively to any form of load or stress on the muscle, particularly if the conditions of their genetics, nutrition and recovery are favourable.

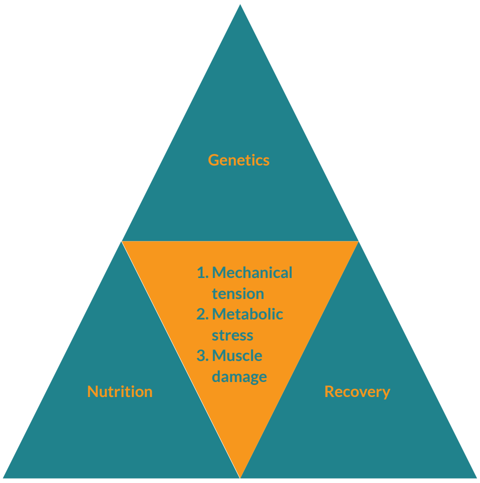


Figure 7. Training stimulus effects

Mechanical tension	A stimulus creates force generation and/or length change in the muscle. Typically created in training by applying an external load
Metabolic stress	Caused by multiple muscle contractions and muscle activity relying on anaerobic stress
Muscle damage	Exercise-induced localised muscle damage (micotrauma) causes satellite cell activity that promotes synthesis of new contractile proteins

THE PENNATION ANGLE

The pennation angle is defined as 'the angle between the muscle fibres and an imaginary line between the muscle's origin and insertion'.[13] Therefore, pennate muscles describe those that attach to their tendon at an angle (ie, attach obliquely) and as such will pull at an angle to the tendon when the muscle contracts. The effect of an increase in pennation angle is twofold: firstly, a greater force production because of an increased number of muscle fibres (ie, cross bridges) in parallel; secondly, slower contraction velocities due to a reduction in sarcomeres in series. The benefits of an increased force-generating capacity associated with an increased CSA is thought to outweigh the reductions in shortening velocity to improve maximal RFD. Although an increase in pennation angle is often reported as an adaptation to heavy strength training, more research needs to be done to fully understand how this type of training can affect pennation angle.[5]

TISSUE ADAPTATION

Ligaments and tendons are both made up of fibrous connective tissue, but tendons connect muscle to bone, whereas ligaments connect one bone to another bone. The primary role of the tendon is to transmit force from the muscle to the bone in order to cause movement. In comparison, ligaments are less elastic than tendons and play a bigger role in stabilising joints.

Although strength training aims to develop muscular tissue, it is important that the supporting structures such as tendons, ligaments and bones are developed proportionally to be able to support the movements produced by the muscles. Tendon injures (ie, strains) are also common in sport, so thicker, stronger tendons will be more resistant to damage.

Tendon stiffness describes the relationship between the force applied to the musculotendinous unit (MTU) and the resultant change in length. A stiff MTU will only change length a small amount when a large force is applied. Conversely, a compliant MTU will change length to a greater degree when the same amount of force is applied.

A stiff MTU can boost force transmission and subsequently improve RFD capabilities,[16,26] which can significantly improve performances in stretch-shortening (SSC) activities.[15] However, recent studies have indicated that adaptations to tendons in response to strength training is slower than muscle CSA and neural adaptations, plus the time-course of detraining responses may be quicker in tendinous tissue. When programming for strength, the S&C Trainer should take into consideration the differing rates that tissues adapt to the training stimulus – too fast a progression may lead to tendinous injuries because they respond at a slower rate than muscle tissue. Therefore, it is recommended that lower intensity resistance training (anatomical adaptation) precedes higher intensity strength training to allow tendon development.

NEUROMUSCULAR RESPONSE

MOTOR UNIT RECRUITMENT

The force a muscle can produce is dependent on both the number and type of motor units that are recruited and it is generally accepted that this occurs in an orderly pattern based on size – smaller, type I motor units are recruited at low levels of force, but as the requirement for force or intensity increases, high force motor units (ie, type IIA & IIX) are activated. Therefore, strength training prescriptions that demand high forces/intensity (ie, low repetition ranges, high load), high speed, and/or maximal intent will specifically target type II motor units. The capacity to fully activate high force motor units is thought to improve with strength training.[2,22]

RATE CODING

Rate coding refers to the frequency of activation of motor units. An increase in the firing frequency can augment both the magnitude and rate of force development generated by the muscle, without increasing the recruitment of additional motor units.[5]

Motor unit recruitment and rate coding both play an essential role in sporting movements that require high RFDs and both can be improved through strength training. Other neural factors such as improved coordination of muscles involved in complex whole-body movements (including agonists, antagonists and synergists) can also lead to greater movement efficiency and force output. Being able to activate the right motor units, at the right time and to the right level to be able to both stabilise joints and generate large forces quickly is a learnt skill that can be improved through strength/ resistance training. The more closely the resistance exercise mimics the sports movement you are trying to improve, with regards to movement sequence and velocity, the more likely you are to improve coordination patterns.[20]

The impact of highly effective intermuscular coordination should not be underestimated because it can result in increases in strength without increasing muscle mass. The generation of high forces can be achieved by agonist activation that is accompanied with increased synergist activity and a reduction in co-contraction of the antagonist muscles,[5] leading to preferential strength to weight ratios for certain athletic groups.

PHYSIOLOGY OF MUSCULAR CAPACITY TRAINING

When performing exercise tasks that involve repetitive, sub-maximal efforts (ie, muscle endurance and hypertrophy training), significant peripheral adaptations occur in skeletal muscle that are critical for improving endurance performance. These include: increases in the activities of an energy source's enzymes; increased fuel availability; increased capillary content in muscle; possible increased mitochondrial content in muscle; muscle fibre type transition from IIX to IIA; and improved muscle buffering capacity.

ENZYME ACTIVITY

Increases in the activities of an energy source's enzymes enables a greater ATP production per unit which can lead to increases in performance. Both creatine kinase and myokinase (enzymes involved in the ATC-PC energy source) have been shown to increase with a period of resistance training. Creatine kinase catalyses the conversion of creatine and adenosine triphosphate (ATP) to create phosphocreatine (PC) and adenosine diphosphate (ADP). Myokinase catalyses the conversion of two ADP molecules to adenosine monophosphate (AMP) to ATP. Both the amount and rate of PC resynthesis is key to sustained repetitive high intensity efforts (eg, strength endurance).

In addition, the activities of enzymes within the anaerobic glycolysis pathway may also be improved following resistance training. These include:

- Phosphofructokinase (PFK) – the key 'rate limiting' enzyme in the anaerobic glycolysis pathway which means that an increase in its activity will increase the rate of glycolysis
- Phosphorylase – the key enzyme in the utilisation of muscle and liver reserves of glycogen. An increase in its activity will allow more carbohydrate to be available to exercising muscle during sustained activity
- Pyruvate dehydrogenase – critical to the process of converting pyruvate produced from anaerobic glycolysis to acetyl CoA so it is available for aerobic metabolism. Increases in the activity of this enzyme will result in less lactate being produced, which will lead to less fatigue experienced during muscle endurance-based training.

MUSCLE SUBSTRATE STORES

Resistance training may increase fuel availability of the anaerobic systems (ie, phosphocreatine, ATP and intramuscular glycogen), allowing a greater capacity for muscle endurance tasks. Because of the anaerobic nature of most endurance-based strength prescriptions, changes to intramuscular triglycerides (eg, fats) is less likely.

CAPILLARY SUPPLY

An increase in the number of capillaries per fibre, or the number of capillaries per cross-sectional area of tissue, enhances the blood supply to the muscle, allowing improved delivery of oxygen and nutrients, as well as better removal of heat and waste products. It should be noted that, in strength training populations, because one of the main adaptations to training is hypertrophy, capillary density may not increase despite a greater number of capillaries being present. However, increased capillarisation is vital for improving exercise capacity, as a better blood supply will increase the ability to remove lactate from the muscle to the blood, allowing an improved tolerance to strength prescriptions that produce high levels of lactate, eg, muscle endurance and hypertrophy.

MITOCHONDRIAL DENSITY

Mitochondria are the 'powerhouses' of the cell, responsible for converting sugars, fats and proteins into ATP aerobically. An increase in the number and/or size of the mitochondria will increase a participant's ability to produce ATP aerobically, reducing the production of lactate at any given exercise intensity. Although traditional strength-based exercise is not typically prescribed to elicit mitochondrial adaptations, recent articles on the effects of high-load strength training have suggested that perhaps it can produce this effect.[11] Furthermore, hypertrophic exercise prescriptions (see 2.4.2 Hypertrophy), using fatiguing (ie, to failure) low-load resistances to create a high level of metabolic stress,[23] have the potential to stimulate both muscle mitochondrial adaptations and myofibrillar adaptations (ie, muscle growth).

Exact effects of strength-based training on mitochondrial adaptations currently remain unknown and have been overlooked in previous training studies. As with capillarisation, mitochondrial density may reduce after a period of resistance training due to dilution effects of hypertrophy.

MUSCLE BUFFERING CAPACITY

During high intensity exercise, the requirement for ATP production is faster than the body can deliver via aerobic mechanisms, so the working muscles generate additional ATP via anaerobic glycolysis. This results in the formation of lactic acid, which dissociates into lactate and H+ (hydrogen ions or protons). During high intensity exercise, the rate of hydrogen ion (H+) production inside the muscle cells exceeds the ability of the intracellular buffers to resist changes in the associated reduction in pH (ie, the muscle becomes acidic). The latter, in addition to other factors, is one of the main mechanisms underlying fatigue development in exercising skeletal muscle as it directly interferes with the muscle's ability to produce force (ie, interferes with cross bridge recycling).

Strength training that involves a large accumulation of lactate and associated H+ (muscle endurance and hypertrophy training) can potentially increase muscle and blood buffering capacity.[29] This will enable the muscle to continue to produce force for longer before fatigue is evident.

MUSCLE FIBRE TYPE TRANSITIONS

A motor unit is made up of a motor neuron and the skeletal muscle fibres innervated by that motor neuron. All of the muscle fibres within the same motor unit are comprised of the same type of muscle fibre and can be divided into groups based on their contractile and fatigue characteristics. Within the body there is a spectrum of motor unit types – slow twitch, fast-twitch fatigue resistant (type IIA) and fast-twitch fatigable (type IIX). Strength training adaptations include a transformational shift from type IIX to type IIA motor units as a strategy to improve metabolic efficiency (ie, the body's ability to use its energy stores more efficiently) which can potentially lead to improved endurance capabilities. It should be noted that a shift from IIA to type I motor units is unlikely.

2.5 ACCELERATION, DECELERATION AND CHANGE OF DIRECTION

It is important for the S&C Trainer to be able to include acceleration, deceleration and change of direction skills as a part of their coaching competency, and the movements associated with these activities are included as running-based foundation movements (see Section 6. Technical models: Foundation Movements 6.9 Running development).

Many participants will be regularly involved in multi-directional sports. Although the greatest percentage of these are likely to be youth participants, the number of older adults taking part in sporting activities is on the increase as awareness grows of the social, psychological and physical benefits of team-based sports participation. These groups will derive direct benefit from improving acceleration, deceleration and change of direction.

There is also good justification for including this type of training for participants who prefer popular endurance activities like park runs, marathons and triathlons, as the physiological adaptations to speed training will improve running efficiency and reduce the risk of injury.

The aim of the speed component in this Foundations of Strength and Conditioning qualification is to enable the S&C Trainer to introduce the participants to good basic mechanics and to coach the movements with sufficient intensity and volume to stimulate the desired physiological adaptations. This effect on the body has many crossovers with strength-based training benefits.

For each running-based movement, the S&C Trainer should be mindful of the following in demonstrating, observation, cueing and feedback:

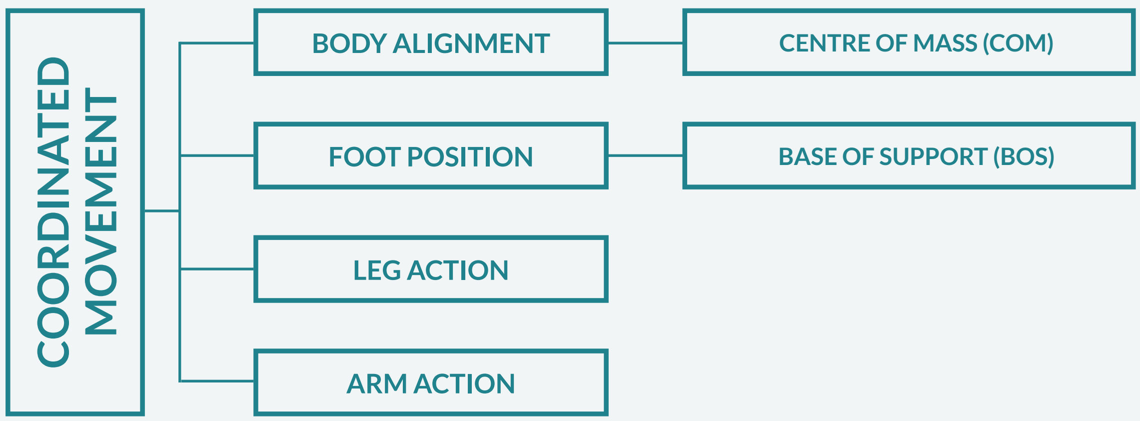


Figure 8. Running-based movement mechanics

2.5.1 ACCELERATION

Sprinting is a key skill in all running-based sports, as is the ability to cover a distance quickly. Linear speed is comprised of the acceleration phase and maximal velocity running. Acceleration is the ability to increase movement velocity in a minimum amount of time and it determines sprint performances over short distances. The majority of high-speed running in the more popular participation sports, such as football, is based on short sprints where acceleration ability is a key performance determinant. For this reason, the focus for the S&C Trainer is on developing competency, coaching basic acceleration technique and not maximal velocity running, which is addressed as a part of further professional development.

For effective acceleration, the individual needs to direct large forces into the ground in the right direction, aiming to accrue horizontal impulse as fast as possible. The key factors here are the magnitude of the forces and the skill of directing the force, which is dependent on technique (see 2.4.4 Rate of force development and 2.4.5 Explosive strength). Acceleration ability therefore requires specific practice and coaching for improvement, as well as strength and explosive strength gains as part of a holistic S&C programme.

In acceleration, the appropriate direction of force is achieved by adopting a position that promotes whole body lean and alignment, the centre of mass is ahead of the base of support, and the leg and arm actions are coordinated and forceful. Effective acceleration requires maximal intent.

IMAGE 1. SPLIT STANCE START

Stand with the feet hip-width apart in a split stance, with the front heel approximately one foot-length ahead of the rear toes. Flex the hips, knees, and ankles with weight distribution on the front foot through balls of feet to toes, and on the rear foot through toes to ball of foot.

The trunk will be inclined forward, maintaining a natural lumbar curve, with a positive shin angle evident. Arms are aligned anteriorly and posteriorly with the opposite leg, front arm flexed at the shoulder and elbow, rear arm extended at the shoulder and elbow.

IMAGE 2. TOE OFF

Drive forcefully through the hips, knees, ankles, and shoulders to accelerate as rapidly as possible and sprint the prescribed distance.

2.5.2 DECELERATION AND CHANGE OF DIRECTION

As outlined above, acceleration ability is directly correlated with performance in many popular participation sports. A feature of most of those sports is that they are comprised of intermittent, multi-directional activity and so the ability to brake is as important as the ability to accelerate. Braking may be necessary to stop completely to execute another skill, (eg, in netball a player must be able to accelerate into space to receive a pass and then stop quickly once in possession as the rules prohibit stepping or travelling with the ball), or rapid braking may be required for an aggressive change of direction.

Braking effectively requires high strength qualities, specifically the management of high eccentric forces as well as awareness of body position to optimise control of braking forces. Training for deceleration should also be addressed in strength-based programmes, through developing jumping and landing mechanics as well as developing the technique of stopping effectively in running-based activities, since this is where most non-contact injuries occur in multidirectional sports.

Providing participants with a stable 'stopped' position is a useful strategy to then improve their ability to stop quickly. The bilateral 'ready' position is a good option for ending the deceleration phase in training, as it is a strong, balanced stance that can either be held or used to transition to other movements.

IMAGE 3: DECELERATION REQUIREMENTS

Foot placement moves in front of the centre of mass (CoM). Force applied to the floor becomes more horizontal, opposite to the direction of travel. CoM is lowered through flexion of hips, knees and ankles. The base of support (BoS) is increased by whole foot ground contact and a wider stance. Step length decreases, step rate increases and ground contact time increases.

IMAGE 4: 'READY' BILATERAL POSITION

CoM is lowered by flexion at the hips, knees and ankles. Knees are aligned with the toes. CoM is slightly in front of the midde of the BoS. The trunk is neutral and braced with the eyeline horizontal. The shoulders are above the knees and the whole body is positioned for rapid response to any stimulus causing a change in movement action.

EFFECTIVE DECELERATION

Braking forces are managed in as few steps as possible and with minimum flexion of the hip, knee and ankle (ie, leg stiffness is promoted). Braking forces should be managed with no loss of trunk form, ie, trunk remains neutral and braced.

In the more chaotic environment of competitive sport, particularly in team sports, deceleration will not always be to a stable bilateral position, and it is necessary to progress to split stance stops and more sports-specific positions once the participant has mastered good basic deceleration mechanics.

The 'ready' bilateral position provides a stance that allows for effective movement when the new direction of travel is to be reactively determined by an external stimulus. Ready positions can also look more like optimal acceleration positions, depending on the context and certainty of direction of movement.

Acceleration and deceleration skills can be linked to improve change of direction.

The primary objectives in change of direction are:

- Optimal deceleration (holding speed as long as possible)
- Stopping in as few steps as possible while creating an effective re-acceleration position
- Accelerating in the new direction as closely as context allows to maximise acceleration speed.

IMAGE 5: 180° TURN

Practising the 180° turn stop requires a moving start that might need to be regressed or progressed to achieve efficient movement patterns. It is important that trainers recognise that faster running speeds will increase the demand of the deceleration activity and should therefore be a consideration, in accordance with the participant's experience and ability.

The deceleration principles of the split-stance stop will apply as the participant approaches the line:

- Decreasing stride length
- Increasing stride frequency
- Widening the base of support, by using a heel/flat foot contact in front of the centre of mass of the lead leg
- Lowering the centre of mass by triple flexion of the hip, knee and ankle.

The S&C Trainer can provide training to improve acceleration, deceleration and change of direction abilities which also offer a varied and enjoyable strategy for improving neuromuscular health and body control in general population groups; he or she can also explore the application of running-based skills with a wide variety of abilities.

EXAMPLE OF A SPEED TRAINING SESSION	
Work time	<6 seconds (phosphate energy system – high intensity)
Distance of run	10 – 60m
Reps per set	3 - 4 reps
Total sets per training session	2 - 4 (= 6 - 16 reps in total)
Total distance of set	80m – 120m
Total distance of session	200m – 400m
Intra-set recovery	45-60 secs per 10m of maximum intensity or 1:6-10, eg, 6s rep = 36-60s rest
Inter-set recovery	2 - 3 x intra-set recovery or 1:20 eg, 6s reps = 120s rest

Table 6. Example of a speed training session

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