CHAPTER 1: *Skeletal and muscular systems*

Practice questions - text book pages 33 - 35

1) A prime mover, also known as the agonist muscle of hip flexion is the:
   a. rectus femoris.
   b. Iliopsoas.
   c. vastus muscles.
   d. gluteus maximus.

Answer:
- *b.*

Explanation:
- *Key word here is prime and iliopsoas (consisting of psoas major and iliacus muscles) is the prime mover for hip flexion.*
- *Rectus femoris (within the quadriceps group) is a secondary agonist for hip flexion as well being the prime mover for knee flexion.*
- *Gluteus maximus is the prime mover for hip extension and lateral rotation.*

2) Which of the following movements occurs in the transverse (horizontal) plane?
   a. flexion and extension of the hip joints during sprinting.
   b. spinal rotation observed during a discus throw.
   c. abduction and adduction of the legs during a cartwheel.
   d. all of the above movements.

Answer:
- *b.*

Explanation:
- *The answer is b. as the transverse or horizontal plane divides the body into upper and lower sections and so any twisting or turning movements will occur within this plane.*
- *Sprinting occurs in the sagittal or median plane which divides the body into left and right sides.*
- *Abduction and adduction of the legs during a cartwheel occurs within the frontal or coronal plane which divides the body into front and back sections.*

3) Characteristics of isometric contractions include all but:
   a. shortening.
   b. increased muscle tension throughout the contraction phase.
   c. absence of shortening.
   d. used in resistance training.

Answer:
- *a.*

Explanation:
- *The answer must be shortening as isometric means same length, so no change in muscle length*

4) In order to control muscle contraction, the cerebellum innervates one or more motor units (each consisting of a single block of muscle fibres and its neurone). Which one of the following statements describes how a single motor unit produces a stronger stimulus?
   a. the motor neurone fires so much so that there is no time for relaxation (tetanine contraction).
   b. by repeatedly increasing the frequency of the stimulus (wave summation).
   c. by increasing the number of motor neurones in succession (spatial summation).
   d. both answers b and c apply.

Answer:
- *b.*

Explanation:
- *The answer is b. since the nervous system achieves greater muscular force by increasing the firing rate of neurones and so the second and subsequent twitches will be stronger that the first and occur before the muscle has completely relaxed. When a fibre is fired repeatedly in this manner, the way in which the force builds up is called wave summation.*
- *Tetan means rigid and so a tetanine contraction happens when muscle relaxation disappears and the contraction fuse into a smooth, sustained contraction plateau.*
- *Spatial summation occurs when different fibre groups are fired in succession and so the total force produced is the sum of the effect of different fibre groups. This produces a constant total force across the muscle bed.*

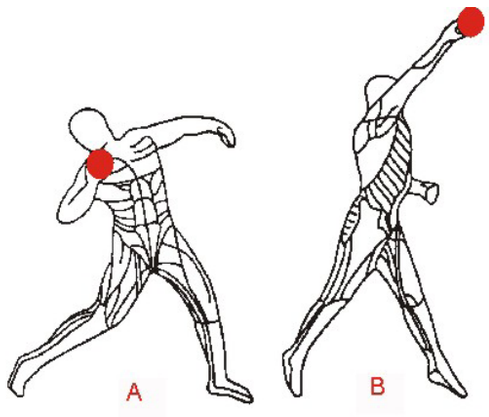
5) Muscle fatigue is a state of physiological inability to contract even though the muscle still may be receiving stimuli. Although many factors appear to contribute to fatigue, which one of the following statements is false during moderate exercise?
   a. it may result when ATP is no longer available for the cross-bridge cycle.
   b. it may be caused by a loss of muscle cell Ca^{++}.
   c. it may be caused by the accumulation of extracellular K^{+}.
   d. it may be the result of lactic acid production.

Answer:
- *b.*

Explanation:
- *During moderate exercise there will still be a plentiful supply of ATP available for the cross-bridge cycle, whereas the other three alternative answers are associated with fatigue factors that are associated with high intensity exercise.*

6) a) The diagram in figure 1.34 shows a shot putter during the delivery phase of the technique.
List the bones that articulate in the shoulder joint. 2 marks

figure 1.34 – a shotputter



Answer:

Bones which articulate at the Shoulder:
- *Scapula.*
- *Humerus.*

Bones which articulate at the Knee:
- *Femur.*
- *Tibia.*
- *Patella.*

b) Briefly explain the movement sequence of the right arm during the delivery phase of the shot put. 3 marks

Answer:

From diagram A:
- *Shoulder is extended and abducted, elbow is flexed, wrist is pronated and hyper-extended.*

From diagram B:
- *Shoulder is flexed and elevated, elbow extended,.*
- *Wrist is pronated and extended, and phalanges are extended.*

7) Describe the following movement terminology, and give a physical activity for each movement:
Abduction, circumduction, rotation and plantarflexion. 8 marks

Answer:
- *Abduction is a movement pattern in which a body segment moves away from the midline of the body.*
- *Example: leg action going into a cartwheel.*
- *Circumduction is a movement pattern which consists of flexion, abduction, extension and adduction to create a cone shape in space.*
- *Example: a small circular hand dance gesture.*
- *Rotation is a movement pattern around the axis down the centre of a long bone.*
- *Example: delivery phase of a discus throw.*
- *Plantarflexion is a movement pattern of the foot that results in the toe being pointed downwards.*
- *Example: diving off a springboard.*

8) Figure 1.35 a-c shows an athlete during the final stride, take-off and flight phase of a long jump. Using these three figures, analyse the action of the left leg (foot in contact with the ground) to include joint type, movement patterns, type of muscle contraction, acting muscles and plane of movement. Identify factors that affect the maximal force required for long jump take-off.

10 marks

figure 1.35 – long jump take-off and flight

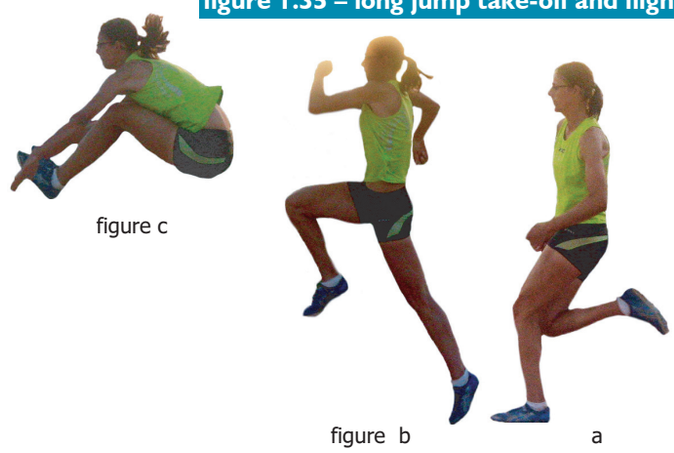


figure c figure b a

Answer:

- *Type of muscle contraction: isotonic, eccentric muscle contraction.*
- *Main agonist muscle: quadriceps group: rectus femoris, vastus medialis, vastus intermedius, vastus lateralis.*
- *Explanation: on this final stride prior to take-off, the hips and take-off leg sink into the board, during which time muscles of the quadriceps muscle group are lengthening under tension.*

Factors affecting strength:

- *Muscle fibre type: Explosive athletes have a greater percentage of fast twitch glycolytic (FG typ IIa) muscle fibres when compared with endurance athletes or sedentary people. This is observed in large powerful leg and bottom musculature.*
- *The synchronous firing of fast twitch motor units (i.e. many motor units recruited simultaneously) enables the long jumper to generate high force quickly.*
- *The faster speed of contraction due to an increased speed of nerve transmission to numerous muscle fibres associated with each fast twitch motor unit.*
- *Preparing the athlete for speed and strength required for take-off.*
- *Increased speed of strength of contraction is also due to an improvement in coordination between antagonistic muscle pairs – known as reciprocal innervation.*
- *Muscle cross sectional area: The greater the cross sectional area the stronger the muscle.*
- *Type and length of body lever: The ankle joint is a 2nd class lever and its mechanical advantage is to move a large load with a small amount of effort. In this example the ball of the take-off foot strikes the take-off board slightly ahead of the athlete's body mass and provides the vertical acceleration into the flight phase of the jump.*
- *The length of lever affects the load exerted by the lever and hence the speed at which the foot can move since longer levers generate greater forces.*

9) Figure 1.36 shows a tennis player completing a forehand drive. Use the figure to help you complete the following joint analysis.

figure 1.36 – tennis forehand

a) For the shoulder joint during horizontal flexion, identify the type of joint, the articulating bones, an agonist muscle, and the type of contraction for the agonist. 4 marks

Answer:
- *Type of joint: synovial, ball and socket.*
- *Articulating bones: scapula, humerus.*
- *Agonist from one of the following muscles: pectoralis major, anterior deltoid.*
- *Type of contraction at agonist: isotonic, concentric.*

b) Using the muscles that create flexion of the elbow during the forehand drive, Explain what is meant by antagonistic muscle action. 4 marks

Answer:
- *The **agonist** is the active muscle, the muscle under tension or doing work and functioning as the prime mover of a joint during the desired movement.*
- *The **antagonist** muscle relaxes to allow the agonist muscle to work as movement occurs.*
- *When the elbow is flexing during the forehand drive, the agonist = **biceps brachii** muscle, and the antagonist = **triceps brachii** muscle.*

c) Identify the movement pattern produced and an agonist muscle responsible for the action on the right hand side of the trunk. 2 marks

Answer:
- *Movement pattern: lateral flexion.*
- *Agonist: internal obliques.*

d) For the right wrist, identify the articulating bones, a fixator or stabilising muscle, and the movement pattern at the completion of the forehand drive. 3 marks

Answer:
- *Articulating bones: ulna, radius and carpals.*
- *Agonist: wrist extensors.*
- *Movement pattern: extension.*

10) Differentiate between concentric, eccentric and isometric muscle contraction, using practical examples to support your answer. 6 marks

Answer:
- *Concentric muscle contraction: a muscular contraction which shortens whilst producing tension.*
- *Example: driving upward phase in a jump or squat.*

- *Eccentric muscle contraction: a muscular contraction which lengthens whilst producing tension.*
- *Example: landing from a jump off a box.*

- *Isometric muscle contraction: a muscle contraction which stays the same length whilst producing tension.*
- *Example: holding a plank position.*

11) Using figure 1.31 on page 31, describe the relationships between motor unit recruitment and exercise intensity. 3 marks

Answer:
- *At light intensity work, slow twitch (ST or SO – slow oxidative) motor units are recruited first and continue to fire at a steady rate as intensity of workload increases further.*
- *At a medium intensity workload, fast oxidative glycolytic (FOG) type IIa motor units are recruited and continue to fire at a steady rate as intensity of workload increases.*
- *At maximal intensity, fast glycolytic (FG) type IIb motor units are recruited to produce maximal synchronous firing rates that supports powerful fast muscle contractions.*

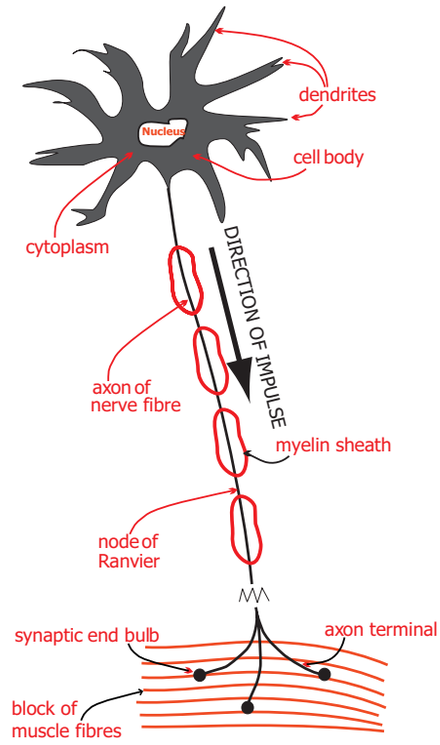
12) Identify and explain the function of the different regions of a motor neurone. 6 marks

Answer:

Note: A diagram, as shown, is good to use when an anatomical structure is required in an answer.

- *Figure 5.3.*
- *Cell body receives stimuli from other neurones.*
- *Via dendrites.*
- *Axon conducts nerve impulses along axon.*
- *At nodes of Ranvier (gaps in myelin sheath) and action potential (depolarisation followed by repolarisation occurs).*
- *As nerve impulse jumps from node to node.*
- *Axon terminal transmits neurotransmitter substances.*
- *Such as acetylcholine.*
- *Which enables nerve impulse to jump across synapse to adjacent cells.*
- *To facilitate action potentials to adjacent cells.*

figure 5.3 – structure of a motor neurone (nerve cell)



13) a) What is a motor unit? 2 marks

Answer:

See figure 5.3.

- *A motor unit consists of a block of muscle fibres connected to a single motor neurone.*
- *Which in turn connects to the brain via the nervous system.*

b) Explain how a motor unit transfers a neural impulse into muscular contraction. 8 marks

Answer:

- *Dendrites receive electrical impulses from other neurones via cell body to axon.*
- *Axon transmits neural impulse away from the cell body towards other neurones or effector cells such as muscle fibres.*
- *Achieved via depolarisation of axon membrane to produce action potential.*
- *An action potential travels down axon via saltatory conduction.*
- *Acetylcholine enables the electrical impulse to jump across the synaptic cleft of neuromuscular junction.*
- *To create a muscle action potential in a block of muscle fibres.*
- *Ca^{++} is released from 'T' vesicles and binds to troponin molecules on actin filament.*
- *Exposing actin-myosin cross bridge binding sites.*
- *Mitochondria produce ATP which provides energy for muscle contraction.*
- *ATP attaches itself to a binding site releasing energy:*
  - $ATP \xrightarrow{ATPase} ADP + P_i + \text{energy}$.
- *Myosin cross bridges swivel towards the centre of the sarcomere (power stroke).*
- *Drawing actin filaments past myosin filaments.*
- *This is the ratchet mechanism (attach, detach, reattach of cross bridges).*
- *To create muscle contraction.*

13) continued

c) The result of an electric impulse reaching the muscle fibres is a maximal contraction of those fibres. Explain this statement and describe how the force exerted by the muscle can vary significantly. 3 marks

Answer:

- *This is the All-or-none law:*
- *The stimulus has to be sufficiently strong enough to make all the muscle fibres within a muscle fibre block (attached to a motor neurone) contract.*

- *The force exerted by the muscle can vary as a result of wave summation.*
- *If the frequency of stimulus increases, there would be no time for the muscle fibre block to relax.*
- *So the force does not drop to zero at the end of a contraction, and the next impulse sends the force up higher (adding on to the force already in the fibres as the next contraction started), then again the force does not drop to zero, and the next contraction sends the force up even higher, until the force reaches maximum.*
- *Hence the force of contraction of this muscle fibre block would increase (see figure 5.9).*

- *Gradation of contraction:*
- *This depends on the number of motor units stimulated at any one time.*
- *The more motor units involved, the more muscle fibres activated and the greater the force exerted by the muscle.*

d) Why is it that muscle fibres attached to different motor units will not necessary contract at the same time? 3 marks

Answer:

- *Motor nerve fibres have different lengths, hence the impulse takes less time down a shorter one, which will cause its muscle fibre to contract earlier (than others connected to longer nerve fibres).*
- *Hence if the shorter of the two motor units is stimulated all the muscle fibres connected to that motor unit will contract - this is the 'all-or-none law'.*
- *But at the same time the longer of the two motor units could be resting and so those muscle fibres connected to that motor neurone would be in a state of relaxation.*
- *It is not necessary for both motor units to be stimulated at the same time = spatial summation.*

14) Analyse how the characteristics of different skeletal muscle fibres help contribute to success in different sports.

10 marks

Answer:

- *There are 2 main types of skeletal muscle fibre - slow twitch (ST) and fast twitch (FT – type 11a, type 11b.*
- *Exercise may produce transitions between FT and ST fibres to create FT-type 11a.*

- *Fibre type distribution varies between individuals.*
- *Endurance-based athletes have a higher percentage of slow twitch muscle fibres in their leg muscles.*
- *Whereas anaerobic-based athletes such as explosive elite sprinters and throwers have a greater percentage of fast twitch muscle fibres in their leg muscles.*

- *These proportions are genetically determined.*
- *And to a degree could account for specialisms of individuals.*
- *Such as whether a person becomes good at marathon running or weight lifting.*
- *ST fibres contain large amounts of myoglobin, mitochondria and blood capillaries.*
- *Mitochondrial proteins and oxidative enzymes are important determinants of the duration during submaximal exercise.*
- *High capillary density and myoglobin content ensure a continuous supply of oxygen to mitochondria (the powerhouse of tissue respiration) which have a high capacity to generate ATP by oxidative metabolic processes.*
- *Supported by high glycogen stores.*

- *Slow twitch fibres split ATP at a slow rate and so have a slow contraction velocity.*
- *Are very resistant to fatigue.*

- *ST fibres have greater triglyceride stores when compared with FT fibres.*
- *And may account for over 50% of the total lipid oxidised during endurance-based exercise.*
- *Thus supporting endurance-based activities such as marathon running.*
- *Type IIb fibres.*
- *These fibres, also called fast twitch or fast glycolytic fibres, contain a low content of myoglobin, relatively few mitochondria, relatively few blood capillaries and large amounts glycogen.*
- *Type IIb fibres are white and are geared to generate ATP by anaerobic metabolic processes.*
- *Because type IIb fibres are unable to supply skeletal muscle fibres continuously with sufficient ATP they fatigue easily.*
- *Type IIb fibres split ATP at a fast rate and have a fast contraction speed.*
- *Elite sprinters and throwers are found to have a greater percentage of fast twitch muscle fibres in their leg muscle, when compared with sedentary or endurance-based athletes.*
- *These characteristics help contribute to the success of high, explosive activity such as sprinting and shot putting where speed and power components of physical fitness of required.*
- *Fast twitch type IIa fibres are red, have a very high capacity for generating ATP by oxidative metabolic processes, split ATP at a very rapid rate, have a fast contraction velocity and are resistant to fatigue.*
- *They manufacture and split ATP at a fast rate by utilising both aerobic and anaerobic metabolism and so produce fast, strong muscle contractions, although they are more prone to fatigue than type I fibres.*
- *Resistance training can change type IIb fibres into type IIa due to an increase in the ability to utilise the oxidative cycle.*
- *This physiological training adaptation contributes to the success in sports that require a mixed contribution of energy supply from aerobic and anaerobic pathways.*
- *For example, a tennis match or football game where both speed, power and endurance are important physical fitness components.*

15) Table 1.13 shows the percentage of slow twitch muscle fibres in three muscle groups of elite male (M) and female (F) athletes and non-athletes. The percentage of fast twitch muscle fibre is calculated as the difference between 100% and the percentage of slow twitch fibres.
(Data from research literature – source – 'Essentials of Exercise Physiology' 2e, McArdle, Katch and Katch)

Table 1.13 – percentage of slow twitch muscle fibres

athletic group	shoulder (deltoid)	calf (gastrocnemius)	thigh (vastus lateralis)
long distance runners		79% (M) 69% (F)	
canoeists	71% (M)		
triathletes	60% (M)	59% (M)	63% (M)
swimmers	67% (M) 69% (F)		
sprinters		24% (M) 27% (F)	
cyclists			57% (M) 51% (F)
weight lifters	53% (M)	44% (M)	
shot putters		38% (M)	
non-athletes			47% (M) 46% (F)

a) Compare and account for the differences in percentage distribution of slow twitch muscle fibres with respect to long distance runners and sprinters. 3 marks

Answer:
- *Male long distance 79% to male sprinter 24% in calf muscle = difference of 55%.*
- *Female long distance 69% to male sprinter 27% in calf muscle = difference of 42%.*
- *Expected trend, could be the effects of aerobic and anaerobic training.*
- *And/or genetic potential.*

b) Calculate the percentage of fast twitch muscle fibres for the long distance runners and sprinters. 2 marks

Answer:
- *Long distance runner: males 21%, females 31%.*
- *Sprinters: males 76%, females 73%.*

c) Data collected for male triathletes shows a fairly even distribution of slow twitch muscle fibres across all three muscle groups. Discuss two possible reasons for this trend. 3 marks

Answer:
- *Male triathletes would be expected to have a fairly high even distribution of ST fibres in all three muscle groups.*
- *This trend could be explained due to aerobically stressing all three muscle groups during the swimming, cycling and running parts of this event, both in training and competition.*
- *On the other hand, it is not fully proved whether fibre type changes in response to training or whether these fibre type distributions are genetically determined.*
- *And so the performances of these elite athletes may be a consequence of abnormal fibre type distribution.*

d) For shot putters, only the calf muscle is given a value in the table. What percentage distribution of slow twitch muscle fibres would you expect in the deltoid muscle for shot putters? Give a reason to support your answer. 2 marks

Answer:

Expected percentage:
- *Less than 30% of ST fibres.*

Reason:
- *Because shot putting is an anaerobic power event it relies on flat-out explosive action.*
- *Stressing the predominant use of FT fibres in the deltoid muscle.*

16) Describe some of the factors which determine muscle speed and tension characteristics. 4 marks

Answer:

Note: You will be expected identify three from the possible answers below:

2 marks for each selected factor.

- *Muscle shape, cross sectional area and fibre type will determine speed of contraction and tension.*
- *Bulkier muscles, such as the biceps brachii, will contract quicker and produce more tension than longer, thinner muscles such as sartorius.*

- *Percentage type of motor units i.e. fast twitch/slow twitch motor units - a greater percentage of ST motor units means decreased muscle tension and speed of movement.*

- *Motor unit recruitment - strength and frequency of stimulus.*
- *The greater strength and frequency of stimulus, the greater the muscle tension and speed of contraction.*
- *By varying the strength of the stimulus from very light to maximal force a muscle can exert forces of graded strengths or gradation of contraction.*

- *Larger diameter motor neurones and myelinated axons conduct action potentials faster therefore giving increased muscle speed.*

- *The use of proprioceptors which provide sensory information which can be used to regulate speed and tension.*

- *Length-tension relationship with muscle tissue is created when the cross bridges on the actin and myosin hook up and energy is released.*
- *And the cross bridges pull actin filaments over the myosin filaments to shorten the length of the sarcomere.*
- *The greater the overlap of actin and myosin filaments, the stronger the contraction or tension.*

- *Type of muscle contraction: isotonic, isokinetic and isometric mc.*
- *During an isotonic muscle contraction (concentrically or eccentrically) the rate of length change is significantly related to the amount of force potential.*
- *When contracting concentrically against a light resistance muscle is able to contract at high speed.*
- *Slight increases in load results in a reduction in muscle speed.*
- *Muscle tension is greater during an eccentric muscle contraction when compared with a concentric muscle contraction.*

- *During an isokinetic muscle contraction there is a constant speed and tension developed over the full range of motion.*
- *This occurs when using hydraulic weights machines such as the Lido.*
- *During an isometric muscle contraction the muscle stays the same length and under great tension.*

17) Skeletal muscle contains both slow and fast twitch muscle fibres but the proportion of each depends upon the function of a muscle as a whole. Table 1.11, page 30, lists some of the differences between slow and fast twitch muscle fibres.

a) Suggest why the muscles concerned in maintaining the trunk posture of the body of the sprinter might be expected to have a larger percentage of slow twitch muscle fibres.
Using table 1.11 explain why fast twitch muscle fibres may build up an oxygen debt during a 400m sprint. 5 marks

***Answer**:*

Postural muscles in the trunk would have more slow twitch fibres because:

2 marks for 2 of:

- *They maintain posture for long periods of time.*
- *It is important for postural muscles not to get fatigues easlity.*
- *No need for fast, powerful contraction.*

Why fast twitch fibres build up an oxygen debt during a 400m sprint:

3 marks for 3 of:

- *Low capillary density.*
- *Few mitochondria.*
- *Therefore less O_2 supplied because they contain fewer oxidative enzymes.*

b) Account for the difference in the speed of contraction between slow and fast twitch muscle fibre types.
Fast twitch muscle fibres are divided into two types, IIa and IIb. Identify the major functional characteristic between these sub groups.
In what sporting activities would the adaptation of fast twitch type IIb to type IIa fibres be relevant to a sportsperson? 6 marks

Answer:

The two types of fibre contract at different speeds because of:

- *High glycogen content of fast twitch muscle fibres (low in slow twitch muscle fibres).*
- *High levels of phosphocreatine (PC) stores in fast twitch muscle fibres (low levels in slow twitch muscle fibres).*
- *Fast twitch muscle fibres have well-developed sarcoplasmic reticulum, which means more Ca^{++} available and improved transportation system for nutrients (e.g. glucose) compared to slow twitch fibres.*
- *Fast twitch muscle fibres are attached to large motor neurones with fast conductive velocity (small contractile time), compared to smaller motor neurones for slow twitch muscle fibres.*

The two types, IIa and IIb, major functional characteristics between these subgroups:

- *Type IIb fibres have a high capacity for glycolytic release of energy (known as FG).*
- *Type IIa fibres utilise both aerobic and anaerobic energy sources (known as FOG).*

Conversion of type IIb to type IIa:

- *Endurance-based events, such as middle distance running.*

18) How can an understanding of motor unit recruitment recovery assist an athlete when planning training sessions?

6 marks

Answer:

6 marks of 6 of:

- *Recovery is dependent on the intensity of the physical activity.*
- *During continuous aerobic training, slow twitch motor units fibres use asynchronous firing patterns and so activity continues with minimal fatigue.*
- *During an aerobic interval training session, recovery between bouts of exercise is short, for example 6x1200 metre runs with half the running time as rest. This is because ST fibres are working submaximally and there is a plentiful supply of oxygen and so recovery between sessions is rapid. In addition there is less likelihood of fibre damage.*
- *So when a training session is predominantly aerobic an athlete is able to train on consecutive days.*
- *When the intensity of an activity is high, synchronous firing of fast twitch motor units ensures maximal power output for only a short duration as the athlete is predominantly working anaerobically.*
- *Recover is dependent on the duration of the high intense activity. For example, recovery from short bursts of activity (stressing the fast glycolytic fibres) is quick as is the case with 30 metre sprints when only a walk back recovery is needed.*
- *When the duration of the activity exceeds 10 seconds, energy is provided predominantly by the lactic acid energy system.*
- *So repetition of an activity, for example 4 x 300m flat out with 15 minutes recovery, causes lactate stacking, resulting in a higher blood lactate than with just one exhaustive effort burst.*
- *Muscle soreness is often felt during the latter stages of a strenuous exercise period, the following day and the day after or at both times.*
- *This may be due to factors such as local muscle tearing of fast twitch muscle fibres and the presence of lactate acting on pain receptors.*
- *Muscle soreness felt the day after strenuous exercise is known as delayed onset of muscle soreness (DOMS).*
- *Recovery from muscle soreness will take longer and so the athlete needs to have a minimum of two days recovery before exercising the same muscle groups, otherwise fatigue carries over and could hinder subsequent training sessions.*