NO 31 RED AND WHITE MUSCLE FIBRES

29 March 2010

1. Last time I said I had reached the end of the series but I found I had left out an important one. So today, I am going to talk about red and white muscle fibres.
2. I am you have heard quite a bit about this in your anatomy talks but it is an area that is always worth another look. It is particularly important to know something about it when we are talking to our pupils about exercise and fitness training.
3. The muscles we are interested in are called the skeletal muscles. The vast majority of these connect to bones which is why they are called skeletal. There are usually said to be about 640 of them in the body.
4. These muscles are also called the voluntary muscles because they are to a greater or less extent under voluntary control. Take the eyelids, for example, I can flutter them if I wish. But like most of the rest of the skeletal muscles, they keep doing their job automatically even if I completely forget about them.
5. Let us look at the overall structure of a muscle. Basically, a muscle is a bundle of fibres. This bundle is wrapped in a sheet of connective tissue which holds it all together and connects to a tendon at either end. The tendons attach to the bones of the skeleton.
6. The overall shape of a muscle varies greatly. It can be flat like a strap or thin like a string or more rounded. The middle part between the tendons is called the belly.
7. When a muscle is activated by the nervous system, the fibres in the belly shorten and the tendons exert a pull on their attachment points. That is all muscles do. They contract and exert a pull on their anchorage points; they never push.
8. Each muscle has a blood supply in the form of artery which carries the bright red fresh blood – and a vein or two which carries the purplish used blood back to the heart and lungs for renewal.
9. When a muscle is required to contract, signals are sent to it from special nerve cells called motor neurons in the brain or the spinal cord.
10. Let us now go inside the outer wrapping of the muscle. We find the muscle is divided into smaller bundles of 10 to 100 fibres, called fascicles Smaller branches of the blood supply, called

arterioles and venules, and branches of the nerve supply run between the fasicles.

11. Let us now go one step further down and look inside the fascicle at an individual fibre – which is where we want to focus our attention. Muscle fibres are sometimes referred to as muscle cells.

12. The individual muscle fibres vary in diameter between 10 and 100 micrometers with an average of about 50 micrometers – which is about one twentieth of a millimetre – it is about the thickness of a human hair. They vary in length and can be up 10 cm long – in the thigh muscles for example.

13. We can think of each fibre as a very thin sausage. It has a coating, which is called the sarcolemma. Within the sarcolemma, is a substance called sarcoplasm. Running through the sarcoplasm are lots of small threads called myofibrils which actually do the contracting.

14. Running alongside the fibre, there are tiny little blood vessels called capillaries. These bring in the fresh blood from the arterioles and carry it back to the venules.

15. Each individual fibre also has its own connection into the nervous system. These connections are arranged so that groups of fibres are connected into a particular motor neuron. A motor neuron and all the fibres it stimulates is called a motor unit. When the signal comes from the nerve, all the fibres in a particular motor unit shorten or contract.

16. All of these muscle fibres need energy if they are to do their contracting work. This energy is in the form of a chemical called adenosine triphosphate (ATP).

17. That is the broad background and now, at last, we get to the fact that there are two broad kinds of muscle fibres – usually called red and white. Sometimes they are referred to as Type I and Type II fibres.

18. We can subdivide these further if we wish. David Garlick talks of two kinds of red and two kinds of white.[1] Tortora talks of three kinds: basically red, white and in between.[2]

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[1] Garlick (D2-8)p32

[2] Tortora (2000) p286

19. But we will simply talk of red and white fibres while bearing in mind that there are intermediate types which have some of the characteristics of both.

20. The red fibres are the smallest in diameter and the least powerful. Their red colour comes from a substance called myoglobin which is an oxygen-carrying protein. When you see the prefix “my” or “myo” in physiology it usually means it is connected in some way with muscle.

21. The main characteristic of the red fibres is that the nearby blood supply brings them the raw materials they need for making ATP. It also carries away the waste products from making and using this ATP.

22. The blood is carried back to the lungs for renewal in the normal breathing process. This is why the energy process going on in red fibres is often described as aerobic.

23. The most important consequence of this is that as long as the activity of the fibre does not exceed the capacity of the nearby bloodstream to bring in the raw materials and get rid of the waste products, these muscle fibres can keep going indefinitely. This is why the red fibres are called non-fatigable – they do not get tired.

24. Because they do not get tired, but are relatively weak and slow to act, these fibres are suitable or adapted for gentler activities like standing or sitting and for slow, rhythmic activities such as walking, jogging or even marathon running.

25. These red fibres are often called slow, or slow twitch, fibres because they come into action relatively slowly when they receive a signal from the nervous system. They are also slow to build up to their maximum contraction.

26. Now the white muscle fibres. They have low myoglobin in their sarcoplasm which is why they are whiter than the others.

27. They are larger in diameter and stronger and come into action much more quickly than the red fibres when they get a signal from a nerve. They are often known as fast-twitch fibres.

28. The energy supply for these fibres is managed in quite a different way from the red fibres. When they are not working, they accumulate a substance called glycogen which they are able to turn into ATP very quickly. Basically they rely on their own built-up stores of this stuff for the production of ATP when they need it.

29. Because this process does not rely on oxygen from the blood it is usually described as anaerobic.

30. White fibres are used when muscles are called upon for sudden or intense activities. They are adapted for short-duration activities, leaping up a tree out of the way of a lion, running a sprint race, or weight-lifting.

31. Muscles relying on white fibres can keep going for a maximum 30-40 seconds of flat-out activity in the case of top-class athletes[3] and in ordinary people it is more like 10-20 seconds. After that, fatigue sets in as a result of the depletion of glycogen and the build-up of waste products, principally lactic acid, in the fibres.

32. Most muscles have a fairly even balance between their red and white fibres. This means that, for example, our arms and hands can be used for gentle activities like stroking the cat or trying to cause brain damage to the other fellow in a boxing ring.

33. But some of the important postural muscles like the multifidus - which runs down the spine connecting the vertebrae – and the gastrocnemius – one of the calf muscles – have a much higher proportion of red fibres than the other skeletal muscles.

34. The way the neuromuscular system deals with the different demands on our muscular system is very sophisticated. Physiologists use the term 'fibre recruitment' to describe the order in which the different fibres in the muscles are brought into action.

35. Basically, it is done in accordance with need. If low force is needed, then red fibres will be called into action; if a bit more force is required, some white fibres will be called into action; and if maximal force is needed, more of the white fibres will be brought into action.[4]

36. But it is even more complicated than that since there are times when we want to make very quick but not necessarily forceful movements. For example, we want to brush away a fly without giving ourselves a punch in the face. In this case, white, fast twitch fibres will be called into action.[5]

37. The two types of fibre and the balance between them make sense in an evolutionary perspective. For early humans, an awful lot of activity was fairly routine, walking and jogging long distances, gathering food and so on. This was what the red fibres

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[3] Ibid.283

[4] Ibid.290

[5] McComas (1996) p210

were there for, to enable people to get on with the normal business of living without getting too tired.

38. But there were always periods when extra speed or strength were needed for short periods and the white fibres were available to meet these short-term demands, escaping lions, catching prey, lifting heavy weights and so on.

39. I now want to turn to the question of exercise. In the broadest sense of the word, exercise means simply using our muscles for moving about and doing things.

40. But it is commonly used to mean doing specific things to develop our muscles in certain ways. This is often referred to as 'training' and generally means going to the gym, running hard, rowing and so on.

41. Exercise in the broad sense of activity is essential for all our muscles. If we do not use our muscles at all, they tend to waste away – the medical term is atrophy.

42. This is very obvious in the loss of muscle bulk that happens when someone has a leg or arm in a cast for a while. It is why people who have had an illness or an operation are encouraged to get moving as soon as they can.

43. But beyond a minimum of activity to prevent the muscles from atrophying, the question is how much exercise should we take. This is quite complex because the different types of muscle fibres are affected differently when we use them.

44. First the red fibres. If we regularly use our muscles in a way that mainly relies on their red fibres – the gentle routine activities of an active life, or properly carried out endurance training - one of the surprising results is that the muscles tend to become more slender.[6]

45. Kamen says

> *…endurance training results in muscles that are not only more effective during sustained activity, but also in the case of long-distance runners, more slender. The explanation for the smaller girth is that the myofibrils, and the fibres themselves, are reduced in cross-sectional area. It is likely that this adaptation allows better diffusion of metabolites and nutrients between contractile filaments*

[6] Ibid.304

and the cytoplasm, and between the cytoplasm and the interstitial fluid.[7]

46. The effect of activities which mobilise the white fibres, like weight-lifting, sprinting, rowing and such is quite different and even more marked. The effect of this kind of activity is to increase the muscle bulk quite dramatically.

47. This is because the white fibres increase in diameter which makes them stronger and enables them to store greater amounts of glycogen.

48. Another particularly important point about training is how specific the result is to the kind of training one does. This is called the Specificity of Exercise principle.

49. You become better at what you are practising. So if you want to be a discus thrower, or a sprinter, or a rower, it is important that you train in a way which develops the muscles you want developed. This is particularly the case with white fibre development. McComas says

> *Endurance training on a bicycle will result in the greatest adaptations in cycling and lesser adaptations in running or rowing. Strength training can even be machine-specific. Gains in muscular strength by training on a machine made by one company may not be so great when measured by a strength test performed on a machine made by another company.*[8]

50. Another interesting point about muscle training is that as soon as you stop, the effects begin to wear off. The changes you have made undo at about the same rate as they occurred when you were doing the training.

51. There can also be a price for intensive training. There is evidence that heavy development of white fibres which gives you a great deal of very focused strength for particular tasks can lead to a reduction in the number of red fibres in the muscles you are using, so your ability to do regular routine tasks may be reduced. You can lift 100 kg but your back begins to ache after five minutes sitting upright in a chair. I have noticed this with some of my pupils.

52. And if intense training can cause problems, over-training can be really disastrous. Here is what the exercise science book says

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[7] Ibid.304

[8] Kamen (2001)p46

Too much training combined with inadequate rest periods can result in decreased performance, reduced aerobic capacity, decreased ability to store glycogen for ATP regeneration, weight loss, muscle soreness, and higher resting and exercising heart rates. Overtrained athletes manifest low levels of important amino acids like glutamine. The immune system weakens so that individuals may be more susceptible to colds and infections…Overtraining also negatively affects the performer's psychological health…The stress of too much exercise adversely influences the body's ability to handle other stressors.[9]

53. What this adds up to is that if you are determined to be a top class athlete, there are major risks and a high price to be paid. But these people are going to do whatever it takes – including the horrible risks of drugs.

54. It also throws a different kind of light on the view of the average office worker who thinks that beating themselves to bits once a week in the gym and building up great big muscles is making them healthier.

55. So how should the ordinary person exercise? The exercise science book says

…very easy exercise (low intensity and short duration) can make the biggest improvements in the health benefits of exercise…the benefits plateau at 50% intensity and 30 minutes duration. Exercise of greater intensity or longer duration provides little additional benefits to general health.[10]

56. The other point is that it is gentle repetitive exercise which builds up endurance rather than the violent bulk-building kind that is best for general health and well-being. Regular walking is probably the best exercise regime one can adopt.

57. This reminds me how Walter used to say that Alexander made a point about his lack of muscle bulk, especially the fact that he did not have big bulging biceps.

58. David Garlick also points out that when we are able to allow the postural reflex system to do its job it mobilises the red fibres rather than the white. So if we are allowing standing to happen in a

[9] Kamen (2001)p48

[10] Ibid.73

properly released way, rather than trying to hold ourselves up with our shoulders, we are using, and developing, the postural muscles in our back and legs.

59. Garlick also makes the very interesting point that when the neck muscles are tightened or contracted, there is a tendency to mobilise white rather than red muscles for posture and simple movements.[11]

60. In fact, we can see that modern life is extremely conducive to doing things which mobilise the wrong fibres. Working in a stressful job, sitting at a computer getting into a state about e-mails, struggling with traffic or public transport, tends to make people mobilise and develop their white fibres.

61. These then take over and there is a relative decline in the red fibre muscles we need for maintaining our proper posture and getting on with our normal daily activities. So because they are relying on their white fibres, these people find they are unable to sit unsupported in a chair for more than a few moments. They wind up using ergonometric chairs with lumbar supports which further weaken their back muscles.

62. So there is a real problem in devising a properly balanced exercise programme. Kamen says

> *…it's not easy to design an all-purpose exercise program that would provide optimum benefit to both aerobic and anaerobic performance systems.*[12]

63. One thing we can tell him is that a very good starting point for such a project is to follow the advice that Alexander gave us.

64. When we are allowing standing to happen, when we are keeping our necks free and encouraging our back to lengthen and widen, we are restoring the proper balance in our musculature. If you like, we are ensuring the proper allocation of activity between the red and white muscle fibres in our body.

65. When we go about our exercise, there is a reasonable chance that we will be able to maintain an appropriate balance and build the specific muscle capabilities we choose in an optimal way.

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[11] Garlick (D1-1)p7

[12] Kamen (2001)p46

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