STRENGTH AND CONDITIONING:
Is the current practice predisposing the sportsperson to injury?

By Mark Alexander July 2004
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For most sportspeople these days, "strength and conditioning" is a major component of their preparation and training. From amateur to elite, strength and conditioning training has the same two main aims:

- to improve performance, and
- to prevent injury.

There is no doubt in the literature that strength and conditioning has improved most performance parameters, such as increasing speed[1] (Dawson, 1998), strength[2] (Hakkinen et al, 1981; Mackenzie & Ng, 1995) endurance[3] (Ricoy, 1998), vertical jump height[4] (Ng & Richardson, 1990) and numerous other parameters such as VO2 max, anaerobic thresholds and immunological activity. So strength and conditioning training is clearly essential for the sportsperson wishing to improve and maximise their performance. But is the existing model for strength and conditioning training also fulfilling its second aim, that of injury prevention?

Despite the prevalence of strength and conditioning programmes at all levels of most sports, sporting injuries still occur – and indeed, injury rates are on the rise[5] (de Loes, 1990; Michaud et al, 2001). My own experience working with elite rugby teams and the Australian Olympic triathlon team highlights the fact that sportspeople develop many common muscle imbalances that may lead to injury. This suggests that our current training practices may need to be re-evaluated, as the focus on performance gain may be inadvertently predisposing athletes to injury.

I believe our current approach to strength and conditioning should be modified by the addition of **slow or static low-intensity sensory-motor exercises**. Support for this belief is derived from within muscle-fibre studies and anti-gravity research.

Muscle fibre types

We must start with a recap of some basic muscle-fibre knowledge. Skeletal muscle fibre generally comes in two forms, Type I and Type II. The Type I fibres are slow-twitch tonic fibres with slower contractile speeds. They have aerobic endurance properties and are fatigue-resistant. All muscles will recruit Type I fibres first for endurance-type activities, and Type II fibres first during speed and power activities.

Type II muscle fibres are fast-twitch and phasic, with faster contractile velocities. There are three sub-types: IIa (slow glycolytic), IIb (fast glycolytic) and IIc. Type IIa fibres are similar in properties to Type I, in that they have aerobic endurance properties, where IIb and IIc fibres are more phasic and fatigueable, with anaerobic properties.

The proportion of Type I and II fibres physiologically determines the functional characteristics of each skeletal muscle. In postural "anti-gravity" stabilising muscles there are higher proportions of Type I muscle fibres[6] (Fitts et al, 2000). Therefore postural muscles working across just one joint, such as soleus, multifidus and vastus medialis, are more resistant to fatigue and are functionally more suited to the longer term low-load tonic contractions required to provide the skeleton with support against gravity. In contrast, the larger two-joint mobilising muscles have a higher proportion of Type II fibres which fatigue quickly. These muscles are generally responsible for producing movement and are recruited first during strength and conditioning training.

Strength and conditioning

Strength and conditioning usually involves weight-training and running / cycling, with an emphasis throughout on speed and power. Most of the exercises are performed linearly, either in the sagittal or frontal planes, and usually with smooth, even contractions. Widely used examples include sit-ups, bench press, squats, lunges, leg press, leg extensions, power cleans, shoulder press, bicep and tricep curls, dips and, of course, running and cycling.

These exercises intrinsically favour the larger phasic, two-joint muscles of the body, such as rectus femoris, hamstrings and gastrocnemius, as these have a higher proportion of fast-twitch fibres with faster contraction speeds. Numerous studies have shown that strength and sprint training have increased the size of muscle via hypertrophy and proportion of Type II muscle fibres and reduced Type I fibres[7] (Abernathy et al, 1990; Dawson, 1998; Ricoy, 1998; Ross & Leveritt, 2001).

The one-joint stabilising anti-gravity muscles obviously have to contract during strength and conditioning exercises, in an attempt to stabilise the joints of the body and maintain an upright dynamic posture. But the training emphasis on speed and power doesn't really allow the stabilising muscles to do their normal job of maintaining low-load constant strength – let alone improve their function. They are, in most strength and conditioning programmes, in effect neglected, with serious consequences, as we shall see below.

Ng and Richardson[8] (1990) showed that after fast ballistic calf strengthening performed in standing there was a reduction in the strength of soleus. Speed training would obviously favour gastrocnemius, with its higher proportion of Type II muscle fibres and it may be that soleus' predominantly Type I fibres are inhibited with calf strengthening performed at speed.

Similar results were found in Richardson and Bullock's (1986) study[9], where subjects performed knee extension and flexion exercises at speed. Biased recruitment of the predominantly fast-twitch fatigueable phasic two-joint muscles, such as rectus femoris and the hamstrings, increased significantly as the speed of exercise increased. The one-joint vastii muscles were not recruited to the same extent during increasing speeds of exercise.

Implications for injury risk

The evidence from these strength and conditioning experiments and the muscle-fibre studies is that the activity of the stabilising one-joint muscles are affected in two significant ways: they become less active; and they begin to be recruited more phasically during movement (literally, switched on and off in shorter bursts.

This has important implications for injury predisposition. These muscles are responsible for the control and protection of the underlying joints. Yet strength and conditioning programmes prioritise the development of Type II fibres, which fatigue quickly, have a lesser endurance capacity and therefore a reduced potential to stabilise and protect the musculo-skeletal system. As a result these programmes may be compromising athletes' ability to maintain the dynamic stability of their joints, trunk and limbs during sport.

And there may be a further adverse knock-on effect: impaired sensory awareness or proprioception. It is logical to assume that a predominantly slow-twitch muscle has greater potential and time for intrinsic feedback via the afferent / efferent nerves within the muscle spindles. When fast-twitch Type II muscle fibres are selectively recruited during ballistic strength and conditioning training, the potential for feedback of position is reduced, because of the less time available for afferent input to reach the central nervous system. This also applies to joint receptors.

So strength and conditioning may also reduce proprioceptive awareness, which has been shown to increase the risk of injury[10] (Alexander, 2004).

Joint, muscle and tendon injury may develop indirectly, through a gradual degeneration of structures resulting from impaired muscle function, motor control and proprioception. In addition, the over-activity in the two-joint muscles may lead to disproportionately higher internal joint forces and hence changed joint biomechanics with potentially increased sheer and / or rotational joint forces[11] (Richardson, 2002). This process may be the pre-cursor of insidious onset musculo-skeletal injury.

Several studies[12] show that in the presence of injury, motor recruitment patterns are altered. The stability tonic one-joint muscles display delayed and / or inconsistent firing patterns similar to the larger phasic mobility muscles. There is no evidence yet to determine whether this motor control dysfunction is the cause or effect of injury. Regardless, there are huge implications for future strength and conditioning training.

Implications for training regimes

I believe the following modifications should be made to strength and conditioning programmes:

- Continue with normal strength and conditioning, as it has been proven to improve performance;
- BUT reduce the volume of open kinetic chain strength exercises, such as leg extensions and hamstring curls, as these eliminate postural anti-gravity load on the musculo-skeletal system and therefore cut out the normal motor control involved;
- AND insert extra slow or static low-intensity sensory-motor proprioceptive exercises.

LOW –INTENSITY PROPRIOCEPTIVE EXERCISES, BASIC PRINCIPLES

- All exercises should be weight-bearing, in order to recruit the postural anti-gravity muscles.
- The exercises should be low-resistance to prevent selective firing of the more powerful Type II muscle fibres.
- Exercises should be performed slowly (MARKS ADDITION “or statically”) so as to favour slow-twitch muscle fibres.
- Exercises should include rotation and weight-shift between limbs to simulate walking / running and to break the pattern of sagittal training in orthodox strength and conditioning exercises.
- Proprioceptive exercises should be performed to increase the afferent input into the central nervous system. Examples include unstable anti-gravity exercises performed on a wobble board, dura-disc, Swiss ball etc

The results in the literature almost unequivocally show that proprioceptive training can improve joint position sense and hence reduce the incidence of lower limb injuries[13] (Carrafa et al, 1996; Soran, 1991; Rozzi et al, 1996). Alexander[14] (2000) added a sensory-motor injury prevention programme to the existing strength and conditioning regime of an elite English rugby league team during pre-season. Daily execution of that programme for approximately 5-10 minutes significantly reduced the pre-season injury rate by 75% and training days lost to injury by 90%.

If strength and conditioning programmes are to fulfil both of their aims – better performance and injury protection – they will need to be redesigned in future. The inclusion of slow or static low-intensity sensory-motor exercises will enable athletes to develop co-ordinated dynamic stability that will help them maximise their performance whilst minimising their risk of acute and over-use injuries.

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