CompassSport Series - Fitness for Orienteering

Part 5 – Strength Training

This series of articles over the next year is aimed at helping the orienteer, irrespective of their age, ability or ambition, to develop their understanding of the fitness aspects of the sport and to help increase their enjoyment of orienteering through a logical approach to fitness development.

The previous article in the series discussed the various methods of increasing the most fundamental aspect of an orienteer's fitness - endurance. Once this aerobic foundation has been established, the orienteer will need to begin concentrating on other elements of their fitness in order to take their performance onto the next level. One of the next building blocks for orienteering-specific fitness is that of improving muscular strength. This article will focus on the various methods of strength training and how this fits within the orienteer's periodised programme.

Scientific Basis for Strength Training

In the first article in this series, brief mention was made of the need for strength development and its relationship to the specific demands of orienteering. Unfortunately, very few studies have examined the direct link between strength training and orienteering performance, with only Garderud et al., (1985) and Lusa & Lonka (1988) existing within the field of sport science research. These two studies, however, have shown some promising results. For instance, running times in terrain and lactate production were lowered, along with an improvement in the subjects' perception of their ability to run through terrain, following a period of strength training.

Also, in related research using distance runners, Hickson et al. (1980) had previously demonstrated that resistance training can improve treadmill running performance by up to 12% in untrained subjects. Improvements in lactate threshold have been observed, also in previously untrained individuals, as a result of resistance training (Jung, 2003). Trained distance runners have also shown improvements of up to 8% in running economy following a period of strength training. Even a small improvement in running economy could have a significant impact on distance running performance, and this is therefore relevant for the majority of orienteering events. Theoretically, this level of improvement has been put forward as a result of 'improvements in neuromuscular characteristics, including motor unit recruitment and reduced ground contact time' (Jung 2003). Other theories behind the increased running economy include 'the reduction in time of the stretch-shortening cycle and the increase in elastic energy return following training' (Laursen et al., 2005).

In one of the most significant recent studies, related to orienteering, Paavolainen et al. (1999) found that the use of strength training can help to make significant gains in an cross-country athlete's running economy, power and resultant 5k time trial performance, but found that it made no difference to overall $\dot{V}O_2$ max or lactate threshold levels. Potential improvements in running economy and time trial performance following a period of resistance training have been supported by further research in this area (Johnston et al., 1997; Millet et al., 2002; Spurrs et al., 2002 and Turner et al., 2003).

Recently the use of core strength training has gained attention from the orienteering community. Although research on the effects of such programmes is sparse, one recent study by Sato and Mokha (2009) indicates that this could have potential benefits for orienteering, as 5k time trial performance was improved by an average of 47 seconds following a six week, intensive core programme. Research on the use of core and strength work to offset injury in runners (Brummit, 2009) has also shown promising findings.

Although the overall body of scientific research at this time is not substantial, and many questions remain about the precise benefits of resistance training, the indications are that the development of strength, through specific, targeted training, can be of significant benefit to the orienteer's physical abilities.

Designing a Strength Training Programme

Having established the potential benefits for the orienteer of incorporating strength training within their overall fitness regime, the complex task of designing an appropriate programme now needs to be addressed. There are a host of variables to consider and, in order for this type of training to be safe and effective, there must be a systematic and detailed process applied to the construction of this programme. Let us consider these variables now, adapting the guidelines from Bompa (2009) to our specific requirements.

1. *Determine the goals of the orienteer.* The aspiring, competitive orienteer needs to identify the points during the year where the best performances are required. The overall programme will be defined by these target races.
2. *Determine the phases of training.* As with the development of endurance, addressed previously, the strength training schedule needs to be built around the general phases of preparation, competition and transition, with the orienteer looking to peak for their identified events in the competitive phase of the year, via a gradual and methodical development of their fitness.
3. *Determine the orienteer's needs.* Here the sport is assessed in terms of its unique characteristics. This will include aspects such as: body and limb movement patterns and muscular involvement; bioenergetic demands (eg. power, strength, muscular endurance); common sites for joint and muscle injury and, finally, particular areas of concern or weakness identified by the athlete and/or coach. We would also consider the trained status of the orienteer and their experience and knowledge of resistance training techniques.
4. *Select the exercises to be used.* Having conducted a needs analysis of the sport and the individual, the exercises most specific to the orienteer can be chosen for the focus of the programme. The orienteer will need to consider the availability of equipment, which will have an obvious impact on mode of resistance training. Ideally, the individual will have access to a range of apparatus, with the preferred method of strength training developed around multi-joint, large muscle mass exercises, using a combination of free weights, weight stack machines, weighted objects (eg. medicine balls) and own body weight.
5. *Test performance.* The specific loads to be used by the orienteer need to be gauged scientifically for the benefits of the programme to be maximised. This can be through a variety of means, such as a 1RM (rep maximum) test or a multiple-RM test. Concerns exist for some over the use of a 1RM test, but as

long as it is conducted correctly and with supervision, it has been shown to be both safe and far more accurate in predicting correct loads for training.

6. *Design the strength training programme.* Once the training loads are established, the orienteer can now put their programme together, with the exercises, loads, sets and repetitions established for the various micro and macrocycles in the periodised year. As strength gains are made, the orienteer will need to periodically re-assess their performance through re-testing and adaptations made to the loads used.
7. *Chart the progress.* Creating and using a training log will assist the orienteer in remaining focussed on their overall goals and allow themselves (and their coach, if relevant) to assess the effectiveness of their training. Factors to record in the log could include exercise type, number of sets and reps performed, loads lifted and rest intervals.

If we now work through these variables in a logical fashion, we can gradually build up a suitable strength training programme that should maximise our orienteering performance. Let us assume in stage one that the orienteer has targeted events within the normal 'competitive' phase of the calendar, ie. the end of March through to end of June, such as the JK and the British Championships, and that, in stage two, the year is established as a mono-cyclical one with only one peak.

Evaluation of the Sport

Movement analysis of orienteering reveals that it is an all-body movement, with the major locomotion provided by the cyclical contraction and relaxation of the main lower limb musculature. The key movements in the running action are flexion of the hip (agonists (or prime movers) – hip flexors, quadriceps), flexion of the knee (agonists – hamstrings, gastrocnemius) and dorsi-flexion of the ankle (tibialis anterior), as the lead leg swings through. This is then followed by extension of the knee (agonists – quadriceps), and extension of the hip (agonists – gluteals, hamstrings), as foot contact occurs and then through the support phase we see further extension of the knee and hip, with the weight coming through over the supporting leg, until we finally toe-off by plantar flexing at the ankle (agonists – gastrocnemius and soleus).

In addition to this, orienteering is primarily conducted off road, where uneven surfaces place additional demands on the movement mechanics. Other muscles, particularly in the core region of the body, will be involved in stabilising the orienteer, enabling them to keep as balanced and economical a running style as is possible. It is logical, then, that a resistance programme must incorporate exercises to strengthen the core musculature, including those muscle groups around the pelvis, abdomen, back and chest, as well as the major locomotive muscles identified above.

Further physiological analysis previously identified that the primary requirement of the sport is the development of a high aerobic capacity and that one of the limiting factors to performance is that of muscular endurance. In other words, the successful orienteer needs to be able to replicate the cyclical contraction and relaxation of the locomotive muscles several thousand times during the course of a race without fatigue impairing that action. The ability to enhance muscular endurance through a strength training programme will thus be the major focus for the individual, particularly as the competitive season approaches.

Selection of Exercises

The individual, when selecting the exercises for their strength programme, will need to focus on those that are most specific to the locomotive, cyclical nature of the running action and also to the need for development of core strength. Generally these functional exercises will be multi-joint exercises, such as a squat, which target two or more primary joints (eg. ankle, knee, hip), as these have a more direct application to the sport and they also help to reduce the amount of time required to train the whole system.

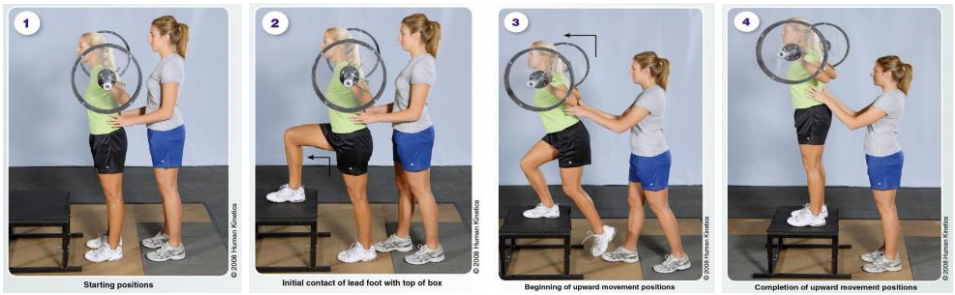
There are a huge variety of exercises for the orienteer to choose from, depending upon the type of equipment that is available and the mode of training that is preferred, but some of the more movement-specific resistance exercises, using a variety of free-weight and weight stack machines, are shown below.

Bent knee sit up (Muscles involved: Rectus abdominus, hip flexors)

Back squat (Muscles involved: Gluteals, hamstrings, quadriceps)

Forward step lunge (Muscles involved: Gluteals, hamstrings, quadriceps, hip flexors)

Step up (Muscles involved: Gluteals, hamstrings, quadriceps)

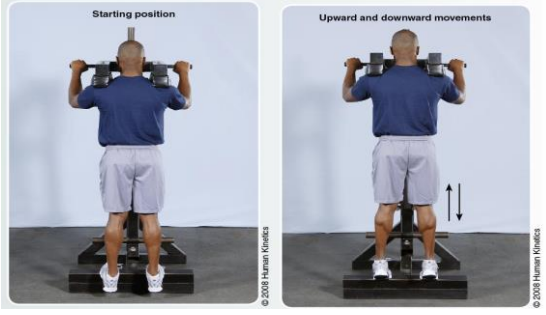


Deadlift (Muscles involved: Gluteals, hamstrings, quadriceps)

Leg extension (Muscles involved: Quadriceps)

Leg curl (Muscles involved: Hamstrings)

Standing calf raise (Muscles involved: Gastrocnemius, soleus)



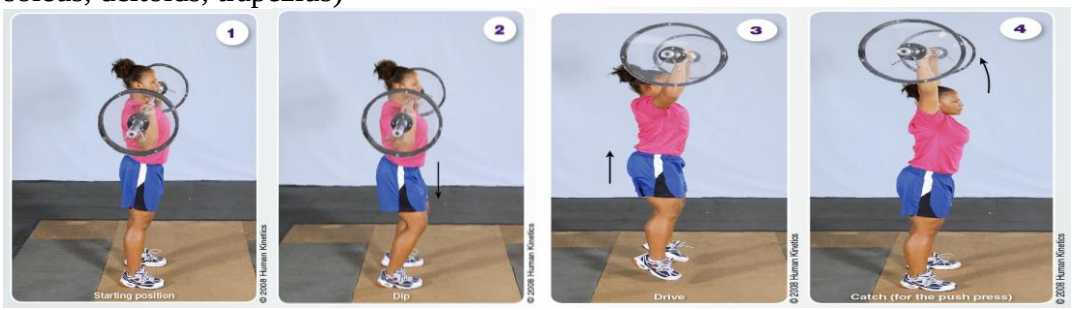
Bent over row (Muscles involved: Latissimus dorsi, teres major, middle trapezius, rhomboids, posterior deltoids, biceps brachii)

Seated row (Muscles involved: Latissimus dorsi, teres major, middle trapezius, rhomboids, posterior deltoids, biceps brachii)

Incline Dumbell Bench Press (Muscles involved: Pectoralis major, anterior deltoids, triceps brachii)

Flat Dumbell Fly (Muscles involved: Pectoralis major, anterior deltoids)

Push Press (Muscles involved: Gluteals, hamstrings, quadriceps, gastrocnemius, soleus, deltoids, trapezius)



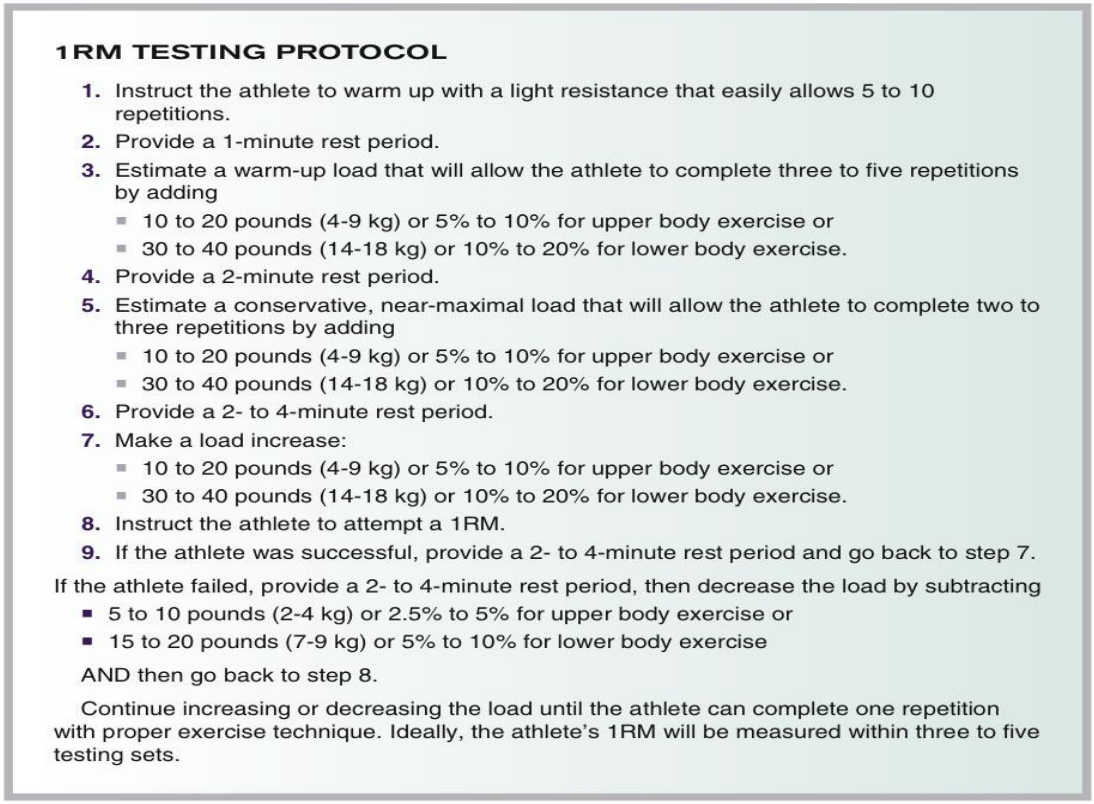
Power Clean (Muscles involved: Gluteals, hamstrings, quadriceps, gastrocnemius, soleus, deltoids, trapezius)

It is vitally important that the orienteer performs the correct technique in any programme of exercises for a number of reasons. Firstly, maximal strength development is ensured only through adopting the right methods and too often people cut corners in technique in their attempts to lift heavier weights. Secondly, resistance training with poor form could easily lead to injury. In particular, the power exercises, such as the push press, are very demanding and are probably best left until the orienteer has developed a good base of strength training and the precise technique can be followed. If a gym instructor is available, get them to assist with technique and identify any issues with your practice. They should also be able to help with 'spotting', ensuring that weights are lifted in a safe and effective fashion.

Test Performance

In order to assign the correct training load, the orienteer should perform a test to ascertain accurately the weight required for each of the selected exercises. There are a variety of methods, but probably the most accurate is via the direct testing of a 1-repetition maximum, ie. the greatest amount of weight that can be lifted with proper technique for only one repetition (Baechle & Earle, 2008). Once this has been tested, the orienteer's training load can be calculated as a percentage of the 1RM, using conversion tables that can be easily accessed online.

In order to ensure safety and accuracy, the orienteer must ensure that the correct technique is adhered to throughout and that assistance with spotting is sought wherever necessary, particularly as the individual gets close to their maximum and the weight used is substantial. If there are concerns about safety, then an estimated 1-RM from a multiple-RM test or a multiple RM test based on the number of repetitions planned for that exercise may be used as alternatives. A number of procedures to evaluate 1RM are available and one method is shown in figure 1 below.



1RM TESTING PROTOCOL

1. Instruct the athlete to warm up with a light resistance that easily allows 5 to 10 repetitions.
2. Provide a 1-minute rest period.
3. Estimate a warm-up load that will allow the athlete to complete three to five repetitions by adding
   - 10 to 20 pounds (4-9 kg) or 5% to 10% for upper body exercise or
   - 30 to 40 pounds (14-18 kg) or 10% to 20% for lower body exercise.
4. Provide a 2-minute rest period.
5. Estimate a conservative, near-maximal load that will allow the athlete to complete two to three repetitions by adding
   - 10 to 20 pounds (4-9 kg) or 5% to 10% for upper body exercise or
   - 30 to 40 pounds (14-18 kg) or 10% to 20% for lower body exercise.
6. Provide a 2- to 4-minute rest period.
7. Make a load increase:
   - 10 to 20 pounds (4-9 kg) or 5% to 10% for upper body exercise or
   - 30 to 40 pounds (14-18 kg) or 10% to 20% for lower body exercise.
8. Instruct the athlete to attempt a 1RM.
9. If the athlete was successful, provide a 2- to 4-minute rest period and go back to step 7.

If the athlete failed, provide a 2- to 4-minute rest period, then decrease the load by subtracting

- 5 to 10 pounds (2-4 kg) or 2.5% to 5% for upper body exercise or
- 15 to 20 pounds (7-9 kg) or 5% to 10% for lower body exercise

AND then go back to step 8.

Continue increasing or decreasing the load until the athlete can complete one repetition with proper exercise technique. Ideally, the athlete's 1RM will be measured within three to five testing sets.

Figure 1. A 1RM testing protocol (From Baechle & Earle, 2008)

Design the Programme

Once the exercises have been selected and the training loads calculated, the final step is to bring this all together in a periodised programme, designed to bring the orienteer to a level of maximum physical conditioning for their targeted races. The overall model for the orienteer is shown below in figure 2, based on a typical mono-cyclical year, as outlined earlier. The theory and practical application of each strength development phase is discussed below:

Base Phase 1 – Anatomical Adaptation (AA)

The main objectives of this phase, usually lasting around 10 weeks for novice athletes, are 'to increase the oxidative capacity of the slow-twitch muscle fibres; strengthen the tendons, ligaments and joints; and increase bone mineral content and proliferation of connective tissue surrounding each muscle fibre.' (Bompa and Carrera, 2005). This phase has the positive aspects of improving the orienteer's cardiovascular fitness, laying the foundations for improvement in muscular strength and developing neuromuscular co-ordination for these sport specific movements, helping running economy and efficiency.

One of the simplest methods for anatomical adaptation is circuit training, which many orienteers will already be familiar with. It has a concomitant effect of improving cardiovascular fitness as well as strength and a wide variety of equipment and exercises can be used here. Generally the individual should look to use core and multijoint exercises and the overall guidelines for circuit training are shown below in table 1.

Training Parameters	Novice Athletes	Experienced Athletes
Duration of AA	8-10 weeks	3-6 weeks
Load (if weights are used)	30-40 percent	40-60 percent
No of stations per circuit	9-12	6-9
No of circuits per session	2-3	3-5
Total time of CT session	20-25 minutes	30-40 minutes
Rest interval between exercises	60-90 seconds	30-60 seconds
Rest interval between circuits	2-3 minutes	1-2 minutes
Frequency per week	2-3	3-4

Table 1. Training parameters for circuit training (Adapted from Bompa & Carrera, 2005).

Experienced athletes do not tend to require as long on this phase to accrue the gains necessary. Also, novices tend to need more stations in order to develop as many muscle groups as possible, due to their lack of previous strength training.

Most body weight exercises (eg. push-ups) will use around 10-20 repetitions per station, with the individual looking to gradually progress the number upwards as their fitness improves during the AA phase. The number of repetitions per set for weighted exercises (eg. leg curls) will be in the range of 10-15, with the number dropping over the AA phase as the weight increases through improved strength and the orienteer approaches the next phase.

Dates	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Phases of Training (Macrocycles)	Preparatory							Competition			Transition	
Subphases	Base 1 - Prep		Base 2 – Volume			Specific						
Period of strength	AA		MxS	M-EM MxS		Conv to M-EL		Maint: Muscle-endurance, (power)			Recovery	

Figure 2. The yearly strength training model for orienteering (Adapted from Bompa & Carrera, 2005)

Base Phase 2 – Maximum Strength (MxS)
This period, usually around 4-5 weeks in length, will probably be the most important for the orienteer's overall strength improvements and will underpin fitness levels in the later competition phase. The individual is looking to increase the ability to recruit muscle fibres rapidly in order to synchronize all the primary muscles involved in the movements specific to running. The true benefits of this phase lie in the orienteer's ability to convert gains in strength to the specific requirements of the sport. Generally, as the period is brief and focussed, there will be improvements in force generation, but without a significant increase in body weight and this phase is also sometimes referred to as 'central nervous system training'. (Bompa and Carrera, 2005)

A variety of techniques exist for maximum strength development, but for the general orienteer the most suitable one is that of the isotonic method. This is due to a number of factors, including: the method has a high neural output helping to improve power; it underpins improvements in muscular endurance; it improves the co-ordination and synchronization of muscle groups; and it is relatively safe for inexperienced individuals, although some practitioners believe that a minimum of two years of anatomical adaptation experience should be gained before using this method. The guidelines for this training method are shown below in table 2.

Training Parameters	Work
Load	80-85 percent
No of exercises	3-5
No of repetitions per set	1-5
No of sets per session	6-10
Rest interval between sets	3-6 minutes
Frequency per week	2-3

Table 2. Training parameters for the maximum load method (Adapted from Bompa & Carrera, 2005).

It is essential that the load is set at around 80% of maximum, so that there is significant neural stimulation. This will enable fast-twitch muscle fibres to be recruited and help with synchronization of the muscles involved. Only exercises using prime movers and large muscle groups should be used here and the ordering of exercises is important to avoid early onset of fatigue. One set of each exercise should be performed before moving onto the second set so that the muscles can recover and maximum strength output is always achieved. The 3-6 minute rest interval between sets is also crucial in ensuring the central nervous system is fully recovered each time and the circuits should not be rushed or strength gains will be impaired. Finally, it is important that movements are performed as quickly as possible in order to fully recruit the fast-twitch fibres and maximise potential training benefits.

Specific Phase – Conversion (M-EM and M-EL)
The primary aim of this period is to convert the gains made from the previous phases into muscular endurance, a key component for high level performance in orienteering. There may be aspects of conversion to power endurance, particularly for elite athletes or individuals who are focussing on sprint racing, but this will be secondary to ensuring a strong foundation of muscular endurance is established. The aerobic and anaerobic characteristics of the musculature will be trained during this time, so that

the orienteer is able to perform repeated muscular contractions without fatigue impairing their performance. Muscular endurance is best increased through a phase where a high number of reps are performed at a steady pace in training and the resistance should be set at a load which is slightly higher than that which must be overcome while competing. Occasionally it may be desirable to combine aerobic training with muscular endurance work, particularly if time is limited, but in this case strength training should be done at the end of the session.

Initially, as the orienteer converts from the maximum strength phase, it may be desirable to undertake muscular endurance work of medium duration, allowing adaptations to take place gradually. The programme can be designed as circuit or interval training. The load is set at around 30-50% of RM performed progressively over a longer duration through increasing the number of reps every second week. The rest interval should be short between sets, so that the individual is exposed to high levels of fatigue and this enables an increased tolerance to competition stress. After around seven-eight weeks of conversion, the orienteer will move to the final conversion stage consisting of muscular endurance work of long duration over six-seven weeks, to fully prepare for the demands of the key races in the competition phase. The key difference here is that the load now drops to around 30-40% of RM and the reps increase, with little or no rest between exercises and only brief rest between sets/circuits.

Guidelines for this conversion phase are shown below in tables 3 & 4, with suggested training programmes relevant to an orienteer in tables 5 & 6.

Training Parameters	Work
Load	30-50 percent
No of exercises	4-8
No of sets per session	2-4
Rest interval between sets	2 minutes
Rest interval between circuits	5 minutes
Speed of execution	Medium
Frequency per week	2-3

Table 3. Training parameters for muscular endurance of medium duration (Adapted from Bompa & Carrera, 2005).

Training Parameters	Work
Load	30-40 percent
No of exercises	4-6
No of sets per session	2-4
Rest interval between sets	1-2 minutes
Rest interval between circuits	2-5 minutes
Speed of execution	Medium
Frequency per week	2-3

Table 4. Training parameters for muscular endurance of long duration (Adapted from Bompa & Carrera, 2005).

Exercise	Number of Weeks		
	2-3	**2-3**	**2**
Half Squats Incline Dumbell Bench Press Forward Step Lunge Step Up Flat Dumbell Fly Leg Extension Bent Knee Sit Up Leg Curls	Load of 30-50% and progressively aim to perform 50-60 reps non-stop.	Perform two-four exercises non-stop, or 100 reps together; for instance 50 half squats followed by 50 incline dumbbell bench press. Pair the remaining six exercises.	Perform all exercises continuously; eight exercises x 50 reps = 400 reps non-stop. Repeat circuit 2-4 times.
Rest interval between exercises	1 minute	1-2 minutes between each group of 2-4.	---
Rest interval between circuits	---	---	4-5 minutes

Table 5. Example circuit for muscular endurance of medium duration (Adapted from Bompa & Carrera, 2005).

Exercise	Number of Weeks			
	2	**2**	**2**	**2**
Back Squats Bent Over Row Forward Step Lunge Calf Raises Leg Extension Leg Curls	Load of 30% and progressively perform 4-7 minutes of non-stop work for each exercise.	Load of 30% and progressively perform 7-10 minutes of non-stop work for each exercise.	Perform two-three exercises non-stop for 10 minutes each exercise (ie. 20-30 minutes of work). Repeat for the remaining exercises.	Perform all exercises continuously for 10 minutes each exercise, (ie. 60 minutes of work).
Rest interval between exercises	1-2 minutes	2 minutes	---	---
Rest interval between circuits	---	---	2-4 minutes	---

Table 6. Example circuit for muscular endurance of long duration (Adapted from Bompa & Carrera, 2005).

Competition Phase – Maintenance

The focus for the orienteer now is to ensure that they are in peak condition for their target races during this phase. It is obviously important that the frequency and overall volume of strength training is now reduced, in order to be fresh for the competitive

programme, but the individual must still undertake some work in order to maintain the gains made in the pre-season phases and ensure that they retain their developed muscular endurance capability.

In order to avoid detraining and ensure peak preparedness for racing, the strength sessions should be as short as possible, usually around 20-30 minutes in duration. Orienteers should use the lowest number of exercises (a maximum of four) to address the conditioning of the prime movers. This helps reduce overall energy demands and leaves the orienteer time and energy for technical training. If no competitions are scheduled for the weekend, then the microcycle could have two-three strength sessions. Otherwise one or, at most, two sessions can be scheduled, usually in the early part of the week. For muscular endurance training, one or two sets per session are suggested and the reps should be kept to a maximum of 30 per exercise, as muscular endurance will also be trained in other sessions during the week. The key here is to stabilize performance, not generate fatigue which could potentially impair race performance. Jones and Bampouras (2007) advocate the use of power training, through plyometrics, in this phase, which may be appropriate for sprint specialists and those who have a highly trained status, but must be used with caution by others.

Transition Phase – Recovery
This phase is crucial to enabling recovery, both physical and psychological, from the demands of the racing season. Usually this phase will be no more than five weeks and by the end of it, the orienteer should be feeling energised and have a strong desire to commence serious training again!

Two or three sessions of general, low key fitness work a week are recommended, in order to help retain elements of strength and endurance, and orienteers should work to involve muscle groups that received little attention in the rest of the year's programme. Informal physical training, with a recreational/play aspect, is important and individuals should perform this at a relaxed pace. The programme should be enjoyable and stress-free, with no focus on loads, reps and sets.

Conclusion
Hopefully the wealth of information provided in this article has enabled the orienteer to plan out a safe, progressive and relevant strength training programme. Certainly not all exercises appropriate to orienteering are included here and it is desirable to mix in a variety of training techniques throughout the year to keep the orienteer fresh and motivated to stay on track. Next time, the final article in this series will focus on other, 'secondary' aspects of fitness development, such as flexibility, and give ideas for how we might improve these aspects.

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