Sept 6, 2013

Competition-Introduction Advanced

(Training to Train)

Strength Training

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1.1 Introduction to Strength Training

1.1.1 The importance of strength training for cross-country skiers

Although cross-country skiers have always been conscious of the muscular demands of competitive cross-country skiing, physical preparation through strength training (all of the procedures involved in improving muscular qualities in athletes) is currently occupying a much greater place in athlete training, and at a much younger age.

Good strength training will be of great benefit to an athlete, even throughout the competition season. Proper strength training will not only improve strength, endurance and muscular power, it will also promote proper technical execution through optimization of the biomechanical efficiency of the movement. Well-balanced muscular development will also encourage better posture and help to reduce the risk of injury.[1]

Even during childhood and adolescence, strength training is a key factor in the development of an athlete, considering the physiological adaptations it generates. Furthermore, several studies[2] have shown physical preparation is an excellent way to improve motor performance in children and adolescents. In short, proper strength training will play an essential role in optimizing the performance of cross-country skiers.

Before going any further with the recommendations for the Train to Train stage, it's important to clearly define the terms used to speak of the development of strength which will serve to describe the priorities for this stage of development.

1.1.2 Definitions

Strength training: In sport "strength training" refers specifically to the development of muscular qualities in athletes. In this chapter, we will not be addressing energy channels, but rather muscular qualities such as strength endurance, maximum force, power, etc.

a) Phases of Physical Preparation through strength training

- General Physical Preparation (GPP): Period of acquisition and development, or recall of basic muscular qualities through training, including movements and exercises more or less specific to cross-country skiing, according to the age and developmental stage of the athlete. This period can stretch over several weeks up to several months.

- Specific Physical Preparation (SPP): Period of acquisition and development of muscular qualities which are essential to cross-country skiing, through training, including movements and exercises specific to cross-country skiing, according to the age and developmental stage of the athlete. This period can stretch over several weeks up to several months.

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- Tapering: A period of modulation in the training program characterized by a reduction of one or more training parameters, in order to obtain optimal performance before a major competition. According to several studies, following an intensive specific strength training phase, the performance of an athlete not only depends on the level of development of performance-related factors, but also on a corresponding level of fatigue. An adequate tapering period will decrease the physiological stress of training, and reduce the level of fatigue without jeopardizing the progress made in the previous phases.

  Four rules of thumb for proper tapering, according to Thibault & Marion[3]:

  1- Over a period of 4-14 days, the total training volume per session is reduced significantly during the entire tapering phase, for example only 2 sets instead of 3 or 4;
  2- The level of difficulty of each session is reduced (more recovery time between sets and repetitions);
  3- The weekly frequency of training sessions is also reduced, and it's advisable to have only one strength training session 5-7 days before a competition. However, shortened sessions of building core or posture and stretching may be maintained.
  4- Training sessions during this period should be specific.

- Maintenance Phase (MP): Period where neuromuscular gains are maintained through training that is more or less specific to cross-country skiing. Maintenance training may vary according to the age and developmental stage of the athlete. This phase generally stretches throughout the whole competition period, and may comprise periods of more specific stimulus training, if the competition period includes long lapses between events.

Example of the physical preparation phases in a periodized training program; one mesocycle is 3-4 weeks:

GPP	SPP	MP
May - August	September - November	December - March
3-5 mesocycles	3-5 mesocycles	4-6 mesocycles

b) Types of strengths and their uses

- Maximal Force (repetition maximum (RM)): The peak force (highest level of tension) produced by a muscle or muscle group during a maximum voluntary contraction while pulling against an immoveable object, regardless of the duration of the contraction. Several studies have shown that this type of strength training generates better neuromuscular adaptations, thereby influencing muscular efficiency by improving motor coordination through greater activation and recruitment of fast twitch muscle fibres. The study made by Hoff, J. *et al*., 2002, as well as many others underlines the advantages of maximal strength training for endurance sports, such as cross-country skiing, "Maximal strength training

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with emphasis on neural adaptations improves strength, particularly rate of force development, and improves aerobic endurance performance by improved work economy."[3] Furthermore, it's been shown that even at a young age, athletes can use the RM method, as a carefully supervised study by Avery D. *et al*., 2003, on eleven-year-olds demonstrates, "These findings demonstrate that healthy children can safely perform RM strength tests, provided that appropriate procedures are followed."[4]

The following table illustrates the estimated number of possible repetitions based on a percentage of 1RM[1]

% of 1RM	Estimated number of repetitions
100	1
95	2-3
90	3-4
85	5-6
80	7-9
75	10-12
70	15
65	20-25
60	25+
50	40-50
40	80-100
30	100-150

Example:

An athlete is able to bench press a maximum of 10 repetitions with a 50kg weight.

According to the table at the left, 10 RM = 75% of 1RM

This athlete should then be able to lift 66.7kg for 1 RM (50kg/0.75)

NOTE: *These extrapolations represent average estimations. Individuals vary greatly one from another and several factors may influence the reliability of these estimations. They are however, considered sufficiently accurate to be used as a guideline in designing weight training and evaluation programs.*

- Submaximal Force (Repetition submaximal RSM): A relatively high value indicating the force produced by a muscle or muscle group during a submaximal voluntary contraction against a given resistance.[1] For example, an individual who bench-presses 12 repetitions with a 15RM weight (or 17RM or 20RM) is using a submaximal force, because theoretically, the individual could perform more repetitions with the same weight, or the same number of repetitions with a heavier weight. In the strength development process for cross-country skiing, this method is useful at the beginning of the GPP in order to activate the

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neuromuscular system and develop a certain muscle mass. This type of training is used for a few sessions only, to start off the strength training plan; its prolonged use is not effective in significantly increasing muscular strength to meet the needs of long-term sport. Rather, it is used as a lead-up to maximal strength training. It is also a good method for rehabilitation – to recondition injured areas of the body without employing excessive tension.

c) Types of strength training

- Strength Endurance: The ability of an organism to produce a force over a prolonged period. This involves the effort of a muscle or muscle group during a voluntary contraction while pulling against a given resistance (reasonably high level of tension) in lactic anaerobic or aerobic conditions. For example, sprinting or skiing for a longer distance accurately reflect these conditions.[1] In regard to strength training for cross-country skiing, this type of training could be specific strength training while skiing or roller skiing, such as with legs only or double poling, either with several repetitions or repeated over a lengthy period of time, and over different terrain (slight incline, steep hill).

- Repetition Maximal (RM) Type Strength Endurance: The peak force produced during a maximum voluntary contraction, repeated more than 12 times (13RM and more). This type of strength development improves the capacity of the neuromuscular system to produce, consistently, sufficient force to perform a given task over a long period of time.[1] It is often perceived as a submaximal force, if it is continued for a high number of repetitions, as it is practically impossible to determine exact loads for maximal repetitions that extend for 30, 40, 50, or 100 repetitions. In other words, if you chose a load that will allow you to perform up to 50 repetitions, there is a good chance that you will not quite make it to 50 repetitions, or, that you will in fact, be able to perform a few more. In the strength development process for cross-country skiing, this type of training will be used at the beginning of the GPP to develop a muscular base and activate the neuromuscular system in preparation for more intense RM training.

- Muscular Hypertrophy (Maximal Force 8-12RM): Muscular hypertrophy is synonymous with increased muscle volume, directly resulting in increased strength. To optimize the effect of muscular hypertrophy, an exercise must be performed using the heaviest weight possible to complete a maximum of 8 to 12 repetitions (8-12RM). According to several studies, hypertrophic training (8-12RM) is the most favourable for developing muscle mass and must precede exercises using maximal force 1-8RM and power training.[1] This type of training will also have a tremendous impact on the development of the neuromuscular system. In the strength development process for cross-country skiing, this method is useful at the beginning of the GPP in order to develop muscle mass

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and activate the neuromuscular system in preparation for more intense RM training.

- Maximal Force (1-8RM): The peak force produced during a maximum voluntary contraction, repeated 1 to 8 times (1-8RM). It encourages the capability of the neuromuscular system to produce, consistently, sufficient force to perform a given task for 1 to 8 repetitions (determined as 1-8RM).[1] This type of training is principally characterized as being extremely beneficial for neuromuscular activation while having little effect on muscular hypertrophy (therefore on increased muscle mass). Its impact on energy economy in aerobic endurance sports has also been proven.[3] In the strength development process for cross-country skiing, it will be used in the middle of the GPP and during the maintenance phase in order to maximise the efficiency of the neuromuscular system and minimize the potential increase of muscle mass.

- Power and Plyometrics: Power is the ability to perform a muscular contraction in order to overcome a given resistance as rapidly as possible (Power = Force X Velocity). By placing the training emphasis on velocity, power training becomes speed strength ($P = {}_{F} X V$). Speed strength has relatively more contribution from acceleration than force and has its greatest effect on the rate of contraction of a muscle. If force is emphasized, power training becomes explosive strength ($P = F X {}_{V}$). This is the ability of the neuromuscular system to produce the maximum force or strength with each muscle contraction.

  Plyometrics refers to a muscular action involving a rapid movement from a state of extension (eccentric phase) to a state of contraction (concentric phase) and therefore requires a certain level of strength. This training method utilizes the elastic strength of the muscles (an accumulation of energy in the eccentric phase), and the stretch reflex (myotatic reflex - protective muscular contraction occurring when an intense stretch is detected) to produce power.[1,5,6] A good example is the box drop, illustrated in figure 1.

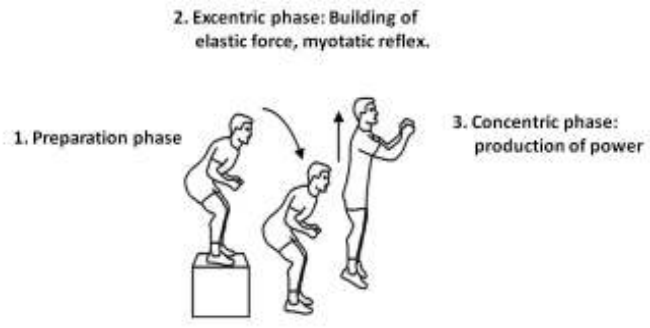

Figure 1. Phases of a plyometric action

Plyometric training increases power through improved intramuscular coordination and faster contractions. These improvements are essentially the result of

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adaptations in the central nervous system and the musculotendinous structures. Also, through plyometric training, it is possible to strive for several strength training objectives, notably core building, posture, coordination, strength, and speed.

It should be noted that before taking advantage of this type of stimulus, the athlete must first develop a solid base in strength training (endurance, hypertrophy and maximal force), core training, and coordination. These are unavoidable prerequisites to plyometric training. If these parameters are not considered, plyometric training can considerably increase the risk of injury. Plyometrics may be used in the middle of the GPP (often in conjunction with strength training) and during the SPP. Several plyometric exercises are specific to cross-country skiing. The most important rule is to reproduce the specific role that the joints play, and the direction of the movement in the cross-country ski technique or task that you wish to improve.

- Power Endurance (or Speed Strength Endurance): The ability to repeat a task requiring a high percentage of maximal force (F X V) for a long period of time or a high number of repetitions, with incomplete rest periods.[7]

The main objective of this type of training is to reduce muscle fatigue. The goal therefore, is to improve the capacity of the neuromuscular system to resist fatigue. Obviously this is an important factor in cross-country ski performance, owing to the fact that at the competition level, this sport repeatedly requires sudden bursts of great power with incomplete recovery (e.g., steep hill, passing, final sprint). See the section "About Fatigue" below.

As with plyometrics, athletes must first develop a good base in strength training (endurance, hypertrophy, and maximal force), core training, and coordination before undertaking this type of training. It is for this reason that we only incorporate power endurance training at the end of the GPP and in the SPP, often through circuit training, with strategically planned rest periods. This is an excellent method for prescribing very specific cross-country ski exercises combining technique, power, and core training (see the definition at section 2.5).[1]

d) Various Methods of Strength Training

- Super-set: Training method wherein two exercises are linked back-to-back, without pause, e.g., performing 12RM at the bench press, then 12RM lat pull-down. This method may be appropriate for example for linking strength RM and power exercises, for agonist muscles (see definition below).

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- Tri-set: Training method wherein three consecutive series are linked without pause, e.g., 12RM at the bench press, 12RM in lat pull-down, and then 1 min of abdominal plank. This method may be appropriate, for example, for linking strength RM, power, and core exercises. We often use this type of training for improving fatigue resistance, especially for core training, as strength and power building exercises necessitate a certain level of core strength (see definition below).

- Circuit: Training method wherein several consecutive exercises are linked without pause, e.g., 12RM at the bench press, linked with 12RM lat pull-down, then 12RM lateral raise with dumbbells, and finally, 1 min of abdominal plank exercise. A circuit may consist of 4 – 10 exercises, depending on one's goal. We use this method particularly when training for power endurance, to improve fatigue resistance.

- Agonist/Agonist: Method of performing consecutive exercises designed to work the same muscle groups, and who therefore, produce a similar movement. In biomechanical terms, the term "agonist" designates the muscle (or muscle group) that is the prime mover in an action. Agonist muscles work together in the execution of one movement, e.g., 12RM at the bench press, followed by 12 explosive push-ups. Here, the pectorals, triceps and anterior deltoids are agonists in the movement. This method is very effective for creating contrasts of strength/power as in the aforementioned example. A rest period may be inserted between exercises depending on one's goal.

- Agonist/Antagonist: Method of performing consecutive exercises involving opposing muscle groups. In biomechanical terms, the term "antagonist" designates the muscle or muscle group which opposes the principal movement created by the agonists, and stretch in reaction to the main contraction produced by the agonist muscle. Each muscle is paired with its own antagonist muscle, according to the movement created. An example of this method would be 12RM at the bench press followed by 12RM lat pull-down with high pulley (pectorals/ latissimus dorsi; push/pull). A rest period may be inserted between exercises depending on one's goal.

e) Other Important Notions

- Core Training: Isometric contraction of the abdominal muscle group – the core, while keeping the lumbar zone neutral.[8,9,10] Figure 2 represents the different layers of abdominal muscles in the torso – these are the core muscles. Obviously, the back muscles, especially in the lumbar region, and the intervertebral muscles (such as the multifidus) which act to support the spine during exercise must not be forgotten. Core training uses the concept of

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isometric contraction; however, in cross-country skiing it may also include torso flexion (a movement which is essential in several techniques such as double poling or diagonal stride). Flexion/rotation movements of the torso are also very important.

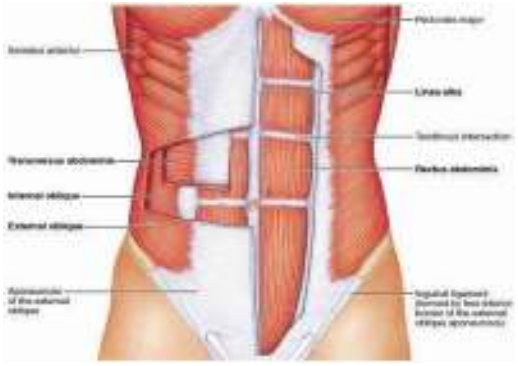

Figure 2. Core muscles

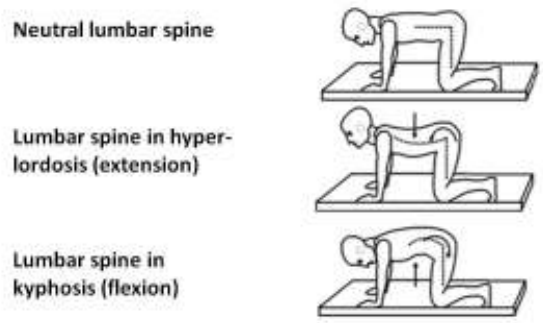

Figure 3. Lumbar spine in neutral position

Why strengthen the core muscles? Cross-country ski races can be 50km long and longer, and are very physically demanding. The longer the race, the more motor control and core endurance are important for optimization of technique, energy (or strength) transfer between the upper and lower body, as well as acute (or chronic) pain and injury prevention(e.g. lumbar area). Adequate core strength and endurance has a direct impact on performance, and plays a significant part in reducing the risk of injury and chronic pain.

Core training must be at the forefront of strength development for cross-country skiing, during the GPP, the SPP, and the maintenance phase – in other words, all the time!

<u>Key Concepts for Core Training:</u>

- ✓ Building muscular strength/endurance (abdominal group) is important for all stages of development.
- ✓ There is a very efficient muscular synergy present in the core muscles. They are all important and work together to optimise the action of each other.
- ✓ Training one core muscle in isolation can lead to its over-activation, which can be harmful to spinal stability, and generate chronic pain (e.g., lumbar extensor muscles).
- ✓ The degree of activation of each muscle must be balanced with that of the other muscles, and be dependent on the intensity of the task required.
- ✓ Endurance and motor control are crucial in maintaining general stability; the application of great force is rarely necessary, for example, a 1-8RM exercise in torso flexion is not very functional and its usefulness is debatable.

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- ✓ Core exercises must never put excessive strain on the spine.
- ✓ The degree of difficulty of core exercises must follow a logical progression such as the one outlined in this document.
- ✓ Core training is closely tied-in with the notion of posture (see the following section).

1.1.3 Other Factors Influencing the Effectiveness of Strength Training

a) Posture

"Strength can only be properly conveyed in the movement if I have excellent postural organization." - Christian Miller

Please refer to the section "Posture & Technique: How to Ski in the Weight Room"

b) Warm-up

Beginning strength training by a specific warm-up is essential. Not only does it ensure adequate activation before the most intense part of the session, it also considerably reduces the risk of injury.

- A Good Warm-up:

- ✓ Must include a short period of light aerobic activity to start, e.g., 5 min of running at 8 km/h.
- ✓ Must include a series of exercises targeting the muscles that will be used in your training.
- ✓ Must include a series of controlled spinal flexion, extension and rotation movements in order to fully activate deep core muscles.

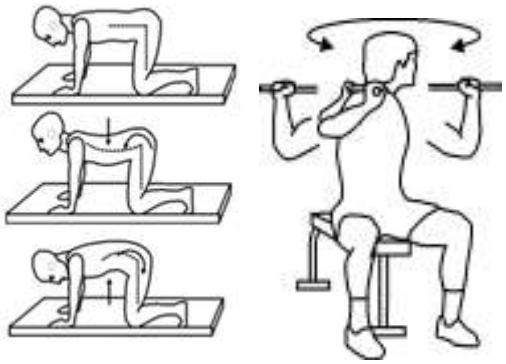

Figure 4. Warm up movements for the spine area

- ✓ Must include some rotator cuff activation exercises, e.g., external and internal rotation exercises with a rubber band, elbow pinned to the body.

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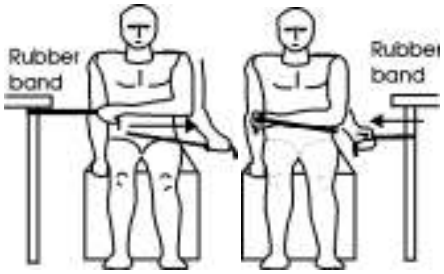

Figure 5. External and internal rotation of the shoulder with elastic band for warming up

- ✓ Must include activation exercises for the hip stabilizer muscles, for example a side plank with abduction and external rotation of the hip.

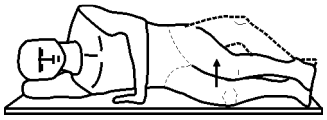

Figure 6. External rotation and abduction of the hip for warming up

- ✓ Must put focus on movement quality, in order to establish good motor patterns for the main training session.

- ✓ The greater the intensity of the main training session, the longer and more progressive the warm-up: slow and controlled exercises; rapid low-frequency; rapid high-frequency. This principle applies especially to power endurance training and plyometrics. In the following table, the insertion of a speed/agility phase with ladder proves to be an excellent way to promote neuromotor activation in plyometric training. However, it is not necessary if you are not planning to include any power exercises in your training session.

- ✓ In four phases:

Phase 1	Phase 2	Phase 3	Phase 4
Aerobic activation	Spinal movements and exercises for the shoulder and hip stabilizers	Ladder speed patterns and jumps feet speed & agility patterns; hand speed & agility patterns	Light plyometrics: Bounding Long jump

c) <u>Rest</u>

The variable of rest is a very important factor in strength development for cross-country skiing. Even within a training session, this variable will be manipulated to increase or decrease the intensity of the training. Considering that cross-country skiing is an endurance sport (strength-endurance, power-endurance and core), it is sometimes necessary to shorten the rest period between sessions and/or exercises, even in

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maximal force, in order to improve the athletes' capacity to resist fatigue (see the section "About Fatigue" below) and thereby generate maximum strength/power for longer periods of time.

During a traditional weight-lifting session (non-circuit), it is mainly the anaerobic alactic energy system that is used. According to theory, the time required for complete recovery of this system - for the integral resynthesis of phosphocreatine and ATP, is 4 to 5 minutes. But the question is, is it always necessary to aim for complete recovery? Considering the nature of the sport, the answer is no. For example, decreasing the rest period from 5 minutes to 2 or 3, between each set, will eventually improve the muscles' capacity to recover from muscle fatigue, as a result. On the other hand, the number of repetitions from one set to the next may have to be reduced, e.g., 6RM the first set, 5RM the second set, and 4RM for the third set with the same load.

For circuit training sessions, according to the stage of development and the capacity of the athlete, the rest period between exercises could vary from 1 minute to none at all.

d) Women and Strength Training

It is well known that men have a greater potential for building muscle mass than women. We attribute this limitation in women to several phenomena:

- ✓ Lower testosterone levels than for men do not contribute to significant muscle mass development
- ✓ A smaller number of muscle fibres than for men
- ✓ The potential for type II fibre development is not as high for women, which limits the potential for hypertrophy.[11]

Nevertheless, strength increase in women is obviously possible, and even considerable. In fact, proportionally, it can be superior to that of men! In this respect, gains are mostly due to improvements in the central nervous system and intermuscular coordination, which are very important parameters for improving technique and explosiveness on skis.[1,12]

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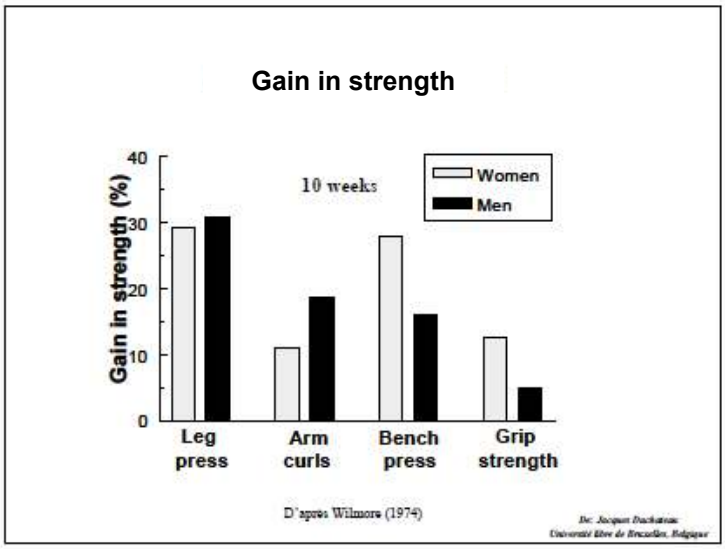

Figure 7. Strength gains for some exercises over a 10 week period : women vs men

Although women have a lower potential for developing muscle mass than men do, it doesn't mean it's impossible; in fact, quite the opposite. Several studies have shown recently that after a maximal strength training program with low repetitions, women were able to achieve significant gains in muscle mass. The hypertrophy of type II muscle fibres is primarily the cause. These fast twitch fibres greatly contribute to women's performance.

Lastly, women often have significantly less upper body strength compared to their lower body, which obviously hinders their performance in cross-country skiing. Several studies have demonstrated that the use of the upper body in cross-country skiing is of increasing importance in performance over the last decade. Clearly, this lack of upper body strength often observed in women also impedes their technical execution. It is therefore of utmost importance to teach young female cross-country skiers how to use their upper body effectively through adequate strength training.[13,14]

e) Muscle Fatigue

We are referring here to the acute type of muscle fatigue that can occur during intense effort and causes a temporary decline in physical capacity. For Enoka and Stuart (1992), fatigue is defined as "an acute impairment of performance that includes both an increase in the perceived effort necessary to exert a desired force and an eventual inability to produce this force." [15]

Fatigue is not only an energetic and muscular phenomenon. As previously explained, the nervous system is also called upon in the production of force, and several studies point to the direct implication of the neuromuscular system in the fatigue process. Figure

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8 illustrates the steps involved in a muscular contraction (within the neuromuscular system), and the sites that could possibly be the source of fatigue.

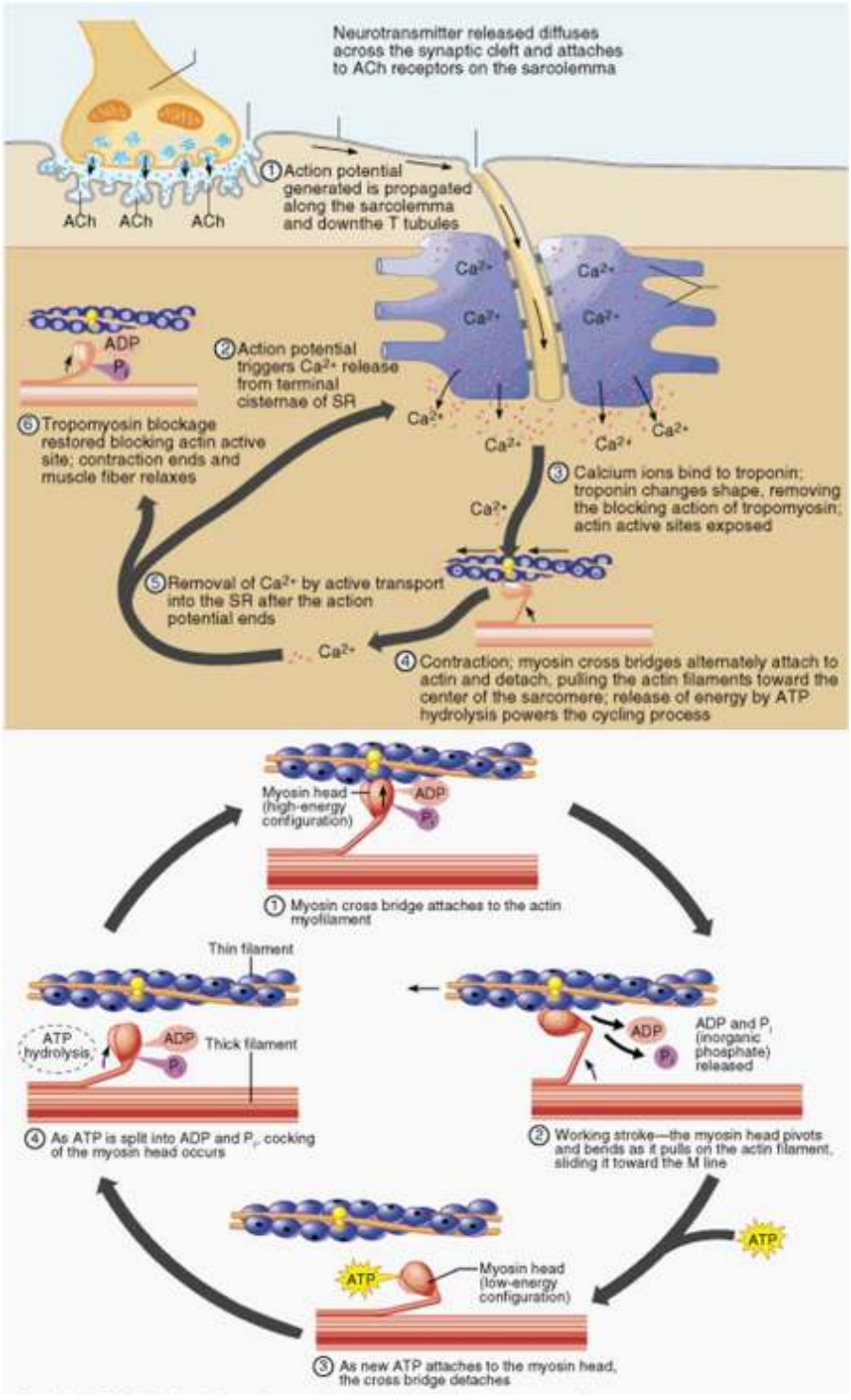

Figure 8. Stages of muscular contraction (neuro-muscular system)

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In another definition offered by Enoka and Stuart, fatigue is described as "a progressive increase of the required effort for the production of a given force, followed by an progressive incapacity of maintaining this force in a continuous or repeated way", which leads to a "diminution of motor performance." (1985)[16]

In cross-country skiing, these declines in motor performance are accentuated by the complexity of the movement (upper limbs, torso, and lower limbs all mobilized simultaneously). This phenomenon is crucial for cross-country skiers, given the importance of maintaining good technique and strength for as long as possible during a competition for better energy economy. The more fatigue sets in, the more technique deteriorates and an increased energy/force is required to maintain the same movement/speed. How can we reduce muscular fatigability and increase the neuromuscular system's capacity to resist fatigue?

With the help of the training methods proposed above (especially power endurance), we can slow the phenomenon of fatigue, which influences the body's capacity to maintain the force necessary to accomplish a given task, efficiently. Raphaël (2008) calls this adaptation "muscular optimization." According to Enoka and Stuart (1992), it is the "voluntary and/or non-conscious mechanism that allows the change in motor units' level of stimulation through nervous centres, thus optimizing the force produced by muscular fibres". This phenomenon occurs with strength and cardiovascular training. Muscular optimization happens when an exhausting exercise is repeated (as in maximal force and power endurance), "while taking into account the intensity of force production and the state of muscle fibres to ensure an efficient activation of the fatigued muscle." This muscular economy will then slow the appearance of fatigue through the generation of nervous adaptations.[11,17]

f) Training the Lower AND Upper Body!

Depending on the age and stage of development of trained athletes, the upper body can sometimes be neglected when developing strength for cross-country skiing. And yet, considering the evolution in ski techniques over the last decade, now more than ever the strength/power of the upper body is a crucial factor in performance. Therefore, it is important for athletes of all ages to carefully balance strength training plans, and focus on the upper body as much as on the lower body—even in plyometrics! This principle is even more important for female athletes, in whom a significant lack in upper body strength is often detected. When looking at the morphology of the best cross-country skiers, both male and female, we can't help to notice a significant muscle mass in the upper body. It's not a coincidence!

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Figure 9. The Norwegian champions, Marit Bjoergen and Therese Johaug have understood the importance of muscular development and strength training!

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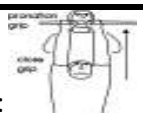
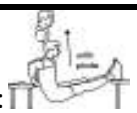
1.2 Strength-Training Exercises

1.2.1 Essential Exercises for the Train to Train Stage

There is a multitude of strength-training programs that exist, designed to meet every goal, and for all stages of development. In this chapter, we present a few exercises that are considered essential for the Train to Train stage.

Training to train, part 1 : Males 12-14, Females 11-13

<table>
<tr><th>Description of the exercise</th><th>Muscle groups</th><th colspan="2">Illustration</th></tr>
<tr><td>#1 -M : Pull-ups, pronation grip, shoulder width
#1 - F : Vertical pulley row, pronation grip, shoulder width</td><td>Lats, Rhomb, Trap, Biceps</td><td>M:  </td><td>F:  </td></tr>
<tr><td colspan="4">Posture : Suspended (or sitting), hands at shoulder width in pronation, open up chest
Execution : Breathe out and pull up to bring the bar to your chest (or the opposite) by keeping the chest opened up; breathe in and go back to the starting position by controlling the return
Error/correction #1: Rounding shoulders forward/Open up chest, look at ceiling
Error/correction #2: Shoulders too high, trapesius contracted/ Lower shoulders using Latissimus dorsi
Error/correction #3: Excessive swinging of the hips/ maintain core tension, control the return (descent)</td></tr>
<tr><td>#2 - M : Push-ups
#2 - F: Inclined push-ups on a bench</td><td>Pec, Delt ant, Triceps</td><td>M:  </td><td>F:  </td></tr>
<tr><td colspan="4">Posture : Supine on hands face down, arms extended, hands at shoulder width, feet together.
Execution : Breathe in and flex the arms to bring the upper body close to the ground (or bench) while avoiding curving the lower back; breathe out and push up until arms are fully extended.
Error/correction #1: Protraction of the head (forward)/ Pull chin in, head aligned with back
Error/correction #2: Pinching scapulas or "winging"/ Keep back wide, push into the hands
Error/correction #3: Excessive lumbar lordosis/Maintain core tension, reduce range of motion</td></tr>
<tr><td>#3 - M : Dips between benches, with or without extra load
#3 - F : Dips, hands on bench, feet on ground</td><td>Triceps, Pec, Delt ant</td><td>M:  </td><td>F:  </td></tr>
<tr><td colspan="4">Posture : Hands on bench, arms extended, feet on bench (or on ground)
Execution: Breath in and bend the arms to bring hips towards ground (up to 90^{o} flexion in elbows); breathe out and push up to full extension of arms
Error/correction #1: Rounding shoulders forward /Open up chest, widen collarbones
Error/correction #2: High shoulders, contracted trapesius/ Lower shoulders, open up chest
Error/correction #3: Little flexion at elbows, too much hip movement / lower difficulty</td></tr>
</table>

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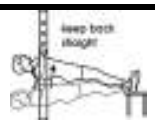
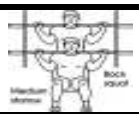
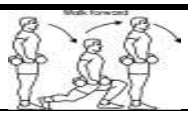
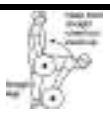
#4 - M : Horizontal pull up, feet on bench **#4 - F : Horizontal pull up, feet on ground**	Lat, Rhomb, Erect. Spin., Delt post, Traps	M: 	F: 
Posture : Suspended, hands at shoulder width apart with pronated grip on bar, open up chest, feet on bench (or ground). **Execution :** Breathe out and pull body up bringing chest to bar, keeping chest opened up; breathe in and return by controlling descent (arms at 45° to torso, back straight) **Error/correction #1:** Rounding of shoulders forward/Open up chest, look at ceiling **Error/correction #2:** Shoulders lifted up, contracted trapesius/ lower shoulders with lats **Error/correction #3:** Excessive swinging of hips / Maintain core contraction, keep hips/back/legs aligned			
#5 - Squat with bar on back	Quads, Gluts, Back, Abs		
Posture : Put bar on trapesius. Grab bar wider than shoulders and bring elbows back; feet wide, aligned with knees. **Execution :** Lift bar up. Breathe in and contract core. Bend by leaning forward (back straight) and bringing hips back (up to 90° knee flexion). Breathe out and push up by extending legs. **Errors/corrections:** See exercise #10 – Deep squat with bar overhead, without load			
#6 - Deadlift with bar, DB or KB	Quads, Hams, Gluts, Back, Abs		
Posture : Standing up, feet wider than shoulders width and aligned with knees; pronated grip at variable widths. **Execution :** Breathe in and grab bar (upper body leaning forward, knees and ankles bent, back straight, hips back, contract core), breathe out and extend legs and torso until standing straight. Control descent. **Error/correction #1:** Starting with rounded back / stick buttock out, keep back straight, contract core **Error/correction #2:** Torso leaning forward at the end of extension/ Extend hips by pushing forward **Error/correction #3:** Starting lift with little flexion at the knees/ Back straight, bring buttocks towards ground			
#7 – Lunges with DB	Quads, Hams, Gluts, Back, Abs		
Posture : Standing up, feet slightly apart, DB in hands **Exécution :** Breathe in and take a long step forward (torso slightly bent forward, back straight, contract core) until reaching 90° flexion at the knee; breathe out and push with forward leg (extend leg at hips and knee simultaneously), take step forward and return to standing postion **Erreur/correction #1:** Lateral translation of hip on descent / tighten hips, contract buttocks **Erreur/correction #2:** Knee moving inward on descent/Keep alignment of hip/knee/second toe **Erreur/correction #3:** Knee passing toes on descent/Descend by lowering hips towards ground, less forward			
#8 - Romanian Deadlift and Single leg Romanian Deadlift with barbell, dumbbell or kettle bell	Hams, Erect. Spin, Gluts	2 legs: 	1 leg: 

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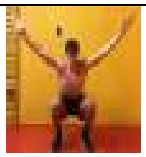
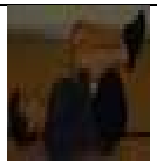
Posture : Standing up, feet at shoulder width and aligned with knees; pronation grip at variable widths.
Execution : Breathe in and grab bar (upper body leaning forward, legs straight, back straight, contract core), breathe out and extend torso up until standing straight. Control descent.
Error/correction #1: Excessive rounding of the back during descent / Keep back straight, contract core, reduce range of motion
Error/correction #2: Bending legs at knees on descent / keep legs straight
Error/correction #3: Excessive rotation of hips on descent / Keep hips parallel to ground

#9 – Box drop and hurdle jumps (plyometrics)	Quads, Hams, Gluts, Add, Abd, Abs	

Posture : Standing up on box, feet slightly apart
Execution : Breathe in, jump off box, land on ground by absorbing impact without pause, keep feet/knees/middle of hips alignment (torso slightly bent forward, back straight, hips back, contract core); breathe out and jump up and over hurdles (explosive extension of legs followed by quick flexion at hips and knees)
Error/correction #1: Weight on ball of feet when absorbing impact / absorb impact with feet until heels touch ground
Error/correction #2: Knees inside on impact/Hips back, contract buttocks while absorbing impact
Error/correction #3: Knees inside on propulsion/Contract buttocks while extending hips

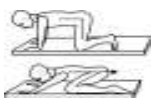
#10 - Overhead Deep squat with no load	Quads, Gluts, Back, Shoulders, Abs (torso)		

Posture : Place bar over head (hands wider than shoulders; feet apart slightly wider than shoulders and aligned with knees.
Execution : Breathe in and contract core. Crunch down, heels on the ground, torso slightly leaning forward (back straight, bar over head) and hips back (up to 90^{o} flexion at knees). Breathe out and come back up.
Why this exercise? Excellent for general mobility of shoulders, hips and ankles
How to detect problems with posture? Here are some strategies :

 Deep squat , arms in V = many restrictions.	 1. Deep squat, hands on shoulders : withdraws restriction at shoulders and spine (mobility and stregth)	 2. Deep Squat holding chair : reduces restriction on general mobility of lower body and core control
 3. Ankle flexion : knee 10 cm ahead of toes, heel on the ground, is optimal flexion in Deep Squat	 4. Mobility of hips : should be able to bring thighs to chest without excessive pulling with arms	 5. Mobility of knees : thighs to chest without much assistance while straightening lower legs up (vertical).

How to correct corresponding source of problem ? Some corrective strategies:

Problem 1. Deep Squat with arms in V, holding elastic band between hands
Problem 2. Deep Squat with arms in V, holding elastic band attached to wall
Problem 3. Stretching calf muscles
Problem 4. Flexion of hips on ground, back straight
Problem 5. Flexion of knee, sitting on ground

1. 
2. 
3. 
4. 
5. 

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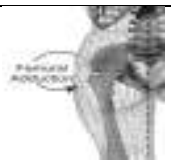
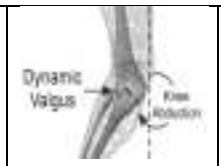
#11 – One leg box jump, stabilizing landing	Quads, Hams, Gluts, Add, Abd	

Posture : Standing up on one foot on a box, 2nd toe/knee/middle of hips perfectly aligned
Execution : Breathe in, flex at hip and knee (leaning forward, heel on the ground, back straight, hips back, contract core); breathe out and push up (explosive extension of the leg); land on box with same leg absorbing impact and keeping the perfect alignment
Why this exercise?: Excellent way to identify weaknesses in hips/knees/ankles stabilisers and make corrections

Focus #1 : Avoid lateral shift or adduction of the hip
Focus #2 : Avoid dynamic valgus angle of the knee (inside)
Focus #3 : Avoid collapse (eversion) of the ankle





#12 – Opposite arm/leg raises	Core, back stability	

Posture : On hands and knees, hands and knees shoulder width apart forming a 90° angle at shoulders and hips (with feet 6 contact points in total)
Execution : Breathe in and contract core; breathe out and raise opposite arm and leg while maintaining a neutral position with the back (not hyper-lordosis); breathe in and return to starting position; to check stability, place a stick along the athlete's spine (the stick shouldn't move during execution).
Why this exercise? : Good way to stabilise torso, lumbar region and core.
Focus #1 : Avoid hyper-lordosis while extending leg
Focus #2 : Contract gluts during leg extension
Focus #3 : Base of skull, middle of scapulas and sacrum in contact with stick on spine

Exercises from « Posture & Technique : How to ski in the weight room» should be introduced and explained to T2T-1 athletes. These are essential exercises for a better biomechanical comprehension of the different cross country skiing techniques.

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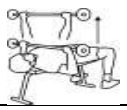
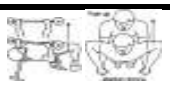
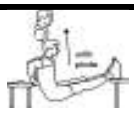
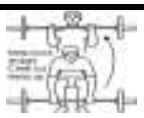
Training to train, part 2 : Males 15-16, Females 14-15

Description of the exercise	Muscle groups	Illustration
#1 - M : Bench Press **#1 - F: Push-ups**	Pec, Delt ant, Triceps	M:  F: 
Posture: Lying on back on a bench, feet on the ground; keep back straight; pronation grip on the bar, wider than shoulder width **Execution:** breathe in and bring bar down in control to 90° angle at elbows; breathe out and press bar up to starting position **Error/correction #1:** rounding shoulders forward/ open up chest, head aligned with back **Error/correction #2:** excessive lumbar lordosis/Maintain core contraction, reduce range of motion		
#2 - G : Dips on stand **#2 - F : Dips between benches, with or without extra load**	Triceps, Pec, Delt ant.	G:  F: 
Posture : standing with hands on stand, arms extended, feet in suspension **Execution :** Breathe in and bend arms down to 90° angle at elbows; breathe out and push up to full extension of arms. **Error/correction #1:** Rounding of shoulders forward /Open up chest, collarbones wide **Error/correction #2:** shoulders raised, contracted trapesius / Lower shoulders, open up chest **Error/correction #3:** not enough flexion at elbows, lots of hip movement / Lower difficulty		
#3 - Clean (bar or dumbells)	Upper body, torso, lower body	B:  DB: 

Starting position : Grab bar on the ground with pronation grip, shoulder width.
Execution :

1- 1st acceleration: start getting back up by accelerating progressively
2- 2nd acceleration: rise up by extending legs and torso, standing on tip of feet and rising shoulders
3- Max speed: arms should remain extended and back straight to transfer maximum momentum to the bar
4- Rearranging of the bar: after this extension, drop down as quickly as possible under the bar and secure it in a crunch position, the bar resting on shoulders and upper part of chest, elbows sticking up.
5- Final position : Stand up, bar still resting on shoulders and chest; once standing up, clean is completed.

Warning : execute this complex movement under expert supervision only (for correct execution and safety)

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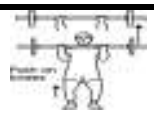
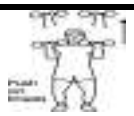
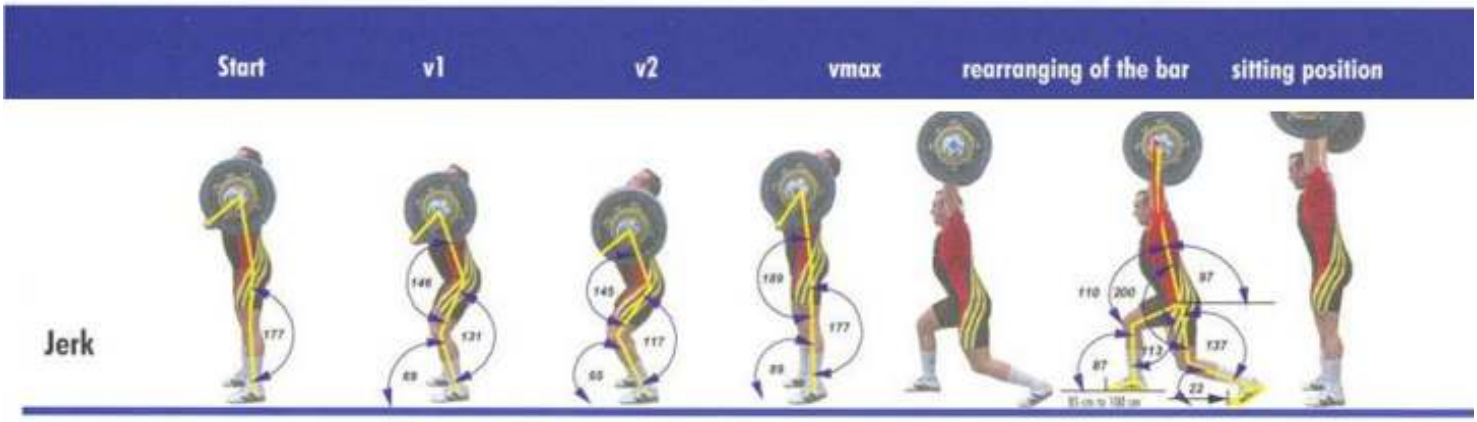
#4 - Jerk	Upper body, torso, lower body	B: 	DB: 



Starting Postion: bar resting on shoulders and upper part of chest, elbows sticking up

Execution :

1- 1st acceleration and max speed: bend knees slightly, throw bar up while dropping body lower to grab bar over head.
2- Rearranging the bar: usually executed with a lunge, one leg forward, one behind.
3- Final position : Stand up to complete movement.

***Warning* : execute this complex movement under expert supervision only (for correct execution and safety)**

#5 - Pull-ups, pronation grip, shoulder width. Male and female. See posture and execution above.

#6 - Horizontal pull up, feet on bench (M), feet on the ground (F). See posture and execution above.

#7 – Squat with bar on lower neck. See posture and execution above.

#8 – Lunges with dumbbells. See posture and execution above.

#9 – Deadlift with dumbbells or kettle bells. See posture and execution above.

#10 - Romanian Deadlift and Single leg Romanian Deadlift with barbell, dumbbell or kettle bell. See posture and execution above

#11- Box drop and hurdle jumps (plyometrics). See posture and execution above.

#12 - Overhead Deepsquat. See posture and execution above.

 # 13- One leg box jump, stabilizing landing. See posture and execution above.

#14 – Opposite arm leg raises. See posture and execution above.

Exercises from « Posture & Technique : How to ski in the weight room» should be introduced and explained to T2T-1 athletes. These are essential exercises for a better biomechanical comprehension of the different cross country skiing techniques.

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Calais-Germain B. (2009) Anatomie pour le mouvement 2; bases d'exercices. ARA. 302 pages

Cook G. (2003) Athletic Body in Balance. Human Kinetics. 222 pages.

Delavier F. (2009) Guide des mouvements de musculation. Vigot. 144 pages

Lafay O. (2009) Méthode de musculation. Amorpha Sports. 221 pages

http://fougeresforce.wifeo.com/les-mouvements-.php

Internet links for further instructions

L'épaulé et le jeté; l'apprentissage technique : http://www.youtube.com/watch?v=E4SQihY0bj0

The clean technique explained : http://www.youtube.com/watch?v=XDxK_8iX__U

The jerk technique explained : http://www.youtube.com/watch?v=kavt9jXA8kw

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1.3 Devising a Strength-Training Program for the Train to Train Stage

1.3.1 General Considerations

It has long been taken for granted that weight-lifting was inadvisable for youths who had not reached puberty or attained their maximum height. The reasons most often cited are:

1. Certain risks for normal development and bone growth
2. The impossibility of making any significant strength gains before puberty
3. Possible decrease in flexibility and speed of movement

However, for the last several years, numerous emerging studies have helped to put our fears in perspective, and even demonstrate the positive effects of youth strength training:

1. The more children's and adolescents' bones are subjected to appropriate mechanical stresses involving external force, the more they increase in volume and mass. Strength training is therefore an excellent way to improve bone density in young people;

2. Children who practice strength training show no decrease in their rate of growth;

3. Neural adaptations increase strength without increasing muscle mass. Considering that activation of the nervous system increases with age (childhood/adolescence), gains in strength due to this factor will increase as they grow. There is no noticeable difference between boys and girls;

4. Neuromuscular adaptations significantly improve speed of movement, and flexibility may be retained if an adequate stretching program is applied in the weight room;

5. Generally speaking, strength training is an excellent way to improve motor performance in children and adolescents.

A young athlete can benefit greatly from proper physical preparation. It will optimize performance and better equip the athlete to meet the rigorous challenges of the intense sport of cross-country skiing. In adolescence, strength training is a key element in the development of the athlete, because of the physiological adaptations it stimulates.

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1.3.2 Progress During the Train to Train Stage

The Train to Train stage is a crucial period in the athlete's development—strength development included. However, keeping in mind that the young athlete is still growing, it is important to follow certain guidelines to ensure balanced physical development.

Additionally, as the Train to Train stage stretches over a period of 4-5 years during adolescence and considering the rapid growth changes during this period, it is wise to split the stage into two parts, as follows:

a) *Part 1: Pre-puberty/Puberty Onset: 12 to 14 years (B) 11 to 13 years (G)*

This period is an introduction to the weight room. It is of utmost importance that, right from the beginning, proper exercising technique is emphasized (use of specific terminology, basic principles and quality of movement). It is important to ensure that athletes are mature enough to follow your instructions. For this reason, and to minimize the risk of injuries, a competent supervisor/coach should always be present in the weight room to supervise the training. Also, to keep the learning atmosphere interesting and fun, it is advisable to vary the training methods occasionally. In this phase, youngsters can also be introduced to RM strength training, touching a little on speed.

Although this stage is strictly an introduction to strength training, it is still a very important stage as it will help to maximize strength gains that occur—which can be significant—during the second half of the Train to Train stage, through proper technique. In this phase, strength increase is mostly due to neural adaptations and better motor coordination. A slight increase in muscle mass may also be observed.

b) *Part 2: During Puberty: 15 to 16 years (B) 14 to 15 years (G)*

This is an optimal period of development for several muscular qualities, especially in girls, as shown in Figure 1. The sudden adolescent growth spurt that precedes the beginning of this period, and the corresponding hormonal activity, stimulate muscle growth and optimize strength gains. The priority in this second part of the Train to Train stage is the development of strength/endurance qualities and maximal force, taking advantage of the natural muscular hypertrophy.

Although they will be maximized over the course of the next stages, the development of the muscular qualities of speed-strength and power will also be very important during this present stage. These qualities will, among other things, help maximize technical effectiveness in cross-country skiing. Obviously, the movement pattern of the exercises, posture and core development must also be emphasized, as they are equally necessary for effective transmission of strength in skiing.

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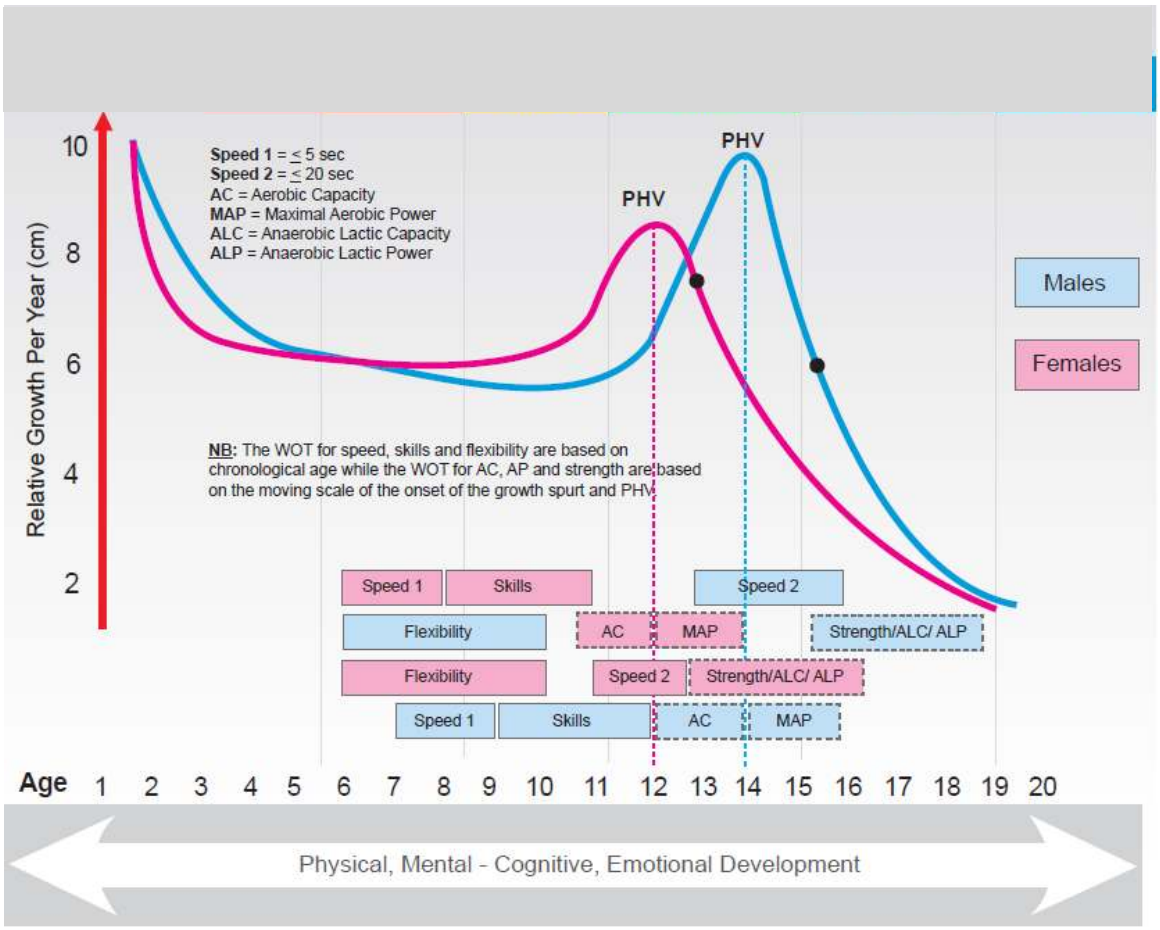

Figure 1. Windows of optimal trainability

1.3.3 Phases of Physical Preparation for Each Part of the Stage

a) Part 1: Pre-puberty/Puberty Onset: 12 to 14 years (B) 11 to 13 years (G)

- General Physical Preparation

Period of acquisition, development, or recall of basic muscular qualities through training, non-specific to cross-country skiing. Here is an example of the progression for this part of the stage:

Meso #1- Strength 12-15RSM / Core/ Posture

Meso #2- Strength-endurance 12-15RM / Core / Posture

Meso #3- Strength hypertrophy 10-12RM and speed ($_F$ X V) / Core/ Posture

Meso #4- Power-endurance (speed: $_F$ X V) non-specific / Core/ Posture

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- Specific Physical Preparation

Period of acquisition and development of muscular qualities which are essential to cross-country skiing through training that is specific to cross-country skiing. Here is an example of the progression for this part of the stage:

Meso #5 – Power-endurance (speed), non-specific / Core / Posture

Meso #6 – Tapering

- Maintenance Phase

Period where neuromuscular gains are maintained through training that is more or less specific to cross-country skiing. This phase generally stretches throughout the whole competition period, and may comprise periods of more specific stimulus training, "recall" periods, if the competition period includes long lapses between events. Here are the priorities for this stage:

Meso #7 – Strength endurance 12-15RM and speed / Core / Posture

Meso #8 – Recalls of power-endurance (speed) specific (see Specific Physical Preparation)

See table 1 for detailed planning.

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Table 1 : Part 1 ; Before and during puberty: 12-14 (M) 11-12 (F)

Period	Meso	Type of training	Reps/Rest or work/rest ratio	Method	Contrast	Sessions/week	Duration	Level of diff.	Focus
General Preparation	#1	Endurance strength RSM	12-15RSM / 2min	Super-s	Antagonists	2 x M	2 weeks	1 to 2 / 5	Q + BP
		Core and Posture	1/1.	Circuit	Mixt	1 x M + 2 x S		1 / 5.	Q + BP
		Stretching		Circuit	Mixt	3 x M		1 / 5.	Q + BP
	#2	Endurance strength RSM	12-15RM / 2min	Circuit 2X5 exercises	Agonists	2 x M	4 weeks	2 / 5.	Q + C
		Endurance specific strength	Intervals 1/2	Skate no poles, dbl P	None	1 x M		2 to 4 / 5.	Q + T
		Core and Posture	1/1.	Circuit	Mixt	1 x M + 2 x S		1 to 2 / 5.	Q + CE
		Stretching			Mixt	1-2 x M		1 / 5.	Q
	#3 et #4	FMax 10-12RM / speed	10-12RM / 2-3min	Circuit 2X5 or Super-s	Agonists	2 x M	4 weeks	2 to 3 / 5.	Q + L + S
		Endurance specific strength	Intervals 1/2	Skate no poles, dbl P	None	1 x M		2 to 4 / 5.	Q + T
		Core and Posture	1/1.	Circuit	Mixt	1 x M + 2 x S		2 to 3 / 5.	Q + CE
		Stretching		Circuit	Mixt	3 x M		1 to 2 / 5	Q
	#5	Power endurance (speed)	12RM ou RSM / 30"	Circuit	Mixt	1 x M	4 weeks	4 à 5 / 5	Q + L + S
		Hypertrophy 10-12 RM / speed	10-12RM	Super-s	Agonists	1 x M		2 to 3 / 5.	Q + L + S
		Endurance specific strength	Intervals 1/2	Skate no poles, dbl P	None	1 x M		2 to 4 / 5.	Q + T + P
		Core and posture	2/1.	Circuit	Mixt	1 x M + 1 x S		2 to 3 / 5.	Q + CE
		Stretching		Circuit	Mixt	3 x M		2 / 5.	Q
Specific Preparation	#6, 7 et 8	Power endurance (speed) specific	12RM ou RSM / 20-30"	Circuit	Mixt	1 x M	4 weeks	4 to 5 / 5	Q + L + S
		Hypertrophy 10-12 RM / specific speed	10-12RM	Super-s	Agonists	1 x M		2 to 3 / 5.	Q + L + S
		Endurance specific strength	Intervals 1/2	Skate no poles, dbl P	None	1 x M		2 to 4 / 5.	Q + T + P
		Core and Posture	2/1.	Circuit	Mixt	1 x M + 2 x S		2 to 3 / 5.	Q + CE
		Stretching		Circuit	Mixt	3 x M		2 / 5.	Q
Tapering	#9	Hypertrophy 10-12 RM / specific speed	10-12RM	Super-s	Agonists	1 x M	4 weeks	2 to 3 / 5.	Q + L + S
		Core and Posture	1/1.	Circuit	Mixt	1 x M + 1 x S		2 to 3 / 5.	Q + CE
		Stretching		Circuit	Mixt	3 x M		2 / 5.	Q
Maintenance	X	Endurance strength 12-15 RM /speed	12-15RM / 2-3min	Circuit 2X5 exercises	Agonists	1 x M	X	2 to 3 / 5.	Q + L + S
		Core and Posture	1/1.	Circuit	Mixt	1 x M + 1 x S	X	2 to 3 / 5.	Q + CE
		Stretching		Circuit	Mixt	3 x M	X	1 / 5.	Q
Recall	Refer to meso #6, 7 or #8 based on athlete aptitudes et level of fatigue								
NB for Fmax 10-12RM ; sessions should be supervised at all time. It is safer to aim for 12 RM with a lighter load. Never neglect the quality of the execution.									

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b) Part 2: During Puberty: 15 to 16 years (B) 14 to 15 years (G)

- General Physical Preparation

Period of acquisition, development, or recall of basic muscular qualities through training, non-specific to cross-country skiing. Here is an example of the progression for this part of the stage:

Meso #1- Strength 12-15RSM / Core / Posture

Meso #2- Strength hypertrophy 10-12RM / Core / Posture

Meso #3- Strength hypertrophy 10-12RM and speed ($_F$ X V) / Core / Posture

Meso #4- Maximal strength 7-9RM and power (F X V) / Core / Posture

Meso #5- Power-endurance, non-specific / Core / Posture

- Specific Physical Preparation

Period of acquisition and development of muscular qualities which are essential to cross-country skiing through training that is specific to cross-country skiing. Here is an example of the progression for this part of the stage:

Meso #6-7-8 – Power-endurance, specific / Core / Posture

- Tapering

A period of modulation in the training program characterized by a reduction of one or more training parameters in order to obtain optimal performance. The priority for this part of the stage:

Meso #9- Maximal strength 7-9RM and specific power / Core / Posture

- Maintenance Phase

Period where neuromuscular gains are maintained through training that is more or less specific to cross-country skiing. This phase generally stretches throughout the whole competition period, and may comprise periods of more specific stimulus training, “recall” periods, if the competition period includes long lapses between events. Here are the priorities for this stage:

Meso X – Strength hypertrophy 10-12RM or max strength 7-9RM and power/ Core / Posture

See table 2 for detailed planning.

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Table 2 : Part 2; During puberty : 14-16 (M) 12-15 (F)

Period	Meso	Type of training	Reps/Rest or work/rest ratio	Method	Contrast	Sessions/week	Duration	Level of diff.	Focus
General preparation	#1	Endurance Strength RSM	12-15RSM / 2min	Super-s	Antagonists	2 x M	2 weeks	1 to 2 / 5	Q + BP
		Core and posture	1/1.	Circuit	Mixt	1 x M + 2 x S		1 / 5.	Q + BP
		stretching		Circuit	Mixt	2 x M		1 / 5.	Q + BP
	#2	Hypertrophy strength RM	10-12RM / 2min	Circuit 2X5 exercises	Agonists	2 x M	4 weeks	2 / 5.	Q + L
		Endurance specific strength	Intervals 1/2	Skate no poles /dbl p	None	1 x M		2 to 4 / 5.	Q + T
		Core and posture	1/1.	Circuit	Mixt	1 x M + 2 x S		1 to 2 / 5.	Q + CE
		stretching		Circuit	Mixt	3 x M		1 / 5.	Q
	#3	Hypertrophy strength RM + speed	10-12RM / 2min	Circuit 2X5 exercices	Agonists	2 x M	4 weeks	2 to 3 / 5.	Q + L + S
		Endurance specific strength	Intervals 1/2	Skate no poles /dbl p	Optional	1 x M		2 to 4 / 5.	Q + T + P
		Core and posture	1/1.	Circuit	Mixt	1 x M + 2 x S		2 to 3 / 5.	Q + CE
		stretching		Circuit	Mixt	3-4 x M		1 to 2 / 5	Q
	#4	Fmax 7-9RM / power	7-9RM / 2-3min	Circuit 2X5 exercises	Agonists	2 x M	4 weeks	2 to 3 / 5.	Q + L + P
		Endurance specific strength	Intervals 1/2	Skate no poles /dbl p	Optional	1 x M		2 to 4 / 5.	Q + T + P
		Core and posture	1/1, 2/1.	Circuit	Mixt	1 x M + 2 x S		2 to 3 / 5.	Q + CE
		stretching		Circuit	Mixt	3-4 x M		1 to 2 / 5	Q
	#5	Power endurance	10-12RM ou RSM / 20-30"	Circuit	Agonists	1 x M	4 weeks	4 to 5 / 5	Q + L + P
		Fmax 7-9RM / power	7-9RM / 2-3min	Circuit 2X5 exercises	Agonists	2 x M		2 to 3 / 5.	Q + L + P
		Core and posture	Intervals 1/2	Skate no poles /dbl p	Optional	1 x M		2 to 4 / 5.	Q + T + P
		stretching	2/1.	Circuit	Mixt	1 x M + 2 x S		2 to 3 / 5.	Q + CE
		stretching		Circuit	Mixt	3-4 x M		2 / 5.	Q
Specific preparation	#6	Specific power endurance	10-12RM ou RSM / 20-30"	Circuit	Agonists	1 x M	4 weeks	4 to 5 / 5	Q + L + P
		Fmax 7-9 RM / specific power	7-9RM / 2-3min	Circuit 2X5 exercises	Agonists	1 x M		2 to 3 / 5.	Q + L + P
		Endurance specific strength	Intervals 1/2	Skate no poles /dbl p	Optional	1 x M		2 to 4 / 5.	Q + T + P
		Core and posture	2/1.	Circuit	Mixt	1 x M + 2 x S		2 to 3 / 5.	Q + CE
		stretching		Circuit	Mixt	3-4 x M		2 / 5.	Q
	#7-8	Specific power endurance	10RM / 20-30"	Circuit	Agonists	2 x M	4 weeks	4 to 5 / 5	Q + L + P
		Endurance specific strength	Intervals 1/2	Skate no poles /dbl p	Optional	1 x M		2 to 4 / 5.	Q + T + P
		Core and posture	2/1.	Circuit	Mixt	1 x M + 2 x S		2 to 3 / 5.	Q + CE
		stretching		Circuit	Mixt	3-4 x M		2 / 5.	Q
Tapering	#9	Fmax 7-9 RM / specific power	7-9RM / 2-3min	Super-s, tris	Agonists	1 x M	1 week-10 days	2 to 3 / 5.	Q + L + P
		Core and posture	2/1.	Circuit	Mixt	1 x M + 1 x S		2 to 3 / 5.	Q + CE
		stretching		Circuit	Mixt	3 x M		2 / 5.	Q
Maintenance	X	Hypertrophy or Fmax 7-9RM / power	10-12, ou 7-9RM / 2-3 min	Circuit 2X5 exercises	Agonists	1 x M	X	2 to 3 / 5.	Q + L + P
		Core and posture	1/1.	Circuit	Mixt	1 x M + 1 x S		2 to 3 / 5.	Q + CE
		stretching		Circuit	Mixt	3 x M		1 / 5.	Q

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Recall	Refer to meso #6 and 7, or #8 (more difficult) based on athlete aptitudes et level of fatigue
Notes for female athletes : depending on functional abilities, it may be too early to move on immediately to 7-9RM. They may stay at 10-12RM.	

GLOSSARY

Abbreviation	Means
M	Main session (ex : 2 x M = 2 main sessions per week)
S	Secondary session (ex : 2 x S = 2 secondary sessions per week); can be a short session of 3-6 exercises after a main session or as a standalone session
Q	Quality: focus on proper alignment and execution of movements
T	Technique : focus on good technique for strength on skis
BP	Basic Principles : breathing, core contraction during exercises, etc.)
S	Speed : focus on speed of contraction; small range of motion
CE	Core Endurance
L	Load : focus on respect of RM (appropriate load to achieve # of Repetitions Maximal)
P	Power : balance between Max Strength and Speed with a good range of motion

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1.3.4 Strength Training Periodization

Example of periodization for the 2013-14 season; mesocycles of X weeks.

Phases	Mesocycle	Dates (No. of Weeks)
GPP	1	May 5 - 18 (2)
	2	May 19 - June 15 (4)
	3	June 16 - July 13 (4)
	4	July 14 - August 10 (4)
	5	August 11 - September 7 (4)
SPP	6	September 8 - October 5 (4)
	7	October 6 - November 2 (4)
	8	November 3 - December 3 (4)
Tapering	9	December 4 - 14 (1)
1st Competition	X	December 15 - 16
Maintenance	Y	December 16 – March 31
Recall	Z	Ex : February 2 – 8 (1)

Number of Weeks in the Mesocycle	Sets/Week
4	3-4-3-2
4	3-3-4-2
4	2-3-4-2
3	3-4-2
2	3-2 (or 3-3)
1 (Tapering)	2

There are several combination possibilities for the number of sets per week. Judgement will have to be used to determine the appropriate ratio of volume/intensity in strength training, according to the other components of the plan. Ideally, the first week is for demonstrating the exercises (2 or 3 sets), and the last week of the mesocycle will be for recovery and will decrease in volume (2 sets).

Depending on the periodization plan, the volume of strength training can be regulated in various ways, according to the athletes' state of fatigue and their recovery ability.

Example 1: The emphasis is to be put on cardio-vascular training (high volume and intensity) for a given week. Therefore, it is not a good idea to use up all the athletes' energy with strength training. A reasonable option would be one strength session of 2 or 3 sets, and 2 core-training sessions. This would also be a good choice for youngsters in the 1st part of the Train to Train stage.

Example 2: The plan is to really work the athletes, both in cardio-vascular and strength training, for a given week. In this case, two strength sessions of 3-4 sets and one core

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session are a viable option. This would meet the needs of athletes, for example, in the 2nd part of the Train to Train stage.

1.3.5 Practical Recommendations and Key Concepts

1. Set realistic training goals.
2. Clearly demonstrate all exercises.
3. Avoid heavy loads initially; rather emphasize proper execution of the movements (priority #1).
4. Never chose a heavier or higher intensity load to the detriment of proper technical execution, especially before the adolescent growth spurt.
5. Remember the importance of core training in all exercises.
6. The rhythm of strength-training exercises must be moderate and controlled.
7. The same is true for power and plyometric exercises. Even if the movement is much faster, it must still be strictly controlled!
8. Give regular feedback about posture and technique during the session.
9. A competent supervisor/coach should be present at all times to supervise the activity, especially for RM strength-training.
10. Progressively increase volume and intensity.
11. Young people have to be introduced to strength training with exercise machines, dumbbells, stabilizer balls, etc. Do not solely rely on body weight—external loads must also be used regularly!
12. Loads must be determined individually.
13. The majority of exercises should involve large muscle masses; targeting specific small muscles is not the most specific for cross country skiing..
14. Exercises that risk putting considerable stress on the spine(compression stress) must be avoided. The development and integration of core exercises in all training is an excellent way to prevent this risk.
15. Athletes' state of fatigue must be considered before training in the weight room—fatigue will significantly increase the risk of injury. Adjust the session if needed, increasing rest periods, and/or reducing the number of sets and exercises (especially in power or speed).
16. The exercises should be arranged in a logical way, according to the time of year and goals set for that period.

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