Exercise Physiology in Soccer

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General Introduction

Conditioning programs are in general terms designed to improve different variables for performance.
1. **General Endurance**. Often expressed in VO2max (= Maximal Oxygen Uptake).
2. **Sport specific Endurance**. Expressed in % VO2max; Lactic values; % Hfmax; Power, etc.
3. **Strength.** Expressed in Maximal Static Strength; >Explosive= Strength (= Dynamic Strength); Isokinetic strength values; etc.
4. **Flexibility or Suppleness.** Expressed in Range of Movement (= ROM); degrees; ratio agonist : antagonist muscles; etc.
5. **Coordination and Speed of movement**. Expressed in m.secAo or balance test results; etc.

Overuse injuries are more and more a critical part in the total conditioning program. Topsport training requires more time to spend in the preparation period than in the competition itself.
Increase not more than one parameter at a time, for example speed **or** intensity, may be called a golden rule to avoid overuse injuries or >staleness=.
Staleness means that point of cellular injury combined with fuel exhaustion that results in breakdown of body defence and endocrine and/or neurological disturbances. (Martin and Coe,1991).
Staleness may require weeks, months or even years to overcome. What is the treatment? **Rest!** But **the best rest is therapeutic rest.** That means changing to other activities, sometimes stopping training for a while, it depends how serious >staleness=is.
A training log or journal can show a lot of information concerning early indications of overtraining or overreaching symptoms.

Warning signs of overtraining and staleness:

Training related
Unusual muscle soreness the day after training
Progressive increase in soreness with continued training
Performance plateau or decrement despite increased training
Inability to complete previously manageable training load
Elevated effort sense or delay in recovery
Thoughts of quitting or skipping training

More in detail are the **Symptoms of Overtraining from a physiological point of view:**

Physiological Performance related:
1. Decreased performance
2. Inability to meet previously attained performance standards or criteria.
3. Recovery prolonged
4. Decreased muscle strength
5. Decreased maximum work capacity.
6. Loss of coordination
7. Abnormal T-wave pattern in ECG
8. Changes in heart rate at rest, exercise and recovery.
9. Decreased body fat.
10. Chronic fatigue
11. Loss of appetite
12. Insomnia with and without night sweats
13. Headaches/ nausea
14. Muscle soreness or tenderness
15. Muscle damage.
16. Tendonostic/ periosteal complaints.

Lifestyle related
Increased tension, depression, anger, fatigue, confusion, inability to relax
Decreased vigour in completing daily activities
Loss of pleasure in previously pleasurable things
Poor sleep quality/quantity

More in detail from a psychological point of view.

1. Feelings of depression.
2. General apathy.
3. Decreased self-esteem
4. Emotional instability
5. Difficulty in concentrating at work and training.
6. Fear of competition.
7. Changes in personality.
8. Gives up when the going gets tough.

Health related
Swelling of lymph nodes, constipation, diarrhoea
Increased frequency of illness (fever, head colds, etc.)
Increased blood pressure, morning rest pulse
Sudden weight loss
Loss of appetite

More in detail from a Immunology point of view:

1. Increased susceptibility to and severity of illnesses, colds and allergies.
2. Flu-like illnesses
3. Minor scratches heals slowly.

4. Swelling of lymph glands.
5. One-day colds.
6. Decreased functional activity of neutrophils / total lymphocyte counts.
7. Reduced response to mitogens.
8. Increased blood eosinephil count.
9. Bacterial infection
10. Reactivation of herpes viral-infection.

More in detail from a Biochemical point of view:

1. Negative nitrogen balance
2. Hypothalamic dysfunction
3. Flat glucose tolerance curves
4. Depressed muscle glycogen concentration
5. Decreased haemoglobin and serum iron and serum ferritin
6. Mineral depletion (Zn, Co, Al, Mn, Se, Cu, etc.)
7. Increased urea concentrations
8. Elevated cortisol levels and ketosteroids in urine
9. Low free testosterone
10. Increased serum hormone binding globulin
11. Decreased ratio free testosterone to cortisol of more than 30 %
12. Increased uric acid production

(Kreider,R.B., A.C.Fry and M.L.O=Toole,1998).

Warm-up and cool-down

Attention to the content of the warm-up and cool-down periods and to the proper execution of those exercises are important.(Ekstrand, a.o.,1983).

Proper nutrition provides the energy needed for performance and the materials necessary for injury repair. Serial weight and skinfold measurements for example can avoid problems in sport-activity. High-carbohydrate diets optimise muscle-glycogen levels.

Adequate hydration is critical, especially in warm climates. The thirst mechanism lags behind the body=s demand for water replacement. Fluid intake should be scheduled and monitored. Waiting till the moment you feel thirsty and start drinking than is from physiological point of view too late! During exercise fluids (>sports drinks=) containing carbohydrate (5-7 %) and dilute sodium are better absorbed, but cool water is probably adequate for most sport activities lasting less than 90 minutes, like a soccer match when the glycogen stores are well prepared for the match.

A Listen to the signals of your own body@ is an important tool in daily training practice especially during warm-up and cool down period. Not only in case of proper nutrition but also in indefinite, hazy >pains=.

Soccer players who learn that prompt treatment of minor illness or injury, such as use of ice, mild analgesics, padding and bandaging, maximizes, rather than decreases, performance and will probably enhance their success.

ARepetition is the mother of learning@

This axiom is in general terms right but overuse must be carefully avoided by employing variable training routines, doing cross-training, limiting practice length and/or frequency and mental drills or performance imaging to substitute for repetitive performance.
Most important is probably the fact that **sudden changes** in practice **intensity** or outdoor/indoor circumstances **should be avoided.**

Practical Guidelines to **lower the risk** of **Upper Respiratory Tract Infection (= URTI)** during heavy training circumstances. (Nieman D.C.,1998).

1. Keep other stress situations to a minimum, like mental stress for example.
2. A well-balanced diet to keep **vitamin and mineral pools at optimal levels**. Training camps and outdoor competition situations must be watched over carefully.
3. Avoid overtraining/overreaching and chronic fatigue.
4. Adequate sleep on a regular schedule. Sleep disruption has been linked to suppressed immunity.
5. Avoid rapid weight loss.
6. Avoid crowds or sick people and don=t put hands to eyes and nose (primary route of viruses).
7. Competing during winter months, than think about **flu shots.**

Few studies have documented both overtraining and immune function during periods of intensive training. In overtrained athletes, compared to well-trained athletes, **secretory IgA** and **plasma glutamine** concentrations have been shown **lower.** In spite of the fact that those markers are easy to control we are wondering that it is still not a practical tool in hands of the medical team of sport teams. Probable that hormonal changes during overtraining and overreaching play a significant role in immuno-modulation during overtraining. (Mackinnon,L.T.,1998).

Procedural details must be standardized, such as define >injury=, >recovery=, >severity=, etc.
Factors that might be investigated are:
1. **Role of re-injury in injury statistics.**
2. Forces on body in various circumstances.
3. **Factors that predict injury** such as age/maturity, physiological and psychological, biomechanical, environmental, coaching, equipment, etc.
4. Impact of interventions on injury statistics such as pre-participation evaluation, taping and bandaging, etc.
5. Occurrence statistic studies.
6. Economic impact studies such as time loss, medical care loss, etc.
7. Use of non-contact practice programs in preparation for contact sports activities. Do they improve injury statistics? or do they produce effective team performance? We don=t know yet the answers.(Weaver,et al 1996).

Accurate data collection; careful data analysis and cautious institution of indicated changes are conditions that if they are fulfilled with proper investigations they will show us results that will be worth the effort expended.
The incidence of soccer injuries appears to increase with the age of the players.

(Backous, et al,1988; Hoff et al,1986; Inklaar,1994; McCarroll, et al,1984; Schmidt-Olsen, et al, 985,1991).
Older players have increased rate of injury because increased strength, speed and aggressiveness led to higher joint reaction forces and higher impact forces on collision .
A higher incidence of head, face and upper extremity injuries was documented in younger players (Keller et al.1987).
Possible reasons for such injuries are:
More frequent falls on outstretched hands, illegal ball contact, increased fragility of the upper extremity epiphyses, insufficient technical expertise in heading the ball, mechanical weakness of growing dental tissue, increased ball-weight to head-weight ratio.If adolescents lagged behind in skeletal maturity they were found to be at greater risk for injuries than their competitors.
Incomplete rehabilitation is an injury factor, for example ankle sprains. Ekstrand and Tropp (1990) found in soccer players with previous ankle sprains that they are at 2.3 times greater risk for ankle injuries (almost 48 % of all players!). Nielsen and Yde (1989) found that 56 % of ankle injuries occurred in players with a history of ankle sprains.
In an investigation of soccer injury mechanisms. Ekstrand and Gillquist (1983) found that a minor injury was often followed within two months by a major one to the same area and of the same type. **Re-injuries are frequently an indication of neglect in the rehabilitation of the initial injury and premature return to play.** They found further on that 42 % of all injuries were due to player factors such as joint instability, muscle tightness, inadequate rehabilitation or lack of training.

A prophylactic program which intended to reduce soccer injuries contended the following items:
1. correction of training.
2. provision of optimum equipment.
3. prophylactic ankle taping.
4. controlled rehabilitation.
5. exclusion of players with grave knee instability.
6. disciplined play
7. increased risk of injury in training camps
8. correction by doctors and physiotherapists.

After six months the test teams had sustained 75 % fewer injuries than the controls. (Ekstrand et al,1983).
Ankle disk training and a semi-rigid ankle arthritis during the rehabilitation period provided a prophylactic effect. (Tropp et al, 1985).
We should suggests that a pre-season examination, besides a routine history and physical examination by the physician/physiotherapist, is followed by exercise physiological measurements of muscle strength, endurance, body composition and flexibility.

The fundamental problem with epidemiological assessment of data on soccer injuries is the inconsistent manner in which injury is defined and information is collected and recorded.
Consistent injury evaluation and diagnosis are necessary for internal reliability as well as comparison of epidemiological studies.

Recording the specific amount of actual playing time for each soccer player for both the practice sessions and games (competitions) can create circumstances to set up the ideal study. Up to recent time in the past this was more or less impossible to realize but nowadays with the help of **video recording and computer analysing equipment** such a study could be realized. We think that such a study is very important to mention and to realize.

Training Plan:

Progressive overload is the foundation of all successful training. Stress causes a temporary decrease in function (**fatigue**) followed by an adaptation that improves function. During training all fatigue is ultimately the result of an inability to generate energy at a rate sufficient to meet the needs of the performance. **Super-compensation** involves reducing muscle glycogen stores to minimal levels with strenuous exercise, during recovery phase, increased carbohydrate diary intake results in 1.5 times more glycogen than usual to be stored in the muscles. Improved performance is the result.

Genetics of cardio-respiratory fitness phenotypes.

Inter-individual differences can be explained by genetic factors in cardio-respiratory fitness phenotypes. Heart size and cardiac functions vary by 30 - 70 %. Also acute exercise and exercise training are influenced by the genotype.
Pulmonary functions are moderate influenced by genetic factors, they also adapt to environmental conditions like hypoxia and altitude. Results in twin and family studies suggest that these adaptations may be partly determined by the genotype.
Heritabilities around 30 % are generally reported for blood pressure, mainly attributable to polygenes. The majority of candidate genes identified to date were not associated nor linked with blood pressure or hypertension.

Principles of Training:

The principle of overload states for that a training effect to occur a system or tissue must be challenged with an intensity, duration or frequency of exercise to which it is unaccustomed.
Adaptation is the overall effect in time.

The principle of specificity means that the training effect is limited to the muscle fibres involved in the activity. Specific adaptation to the type of activity like mitochondrial and capillary adaptations to endurance training and contractile protein adaptations to resistive weight training programs are the results.

In **cross-sectional studies** the investigator examines groups differing in physical activity and records the **differences** that exist in VO2max or fibre-type distribution, etc. **Longitudinal studies** examine **changes** in VO2max, fibre-type distribution, etc. occurring over the course of a training program. **The same subject is repeatedly tested** and allow one to investigate the **rate** at which the variables respond to training or detraining.

Endurance training programs that increase VO2 max involve a large muscle mass in dynamic activity for over **20 minutes per training session, 3 to 5 times per week at an intensity of 60 to 85 % VO2 max.**
Genetic predisposition accounts for 40 - 66 % of one=s VO2 max value. Strenuous training or prolonged training **can increase VO2 max** in normal sedentary people by **more than 40 %.**

Maximal Oxygen Uptake (= VO2 max).

Oxygen uptake is the product of systemic blood flow (= cardiac output) times systemic oxygen extraction (= arterio-venous oxygen difference). Changes in VO2 max are changes in HR max (= maximal heart rate) and/or Stroke Volume
(= ml.blood per heart beat contraction brought into circulation) and/or arterio-venous difference expressed in ml. oxygen per litre blood).
Maximal stroke volume differences are the most important cause of difference between peoples VO2 max values. Stroke volume is equal to the difference between end diastolic volume and end systolic volume. There is evidence that left ventricle size increases as a result of endurance training with little change in ventricular wall thickness, while isometric exercises cause an increase in wall thickness with little or no change in ventricular volume.
Another training effect after **endurance training** is the fact that the **heart beats slower at rest** than before the training program started. **(= bradycardia).** End diastolic volume increases as a result of endurance training and according to the Frank-Starling mechanism an increased stretch of the ventricle leads to an increase in stroke volume. The training induced increase in maximal stroke volume is due to both an increase in pre-load and a decrease in after-load.
In young sedentary subjects 50 % of the VO2 max increase is due to an increase in the systemic arterio-venous difference (increase in the number of mitochondria) and 50 % of the increase is due to an increase in maximal stroke volume. (HR max remains the same!).

Detraining and VO2 max.

The initial decrease in VO2 max (during the first 1 or 2 weeks) is due entirely to the decrease in maximal stroke volume (heart rate and arterio-venous difference remains more or less the same or slightly increase).
How this happens ? This sudden decrease in maximal stroke volume appears to be due to the rapid loss of plasma volume with detraining. When plasma volume is (artificial) restored by infusion, VO2 max increases toward pre-training values. **Decrease in muscle mitochondria during detraining phase is associated with the decrease in arterio-venous difference.**
Changes in VO2 max due to training or detraining are caused by changes in stroke volume and the capacity of the muscle to extract oxygen.

The biochemical changes in muscle due to endurance training influence the physiological responses to exercise. The reduction in feedback from chemoreceptors in the trained muscle and a reduction in the need to recruit motor units to accomplish a work task results in reduced sympathetic nervous system, heart rate and ventilation responses to work on sub-maximal level.

Training intensity:

The timing and length of recovery intervals, either during sets of a single exercise session or from session to session **should be watched carefully.** All-out bursts of activity overload the high energy phosphate systems. For optimal adaptation, complete recovery should occur before a second stimulus is given. On the other hand , to build up tolerance to high lactate levels, initiating a second stimulus before complete recovery may be desirable. **If the time to the next training is too long,** the overcompensation will regress to the original state and **no** progressive improvement will occur.
Conversely, if the training stimulus is given **too frequently**, such that it interrupts the recovery/overcompensation phase, **adaptation will not occur.**
A delicate balance between both variables may be called A the golden key@ to avoid overreaching or overtraining!
Relative intensity is based on an individual=s 1 RM, where training is performed at a set or known percentage of their 1 RM. For example: two athletes may possess different maximal strength levels like 1 RM = 100 kg and 150 kg respectively. Than 80 % of one=s individual maximum of 100 kg and 150 kg = 80 kg and 120 kg the load to work with.
Absolute intensity refers to the **actual load** on the barbell or the machine or Hfmax. The athlete training with 120 kg above mentioned is exercising at a greater absolute intensity than the athlete using 80 kg.
Absolute intensity can be defined as the amount of work (= force times distance expressed in Joules) performed in a set time period (work/ time = power expressed in Watt)

Periodization in Soccer:

Definitions:

Inter-muscular coordination: Several different muscles cooperate in performing an action.
Intra-muscular coordination: Many neuromuscular units act simultaneously to perform an action or move.
External resistance: Attempting to move a weight as rapidly and forcefully as possible through the entire range of motion.
Internal strength: The force necessary to defeat the inertia (mass) of a weight.
The more internal strength exceeds external resistance, the faster the acceleration.
Ballistic Training method: Use for example a medicine ball in explosive actions.

The Micro-cycle and Macro-cycle:

A micro-cycle is a weekly training program. A very important planning tool. Throughout the annual plan, the nature and dynamics of micro-cycles change according

to the phase of training, the training objectives and the physiological and psychological demands.
Intensity during a micro-cycle follows the principle of progressive increase of load in training.
Several micro-cycles together forms a Macro-cycle, for example 4 micro-cycles in one month.
A more or less traditional macro-cycle could be designed as follows:
First week a load percentage of 70 % of maximum, second week 80 % max and the third week 90 % max, the fourth week is the **regeneration** micro-cycle with **>only= 60 % max. Removal from fatigue, replenish the energy stores and allow psychological relaxation are the main targets in that period. Recovery after strenuous exercise training in the right way is probably the most underdeveloped, but very important,! training session in modern training.** (Vos,1994).
The overall amount of training volume and intensity of technical and tactical training work should be considered carefully when planning strength training. **Strength training in soccer is subordinate to technical and tactical training.**

Regeneration processes or times during different training loads:

General and local aerobic training:
Training **intensity: 60 - 70 % max**, than permanent regeneration takes place.

Aerobic/Anaerobic training:
Fast generation (but very incomplete) within 1.5 to 2 hours after training activity on that level. Training **Intensity: 75 - 90 % max**, than about 12 hours after a regeneration of 90 - 95 %! Complete regeneration after this type of activity takes around 24 - 36 hours.

Intra-muscular coordination/ explosive power training:
With so called Repetition method (long-pause interval) there will be continuous regeneration.
During **heavy training load**: fast regeneration (but very incomplete) in 2 - 3 hours after ending training activity. Almost complete regeneration: 18 - 24 hours.
Complete regeneration: after around 72 hours.

Anaerobic with lactic building processes:
Fast (but very incomplete) regeneration takes place during 4 - 8 hours. Almost complete regeneration (= 90-95 %) after 12 - 18 hours and complete regeneration after 36 - 48 hours.

Anaerobic without lactic building:
Fast (but very incomplete) regeneration after 2 - 3 hours, almost complete regeneration (= 90-95 %) after 12 - 18 hours and complete regeneration after 36 - 48 hours.

Strength Training in Soccer.

Let us consider the place of **strength training in soccer training** from **physiological point of view.**

>Classic= requirements in soccer training ask for developing motor abilities of strength, speed and endurance. Each ability ask for a particular energy system (ATP, CP, glycogen, etc.), rate of recovery and restoration of the fuel. **Restoration of glycogen depots for example takes at least 24 hours after strength training** (considered as intermittent activity) **and 48 hours after continuous work. Maximum intensity training in which the central nervous system (= CNS) is involved takes also up to 48 hours recovery**.

In contrary the rate of regeneration from aerobic activities is much faster, up to 8 hours >only=.

A normal, logic thought could be: Intensive training sessions on Monday, Wednesday and Friday and so called >easy days= on Tuesday and Thursday. So glycogen can reach full restoration before another intensive training day arrives. **IF** the coach/trainer schedules intensive strength training sessions on the easy days, the pupils are every day >attacking= their glycogen stores and now strength training is suddenly an obstacle to energy expenditure- restoration ratio and can bring the soccer players into a state of fatigue or exhaustion. Than overtraining is close by!

So we propose to plan strength training on the same days as technical and tactical or speed and power training are planned to do. Of course the players deplete all their glycogen stores and feel >empty= after such training days, but the training program does not interfere with its restoration before the next high-intensity training which is scheduled 48 hours later.

Two short strength training sessions following technical or tactical work could be done with **young players** to introduce them to strength training. In 2 to 4 years this program could be increased to three or maximal four sessions, mainly during the preparatory phase. In all types of sport in which power and speed are dominant, like in soccer, strength training must have a place. Especially during the preparatory and/or preseason phase this type of work has to be done.

The number of strength training sessions depends on the phase of training: three to five during the preparatory phase and two to three during the competitive period to maintain the result.

The main benefit of strength training for soccer players may be related to the fact that the number of sets can be increased and the prime movers can contract more times. Result is power development for the required muscles.

Six acute training variables such as :1). Order of exercise; 2).Choice or character of exercise; 3).Load or resistance used; 4) Volume of exercise ; 5). Number of repetitions/series and 6). Recovery between sets can have impact on the effect of the training program. **Such variation of the training program is called periodization** and has been shown to be very effective for the attainment of maximal performances.

Physiological mechanisms causing increased strength:

In training studies of short duration (8 to 20 weeks), neural adaptations related to learning, coordination and the ability to recruit movers play a role in the gain in strength. In long term training programs an increase in size of the prime movers plays the major role in strength development. **Gains in strength, especially in the early phase of a training program, are due to neural adaptations and not enlargement of the**

muscle. An improved synchronization of motor unit firing and improved ability to recruit motor units to enable a person to match the strength elicited by electrical stimulation. (Sale,1988).
Short term strength training programs do not change capillary density, but mitochondrial density is decreased in proportion to the degree of hypertrophy.
Our muscle size increases many fold from date of birth till adulthood. Without specific training no change in the number of muscle fibres will occur. Real hypertrophy means muscle enlargement of existing fibres and not a generation of new fibres (= hyperplasia). **Hyperplasia might occur with long term training regimen.** A study shows that resistance training resulted in a 24 % increase in muscle mass, but only 11 % increase in fibre cross sectional area. The difference could be the result of hyperplasia (Mikesky et al,1991).

Hypertrophy and hyperplasia.

During normal human development, from birth until adulthood, muscle size increases (hypertrophy) with no change in the number of muscle fibres! Perhaps some of the muscle enlargement due to training is the result of hyperplasia like in the study of Mikesky et al,1991 is suggested. During heavy resistance training with result in muscle enlargement shows an actual decrease in capillary density. Short term strength training programs do not change capillary density but mitochondrial density is decreased in proportion to the degree of hypertrophy. (Tesch,1988).

An important question : Does one type of training interfere with the effects of the other ?

Hickson (1980) showed that a 10-week combined strength and endurance training program resulted in similar gains in VO2 max compared to an endurance-only group, but there was some interference with the gains in strength. The strength-only group increased in strength throughout the entire 10 weeks, but the combined strength and endurance group showed a levelling off and a decrease in strength at week 9 and 10. After a group had levelled off in endurance performance, a 10-week strength training program (3-day per week) was added. Result: 30 % gain in strength without hypertrophy(!), unaffected VO2 max but at 80 % VO2 max level performance increased from 71 to 85 minutes. So strength training can improve the performance of prolonged heavy endurance exercise (Hickson ,et al 1977)
When endurance training and strength training are done on the same days of the week there is less strength development compared to when strength and endurance training are done on different days (Sale, et al.,1990).
Another study showed the following interesting results. During a two times 7.5 weeks program **high resistance-low repetition** (to improve strength) and **low resistance-high repetition (** to improve muscular endurance) 2 groups were trained. After 5 weeks recovery pause between the first trial and the second trial the opposite program was done. All major fibre types (Type I, IIa, IIb) increased in cross-sectional area after the first program independent of type of training! However in the second program of 7.5 weeks the strength program caused a further increase in the cross-sectional area of the Type I and IIb fibres, while a decrease occurred in those doing the endurance program. (Ratzin, et al, 1990).

Muscular strength refers to the maximal force that a muscle or muscle group can generate and is commonly expressed as 1 RM (= one repetition maximum), the maximum load moved through a range of motion in a technical correct way.
Muscular endurance refers to the ability to make repeated contractions against a sub-maximal load.
Like in gains obtained in VO2 max through endurance training, large individual differences exist in the response to strength training programs, they imply a genetic limitation. An important question is:

What physiological changes occur with resistance training that result in improvements in muscular strength and endurance ?

In the development of muscle tension motor unit recruitment, stimulus frequency and synchronous firing of motor units and the fact that Type II motor units develop more tension than Type I motor units plays an important role. Further on stimulatory (muscle spindle activity) and inhibitory (Golgi tendon organ activity) muscle reflexes affect tension development. All together those factors are most important to improve strength with adequate training.
Gain in strength obtained during short training sessions of 2 till 5 months are affected by neural adaptations (learning effect), coordination and the ability to recruit prime movers.
Gain in strength obtained during long training sessions shows an increase in size (cross-sectional area) of the prime movers.
Neural adaptations includes an improved synchronization of motor unit firing and an improved ability to recruit motor units to enable a person to match the strength elicited by electrical stimulation.

Muscles respond to strength training.

Understanding muscle adaptation and its dependence on load and different training methods makes it easier to choose the right training method for some sports and not for others. What type of contractions are working and which are the best for your sport, in our case soccer will be discussed in this chapter.
Better knowledge of strength training will help you to understand the concept of planning and periodization in a better way.
Our skeletal frame is covered with more than 600 muscles, almost 40 percent of our total body weight. Dense connective tissue called tendons connects both ends of the muscle to the bone. The tension in the muscle is directed to the bone through the tendon. Powerful movement of the limbs are in a large matter dependent on the strength in the tendon developed.
Some important statements:
Agonistic muscle: A muscle directly engaged in a muscular contraction and working in opposition to the action of other muscles.
Antagonistic muscle: A muscle that has an opposite effect on a mover or agonistic muscle by opposing its contraction.
Cardio-respiratory endurance: The ability of the lungs and heart to take in and transport adequate amounts of oxygen to the working muscles, allowing activities that

involve large muscle masses (e.g. running, swimming, cycling) to be performed over long periods.
Prime movers: The muscles primarily responsible for performance of a technical movement.

Muscle Physiology:

Muscles are supplied with motor nerves (related to movement) and sensory nerves. Each motor nerve sends impulses from the central nervous system (= CNS) to the termination point on a muscle fibre, called the motor end plate, resulting in a muscle contraction. Sensory nerves relay information concerning pain and coordination to the CNS.
One muscle consists of special fibres of a few inches long to more than three feet that extend the entire length of the muscle. These fibres are grouped in bundles called fasciculi, held together by a sheath called the perimysium. The threadlike protein strands are called myofibrils which hold the contractile units, the sarcomeres. Each sarcomere contains a specific arrangement of the contractile protein=s myosin (= thick filaments) and actin (=thin filaments), whose actions are important in muscle contraction.
Contraction and exerting force are determined by its design, the cross-sectional area, the fibre length and the number of fibres within the muscle. The number of fibres is genetically determined and probably not effected by training, the other variables can be effected by training. Training can increase the thickness of muscle filaments so the muscle can grow in size and force of contraction.

Sliding-filament Theory (Huxley).

Six actin filaments surround each myosin filament. The myosin filaments contain cross bridges like small >hockey-sticks ends= that reach toward actin filaments. Impulses from the motor nerve stimulate the whole fibre, creating chemical changes that allow the actin filaments to join with the myosin filaments cross bridges. This movement releases energy, causing the cross bridges to swivel, pulling or sliding the myosin filament over the actine filament and the muscle shortens. When the stimulation ends the actin and myosin filaments separate, and the muscle lengthen to its rest position and the contraction is ended. From the resting point the optimal length for muscular contraction is created because from this position all the cross bridges can connect with the actin filaments, allowing maximum tension.
Contractile force decreases when muscle length prior to contraction is shorter than in the rest situation, the actin and myosin filaments overlap. Contractile force diminishes when muscle length is either shorter or longer than resting length. Highest force output occurs when contraction begins at a joint angle of about 110-120 degrees.

The motor unit.

All muscle fibres activated by an individual motor nerve contract and relax in unison. Every motor nerve entering a muscle can innervate one to several thousand muscle fibres. A single motor nerve together with the muscle fibres it activates is called a motor unit.

When a motor unit is activated (stimulated), the impulse sent to the muscle fibres within the motor unit follows the **A all-or-none law A.** Not all motor units are activated during a muscle contraction. It depends on the load imposed on the muscle and directly effects the force produced. Maximal force output requires the recruitment of all motor units available.
In average 200 muscle fibres within a motor unit are activated when muscle force is exerted. **Genetics determines the number of fibres which is the reason why some people can increase the size and strength of their muscles easily and others have to fight for a small gain.**

Muscle fibre types.

Motor units behave the same but not all muscle fibres do! Not all muscle fibres have the same biochemical (metabolic) functions, because some of them are physiologically better suited to work under anaerobic conditions while others are better working under aerobic conditions. Type I (>red=) or slow-twitch fibres (= ST fibres) rely on and use oxygen to produce energy aerobically.
Fibres that do not require oxygen for energy delivery are called anaerobic, Type II (>white=) or fast-twitch (= FT) fibres. In >normal > human beings the ratio between Slow and Fast twitch fibres is 50 to 50 %. This relationship is hardly or not effected by training itself. **Strength training does effect the fibre size.**
Moderate to low intensity activity recruits ST fibres, as load increases the FT fibres are doing the work. Distribution of fibre types can vary within the same muscle and between different muscles. Arms have a higher percentage FT fibres than legs have, the m. biceps have around 55 % FT fibres and the m. soleus in the calves has just 25 % FT fibres (Fox et al,1989).
Fibre composition (how much FT fibres within a muscle) plays an important role in strength training for different types of sport. A high percentage of FT muscle fibres means more powerful, >explosive= actions are possible. Training can significantly increase the ability to display power and maximum strength (Gollnick, et al, 1972). Peak power is related to fibre type distribution and so does velocity also. Excellent sprinters can be >transformed= by training to middle or long distance runners but in that type of sports they will never reach the same level like in more >explosive=sports.

Agonists or synergists are muscles that cooperate to perform a movement. Antagonists act in opposition to the agonists during movement. In highly experienced athletes the antagonists relax, they allow easy motion. Rigid movements might result in an improper interaction between agonists and antagonists.
Prime movers are muscles primarily responsible for producing a comprehensive strength movement. A smoothness muscular contraction can be improved while relaxing the antagonists.
Stabilizers are usually smaller muscle groups that contracts isometrically to anchor a bone so the prime movers can do their work properly.

Types of muscular contraction.

In general terms we distinguish **three types of muscular contractions**.

1. **Dynamic (= isotonic) contractions. Tension should be the same during the whole range of motion. In dynamic movements there are two types of contractions, namely concentric and eccentric dynamic contractions.**
Concentric contractions refers to contractions in which the muscle shortens. In concentric contractions you are working with loads which are under your maximum potential.
During eccentric (>negative work=) contraction the muscle lengthens as the joint angle increases.
2. **Static (= isometric) contraction** implies the application of **force against an immovable object** that causes the muscle to develop high tension without altering its length. The tension developed from this type of contraction is most part of the time higher than the force developed during a dynamic contraction.
3. **Isokinetic is a contraction of constant velocity over the full range of motion.** Equipment to train or measure isokinetic movements are special designed to allow a constant velocity of contraction, regardless of load. Eliminating the weak spot in the whole movement is possible when using this type of machine.

Strength training types.

The foundation of the entire training program is general strength training. During the early training phase, often called anatomical adaptation phase, this type of training is important, because when a soccer player develops a poor general force, this will be a limitation in further progress as a player later on. Increased risk for injuries may be mentioned also.
Movements in specific sport circumstances requires specific strength training development.
To the end of the preparatory phase specific strength should be developed to the maximum.
Maximum strength refers to the highest force that can be performed by the neuromuscular system during a maximum contraction. **Often it is expressed as 100 % of maximum = one repetition maximum (= 1 RM).**
Calculating in percentages for training loads are often done to prepare a training schedule.
Power is the **product of two abilities, namely strength and speed (velocity).** Maximum force in the shortest time express power in the best way.
Muscular endurance is a muscle=s ability to sustain work for a prolonged period of time and is connected to cardio-respiratory endurance.
Absolute strength refers to the ability of the athlete to exert maximum force regardless of body weight.
Relative strength represents the ratio between absolute strength and body weight.
In some types of sports like gymnastics relative body weight is extremely important to control regularly.
Strength reserve is the **difference between absolute strength and the amount of strength requires to perform a skill under competitive circumstances.**

General Strength Training Schedule:

	Load in % max	**Repetitions number**	**Sets Number**	**Recovery time**
Maximal Strength (Anaerobic)	**90 - 95**	**1 - 3**	**4 - 8**	**2 min - 4 min**
Explosive Power (Anaerobic)	**75 - 90**	**8 - 12**	**3 - 5**	**1.5 min - 2 min**
Explosive Power/ Endurance (Aerobic/ Anaerobic)	**50 - 75**	**10 - 15**	**3 - 5**	**45 seconds - 90 seconds**
Speed/ Endurance (Aerobic)	**< = 50**	**10 - 50**	**3 - 5**	**< = 45 seconds**

(J.A. Vos,1969).

Different types of adaptation.

Hypertrophy.

Increase in cross-sectional area in muscle fibres causes hypertrophy. There exists a short term hypertrophy as a result of fluid accumulation (oedema) in the muscle, so called >pump= effect.
Chronic hypertrophy results from structural changes in the muscle.
Muscle training using extremely heavy loads can cause (but concerning this topic no general agreement exists) >muscle splitting=or hyperplasia. Partly an increase in the number of fibres causes hypertrophy besides normal training effects.
In myosin filaments heavy loads increase the number of cross bridges, leading to an increase in cross-sectional area of the fibre and to visible gains in maximum contraction force.
Not all factors causing hypertrophy are fully understood. Disturbance in the equilibrium between consumption and remanufacturing of ATP (= adenosine tri-phosphate) will stimulate muscle size growth. During and after heavy load training ATP stores are depleted and the protein content in the muscles is very low. Between training sessions the muscles are replenished by protein. During this process the protein content exceeds the initial level, resulting in an increase in muscle fibre size. Following a protein rich diet should be done.
The hormone testosterone (serum androgen) causes also hypertrophy.
Neuromuscular coordination for strength movement patterns takes time as a function of learning process. Practice, means repetition, makes perfect.

Young soccer players exposed to strength training will show visible strength improvements without a corresponding increase in muscle size within 4 to 6 weeks.
No hypertrophy but real gain in strength how is that possible ? An increase in nervous coordination is the reason. Use your muscles more effectively is what they have learned during those 4 to 6 weeks. Hypertrophy will occur in the time after.

Five basic laws of strength training.

1. **Develop joint flexibility.** This will prevents the athlete from stress injuries. Start ankle flexibility during pre-pubescence for example and later on you have only to maintain it.

2. **Develop tendon strength.**
Muscle strength develops faster than tendon and ligament strength. During anatomical adaptation an important phase for tendon and ligaments strength grow exceeds. Use this period in the right way.

3. **Develop core strength.**
Strength first the core muscles before arms and legs. The core muscles are important shock absorbers for jumps, rebounds. They stabilize the body and forms the link between arms and legs. For example, the best prevention against back problems is a well developed back and abdominal muscle group.

4. **Develop the stabilizers.**
Strong stabilizers are very important for prime movers to do their work properly.
Weak stabilizers inhibits the contracting capacity of the prime movers.

5. **Train movements, not individual muscles.**
Strength training should stimulate sport skills. Multi-joint movements occur a certain order, called kinetic chain. During a takeoff to catch a ball the kinetic chain will be as follows: hip extension, than knee extension and finally ankle extension in which the feet apply force against the ground to lift the body.

Some important statements concerning strength training:
ATP = Adenosine tri-phosphate. A complex chemical compound formed with the energy released from food and stored in all cells, particularly the muscles.
EMG = electromyography. Measurement of the electrical activity of the muscle stimulated by a given load.
Fatigue.= Discomfort and decreased activity of the muscle stimulated by a given load.
Volume = A quantitative element of training. In strength training it measures the total work for a given exercise or training phase. (= sets x repetitions x load).

Table A.

Slow and Fast twitch fibres characteristics compared.

Slow twitch fibres (= ST) = Type I	**Fast twitch fibres (= FT) = Type II**
Type I aerobic work, (>red >)	Type II anaerobic work (>white >)
Slow fatiguing	Fast fatiguing
Smaller nerve cell innervates 10 to 180 muscle fibres >only=	Large nerve cell innervates 300 to > 500 muscle fibres
Develops long, continuous contractions	Develops short, forceful contractions
Endurance activities	Speed and power actions
Recruited during low- and high intensity work	Recruited only during high intensity work

<u>Soccer</u> and <u>Youth</u>:

Growth:

Our muscle mass increases steadily along with weight gain from birth through adolescence.
In **boys** muscle mass peaks at age 18 - 25 years when testosterone production increases **by a factor 10 !**
In girls muscle mass peaks at age 16 - 20 years **without** sharp increase. As children nervous systems develops, improvement of balance, coordination and agility occurs.
Myelination of nerve fibres must be completed before fast reactions and skilled movements are fully developed (myelination speeds the transmission of electrical impulses).
VO2 max (= maximal oxygen uptake) peaks between ages 17 - 21 years in males and 12 - 15 years in females, **after** which it **steadily decreases.**
A child=s VO2 max is similar to an adult=s in distance running, child=s performance is inferior to an adult=s performance because of differences in economy of effort!

Anaerobic capacity is lower in children than adults!

Reason: **lower concentration** in **children** of the key rate-limiting **enzyme phospho-fructokinase**. Children cannot attain high respiratory exchange ratios during maximal exercise, suggesting **less lactate production**.

Regular training results in: decreased total body fat, **increased fat-free mass (= FFM) in boys, increased total body mass**, **no** apparent effect on **growth** in height or maturation (Malina,1989).

Player development:

From 9 years onwards accent on:

Movement patterns and skills development.
Coordination and balance training.
Proprioception training.
NOT only during the in-season time but the whole year around!
Aerobic development instead of >only= anaerobic exercises!

Strength Training:

Recommendations for **prepubescent children.**

Equipment:
1. Appropriate design (size and degree maturity)
2. Save, free of defects and inspected frequently.
3. Area free of obstructions with adequate lightning and ventilation.

Program considerations:
1. **A pre-participation physical exam is mandatory.**
2. Child must have emotional maturity to accept coaching and instruction.
3. **Coaches must have knowledge concerning strength training and the special problems of pre-pubescents.**
4. Strength training should be a part of an **overall comprehensive program**, designed to increase motor skills and level of fitness.
5. Warm up and cool down period included.
6. **Dynamic concentric contractions should be emphasised.**
7. All exercises through **full range of motion.**
8. **No** maximum lift attempted; **competition is prohibited !!**
9. **Avoid >negative feed back=!**

Prescribed program:
1. Training is recommended **two or three times a week** for **effective 20 - 30 minutes periods**.
2. **No resistance** should be applied **until proper form is demonstrated. 6 - 15 reps in 1 set; and 1 - 3 sets per exercise should be done.**
3. Weight or resistance is increased in **0.5 - 1.5 kg increments** after **15 reps in good form** are shown.(Workshop / ACSM; NSCA; NATA; USOC; AOSSM; AAP; SPO).

Basic guidelines for resistance exercise progression in children.

Age group considerations:

Age group strength training programs.

Youngest group (7 - 9 years).

With Dumbbell exercises or own body weight:

Most exercises described above can be done with young children (7 - 9 years) in a way that of course the number of repetitions and sets are low and the weight of the dumbbells most be acceptable to carry out the described program. Pay attention to correct technique and safety!!
A general rule could be :
Do not specialize exercises other than general strength training purpose! The pupil must accept that general development of the body and habituation to strength training drills are the main targets for overall strength training in this age group.
So train the muscle groups described above in 10 - 15 repetitions per set. Only one set per exercise or station at a frequency of maximal 2 times per week.
Junior players at the age group of 10 - 12 years train the same muscle groups as described above but now you can extend from 1 to 2 sets per training session, especially when multi-muscle exercises are involved, with a training frequency of 2 to 3 times per week. Of course such training sessions can be combined with other training activities.
Per set not more than 10 - 15 repetitions!

7 years:!

* introduce child to **basic** exercises with **little or no weight;**
* develop the concept of a training session;
* teaching exercise **techniques;**
* progress from body weight callisthenics;
* partner exercises and lightly resisted exercises and keep volume low.

8 - 10 years:

* **gradually increase the number of exercises;**
* practice **exercise technique in all lifts;**
* start gradual progressive loading of exercises;
* keep **exercises simple;**
* gradually increase training **volume**;
* **carefully monitor toleration to the exercise stress**.

Pre-puberty: (Age group 11 -13 years) Simple exercises; accent on games/play ; informal ; circuit training form of 9 to 12 stations; low volume and low intensity; own body weight; partners and light medicine balls.
Coordination training optimal during this age group!(Boys and girls!).
Do NOT train Anaerobic Power and Maximal Strength during so called >second-growth spurt=! (Girls between 10 - 14 years and Boys between 12 - 16 years, at least in Europe).

There could be a large difference in biological age and calendar age, up to 3 years or more is possible. So being a >great > champion at the age of 14 years does not say that he will be a great sportsman at the age of 20 also!
Accent on strength training to develop more force for boys after 14 years and for girls after 12 years of age.
Accent on maximal force for boys after 17-18 years and for girls after 16 years. Let the body (skeleton, joints, tendons, etc.) be first outgrown first to adult.

In the age group of 13 - 15 years you can extend and vary the exercises to the program you are interested in, but a general advice remains, namely: 1 to 2 sets of exercises and during the first set always 10 - 15 repetitions, but after increasing the load, the second set now with 8 - 12 repetitions per set. Training frequency is 2 to 3 times per week.

11 - 13 years:

* teach **all basic exercise techniques;**
* **continue progressive loading** of each exercise;
* emphasize training exercise techniques;
* introduce more advanced exercises with little or no resistance.

Puberty:(Age group 14 - 15 years) Build up phase/anatomical adaptation exercises; relays; games; circuit training form; low/medium volume; low intensity; own body weight; light free weights; tubing; medicine balls.

14 - 15 years:

* progress to more advanced youth programs in resistance training;
* add sport-specific components;
* emphasize training exercise techniques;
* increase volume.

Post-puberty: (Age group 16- 17 years) More specialization; build up phase/anatomical adaptation; more specific strength; circuit training; medium volume; low/medium intensity; own body weight/partners; medicine balls; light machines; tubing.
Energy supply:

Energy stores (in mMol.kgAo muscle):

	Rest B	Exercise/training	
ATP	3.5	5	child = adult
CP	12	22	child <= adult
Glycogen	45	75	child < adult

(Bar-Or,1983).

16- 17 years:

* move child to entry-level adult or older programs after.
All background knowledge has been mastered and a basic level of training experience has been gained.(Kraemer and Fleck,1992).

Adults: (Age > 18 years) High performance/specific; strength/hypertrophy; power; muscular-endurance; medium/high volume; medium/high/maximum intensity; own body weight/partners; free weights and 3 to 6 exercises directed to prime movers.

Talent Detection.

There are two possibilities to >discover= talented sportsmen or women. The first holds that the talented athlete emerge from the **sport pyramid**. A large base of the pyramid offers a great number of young people to participate in competition and if they perform well and are eager enough to continue, they get a chance to reach higher levels, depending on talent, economic circumstances, motivation, study facilities, etc. This approach is still very often connected to the basic philosophy of sport governing bodies in many nations worldwide and not only from the past history in countries like former DDR or Sovjet Union.
A second approach is the one in which young people shows their favourable traits. Large numbers of children and adolescents are measured and tested with battery of tests that tend to be sport specific. Those talent-detection test batteries includes very often variables like:
Stature, body composition, maturity level, endurance capacity, strength, speed, agility, aerobic and anaerobic skill tests. The best pupils are offered, as talented subjects, to take part of a special school curriculum in which , besides normal education programs, well educated trainers learn the skills of the particular sport, in our case soccer. A limiting factor to participate can be the opportunity to take part in time, which may prevent talented youngsters from being identified. Talent detection is one but for example social, dietary, chemical or commercial manipulation are other >tools= to watch over carefully.

Future.

Progress in molecular biology and exercise sciences concerning talent detection will change the >classical way= of talent detection rather soon. Traditional tests will be never sufficient enough to predict who will become an elite athlete or not. Therefore tests will be done to identify the carriers of **DNA** sequence variations desirable for sport performance. Those methods will be very attractive to some people if they are able to found a small number of genes which have a substantial influence on the development of a young sportsman. Very ambitious parents, entrepreneurs, coaches, politicians, etc. may take advantage of the progress made in biology to advocate embryo selection based on specific athletic probes to allow parents to fulfil their dreams or frustrations. And this is certainly not science fiction but soon reality. Technology to realize the scenario above described is already available in specialized centres all over the world. What are they waiting for? Knowledge about the most important genes upon which athletic genotypes can be defined and embryo selection will be designed is yet the weakest point. Such practices will be outlawed in most democratic countries in the world but there will be always places where people could establish their wishes. >Key genes= associated with determinants of high sport performance will create ethical problems to solve, which are far more important or >heavy > compared to the >nandrolon= or food supplements problems we have nowadays. (Bouchard, et al,1997).

Anaerobic system changes.

1. **Increases** in resting levels of **anaerobic substrates.**

Before and after resistance training :

28 % improvement in strength;
5 % improvement in creatine-phosfate (= CP);
35 % in creatine;
17 % improvement in ATP;
32 % in glycogen.

(Houston,1977; Karlsson,1972; Macdougall,1977)

2. Increases in the quantity and activity of key enzymes that control anaerobic phase of **glucose breakdown**.

The most important alterations in anaerobic enzyme function and increase in fibre size occur in the **fast-twitch (Type II a and b) muscle fibres.** (Fouriner,1982; Jacobs,1987; Thorstensson,1975)

3. Increases in capacity for levels of blood lactate during all-out exercise that follow anaerobic training.

Metabolic adaptations; improved motivation; pain tolerance to fatigue; enhanced levels of glycogen and glycolytic enzymes. (Jacobs,1987)

Aerobic system changes.

1. Mitochondria from trained muscle have a greatly increased capacity to generate ATP aerobically by oxidative phosphorylation. (James,1978)

2. Increase in size and number of mitochondria and a potential twofold increase in the level of aerobic system enzymes.

To a large extent this response is **independent** of the aging process

(Barnard,1970; Kiessling,1971)

3. Skeletal muscle myoglobin content of animals increases by as much as 80 % !!

Not established (yet) in humans ! (Holloszy,1967).

4. There is an increase in the trained muscle=s capacity to mobilize and oxidize fat.

At all sub-maximal levels a trained person uses more free fatty acids than an untrained person. It conserves the carbohydrate stores! (Donovan,1983; Riviere,1989)

5. Trained muscles exhibits a greater capability to oxidize carbohydrate.
(Gollnick,1973)

6. Aerobic training produces metabolic adaptations in the different types of muscle fibres. (Gollnick,1972; Thorstensson,1975)

7. There may also be selective hypertrophy of different muscle fibres to specific overload training.(Gollnick,1972; Thorstensson,1976)

Adaptations after resistance training.

Variable:	Response:
muscle fibres	
number ----------------------	equivocal
size ----------------------	increase
type -------------------------	probably no change
capillary density	
In bodybuilders ------------	no change
In power lifters ------------	decrease
mitochondrial	
Volume ----------------------	decrease
Twitch contraction time -----	decrease
enzymes	
Creatine phosphokinase ---	increase
Myokinase -------------------	increase
enzymes of glycolysis	
Phosphofructokinase------	increase
Lactate dehydrogenase ----	no change

Aerobic metabolism enzymes

Variable:	Response:
Carbohydrate metabolism -----	increase
Triglycerides -----------------	not known
Intramuscular fuel stores	**Response:**
Adenosine-tri-phosphate(atp)---	increase
Phosphocreatine(cp) -----------	increase
Glycogen --------------------------	increase
Triglycerides -----------------------	not known
VO2 max	
Circuit resistance training -----	increase
Heavy resistance training ------	no change
Connective tissue	
Ligament strength-------------	increase
Tendon strength----------------	increase
Collagen content of muscle ---	no change

Bone / Skeleton

Mineral content -----------------	increase
Cross-sectional area------------	no change

(modified from Kraemer and Fleck,1988)

Growth development.

* **peak rate** of height growth occurs at **age 12 in girls** and at **age 14 in boys**.
* **full height** 16-17 years in girls and **18 years in boys**
* **growth in weight *same as* in height**
* bones are formed through ossification primary (diaphysis) and secondary (epiphysis).
* **injury at the epiphysis cause early termination of growth.**

High risk sports: baseball (pitching) ; tennis, swimming.

Fat.
* number of fat cells can continue to increase throughout life.

Fat added to the body, existing fat cells continue to fill with fat to certain critical volume new fat cells are formed.
* fat storage occurs through increasing number of fat cells and increasing size existing fat cells.

Muscle Mass.
* primarily from hypertrophy

(increase in size) no hyperplasia (= increase in fibre number) .
* hypertrophy increases in the myofilaments and myofibrils.
* increases in muscle length; increases in the number of sarcomeres.
* **muscle mass peaks in girls at the age of 16 - 20 years and in boys at the age of 18 - 25 years.**
* exercise and/ or diet ; increases more.

Individual programs are very important nowadays and should be developed on base of individuals physiological profile and playing position!
Regular testing is the key to arrange the right direction in training and competition for the trainer/coach.

Flexibility.

The common assumptions of stretching and flexibility are:
Injury prevention and prevent and reduce the **d**elayed **o**nset of **m**uscle **s**oreness (= DOMS).
Aids and improves performance.
But ...... only a very few well controlled (with control group for example) scientific based research supports the statements mentioned above.
Fatigue was found to be a far more important risk as cause of injuries at the end of the first half and the second half of the game.
From the psychological point of view stretching may result in some benefit for the players. In the case that somebody believes in it, keep it and continue to stretch.

Use other tools to develop balance and coordination than only your own body or exercises with partner. Those tools can be:
1. Rubber cords or >Dyno=rubber bands.
2. Footballs and light medicine balls for reaction exercises.
3. Wobble boards, cushions, small trampolines, etc.
4. Controlled landing and jumping in plyometric circumstances.

To avoid boredom and monotony and keep motivation, incorporate as much variety as possible into training routines. Strength training requires also individualization.
As trainer: do not follow only training programs of successful athletes, disgarding their needs.
Athletes equal in performance do not necessarily have the same work capacity!
One way to discover those differences is testing and measuring in the right way and with the right equipment. Strength training is overload training par excellence so the trainer must be very careful when designing the strength training program.
First general/multilateral development (all muscle groups, ligaments and tendons are developed. Depending to the athletes age this takes 2 to 4 years(!!) to train this way. than more specialized training and finally high performance training should be the right way to do it. Alternate exercises designed for the prime movers as often as possible especially prior to and during the competition phase. Increase the number of sets per prime mover.
Use the principle of progressive increase of load in training.
Vary the type of muscle contraction, especially between concentric and eccentric exercises.
Vary the speed of contraction (slow , medium, fast) in the preparatory phase. Slow to medium contractions may not be possible during later phases, as periodization requires mostly heavy loads with high application of force and explosive actions.
Vary the equipment from free weights to heavy implements, isokinetics, etc. Vary between training phases.

Exercise specificity.

Soccer.

Players use often sprint, change direction and sprint again. The muscles largely responsible for these rapid accelerations and decelerations are the quadriceps, hamstrings group, gluteals and calves. Basic exercises are squat, leg press and heel raise (with straight legs) to strengthen these muscles groups. Because many lateral movements are done in soccer as well, hip adduction and hip abduction exercises has to be done regularly.
Very often the rotary movements (oblique muscles) are >forgotten= in the training programs but we think you need to train them as well as the other muscles groups mentioned above.
The kicking action in soccer involves the hip flexors. To strengthen them an exercise like hanging-knee raise performed from dip bars are effective. Well conditioned triceps are used during throw-ins.

Strong neck muscles are essential for heading the soccer ball safely. Dumbbell shrug and 4-way neck machine are effective training tools to strength the neck part.

The angle between body parts or limbs influences how and which parts of a given muscle contracts. Effective training asks for this aspect full attention.
For example: Abdominal exercises: body position changes difficulty of exercise as well as the part of the muscle involved. Horizontal sit-ups involve mostly the upper part of the m. rectus abdominis, inclined sit-ups primarily benefit the central section of the muscle and if the trunk is fixed and the legs are lifted the role of the abdominals decreases and the action is performed mostly by the hip flexors (m.iliopsoas).In inclined position with the legs resting on a bench could be called the best position to train abdominals optimal.
Another example: Bench press. If the bench press is performed on a flat bench, the central parts of the pectorals, the triceps and parts of the deltoid muscle benefit. If the same exercise is performed on a inclined bench, the upper parts of the pectorals fully contract. To train the lower parts, athletes should place their heads at the lower end of an incline bench. The grip influences also the effect of the exercise. A wide grip mainly stresses the exterior part of the pectorals and a narrow grip activates mostly the deeper part of the pectorals and the triceps.
Shoulder width grip develops the inner part of the pectorals.
To achieve maximum training specificity, an exercise has to imitate the angle of the skill performed.

Power and speed sports, like soccer, requires quick, explosive actions and the nervous system has to be trained. That means many power exercises and maximum loads (greater than 80 % of 1 RM) that results in neural adaptation.(Enoka,1996; Sale,1986; Schmidtbleicher,1992).
Neural adaptation means no increase in muscle mass, but surely increase in power and speed of contraction.

Physiological demands for soccer players.

Activities on the play-ground:
Every 4 to 8 seconds changes every player his type of behaviour or level of acting.
There is no activity during the game which takes more than 8 seconds continuous.
Average distance covered during the game (walking/running/sprinting/running backwards) is 9 to 12 Km, with exception like > 14 Km.
Over 75 % of all actions are done in low intensity pattern. 10 to 15 % are so called >static pauses=. Around 10 % of all activities are done on a high intensity level.
Every 2 minutes during 3 seconds the player is doing nothing at all. Every 90 seconds the player runs fast, like sprint activity and every 30 seconds some action with high degree of activity takes place. (Reilly,T,1996)
Heart frequency during the game will be between 150 - 190 beats per minute, around 70 % of VO2 max. (Vos,J.A.,1989).
In contrast to the overall opinion there is only in 2 % of all actions ball-contact!
The difference between players covering the largest distance during the match is Midfielders most, than Backs and after them Forwards.

Central defenders jumps most, makes most for- and backwards movements and are running less than the other players.
Their anaerobic power must be well developed for a right task performance.
A player will be after around 10 years training at his technical high point, in average of course!

Summary of specificity of strength training.

1. Strength training methods must be specific to the speed of contraction used in sports. (Coyle et al, 1991). After the second half of the preparatory phase through the competitive phase, trainers should select methods that specifically increase the speed of contraction and level of power.
2. Training must increase contraction force in the intended direction of movement. Only weightlifting and bodybuilding exercises are waste of time during the second part of the preparatory phase.
3. Selected exercises must be sport-specific and activate the prime movers, they increase the activation and excitation of the prime movers.
4. Training must stimulate the muscles to perform an athletic action with power and high speed. Motor neurons innervate, stimulate and arouse the muscles and training should increase the discharge rate of motor neurons.
5. Motor unit recruitment and firing rate increase with higher loads and faster contractions (De Luca et al,1982).
6. Exercises have to be performed along neural pathway, that means that contractions are performed in the same direction as nerve stimulation.
7. The sequence in which muscles are contracted during an exercise is crucial to the specifics of adaptation. Multi-joint exercises must stimulate the sequence in which muscles contract while performing a specific skill.
8. Neural adaptation resulting from specificity of training increases the number of active motor units. (Bompa,1999).

Important definitions.
Muscular endurance = the ability to perform many repetitions against a given resistance for a prolonged period.
Power = the ability to perform an explosive movement in the shortest time possible, result from collaboration of maximum strength and speed.
Agility = the product of a complex combination of speed, coordination, flexibility and power like in soccer is demonstrated.
Mobility = combination of agility and flexibility. Good timing and coordination are the most important >tools=here.

Statement: Strength training slows down the athletes and affects the development of endurance and flexibility.
Answer: Not true!

Misleading, unfounded theories have suggested that strength training slows down athletes and affects the development of endurance and flexibility.
Research shows an complete different picture, namely the facts that combined strength and endurance training does not affect improvement, so **NO** negative transfer of aerobic

power or muscular strength.(MacDougall et al,1987; Hickson et al,1988). Strength training programs pose also no risk to flexibility. High acceleration, fast limb movement and high frequency are possible when strong muscles contract quickly and powerfully. **Speed training should ALWAYS be performed before strength training!!**

Sport-specific combinations of strength, speed and endurance.

Cyclic movements are repeated continuously like in running, cycling, etc., typical endurance sports activities
A-cyclic movements constantly change and are dissimilar to most others like many technical elements in team sports.
Soccer requires speed, power and endurance. Jumping to head the ball in soccer is typical a power-endurance activity, many times repeated during one game. Not only one high jump is important but also to duplicate the jump height many times should be trained.
Muscle-endurance of short duration (40 seconds to 2 minutes) refers to both power and power-endurance.
Muscle-endurance of medium duration (2 to 5 minutes) and muscle-endurance of long duration (6 to 10 minutes) requires the ability to apply force against a standard resistance for a longer period of time, like in rowing, speed skating, middle distance running. etc.
Speed-endurance refers to maintain or repeat a high velocity action several times per game like in soccer.
Speed-endurance sports require training velocity **around the anaerobic threshold (around 4 mMol of lactate or heart rate around 170 beats per minute for young adults).** When distances increases training velocity must be around aerobic threshold (= 2 mMol lactate and up to 140 beats per minute heart rate).

Landing and reactive power is a major component in many types of sports, like gymnastics or in team sports like soccer. Often players train only the take-off part of a jump, but no control of a well balanced landing can cause serious injuries. Players must train eccentrically to be able to perform a correct landing, right absorption of the shock and maintain a good balance to continue further movements in the game. Remember that a player requires 3 to 4 times his own body weight to absorb the shock of landing. With stiff legs it will be even 6 to 8 times his own body weight.
Strength training can train landing better, faster and more consistent than skill training does!
Higher tension developed by adequate power training means improvement in landing. Eccentric training exercises can built up more power reserve, that means a force greater than the power required for a correct and controlled landing.
Reactive power is the ability to generate the force of jumping immediately following a landing, like it happens often in soccer playing. The player=s body weight, leg power and height of the jump plays an important role in this. The force required for reactive jumps is about 6 to 8 times your own body weight. From 100 cm height like during a drop jump, a reactive force of 8 to 10 times your own body weight will be measured!

Starting power require high speed to cover a given distance in the shortest time possible. Reaction time and power are the key abilities to perform well in this matter.
Accelerating power refers to the capacity to achieve high acceleration which depends on power and muscle contraction. The shortest contact phase to the ground, the highest stride frequency and the highest propulsion when the leg pushes the ground are the main tools to achieve a powerful forward drive.
Decelerating power is important for example in soccer. Run fast and change constantly direction with little loss of speed then accelerate quickly in another direction, etc.
The same muscles used for acceleration are used for deceleration like quadriceps, hamstrings or calves, only in deceleration they contract eccentrically!

Sport specific strength in soccer players.

Full backs: Reactive power; acceleration power; deceleration power.
Midfielders: Acceleration power; deceleration power; muscle-endurance medium.
Forwards: Acceleration power; deceleration power; reactive power.

Order of exercises.

If all parts of the body are exercised the following order is suggested:
Legs; arms; back; etc. **The vertical sequence leads to better recovery for the muscle groups involved.**
In spite of the fact that we strongly recommend that strength training for soccer players should be done with their own body weight resistance, partner or free weights there is certainly a phase during the annual plan that more or less separate muscles groups will be better trained by the use of machines. A mixture of these combinations results in the following s**uggested exercises for strength training in soccer:**

Incline/Bench press; Seated rows/Upright rows; Back extension/Hyperextension; Good Morning (bent knees!); Abdominal curls/ Weighted sit-ups; Knee lifts; Leg curls; Squats; Jump half squats; Toe raises; Low impact plyometrics; High impact plyometrics; Drop jumps; Bounding exercises; Reactive jumps; Combined weights/plyometrics.

Incline/Bench Press: **region: chest; upper arms.** Primary muscles: pectoralis major; anterior deltoids; triceps.
Seated rows/ Upright rows: **region: shoulders.** Primary muscles: latissimus dorsi; trapezius; biceps; deltoids; brachialis; brachioradialis.
Back extension/Hyperextension: **region: lower back.** Primary muscles: erector spinae; gluteus maximus.
Good Morning (bent knees): **region: lower back.** Primary muscles: erector spinae; gluteus maximus.
Abdominal curls/ weighted sit-ups: **region: trunk**. Primary muscles: rectus abdominis; external obliques/internus abdominis.
Knee lifts: **region: hips.** Primary muscles: iliopsoas.
Leg curls: **region: upper legs; hips.** Primary muscles: hamstrings; gluteus maximus.

Squats: **region: upper and lower legs.** Primary muscles: gluteus maximus; quadriceps; erector spinae; abdominals.
Jump Half Squats: **region: upper and lower legs**. Primary muscles: gluteus maximus; quadriceps; erector spinae; soleus; gastrocnemius; vastus lateralis and medialis.
Toe raises: **region: lower legs.** Primary muscles: gastrocnemius; soleus. (Bompa, 1999)

Proportion among different types of strength training during competitive phase.

Soccer:

Goalie/Back players: Maximal strength concentric 20 %; Maximal Strength eccentric 10 %, Power 60 % ; Power-endurance: 10 % .
Midfielders/ Forwards: Power 60 %; Power-endurance 20 %; Muscular-endurance 20 %.
Maximal Strength: Load: 85 - 100 %; Number of exercises: 3 - 5; Repetitions per set: 1 - 4;
Sets per session: 6 - 10; Recovery/rest interval between sets: 3 - 6 minutes; Training sessions per week: 2 - 3 times.
Muscular-endurance: Load: 50 - 60 %; Number of exercises; 3 - 6; Duration of activity: 30 - 60 seconds; Sets per session: 3 - 6; Recovery/rest interval between sets: 60 - 90 seconds; Speed of execution: medium to fast; Training session per week: 2 - 3 times.
Power: Load: exercise related; Number of exercises: 2 - 4; Repetitions per set: 4 - 8; Sets per session: 3 - 5; Recovery/rest between sets: 2 - 4 minutes; Speed of execution: explosive; Training session per week: 1 - 2 times.
Power-endurance: Load: 50 - 70 % Number of exercises: 2 - 3; Repetitions per set: 15 - 30; Sets per session: 2 - 4; Recovery/rest interval between sets: 5 - 7 minutes; Speed of execution; very dynamic. Training session per week: 2-3 times.

Restrictive factors in performance in relation to time:

0 - 10 seconds	**10 - 60 seconds**	**1 - 60 minutes**	**60 - 120 minutes**	**2 - 5 hours**	**> 5 hours**
Anaerobic Power	**Anaerobic** Power	VO2 max absolute	VO2 max **in %**	VO2 max **in %**	Food intake
Reactive Power				Glycogen stores	Triglycerides stores
Strength **Maximal**	Strength **Explosive Power**	Strength **Explosive Power/ Endurance**		Fat mobilization	Fat mobilization
Co-ordination	Co-ordination		Hydration Balance	Hydration Balance	Protein Reserve

Flexibility			Heat elimination	Heat elimination	Musculo-Skeletal system

Plyometric training.

Concentric contraction involves force created when the muscle fibres shorten, eccentric contraction involves force created when they lengthen.
When you land on two feet after a jump and bend your knees, the quadriceps are lengthening, but also creating a force to control the landing, other while the jumper will be seriously damaged. When extending your knees because you spring back after landing in the air, the quadriceps are shortening as they create force to push you off.
Total EMG (= electromyography) activity signal is greater during concentric phase (researchers think: more muscle fibres are active at this time) while the mean frequency of the EMG signal was greater during the eccentric phase, what suggests more fast twitch fibres are recruited at this action. During a maximal concentric contraction all the muscles fibres are used and during a maximal eccentric contraction there is a less total muscle fibre recruitment, the fast twitch fibres are recruited in preference to slow twitch fibres. So IF you want to train your fast twitch fibres, eccentric contraction movements like in plyometric training circumstances are created, are more useful than concentric exercises. For example in depth jumps the landing phase is the eccentric one, and the bigger the depth jump the greater the eccentric forces. **A warning should be given. Like so often in sport practice trainer and pupils think only in superlatives. The higher, the =better=. In this case depth jumps are connected to a subtle >border-line=.** If one starts with this very severe exercise program remember that adaptation for muscles, ligaments and joints should taken place in advance.
Pre-conditioning should be done adequate. In practice this means that the athlete should be able to do half squat at least with 1.5 times his body weight before starting a plyometric training program. **Start with depth jumps from >only= 20 cm and finish after months (not weeks!!) up to 80 cm.** Progress should be incremental. Over 80 cm has no benefit >extra= at all, only a terrific increase in risk to be injured seriously!

A larger and stronger muscle built up with weight training will be able to generate greater force plyometrically. Tendons and muscles will be less prone to strains and pulls.

What are the right plyometric exercises ?

Consider first what is sport specific, for example in soccer. Players role in the team, his maturity, his level of pre-conditioning, ability to handle complex exercises like the difference between single and double leg moves, use of one or both arms, etc.

Plyometric drills ranked by intensity: Table B.

Type of Plyometric move	Examples	Intensity
Standing-based jumps performed on the spot	Tuck-jumps Split-jumps Squat-jumps	Low
Jumps from standing	Standing long jump Standing hop Standing jump for height	Low-medium
Multiple jumps from standing	5 consecutive bounds 2 x 6 bunny jumps Double-footed jumps over 4 hurdles Double-footed jumps up steps	Medium
Multiple jumps with run-up	3 x 2 hops and jumps into sand pit with 11 stride approach 2 x 10 bounds with a 7 stride run-up	High
Depth jumping, recommended heights: 40 - 80 cm	2 x 6 jumps - down and up Run to hop off low box onto one leg landing followed by three subsequent hops Bounding uphill	High Very high Very high
Eccentric drop and hold drills	Hop and hold 5 times Bound/hop/bound/hop and hold over 30 meter, stop after each landing! Drop and hold from height above 80 cm	High High Very High

During the pre-competition phase players should concentrate on quality that means plyometric exercises that replicate the speed and movement patterns of their chosen sport, for example soccer drills. **Fatigue do not impair performance should be the slogan during training.** High intensity drills should be chosen.
During competition phase high quality drills should be chosen in low numbers and keep this type of training away, at least one week or more from important matches. During low-intensity workouts medium/high quality drills are the best choice.
Intensity and training target are key words for decision in case of recommended volume of sport specific jumps during one training session. In general terms one could start with 60 - 100 foot contacts of low-intensity exercises. Later on 100 - 150 foot contacts still of low-intensity exercises during one workout and 100 of moderate-intensity exercises in another will be advised. More experienced athletes might be able to exercise 150 or more foot contacts of low-to-moderate intensity in one single session.
Intensity is the key!! Higher intensity indicates more power is generated and fewer foot contacts are required.
Bounding and hops are best measured in terms of sets and repetitions (= reps), distance covered, standing start or with a run-on situation. 5 to 10 bounds per set

should not be exceeded. Optimum sports specific training effect is connected to the fact that the athlete is not allowed to become fatigue.
Recovery interval between the sets should be at least 1 - 2 minutes. Depth jumps or drop jumps should be separated by intervals of at least 15 - 30 seconds or longer!
Number of sessions should not go beyond 2 to 3 sessions per week and surely not be performed on consecutive days or one week before an important match!

Table C. **Plyometric exercises : Level of Intensity.**

Intensity level	**Type of Exercise**	**Intensity of Exercise**	**Number of reps x sets**	**Number of reps per train. session**	**Recovery interval between sets**
1	Shock tension; high reactive jumps > 60 cm	Maximum	8-5 x 10-20	120 -150	8-10 min
2	Drop jumps 80-120 cm	Very High	5 - 15 x 5 - 15	75 - 150	5 - 7 min
3	Bounding exercises * two legs * One leg	Sub-maximal	3 - 25 x 5 - 15	50 - 250	3 - 5 min
4	Low reactive jumps 20 - 50 cm	Moderate	10 - 25 x 10 - 25	150 - 250	3 - 5 min
5	Low-impact jumps/throws * On spot * Implements	Low	10 - 30 x 10 - 15	50 - 300	2 - 3 min

Over 2 to 4 years (!!) are needed to incorporate low-impact plyometric exercises into the training schedule for young sportsmen. During this time progressive adaptation of muscles, ligaments, tendons and bones is possible. Shock absorbing sections like knees, hips and spine
needs also time to accept this strenuous type of exercise. NOT the plyometric exercises itself are responsible for injuries or discomfort but the way trainers use the method without enough knowledge!
In intensity level 1 and 2 the main purpose is to induce the highest level of tension in the muscles. Developing maximum strength and power is the target.
Multiple response exercises result in developing power and power endurance like in intensity levels 3,4 and 5.
Recovery time is often ignored and only moving from one station to another is >recovery time=. This is certainly insufficient and when somebody understands a little bit more concerning the physiological background of plyometric training than especially the recovery/rest period should be taken in full consideration!

Landing involves an eccentric contraction. At the instant of ground contact athletes experience an inhibitory effect, a protection system that shields against injuries.
Landing should be performed without touching the heels on the ground.
During the dropping phase the muscles adopt a reflex or ready-to-work position, **which activate the tension and the elastic properties of the muscles. At landing, especially when followed by a jump after, energy is stored in the elastic elements of the muscle.** At the jumping movement this available amount of energy releases a stretching reflex (inclusive the muscle spindle reflex) that recruits more FT fibres than under normal strength training circumstances. **These reflexes are trainable!**

Summary:

Trainer/coaches often refuse to read scientific text books or articles with >difficult= terminology. In our paper we try to inform you in clear words concerning the scientific basis of training and in particular strength training effects in relation to young soccer players. Learning about muscle fibre types and how they adapt to training stimulus can be of great advantage to the trainer to understand better the work he is doing. What type of contractions are available and the best for your type of sport, in our case soccer or football, is what we try to explain in this paper.
Increases in strength due to short-term training (10-20 weeks) are mostly the result of neural adaptations, hypertrophy or increase in size of the muscles occur only after long-term training programs. Special attention we ask for the position of children who are certainly not >adults in pocket form= but they need to be treated in a special way what belongs to their special development, for example during the >grow-spurt= phase.
Strength training is far more than >only= overload with some weights or work in machines.
A proper factor-analysis of the game soccer has given last decades a lot of information concerning one of the most popular sports on earth. We surely does not want to make this game so >scientific= or >clean= like for example American football, but if we can use the scientific knowledge and principles to avoid serious mistakes in overloading young people, we think that this method of training can be valuable to someone=s health and also for the development of soccer or football it will be of great advantage.

Table A: Professional and Amateur Soccer Players in Holland:

Average values ± Standard Deviation(SD) ; N= number players.

	Professionals (n=1601)	SD Profs	Amateurs (n=1306)	SD Amateurs
Age (yrs)	25.5	3.1	25.6	3.7
Length (cm)	179.8	4.6	179.8	5.0
Body Weight (kg)	75.8	5.2	74.7	5.6
Sum 4 Skinfolds (mm)	26.6	4.9	30.8	8.1
Percentage Body Fat (%)	11.7	2.5	13.3	3.3
FatFreeMass (kg)	66.7	4.3	64.6	4.3
Normal Body Weight (kg)	75.9	4.3	74.9	4.5
Rest Hf. (bpm)	63	7	67	6

VO2max(L.min)	4.31	0.4	3.89	0.4
VO2max(ml.kg.min)	57	6	52	6
VO2max(ml.kgffm.min)	64	6	60	7
Maximal Jump (Sargent),(cm)	49	4	52	5
Maximal Jump (sec)	0.51	0.03	0.48	0.03
Endurance Jump(15sec)(W.kg)	20	3	18	3
Chin-up's (number)	5	2	8	3

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Appendix I.

Muscle group:	**Free-weight exercises: (Dumbbell)**	**Machine exercises:**
Pectoralis Major (Chest)	Bench Press	Chest Press
Latissimus Dorsi (Upper Back)	One-arm Row Pullover	Seated Row Pullover Front Pulldown
Deltoids (Shoulders)	Lateral Raise	Overhead Press
Erector Spinae (Lower Back)	Prone Back Raise*)	Low-back Extension
Rectus Abdominus (Abdominals)	Trunk Curl*)	Abdominal Curl
Biceps (Front Arms)	Biceps Curl Incline Biceps Curl	Biceps Curl
Triceps (Rear Arms)	Triceps Kickback Triceps Overhead Extension	Triceps Extension
Extensors/Flexors (Forearms)	Wrist Extension Wrist Curl Wrist Roller*)	Super Forearm
Quadriceps (Front Thigh)	Squat Lunge Step-up	Leg Extension Leg Press
Hamstrings (Rear Thigh)	Squat Lunge Step-up	Leg curl Leg Press
Hip Adductors (Inner Thigh)	Side Lunge	Hip Adduction
Hip Abductors	Side Lunge	Hip Abduction

(Outer Thigh)

Gastrocnemius/Soleus. Heel Raise Heel Raise
(Lower Leg)
*) without Dumbbells, own body weight.

Appendix IIa.

Free Weight Exercises for Soccer:

1. Barbell Squat	Quadriceps;Hamstrings;Gluteals
2. Dumbbell Step-up	Quadriceps;Gluteals;Hip Extensors.
3. Dumbbell Side Lunge	Quadriceps;Hamstrings;Gluteals;Hip Abductors and Adductors.
4. Hip Adduction	Hip Adductors
5. Barbell Bench Press	Pectoralis Major; Front Deltoids; Triceps
6. Dumbbell One-arm Row	Latissimus Dorsi; Rear Deltoids; Biceps
7. Dumbbell Overhead Press	Deltoids; Triceps
8. Dumbbell Biceps Curl	Biceps
9. Dumbbell Triceps Overhead Extension	Triceps
10.Chin-up	Latissimus dorsi;Biceps
11.Bar Dip	Triceps;Pectoralis Major;Deltoids
12.Prone Back Raise	Spinal Erectors
13.Diagonal Trunk Curl	Abdominals
14.Hanging Knee Raise	Abdominals;Hip Flexors.
15.Dumbbell Shrug	Upper Trapezius
16.Medicine Ball Squat Toss	Quadriceps; Hamstrings; Gluteals
17.Medicine Ball Lunge Pass	Quadriceps; Hamstrings; Gluteals
18.Medicine Ball Chest Pass	Pectoralis major; Front Deltoids; Triceps

Appendix IIb.

Machine Exercises for Soccer:

1. Leg Press	Quadriceps;Hamstrings;Gluteals.
2. Leg Extension	Quadriceps
3. Leg Curl	Hamstrings
4. Hip Adduction	Hip Adductors
5. Hip Abduction	Hip Abductors
6. Heel Raise	Gastrocnemius; Soleus
7. Chest Press	Pectoralis Major; Front Deltoids; Triceps
8. Seated Row	Latissimus Dorsi; Rear Deltoids; Biceps
9. Overhead Press	Deltoids; Triceps
10.Biceps Curl	Biceps
11.Triceps Extension	Triceps
12.Weight assisted Chin-up	Latissimus Dorsi; Rear Deltoids; Biceps.
13.Low-back Extension	Spinal Erectors;Hip Extensors
14.Abdominal Curl	Rectus Abdominus
15.Rotary Torso	Obliques internal and external; Abdominals
16.Hanging-knee Raise	Abdominals;Hip Flexors
17.Neck Extension	Neck Extensors
18.Neck Flexion	Neck Flexors
19.Super Forearm	Wrist Flexors and Extensors, Supinators and Pronators; Finger grippers
20.Medicine Ball Squat	Quadriceps; Hamstrings; Gluteals
21.Medicine Ball Lunge Pass	Quadriceps; Hamstrings; Gluteals
22.Medicine Ball Chest Pass	Pectoralis major; Front Deltoids; Triceps

Appendix III.

Body Composition:

Summary of techniques providing information about composition of the whole body and the development or change in specific tissues of the body.

1. **Isotope Dilution.** Total Body Water (= TBW) is determined by the isotope dilution method. People with large TBW volumes possess more lean tissue and less fat tissue so TBW can be used to determine body fatness.
2. **Potassium-40**. Potassium is located in within the cells with radioactive isotope of potassium 40K which can be measured in a whole-body counter and is proportional to the mass of lean tissue.
3. **Hydrostatic (underwater) weighing**. Water has a density of about 1 gm.ml and body fat with a density of about 0.9 gm.ml will float in water. Lean tissue has a density of about 1.1 gm.ml in adults, so this will sink in water! Whole body density provides information about the portion of the body that is lean and fat.
4. **DEXA (= Dual Energy X-ray Absorptiometry).**In this new technology a single X-ray source is used to determine whole-body and regional estimates of lean tissue, bone, mineral and fat with a high degree of accuracy. With further developed software this method will be popular in close future for body composition analysis.
5. **NIR (= Near Infrared Interactance) method**. Based on absorption of light, reflectance and near infrared spectroscopy. The light passes through subcutaneous fat and muscle and is reflected by bone back to the probe. This technology has still a way to go before it will be general accepted.
6. **Ultrasound. Sound waves** are transmitted through tissues and the echoes are received and analyzed. Thickness of subcutaneous fat measuring is the purpose uptill now but new technology allows also the determination of whole body scans and the volumes of various organs.
7. **TOBEC (= Total Body Electrical Conductivity)**.TOBEC analyses on the base that lean tissue and water conduct electricity better than does fat. The electromagnetic field developed in the space around a cylindrical coil is effected by the subject=s body composition.
8. **BIA (= Bioelectrical Impedance Analysis).** The basis is similar to the TOBEC method.
Total body water is calculated and the value can be used to estimate percent body fatness.
This method will be in close future a good alternative for skinfold measurements in field test circumstances especially in testing the elderly.
9. **Skinfold Thickness.** An estimate of total body fatness is made from a measure of subcutaneous fat. A number of skinfold measurements are obtained and the values used in equations to calculate body density.

Some of the procedures mentioned above are expensive (personnel, equipment) and will never be available in routine settings for body composition analysis. BIA and skinfold measurements are more likely to be accepted in field test circumstances.
Several models can be used:

A. Four-component model. This model uses information on mineral, water, protein and fat to access body composition.
B. Three-component model. The body is divided into three compartments: 1) body water, protein and mineral, and fat or 2) body water and protein, mineral and fat. This model allows to account for variations in bone density or body water and estimates of body fatness.
C. Two-component model. Fat mass and fat free mass. The oldest model. Underwater weighing and skinfold measurements are the most well known methods in this area.

Appendix IV.

Testing Strength:

When somebody complains about movement problem in sport activities, muscle strength is often part of the problem. The need of strength testing for people with movement disorders is, with a wide variety of techniques, available. A reliable and valid measurement of muscle function is necessary for determining the causes for musculo-skeletal symptoms and following the efforts of training and rehabilitation. Pre-training fitness-levels should be established to provide a baseline for monitoring training changes. The components are:
Body Composition; Aerobic and Anaerobic Power; Strength and Coordination/Flexibility. With only some slight modifications to testing protocols it is possible to test all these components in disabled athletes.
In our workshop we concentrate ourselves on the topic of physiological measurements of strength testing and protocols.

Physiological basis for strength testing

Skeletal muscle strength is the ability to generate maximal tension via the activation of muscle fibres and filaments. Energy requires for a (very) short time of sustained maximal contraction is stored as ATP and CP. Glycolysis or anaerobic metabolism results in the formation of lactic acid and can regenerate ATP relatively quickly so that up to 3 minutes sustained maximal effort is possible. Lactic acid accumulation inhibits maximal physical effort. Aerobic metabolism supports efforts of prolonged duration.
Skeletal muscle possess the capability for short bursts *and* for sustaining activity over long periods of time. The force output of the muscle is greatest for short duration efforts and falls rapidly as the length of contraction increases. Individuals may differ strongly in the metabolic capacity to support the various intensities of muscle contractions. Classification based on twitch contraction time and fatigue has been developed.
Muscle strength can be defined as the ability to generate maximal force for very short durations or for a small number of repetitions.
When a large muscle mass is used the capacity of the heart and circulatory system often is reached before the true capability of the slow twitch fibres has been exceeded.

Muscle Strength testing with dynamometers

Hand-held dynamometry. Hydraulic and spring devices are non-electrical, so they do not require a power source or batteries. Load cells or strain gauges systems are

generally digital based on units on the dynamometer itself, often integrated with a computer.
A disadvantage of spring-based dynamometers is that their springs can fatigue over a period of time so that the forces registered may not reflect the actual forces.
Hand-hold dynamometry will yield valid and reliable results *only* when the tester=s strength is adequate. A 25-30 kg limit should be considered carefully. Before hand-held dynamometry can realize its full potential, more extensive normative data must become available.

Static (= isometric) muscle strength testing

Recent technologic advances in strain-gauge design, signal conditioning, analog-to-digital converters, PC=s and mechanical engineering have allowed us to develop a system for measuring static muscle strength (Vos,a.o.1965-=98). Our system consists of several frameworks that allows a subject to be securely and conveniently stabilized and provides moveable attachments for strain gauges. The strongest *and* the weakest muscles can be accurately and reliably tested. All major muscle groups of the body can be tested and the whole equipment requires little floor space. The system is providing accurate peak force values when the subject is stabilized and can be tested also in functional positions.
The length of the muscle, the lever arm and the type of contraction can cause very large differences in force output. The force generated during a maximal contraction by a subject produces a curve characterized by a short reaction time, rapid rate of increase in force and a definite but much slower rate of decrease in force.

Advantages to measuring static strength

There are advantages to measuring static as opposed to dynamic (= isotonic) strength. Good stabilization is much easier to realize with static testing. Effective stabilization isolates the muscle group being tested and minimizes the effect of joint traction or compression forces like during dynamic testing.
Security, safe feeling is another advantage, like less systemic fatigue in comparison to dynamic testing, so more muscle groups can be tested. When movements or contractions cause pain, static testing is often very well possible. The same situation occurs when there is a joint contracture or painful arcs of joint motion. Also in distinguishing between contractile and non-contractile tissue pathology static testing is very often possible to realize.
Precautions should be observed in maximal muscle contractions for example in the presence of active muscle problems, acute disease, osteoporosis, cardiovascular or respiratory pathology, uncontrolled hypertension, etc. Muscle testing is completely contra-indicated in the presence of unsplinted fractures or unhealed torn or sutured tendons.

General procedure for maximal static strength testing

1. Measure current Body Weight and Height. Determine Body Composition (Percentage Body Fat; Lean Body Mass). We use the Method of Durnin,a.o. (1974).

2. Ensure correct position of the subject and do one contraction that builds slowly to maximum (warm-up).
3. Actual test: Instruct the subject as follows: A When you are ready, I will say: Ready....Start!
Push or pull as hard *and* as fast as you can against the device. Continue to maintain your maximal force against the load cell for as long as about 6 seconds. A signal will warn you when the time is over. If you have any discomfort, pain or feel at all unstable: stop immediately@.
4. Check the subject=s discomfort level periodically throughout the testing process.
5. Take the best score out of three well done tests as the subject=s maximal strength.

Appendix V.

Comparison Shuttle run with VO2 max values in Dutch First Division Soccer Players (N = 18).

	A	**B**	**C**	**A**	**B**	**C**	
Name player:	**Shuttle Run**	**VO2 ml/kg/min**	**VO2 ml/kg ffm/min**	**Ran-king**	**Ran-king**	**Ran-king**	**Total + final ran-king (..).**
1.G.K.	14	71	80	**2**	**1**	**1**	**4 (1)**
2.J.v.R.	14.5	66	76	**1**	**2**	**2**	**5 (2)**
3.R.S.	14	64	72	**3**	**3**	**4**	**10 (3)**
4.M.v.O.	14	62	75	**4**	**4**	**3**	**11 (4)**
5.R.G.	13.5	57	69	**5**	**8**	**6**	**19 (5)**
6.M.N.	13.5	48	56	**6**	**15**	**15**	**36 (12)**
7.E.L.	13.5	45	56	**7**	**16**	**16**	**39 (15)**
8.J.W.	13	54	62	**8**	**12**	**11**	**31 (10)**
9.H.S.v.d.B	12.5	59	68	**9**	**6**	**7**	**22 (6)**
10.E.v.V.	12.5	58	66	**10**	**7**	**9**	**26 (8)**
11.P.U.	12.5	51	59	**11**	**13**	**14**	**38 (13)**
12.J.B.	12	61	67	**12**	**5**	**8**	**25 (7)**
13.E.B.	12	56	71	**13**	**9**	**5**	**27 (9)**
14.M.D.	12	56	63	**14**	**10**	**10**	**34 (11)**

15.B.O.	12	56	62	**15**	**11**	**12**	**38 (14)**
16.M.H.	12	51	60	**16**	**14**	**13**	**43 (16)**
17.M.S.	11	42	49	**17**	**17**	**17**	**51 (17)**
18.T.M.	10.5	39	49	**18**	**18**	**18**	**54 (18)**

Appendix VI.

Average Values + Standard Deviation (=SD) of Young Soccer Players from Korea compared with Dutch (N = 17).

Soccer Players (n = 17)	Korea Average	Korea S.D.	Nederland Average	Nederland S.D.
Age (yrs)	19.4	1.6	19.4	2.0
Body weight (kg)	73.3	5.5	73.3	6.3
Height (cm)	180.4	4.9	185.0	5.1
Sum 4 Skinfolds (mm)	32.5	6.0	27.6	6.6
Percentage Body Fat (%)	13.7	2.1	11.6	2.7
Fat Free Mass (kg)	63.3	4.4	64.7	4.8
Heartfrequency Rest (bpm)	67.1	3.6	66.6	4.5
VO2 max (L.min)	3.8	0.1	4.3	0.3
VO2 max (ml.kg.min)	52.2	3.5	58.8	5.5
VO2 max (ml.kgffm.min)	60.5	3.7	66.4	6.0
Standard Body Weight (kg)	78.6	6.4	77.6	4.8
Maximum Jump (sec)	0.57	0.04	0.49	0.04
Endurance Jump (W.kg)	24.0	4.1	18.6	2.2
% Fat Omron (%)	11.5	2.9	11.5	4.8