Electronic Muscle Stimulation {EMS} for Maximum Speed Enhancement

By Charlie Francis

www.charliefrancis.com

FORWARD

This book was written by Coach Charlie Francis in 2008 to highlight the key concept of Electric Muscle Stimulation (EMS) for Maximum Speed Development. The first part of this book focuses on EMS' potential for maximum strength enhancement for speed. In Coach Francis' own words: "My own results have been so favorable that I am not interested in debating whether or not EMS works but rather optimizing the use of EMS in the training of elite athletes."

As a bonus I have added the chapter on EMS from the book "The Charlie Francis Training System" which was written by Coach Francis in 1988 to generally cover all aspects of his methods. This chapter covers four parts of EMS: 1. EMS in regeneration 2. The treatment of injuries with EMS 3. EMS in Maximum strength training including the principles and techniques of application and finally 4. Periodization of EMS. It may be slightly repetitive to the first part of this book but it gives a look at EMS from a slightly different angle than just maximizing strength.

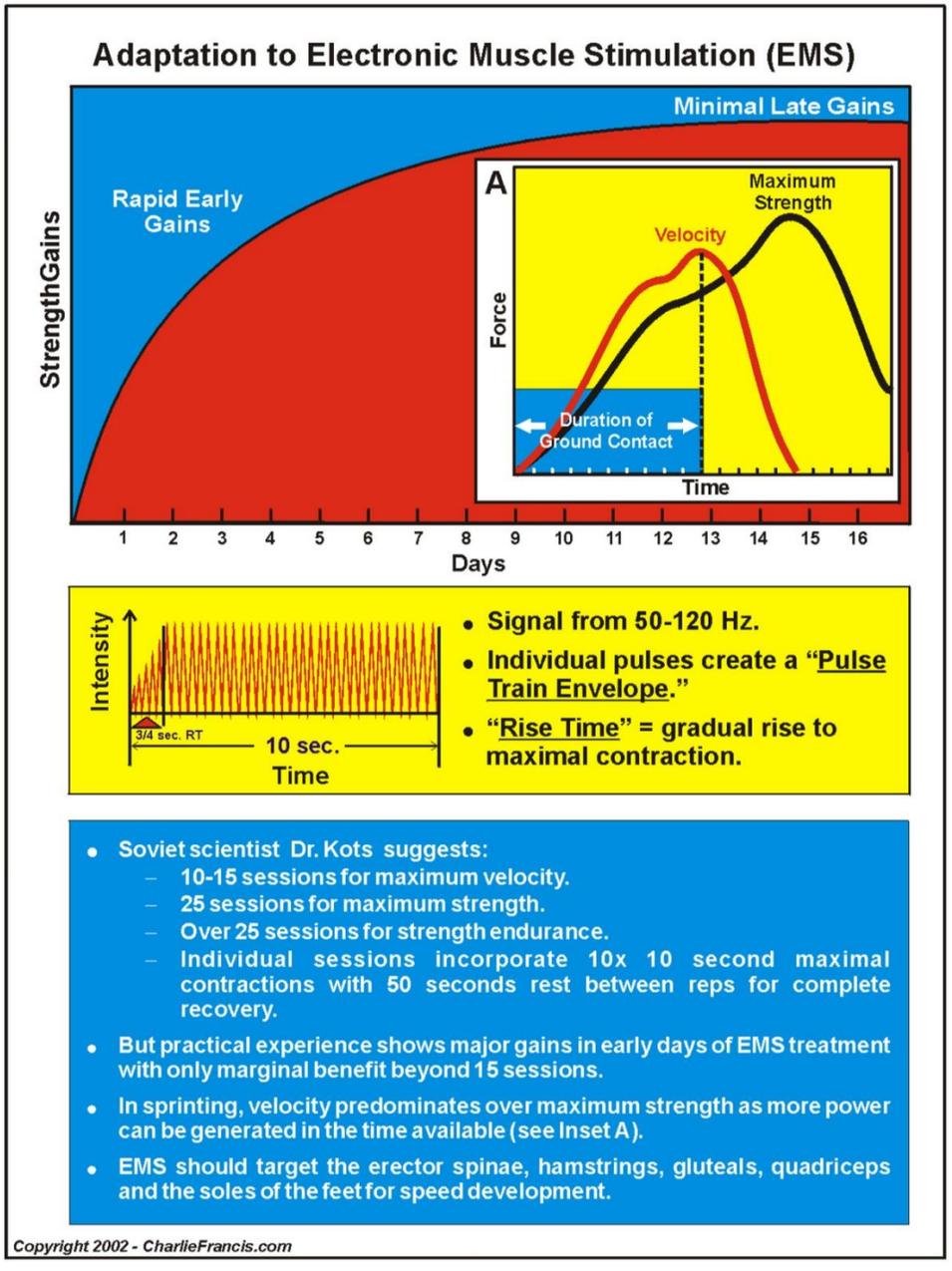
To learn the specifics of the other books in the Charlie Francis "Key Concepts" series, please read "The Structure of Training for Speed", "Training for Power and Strength in Speed", "Super Compensation and Recovery", "High Intensity Training – Expanding the Limits of Performance" and "Race Dynamics and Sprint Techniques". Further information can also be found in the books "The Charlie Francis Training System" and "Speed Trap". Many of the Key Concepts are also highlighted in the video training series called "GPP Essentials" and "Inside the SPP" which are available at www.charliefrancis.com.

Electric Muscle Stimulation is very easy to use, it's affordable and extremely effective for maximum strength enhancement. The scope for use of EMS is wide open for athletes and coaches who are armed with the knowledge presented in this book. Furthermore, Coach Charlie Francis' results are worth understanding and utilizing in or outside of elite sport for speed development, strength enhancement and total system recovery for athletes to train harder. I wish you all the best in your pursuit to learn more about the process of training.

Best,

Angela Coon

ADAPTATION TO EMS



Background and History of EMS in Training

If EMS *is* effective then when and where should it be applied? What exactly is its effect on the muscular and central nervous systems? And what improvements should be expected, over what periods of time? All of these questions will be answered in considering the body's adaptation to EMS.

"EMS" is electronic muscle stimulation, operated indeed for many functions among many different types and classes of users. In these diagrams, we will focus only on its potential for maximum strength enhancement, and not its value as a means of recovery, as a rehabilitation tool, or as motor learning and muscle recruitment technology - all of which, by can indeed utilize EMS extensively.

EMS had been used in Eastern Europe in the Communist Bloc countries from 1950 onwards, but made its arrival in the West in 1973 only when Dr. Y. Kots of the Central Institute for Physical Culture in the USSR presented a paper on its use at Concordia University in Montreal.

He outlined what he perceived to be a remarkable potential for strength enhancement well beyond that which was possible by traditional - voluntary, at the muscular level - means. Naturally, much as EMS infomercials exact suspicion and distrust, many were skeptical of Dr. Kots' studies, and claimed that EMS was not nearly as effective as Kots had demonstrated.

Experiments attempting to prove the ineffectiveness of EMS used a crude comparison of voluntary contracted muscles and those contracted using an EMS stimulus. The fallacy is that the two contractions are essentially incomparable.

Voluntary muscular contractions roll through the muscle in a wave to generate a coordinated, directed force, while an EMS stimulus fires all motor neurons in the treated area simultaneously, creating an uncoordinated contraction. The EMS contraction is primarily isometric in nature, against resistance without significant shortening of muscle fibres, and with marked increase in muscle tone.

Kots showed, using a tensiometric device, that the muscle tension produced in a maximal EMS contraction can be up to 30% higher than over a maximal voluntary contraction. The reason for this is that since individual muscle fibres can become exhausted in just seconds, the body has several safeguards to maintain the utility of muscle fibre and prolong endurance. There is never a period of time, even in the most intense activity, that every muscle fibre is fired.

EMS Impact on Muscle Fibre and Recruitment Velocity

Slow-twitch red fibre is used first in voluntary contractions, as it represents the most energy efficient means of contraction. Fast-twitch white fibre is only added when the load requires it; white fibre is the "power" fibre. Muscles fire their individual fibres in relays, so that some fibres are kept as a reserve for when those in use are exhausted. These reserve fibres will be predominately white under voluntary contraction. All of these safeguards are instituted biomechanically with the aim to prevent overstress on the central nervous system.

EMS bypasses the CNS, and works directly on the muscles it is applied to, with no crossover effect. Thus there is no limit to the amount of fibre that can be activated, as the EMS stimulus "spills over" to the white fibre, a training stimulus unattainable by any other means. Given sufficient current, this exercise is supra-maximal; in other words, above the natural maximum. Thus it enhances muscle density by favouring improved muscle recruitment over cross-sectional growth (bulk). In addition, *EMS training optimizes fibre splitting and the conversion of intermediate fibre to fast-twitch white fibre.*

Recruitment velocity refers to the rate at which a given muscle fibre can achieve maximum tension, and corresponds to the power force output. There are of course various classes of fibre, including some intermediate fibres, but in general white fibre has a recruitment velocity of approximately twenty milliseconds, and red fibre has a recruitment velocity of sixty-five milliseconds. Red muscle fibre has preference in voluntary contractions as white fibre is only added when it is determined that additional force is required.

In EMS, the opposite phenomenon is observed. The nonspecific current of EMS stimulus reverses the natural recruitment order, because it flows more easily through the larger neuron of the white fibre - there is less resistance. This forces red and intermediate fibres to speed up their recruitment rates in order to compete with the white fibre, resulting in the conversion to fast-twitch.

For these reasons, EMS is an ideal means for improving recruitment velocity across all fibre types, as well as attaining strength gains, especially in explosive events.

Prioritizing EMS

As mentioned earlier, EMS plateaus the most quickly of all training components. At the top of the diagram, the period of diminishing returns is once again expressed. As you can see, most of the gains are achieved after ten sessions, with smaller gains over the next five sessions, and negligible benefits thereafter. The period ten to fifteen sessions is also an ideal period to maximize recruitment velocity, and thus it is logical to perform ten to fifteen sessions at most over a training period.

The curves of recruitment velocity and maximum strength are charted with reference to the number of weeks that it would take to achieve each maximum. Maximum strength, naturally, peaks at the end of the window for effective gains from EMS.

Recruitment velocity, however, peaks at an earlier time. This is a very important graph when it comes to EMS. Generally speaking, a sprinter would place an emphasis on maximum recruitment velocity rather than maximum strength. Simply put, it is increased recruitment velocity that will lead to the explosive power that a sprinter desires at the start of his race.

The top sprinter experiences a much smaller time of ground contact than the beginner, because he is stronger and more explosive and is simply moving faster off the ground. Since the force-time of the top sprinter would be so steep, ground contact may have ceased by the time that maximum strength would be necessary and of relevance. This is illustrated on the graph. Thus the extra strength is likely to be extraneous.

To be explosive, a sprinter does not need to be a champion weightlifter. Besides, much of that extra maximum strength work will have most its value when competition arrives. In addition, more sessions of EMS translate into a longer tapering period and reduced opportunities for other high intensity work.

Most relevantly, though, as maximum strength continues to increase after the twelfth or thirteenth session, until about twenty-five sessions, recruitment velocity in fact begins to decrease. And since it is recruitment velocity, and not strength, that is the ultimate goal, it seems logical to stop before the point of maximum strength. Strength gains at that point would be relatively small and unlikely to make a significant difference in a race situation regardless.

There are two reasons for which attaining maximum strength by performing more EMS sessions would make logical sense for a sprinter. First, beginners will have longer ground contact and thus will need to utilize fibres over a longer duration along the strength continuum.

Second, the curve of maximum strength may be shifted. An athlete who lacks strength and muscle bulk as well as density may need to acquire a certain level of strength for fibre conversion. In this case, reaching the peak of the maximum strength curve might have positive consequences later in training.

In a more advanced situation, the curve might be shifted, as if on a string, so that the peak of maximum strength would rest above - directly above or nearly - the curve of recruitment velocity. Of course, all of this applies mostly to the sprinter. The Olympic lifter clearly places less of a priority on recruitment velocity and more on maximum strength. He might perform EMS closer to the peak of maximum strength.

This is tied in part to the concept of EMS conversion. While it is recommended that no conversion weights be performed, and no other conversion exercises, EMS *is* used in conversion to some degree.

As far as movement and velocity goes, EMS rests at the bottom; there is no movement and no velocity. And since the strength gains are lost so quickly after plateau with EMS, it makes sense to utilize the gains from EMS in explosive power and speed work, as well as in the development of recruitment velocity and fast-twitch fibre.

Individual sessions on a three high intensity day per scheme would be performed the night after each of the high intensity days. In theory, EMS could be performed every day, even three times a day with four hour breaks, because it has no CNS demand and can be recovered from muscularly in that time. But it acts as a natural complement to high intensity speed work and ensures that there is not too much high intensity work on the low days.

In addition, in case some bruising or muscle damage occurs, or recovery takes longer than expected, there is maximum interval before the next high intensity speed training session. It should be separated from work by at least two hours, and preferably four. If it is done before bed - even in bed - the supra-maximal stimulus it provides promotes the release of growth hormone during sleep.

The EMS Session

In preparation, a hot shower will provide adequate initial stimulation, heating the muscle motor neurons, lowering electrical resistance, and making them more receptive to EMS. Contrast showers are an alternative, and of course have the added benefit

of promoting CNS recovery. However before EMS the final shower should be hot. The EMS session should begin in a gentle pulsing mode for three to five minutes; this would be the same mode as used by massage therapists for muscular recovery. The same pulsing session should follow the intensive EMS.

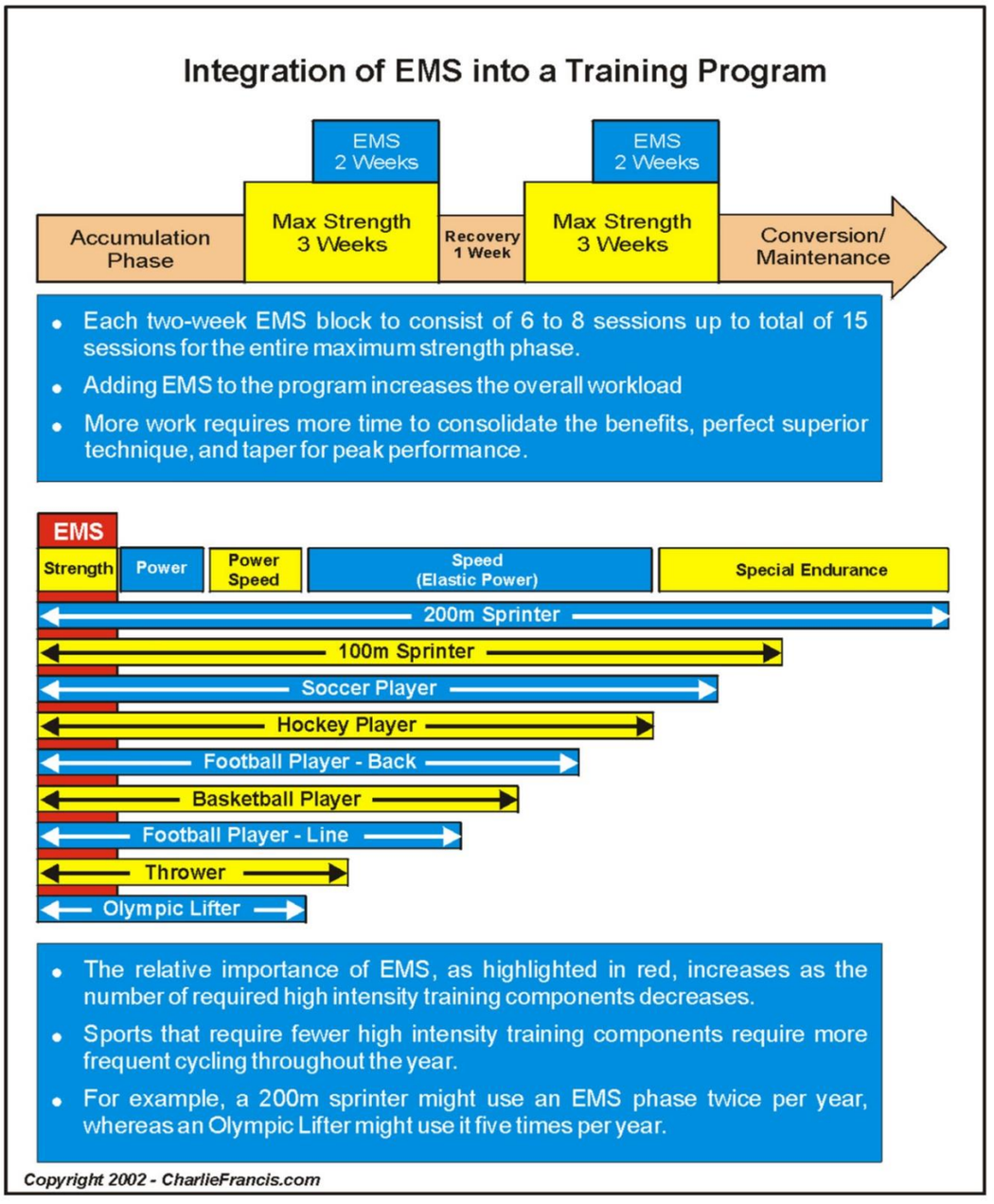
The length of a given contraction varies among athletes and muscle types. Normally, a sprinter would use a guideline the maximum contraction time of ten seconds, with ten repetitions at this duration. There must be a fifty second rest between contractions; otherwise, the athlete will be unable to maintain maximum contraction on the next repetition. In fact, a rest period that is too short may change the nature of the exercise so that it enhances red muscle fibre rather than white.

Shot-putters and other athletes that require less of a speed and speed endurance component in their training often find that they can maintain a maximal contraction over about six seconds. In any case, the full rest period must be observed.

The most common misuse of EMS is that athletes never come near the level of contraction that they need for optimal results. A target EMS intensity would be 30% more than the maximum possible voluntary contraction. The contraction is very large, and feels that way. With proper current, some athlete may need to bite down on a piece of leather (or whatever is available). The feeling is similar to riding on a bike up a long and steep hill; an intense burn. This is normal and should not be avoided or shied away from.

Of course, the next issue is where EMS should be applied. As a general rule, no more than two muscle groups should be stimulated simultaneously, as the athlete must be able to determine the origin of the stimulus. Maximum strength EMS is applied to the quadriceps, hamstrings, gluteals, and erector spinae primarily in a sprinter. At maximum speed, it is these muscles that play the greatest role in power development around the hip joint, where the power output is seven times that of any other joint.

The abdominals play a role also, but as they have rotational movement and focus on primary support, they are more of a factor in speed endurance and longer distances. When cases of insufficient foot strength arise, the soles of the feet may be treated with EMS as the pods are applied with the athlete in a standing position.



The Relevance of EMS

Late-night television infomercials swear that EMS is the shortcut to tremendous - even unnatural - maximum strength gains. Many athletes use it and see limited results, especially for the price... literally and muscularly. And most Olympic sprinters use EMS - presumably effectively - to build strength and power. EMS has been one of the most hotly-contested topics on the athletic circuit.

Its claimed benefits, to maximum strength, could potentially make it a useful and vital tool for athletes as diverse as the Olympic lifter and the basketball player.
But is it just a cleverly-disguised technological gimmick not worth the time and expense of money or energy? Or is it the best strength machine ever made, strength training for the lazy everyman and the top athlete alike? As in almost all situations, the answer lies in that grey area between the two extremes. Joe the Couch Potato is not going to end up with muscles that look like Schwarzenegger, but EMS can be an extremely effective tool for any athlete and is well worth the investment for many events.
In order to determine the relevance for a given event or sport, examine the graph on the low half of the diagram. The red portion - strength - is what is gained by training with EMS.
Of course, these strength gains would not be achieved entirely by EMS; even when EMS use in a training career is at its peak, other maximum strength weights would be performed, along with accumulation weights, and even conversion weights in some cases. But in some cases EMS can account for well over the majority of potential strength gains.
In any event, it is clear that strength has a lesser significance in the 200metre race than in the Olympic lift. This is intuitive: a relatively weak lifter has never won a weight-lifting competition, but there have been successful 200metre runners who were not exactly ripped.
But it is also theoretical, and this can help distinguish the relative relevancies of EMS for a 100metre sprinter and a basketball player. Earlier, it was explained how strength is of principal value over the first ten metres of a race, as the sprinter require enormous force to power himself out of the blocks and create the necessary acceleration. It is somewhat important over the next ten metres, and less important between twenty and thirty metres. At this point, as the athlete adopts a more upright position, strength ceases to be a major factor in terms of speed generation and maintenance. And the sprinter still does have seventy metres to run.
Clearly, strength does play a major role in deciding races among top sprinters; Ben Johnson always had an advantage because he was the strongest starter and the fastest over the first ten metres. But strength alone will not decide a race. The relative importance of strength training for a 100metre sprinter would be between ten and fifteen percent. A basketball player, conversely, requires large amounts of strength under the hoop, using tremendous force to propel himself into the air for a block or a rebound. He does use speed running down the floor, but certainly not at maximum for long distances. Strength, then, is of greater relative importance for a basketball player, in the order of twenty to twenty-five percent.
The Olympic lifter performs all of his lifts in the strength, power, and power speed stages. Thus strength is of extreme significance, and EMS of extreme relevance to training. The relative importance of EMS increases, in conjunction with the body's ability to tolerate it, with fewer and fewer additional high intensity components that need to be executed.

EMS and Plateaus of High Performance

As discussed earlier, those sports that require fewer high intensity components in training also should have more cycles - periodizations - throughout the year. Again, this is for two reasons. First, there are less other components that need to be improved in a given period so improvements in one component can be achieved more rapidly.
Second, the fewer components also by nature are those that require shorter lengths of time before a performance plateau, and also are lost faster after training is stopped on the component. Refer to the diagram on effective plateaus of high performance. Maximum strength EMS training can reach a plateau after just four weeks of work. But the corollary to this is that the strength gains from EMS begin to be lost appreciably just four weeks after training on maximum strength EMS ends. Therefore if EMS is very important relatively to a sport, it should be cycled frequently so that there are opportunities for multiple plateaus of high performance, and also lesser risk of maximum strength gains from EMS depreciating significantly before an event.
Under this system of guidance, the same that should be applied to decide which periodization scheme fits a sport, a 200mtere sprinter might train with EMS two blocks per year, while a 100metre runner might use it three times and an Olympic lifter five. Among different 100metre sprinters, there would also be a wide range of EMS uses. Some sprinters would place a priority on their strength and explosive power and would perform the full three sessions, while some would work more on speed endurance and perform just one session. Because a curve of diminishing returns applies to EMS work, as it does to all other exercise, most of the gains happen over the first stages of EMS work anyways.

Scheduling EMS

That was an examination of EMS on the macro level, but more specifically, EMS is integrated into the training scheme just like any other high intensity component. EMS does not have CNS demand, but of course does impose great demand on the muscular system; although it may be self- administered and performed on a couch or bed, it is still very much work, and very high intensity work at that.

Adding EMS to the program *does* increase the overall workload, just as one might imagine it would. If it creates stress and burns and feels like work, it is. Adding EMS to a program will shift the period for peak performance later in the season by about two weeks later than before, as the increased workload will require a longer period for tapering.

The EMS maximum strength phase illustrated at the top of the diagram is not unlike one many 100metre runners would perform. However, it is not necessarily specific to the 100metre sprint. Ten to fifteen sessions per training block is an ideal number, and with an EMS period of two weeks in each maximum strength phase, this equates to between three and four sessions per week. EMS is integrated into the maximum strength phase, when other maximum strength weights are being lifted; the two modalities are synergistic. Potential gains are greatest in this period as in the vertical integration scheme significant high intensity work would not be performed in opposition.

Because EMS is in fact the most intense strength building exercise and also has the briefest period for improvement before plateau, it would be performed in the latter stages of a block intended for maximum strength work. The lines for the maximum strength blocks would not be as clear-cut as illustrated, however.

EMS would not be performed at the same volumes throughout the year. For the 100metre sprinter, the first training period might feature ten to fifteen weeks of EMS use, but the second would likely feature less, and the third less or none at all. The first period would have more EMS both because it is simply longer and because, in the short to long program, it would be complementary to the short-distance speed work requiring at greater relative dependence on strength.

FORUM DISCUSSION FROM www.charliefrancis.com

The following questions and answers were taken from the thousands of questions and the resulting discussions posted by coaches from around the world on the Forums at charliefrancis.com. Charlie posted over 10,000 responses on various topics and chose a selection of EMS related ones to consolidate into this book. The questions and responses offer a real world look at the application of theory and the success resulting from Charlie's methods. There are vast amount of other posts on the topic and I urge you to seek them out. The only alterations you may find in the following questions and answers included in this book are grammatical as generally online posts are made without much formatting in mind. Happy reading - Angela Coon.

Question

There are many EMS unit types. Can you explain so of the basics of connecting them?

Answer

Most units now have fairly good istructions on how to set them up and use them. Much better than a few years back however they are fundamentally sold as muscle recovery untits and not strength units. The strength programs on them should be analyzed and cross referenced with what you read here.

If you don't have good instructions here are some basic checks - If you have 2 channels, stim two muscles (i.e. both hams at once with 2 pads on each [not crossing])

Check if the stim is Mono-phasic or Bi-phasic. If mono the poles won't change and you should have the negative lead on the biggest bulk of muscle (top) as the contraction is slightly stronger there. If the machine doesn't say anything, it may well be Bi-phasic (positive and negative alternate), in which case placement is the same either way.

With split leads, giving 4 pads per channel- cross over, i.e. top right to bottom left and vice verse. Ask the manufacturer about recommendations re width, but keep the rate around 80 to start and see how the contractions go. Contract isometrically with the stim as it starts up and make sure the juice is sufficient to carry the contraction beyond your voluntary capacity.

You can use 2 pads for strength building as well (you may need to go to a larger pad for better coverage. I'd use 80 for the strength building and you can pulse at a much lower rate. As for width, take it out to a number that gives you the highest contraction you can tolerate.

You can use varying pulse speeds from slower to faster, depending on its effect on you (personal preference. As for pad placement, I've provided a few diagrams, which you've no doubt seen, but you'll have to experiment a little to find the ideal individualized placement. If your unit has sufficient power, you might want to move to a split lead system, which will give you 4 pads per muscle group, in which case you can use a crossover pad setup (top left to bottom right and top right to bottom left).

Simply put, the real issue is the juice behind the contraction (you'll be the best judge of that!) and the frequency seems to be more of an issue of comfort (as long as the hertz is high enough to maintain a tetanic contraction- a series of pulses close enough together so that the athlete can't differentiate/relax between them- at least 24 for a sprinter) Most stims push for the lowest hertz possible to maintain battery life (2500htz uses up a battery 25 x faster than 100htz) though for comfort, I've found 80 to 120 work best.

Question
Does frequency dictate the type of fibre
Answer
Frequency does not dictate the type of fibre.
With sufficient intensity, current "spills over" throughout the muscle, moving from white (which is picked up first, in the reverse of the natural order) to red fibre. When using Max EMS you should contract the muscle as the contraction starts and the EMS should lift the contraction above what you could generate by yourself. The recovery pulse rate is individual but obviously must be below tetany (when the muscle can't relax between pulses) this will occur around 18 pps. Probably between 8 and 12 will work.

Question
In "Training for Speed" you said you should be laying down when doing this. I found this hard to do laying on my stomach and I felt better sitting up leaning forward a bit and when the contraction started holding my breath to try and contract the area. Is that ok to do it that way? Also in "Training for Speed" you said "EMS electrode placement on lower core (back and stomach) is such that bilateral strength imbalances are corrected (i.e. if right side of back is weaker -only that side will be stimulated)" Can you explain? And my last question is: when using EMS for max strength is it necessary to put it in pulse mode for each muscle being stimulated to warm up before doing max contractions?
Answer
1: That's fine.
2: I would stick to bi-lateral stim and leave any balance correction to an expert- it's unlikely you'd have an imbalance sufficient to present a problem anyway.
3: Once you're warm enough to start the max strength anywhere, it's fine to go straight in with max stim everywhere else.

Question
I have just bought an EMS machine but have noticed two things... It has a contraction of only 8 secs and a pause of only 25 secs... how will this effect the 10-10-50 plan that Charlie recommends? How should I adapt it to my machine's specs?
Answer
The main problem is the relaxation time at 25sec (half the usual 50sec rest), so 8 sec contraction is more than you can use unless you turn the machine on and off. I'd experiment with 6 sec contractions and see how that goes with the max relaxation time you have available. If the contractions start weakening substantially towards the 10th rep, you might:
First: Drop the number of reps to the point of drop-off
Second: Shorten the contraction period to 5 sec and adjust accordingly, if you still drop off before 10 reps.

Another possibility is to split the sessions, separated by at least 4 hrs, in any combination you want to total up to 10.

I'd set pulse mode at 1.5 sec with .5 at the max that you want. That should be pretty comfortable

Post from a Member
Charlie often refers to the state of the muscle and muscle tone or tonus. I found a great description from a book by John Jerome - The Elements of Effort: Reflections on the Art and Science of Running. It's basically a book for the recreational runner/jogger, but has some great info in it. He is a fabulous writer (he's a writer by trade, not a physiologist or sports expert) that does not get overly scientific in his writings, but is very concise with his descriptions.
Anyways, here is the quote:

"Skilled movement is possible only if the muscle can read its own state of tension: it must be informed, in contact with itself. The contact is maintained, the muscle kept at the ready -- cocked, in effect -- by muscle tone, a low level contraction maintained by signals from a neural loop call the gamma system. Keep the signal turned on and tone takes up the muscle's slack, keeping it purring away at idle, ready to respond without lurching.

Good muscle tone works as a buffer against the shock of sudden action, absorbing forces that can, over time, prove harmful to the less elastic tissue of tendons and ligaments. But it is more than a shock absorber: it is part of our very liveliness, the simple underlying tautness that keeps us quick and responsive to the world.

Of course maintaining muscle tone requires nothing more than that we continue to move."

The following is Chapter 9 from the Charlie Francis Training System which was written in 1988. I've included this as bonus material as it was the first time Charlie published anything on the use of EMS within the various aspects of training for speed and power. Some of this is repetitious as it was covered earlier in this book but there are some additional concepts and information which I know you will find useful.
Angela Coon

Electronic Muscle Stimulation (EMS)

"My own results have been so favourable that I am not interested in debating whether or not EMS works but rather in optimizing the use of EMS in the training of elite athletes."
C. Francis

Introduction
This chapter is divided into four parts: EMS in regeneration; the treatment of injuries; EMS in maximum strength training including the principles and technique of application; and periodization of EMS.
The Use of EMS in Sport
EMS has been used by athletes in former Communist block countries for sports training since the early 1950-s. while western countries have become aware of the use of EMS only in the early 1970s.
In 1973, Dr. Y. Kots of the Central Institute of Physical Culture in the USSR, presented a paper on Electronic Muscle Stimulation (EMS) at Concordia University in Montreal, outlining the tremendous potential for strength enhancement beyond that which was possible by voluntary training methods. These claims raised many eyebrows and considerable effort was expended attempting to validate Kots' claims. Crude studies pitted EMS-fired muscles against voluntarily contracted muscles, and some studies, using EMS in combination with Cybex machines, appeared to show that EMS was not as effective as Kots had indicated in producing strength gains. The design of these studies, however, was flawed due to poor understanding of how EMS works on the neuro-muscular system. An EMS stimulus fires all motor neurons in the area being stimulated. It creates an uncoordinated contraction which is isometric in nature. Kots was able to show, using a tensometric device, that the muscle tension produced by EMS is up to 30% higher than a maximal voluntary contraction. This finding was corroborated by Ikai et al (Sport Science and Sport Medicine 1967). Bigland-Ritchie el al (Clinical Science and Molecular Medicine. Vol. 57 - 1978) and others.

There is a motor learning aspect related to using EMS in the context of maximum strength work. It helps an athlete learn how to recruit and fire greater numbers of muscle fibre, for example if you are having trouble learning how to wiggle your ears - incorporate EMS stimulation of the desired muscles into your training. You will not only learn to fire the intended muscle group but also greater numbers of motor units within that muscle.

The implications of using EMS in athletic training are clear, particularly in relation to strength training. I believe that EMS helps an athlete learn how to recruit greater numbers of both red and white muscle fibres.

Given this fact EMS can help an athlete experience a training stimulus which is otherwise unattainable, or at the very least difficult to attain. It is also hypothesized that EMS creates intramuscular changes at the enzyme level (ATPase, SDH) resulting in gains in both work and In recovery capacity.

The Role of Electronic Muscle Stimulation (EMS) in the Prevention and Rehabilitation of Injuries

Injuries are often a result of imbalances of strength between extensors and flexors and between left and rigid sides of the body. In addition inappropriate strength training and incomplete recovery all predispose the athlete to injury.

It is prudent to use every possible tool to minimize the chance of injury and to enhance recovery should injury occur. A coach should be aware of the role of EMS in modern rehabilitation programs. The coach should also be aware of the risks of re-injury as a result of incomplete rehabilitation of an original injury. The use of EMS in rehabilitation is universally accepted as a technique of physiotherapy. However the time frames employed by physiotherapists are usually excessive and are not applicable to athletes.

The Role of Improved Speed and Strength in the Prevention of Injury

The athlete with higher performance capacities in speed and strength will always be able to carry out a given training task at a lower percentage of his absolute capacity than an average or incompletely trained athlete, (i.e.. if an athlete can squat 600 lb he is unlikely to be injured while squalling 400 lb).

Poor Athlete Preparation/Conditioning as a Source of Injury

Without a doubt, the leading cause of hamstring injuries, indeed all muscle injuries — is poor conditioning and incomplete preparation. Often overlooked in the search for specific injury factors and causes is the fact that the source of injury may be the training program itself.

The overall performance of the athlete and even the success of an athlete's career is directly related to injury prevention. The coach who is able to employ a sophisticated training program will reap a double benefit in terms of avoidance of injuries, and ultimate performance results.

Immediate Post Injury Application of EMS

Kots of the Soviet Union suggested that EMS could be allowed within two hours post injury. He recommended that a gentle pumping or pulsing type of EMS be accessed via an interferential electro-stimulator involving two pairs of electrodes. The electrodes are placed on the periphery of, but not directly over, the injured area. The gentle pulsing mode is applied for a period of ten minutes. After ten minutes a very gentle contraction (well below the pain threshold), is maintained for 12 seconds followed by an eight second rest interval. This procedure is repeated for another ten minute period followed by a further live minutes of EMS in the gentle pulsing mode (ie., a series of one second contractions and one second relaxations).

EMS is used in combination with elevation and compression to prevent edema (the accumulation of fluid) and the resultant swelling. This would follow the application of ice to the injured area to control inflammation and swelling.

At the outset, a careful appraisal of the circumstances of the injury is more important than the immediate post-injury physical examination. The immediate post-injury probing, in combination with any functional tests, might only exacerbate the problem and since ice/elevation/compression are called for in any case, immediate post-injury testing serves no real purpose. A clearer assessment can be made the following day. If it is suspected that the athlete has sustained a third degree strain, the application of an EMS treatment should not be used.

Prevention of Adhesions

Approximately 48 hours after a muscle-pull type injury occurs. EMS can be applied in a slow pulsing mode to provide a low level of strength exercise to the injured muscle. This helps prevent the formation of adhesions which can complicate and prolong rehabilitation. EMS provides a gentle, predictable, and fully controlled form of strength exercise which Is ideal for this purpose.

Increased Circulation (EMS and Heat Therapy)

EMS used in a pulsing mode will cause vasodilation in the area being treated. This will increase blood supply and oxygen to the area to promote healing. This is particularly valuable for treating injuries to tendons which are not naturally well supplied with blood. Soviet research has shown that EMS can increase blood flow to tendons by up to 45%. In addition EMS works well in conjunction with heat therapy.

Exercise of Non-Involved Muscles During Injury Period

One of the biggest problems presented by an injury such as a hamstring injury, is the loss of fitness it can cause. The athlete normally detrains while recuperating from injury. The problem is compounded when the athlete overextends himself/herself later on in an attempt to make up for lost time. By using EMS in it's strength building mode, the strength fitness (power and muscle cross-section) of non-injured muscle groups can be maintained during the recovery period, and thereby prevent detraining.

The rehabilitation strategy in the case of a hamstring injury is based on the fact that the level of hamstring involvement in running is directly related to the speed attained. During a smooth acceleration (which in itself is a recovery cue), the distance over which the athlete can continue to accelerate, from the standing start, will predict accurately the final speed. Improved accelerations, both in terms of smoothness and total distance, then determine the recovery status.

Running speed is determined by the distance over which the athlete is able to accelerate. From this data any speed deficit can be determined which in turn gives rehabilitation status.

Once top speed for that workout is reached, the athlete can then maintain that speed for the desired training distance. Since this procedure requires confidence on the part of the athlete, he should be taught these procedures as part of his regular training when he Is healthy to facilitate the same procedure when he is injured. The athlete begins with ten metre accelerations and proceeds to increase the distance by two to five meter Increments. Tape marks must always be used and the athlete must always start from a standing position.

Regeneration Enhancement with EMS

The use of Electronic Muscle Stimulation (EMS) to aid recovery/regeneration is a relatively new technique, although similar modes such as interferential electro-stimulation have been used for some time. For example, interferential electro-stimulation involves the use of one pair of positive electrodes and one pair of negative electrodes. The area of the body to be stimulated is then bounded by the four electrodes.

The action of the EMS is to stimulate circulation and promote relaxation with a rhythmic pulsing action. The key areas of focus are the feet, calves, and upper thighs. During the treatment the athlete should be lying down with the feet slightly elevated above the head. For best results a quiet, calm environment should be maintained.

Pulse cycle consists of a one-second contraction during which blood is forced or pumped out of the muscle, followed by a one second relaxation during which fresh blood enters the muscle. The intensity of the pulse should be adjusted to personal preference. This treatment should be used anytime accelerated recovery from a workload is required and massage is not available.

During and following intense exercise, individual muscle fibres swell with fatigue by products and remain in an excited state for a few hours after the cessation of exercise. These by-products must be transported out of the muscles before the circulatory system can transport nutrients into the muscles to initiate the recovery cycle. This is why recovery lends to be slower in the early stages of the recovery cycle and faster later on. EMS, when used in its pulsing mode, particularly during the delay phase of adaptation increases blood flow and lymphatic drainage. The 'EMS massage' can reduce the delay period and speed up the onset of recovery and the subsequent overcompensation process.

Manual massage has long been used for accomplishing this task. However, when dealing with large numbers of athletes — particularly in a team setting, manual massage may be unavailable. EMS then is the next best alternative therapy. To facilitate optimal recovery both EMS and massage should both be used in conjunction with a range of other regeneration techniques such as sauna/shower/contrast baths and hot wax.

EMS — Training of Strength and Explosive Power

Tremendous improvements in strength are reported to have been achieved when EMS was added to the strength building regimes of Soviet weightlifters and throwers. Kots of the USSR reported strength gains after 10-15 treatments of up to 30% in a period of three weeks. This is remarkable because these athletes had already been doing everything possible to be as strong as possible.

Maximum strength gains are usually achieved after 10-15 treatments and there is no advantage to going beyond 10-15 treatments. These strength gains are not accompanied by increases in muscle mass or cross-section. This characteristic is consistent with CNS related strength training such as maximum weight methods, eccentric methods, and plyometrics.

EMS - Training of Speed

It has always been assumed that two unalterable factors determined an individual's ultimate capacity to run fast:

1. A high inherited ratio of fast twitch (explosive) muscle fibres to slow twitch (endurance) muscle fibres.
2. Different mounting points for the muscles on to bones providing different mechanical advantages (there is individual variation in tendon attachment distance from the joint fulcrum, resulting in varying lengths of lever arms and of resulting mechanical advantage. Larger distance equals larger mechanical advantage).

Electronic Muscle Stimulation (EMS) preferentially contracts white fibre before red fibre, which is opposite to the natural recruitment order of the body. Kots described a significant reduction of the time necessary to achieve 100% tension within the muscle after 10 to

15 treatments with EMS. Similar results were found by Dr. Ianuzzo of York University in Toronto (Journal of the Canadian Athletic Therapists Association . Vol. 7. No. 1 Issue 24. Mar 1970). Fast twitch fibres generally reach maximum tension in 20 milli seconds and slow twitch fibres in 65 milli seconds. Ianuzzo states that the speed of contraction of slow twitch fibres can be improved with systematic EMS training (principle of 'adaptation to demand'). The implication is that EMS training improves the rate of force development (i.e. power), in a contracting muscle beyond that which is possible by any other means. (Note: This would explain gains in power without gain in muscle sizel.

The Use of EMS in Training Hamstrings/Ankle/Abdominal Strength

Function of the Hamstring Muscle

The hamstring muscles are the most vulnerable to injury. This vulnerability warrants an understanding of how the hamstring muscles function. In running, this may help clarify how injury can occur, and why there is some confusion as to the mechanism of hamstring injury.

Multiple Roles of the Hamstrings

The hamstrings function as a primary flexor of the knee joint as well as an extensor of the hip. In view of the dual role of the hamstrings and the tremendous rapidity with which muscle contraction takes place, the need for implementing correct running technique at high speed is obvious. Any disruption in technique can have disastrous consequences. The coach should keep this in mind when confronted by an athlete who is constantly injured in the hamstrings despite all preventative and therapeutic regimes. The hamstrings of this athlete may have been trained only for knee flexion and not hip extension.

Insufficient Hamstring Strength Relative to Quadriceps

It is well known that an imbalance between hamstrings and quadriceps strength is a leading cause of hamstring injury. In running, during the support phase the hamstrings and quadriceps contract simultaneously to maintain the knee position. If one force is greater than the other and external resistance is maintained, something must give. In most cases it is the hamstrings. Traditionally, the strength ratio between quadriceps and hamstrings has been assumed to be about 60/40. However additional research has put these findings in doubt. An informal strength assessment of the six leading sprinters in Canada (all world ranked), done at Bishops University in 1982, showed that in all cases, when tested at high velocities on the Cybex, the hamstrings actually exceeded the quadriceps in producing power. Results ranged from 100% to 130% of quadriceps power at the highest test speed. This very informal look at Canadian sprinters seems to confirm the study on 1972 Olympic Champion Valery Borzov done in the USSR. This suggests that, since the hamstrings tend to have a higher ratio of fast-twitch fibre than the quadriceps, then as contraction velocity increases the strength ratio will increase in favour of the hamstrings. Further, a balance must be achieved between the hamstrings of the left and right leg. This is difficult to achieve with traditional strength building techniques because, generally, both legs are involved in the exercise simultaneously. Strength levels are improved in both legs but the percentage imbalance can remain unchanged. In general a 10% difference in strength between the left and right legs is considered significant. Electronic Muscle Stimulation is extremely effective in correcting strength imbalances because of its great strength-building potential and the fact that It is applied specifically to deficient muscle groups.

Insufficient Strength and Endurance Qualities in Related Muscle Groups

Ankle Strength

Electromyography has demonstrated that, during the running stride, most of the absorption of force at the point of ground contact is accomplished during a slight dorsiflexion at the ankle joint. This knowledge has resulted in a great deal of emphasis being placed on the development of foot and ankle strength. Foot strength is difficult to develop through traditional strength training methods; EMS is used, in this area, particularly by the Soviets.

Abdominal Strength

In sprinting, abdominal strength is critical to success. If the abdominals fail in the late stages of a race the athlete will begin to lean back, in an attempt to maintain knee lift. This backward lean causes the foot strike to occur loo far ahead of the center of gravity. This results in deceleration and overstress of the hamstrings, potentially leading to injury. Strength and endurance In the abdominal muscles can be developed relatively quickly with EMS.

Planning and Periodization of EMS into a Modern Training Program

Since EMS can influence so many training components, it should be introduced into the training program very early so that the development of adequate strength and power always precedes the performance of all other training components.

If an athlete cannot attend all training camps and if they train for periods of time away from coach supervision, it may be advisable for them to consider the use of EMS. A muscle stimulator which is portable, simple to use by the athlete, and relatively inexpensive, is required.

Periodization of EMS

The partial season graph (see figure 4-3. Chapter 4), shows how the individual components of a training program fit together with EMS. When strength and power are key elements of performance even shorter cycling periods should be used - cycles as short as three weeks operating on a loading principle of 80% in first week, 100% in second week and 60% unloading in the third week in terms of workload (volume) capacity. Note how explosive power work is increased at the end of each EMS treatment series to compensate for the overall reduction in CNS work. (ie. as the EMS work ends, explosive power work is increased to maintain a consistent overall volume of CNS related work).

Each component, if introduced in isolation, will cause stiffness in the initial stage but when introduced in combination with other components, the athletes can move from one training element to another without experiencing stiffness. Each component prepares the body to handle the next. In designing the training plan the coach should realize that the EMS component works primarily to enhance the qualities of speed/strength and speed endurance. Once the overall approach to training has been mapped out. the composition of the individual EMS phases can be planned.

Kots (USSR) indicates the following guidelines for EMS use:

1. Speed Enhancement — 10 -15 treatments
2. Strength Development — 20-25 treatments
3. Strength Endurance — more than 25 treatments

However my own experience indicates that 10-15 treatments of EMS are optimal for both Speed Enhancement and Strength Development. In deciding on the number of treatments to use in a given EMS series — one must consider the training phase and time available within that phase. One should also keep in mind that best results are obtained with shorter EMS phases applied more often in the year.

It should be noted that the training gains from EMS are rapid in the beginning of the series and slower towards the end. This would indicate that the training returns from a series of more than 25 treatments would be marginal. A consolidation period of between two and four weeks should be allowed between treatment series.

Single EMS Session Characteristics

When used for training purposes as opposed to rehabilitation each EMS treatment for each muscle group involved in the EMS session should consist often repetitions of:

10 second stimulation (maximal contraction) followed by 50 second rest: The rest period must never be shortened - this reduces the effectiveness. Note also that no more than ten contractions (repetitions) should be administered to any one muscle group within a 24 hour period.

In sprint training we target the following muscle groups:

* Lower Back 10 repetitions of EMS
* Abdominals 10 repetitions of EMS
* Quadriceps 10 repetitions of EMS
* Hamstrings 10 repetitions of EMS
* Gluteals 10 repetitions of EMS
* Feet 10 repetitions of EMS

It is of critical importance that any time the quadriceps (front thigh) are stimulated, the hamstrings (rear thigh) must also be treated in order to avoid (or correct) a quadriceps/hamstring imbalance which can lead to injury. The lower back, abdominal, and leg muscle groups are treated while the athlete is lying down with legs extended.

Optimal sites for pad placement will vary between individuals and some experimentation will be needed. Furthermore, the athletes being treated should always be in control and set the intensity levels themselves: the electric current required for a maximum contraction can vary greatly among athletes so the coach should be careful not to push the athlete to use an intensity which the athlete is not prepared for. An athlete's tolerance and comfort will almost always improve dramatically after the first week of treatment. Just as with the onset of weight training the athlete may experience some soreness and stiffness initially with EMS but this will diminish as the treatment series continues.

With the advent of multi-pad machines, more than one muscle group can be stimulated at the same time. This greatly reduces treatment time, however the extensor and flexor of a given joint should never be stimulated at the same time.

Example Microcycle (week)

In a given microcycle, high intensity work is separated by at least one day of rest. EMS should be done three or four times per week, generally on the same days when high intensity power work is done. The microcycle illustrated would be typical of a general preparation period.

The one day separation between speed work and speed endurance work allows for the recovery of the central nervous system. Any departure from this general principle will eventually lead to diminished performance gains and result in 'overtraining.'
By itself EMS treatments, since they act on the muscle motor points directly and. bypasses the normal pattern of activation of the Central Nervous System (CNS), could be used every day; but, to adhere to the variety principle they are periodized over the week or microcycle. Four EMS sessions per week are possible. If three sessions per week were used, then they would occur on Monday. Wednesday and Saturday. For best results EMS should be used at the end of the day, no sooner than 2 hours after the last workout.
As with any other type of exercise an EMS treatment should be preceded by a warm up. The skin must be clean and free from oils to allow for good conduction of current through the skin to the target muscle. A warm bath or shower will warm the muscles as well as clean the skin. This should be followed by a short period of relaxed stretching and a few calisthenics exercises to complete the pre-EMS warm up.
Supercompensation
Supercompensation is the desired result which caps the 'stimulus — recovery — supercompensation' training cycle and on the basis of which all training and performance improvement occurs. In effect 'supercompensation' is the amplified rebound response of an organism to an environmental stressor.
When work is performed the body is fatigued as a result. At the end of a training session the body responds by attempting to restore itself to it's pre-workout level. As the body regenerates, it's capacity not only reaches the pre-workout level but rebounds above its pre-workout level temporarily, and if no further training stimulus is applied, will return to normal. At this point it should be noted that the Central Nervous System takes longer to recover than the peripheral musculature and different individuals recover at different rates. Muscles will generally recover within 24 hours while the Central Nervous System requires 48 hours or longer to recover after high intensity work. After particularly demanding high intensity work the CNS can require up to 2 days and even longer to regenerate fully. It is not always possible to adjust workouts to accommodate this fact, especially in team training situations where high stress tasks must be carried out at the same time with many athletes. The first adjustment which should be made is to apply Central Nervous System stressing activities very sparingly whenever possible, to compensate for the high stress tasks which cannot be avoided.
Since Electronic Muscle Stimulation bypasses the Central Nervous System, the use of EMS to replace or partially replace heavy weights during a competitive phase is a very effective way of reducing CNS stress. During the competitive phase, four to six contractions per muscle group would be sufficient to maintain strength.
In addition, the training gains made earlier in the program through the use of EMS can change the perceived effort of a given task from high stress to medium stress.
Q & A
Question: What is the place of electro-stimulation in the recovery process?
Answer: For recovery you are using a short duration pulsing type of stimulus one second as opposed to the ten second contractions you would use for strength development.
Question: Is it the pumping or pulsating action which facilitates recovery?
Answer: Yes. EMS can function as a form of massage or it can function by stimulating certain nerve points to release hard contracted muscle or muscle spasm. There are many different ways in which it can be used, depending on the expertise of the person that is using it.
Question: Do you use the same device for recovery/regeneration as you do for maximum strength?
Answer: You can use any EMS machine and convert it, provided it has a small enough contact point to hit the sites that you select. When you are targeting nerves you use the smaller pads, to stimulate a smaller area. It depends on what you want to accomplish — there is a wide variety of uses.
EMS has been used within the Eastern Block countries since the 1950's but is still considered novel in the West. Similar in theory to acupuncture, EMS can isolate the tiniest nerve point for a wide range of effects. It can relieve pain, reduce swelling and increase circulation to the treated muscles thereby hastening recovery from injury or fatigue.
Question: Can EMS be sell-administered or does it have to be administered by a professional?
Answer: When you need to stimulate specific motor points, then it's much more difficult for the athlete to do the therapy. But when using EMS for recovery purposes the athletes can operate the stimulator themselves.
Question: Would EMS be applied before competition?
Answer: Muscle stimulation wouldn't be used before competition in the strength mode but in the ease of injury it could be used in a pulsing mode for a massaging effect.
Question: What place does EMS have in strength training?

Answer: EMS can be used as an adjunct to weight-lifting and other strength work. EMS can also be used to improve an athlete's explosive power.
Question: Can you elaborate on the difference in recruitment order during an EMS contraction as compared to a voluntary contraction.
Answer: EMS recruits white muscle fibre preferentially before recruiting red fibre. During a voluntary contraction it is just the opposite — red muscle fibre is recruited initially because it is more efficient but as the intensity of contraction increases white fibre is fired.
In young athletes you also are training the transitional fibre to take on the firing characteristics of while muscle fibre because of the nature of the EMS stimulus. I also believe that regular use of EMS will shorten the time required by the muscle to achieve maximum tension. Generally white fibre requires 20 milli seconds and red fibre 65 milli-seconds. I think EMS promotes a shortening of contraction time in the red fibre as well,
Question: Your periodization model illustrates that you apply EMS in conjunction with a maximum strength phase of training. Do you use any EMS repetition configurations with EMS other than 10-15 repetitions?
Answer: No. We have tried different configurations earlier but we don't go beyond 10 15 treatments anymore. It seems that maximum power gains are made in this range. Again though, sometimes individual adjustments have to be made.
Question: What is the place of EMS in strength maintenance?
Answer: Sometimes the athletes do not have access to strength training apparatus or weights when they are off shore. In this situation they may resort to brief sessions of EMS. A graphic example of the value of EMS in preventing detraining occurred with Molly Killlngbeck. She sprained her ankle severely and couldn't run at all in December of 1981. She was placed on muscle stimulation exclusively for almost 3 weeks. She could only do calisthenics and muscle stimulation — no running whatsoever. She was back in form two days after beginning to run again. She ran the fastest time in the world for the year 1981 in the 400 metres. I found that pretty interesting that she was able to prevent detraining with EMS for that period of time and achieve a personal best immediately after.
Question: When in the course of a day's workout do you schedule EMS work?
Answer: EMS work is always done at the end of the day, after all skill related work is completed. It can be done by the athlete before going to bed. According to Waldemar, an EMS session is never followed by massage. The massage is usually done the next day.
Question: How difficult is it to use the EMS device?
Answer: The device we use is a 'Powerstim" unit which is very easy to use. It is equipped with four sets of two pads so that the pads can be moved from muscle group to muscle group quickly. It takes 10 to 15 minutes to work each muscle group. This consists of one set of 10 x 10 second contractions interspersed by 50 second rest intervals.
The muscle groups normally exercised with EMS are the hamstrings, the quadriceps, the gluteus, sometimes the soles of the feet, and the lower back and abdominals.
Question: How is EMS used to strength train the feet?
Answer: Foot strength is very important. When you can hear the feet smacking down on the running surface - this is an indication of weak feet. You have to be careful however, because the same sound can indicate not only weak feet but also that the foot is spending more time on the ground due to fatigue.
EMS is one of the few options I know of for dealing with weak feet. Running in bare feet on grass is another. There are other ways of strengthening feet such as rolling a towel up with your toes and this kind of thing. But most certainly EMS is a very effective and easy method of dealing with the problem. You stand on the EMS pads with one contact pad at the front and one at the back of the foot. That way you prevent the foot from rolling up into a cramp. The athlete stands on the pads for the duration of the EMS treatment.
Question: What is the specific muscular effect on the foot as a result of EMS work?
Answer: The effect is directed at the muscle action of the toes and the musculature which supports the arch. The performance result is that a stronger foot spends less time absorbing shock when it contacts the ground and is thus able to transmit force against the ground more efficiently (i.e. run over the ground not on it|.
Question: Would you say that the training effects differ between maximum strength work and EMS work?
Answer: It is not so much that the effects are different as that with the combination of the two methods, the cumulative CNS cost of a given training session is lower than it would have been had you applied the same total stimulus through maximum weight-lifting methods alone.
With weights there is a crossover effect of strength from the exercising limbs to the non-exercising limbs. For example, when you work the left side of the body you have a crossover strength effect to the right side of the body. When you use EMS you focus only on the target muscle(s) and there is no cross-over effect impacting on the entire organism.
Question: How important is EMS as a recovery/regeneration option?

Answer: It is another regeneration option but where it has particular value is to complement the work limitations of a massage therapist. We have a full time massage therapist but he can massage only so many bodies in a given day. The athlete has another option through using the EMS in a pulsing mode. For athletes who have no massage therapist, or very limited access to massage, the regenerative capability of EMS provides an adequate alternative.