FOOTBALL FITNESS

how to train to win

FOOTBALL FITNESS

how to train to win

FOOTBALL FITNESS

how to train to win

A CIP catalogue record for this book is available from the British Library.

Printed by: Peach Print Limited
Impressions House, 3-7 Mowlem Street, London E2 9HE

Published by P2P Publishing Ltd

Registered office: 33-41 Dallington, London, EC1V 0BB
Tel: 0845 450 6402 Registered number: 06014651

ISBN: 978-1-905096-80-0

Publisher Jonathan A. Pye
Editor Andrew Hamilton
Designer Lorraine Gourlay

OTHER TITLES IN THE PEAK PERFORMANCE SPECIAL REPORT SERIES

ACHILLES TENDINITIS – PREVENTION AND TREATMENT
CARBO LOADING – FOR THAT EXTRA EDGE
COACHING YOUNG ATHLETES
CREATINE – CUTTING THROUGH THE MYTHS
DYNAMIC STRENGTH TRAINING FOR SWIMMERS
TRAINING FOR MASTER ATHLETES
FEMALE ATHLETES – TRAINING FOR SUCCESS
SHOULDER INJURIES – PREVENTION AND TREATMENT
MARATHON TRAINING – FOR YOUR PERSONAL BEST
NUTRITIONAL SUPPLEMENTS – BOOSTING YOUR PERFORMANCE
SPORTS PSYCHOLOGY – THE WILL TO WIN
TRAINING FOR SPEED, POWER & STRENGTH
ALL WEATHER TRAINING – BEATING THE ELEMENTS
BODY FUEL – FOOD FOR SPORT
TRAINING FOR ENDURANCE
FOOTBALL PERFORMANCE – HOW TO RAISE YOUR GAME
TRAINING FOR RUGBY
TRAINING FOR CYCLING
RESISTANCE TRAINING – THE NEXT LEVEL
CORE STABILITY – INJURY FREE PERFORMANCE
TRAINING FOR ROWING
SPORTS PSYCHOLOGY II – THINK YOUR WAY TO SUCCESS
ANTIOXIDANTS – TRAIN LONGER, TRAIN HARDER
TRAINING FOR TRIATHLON
FOOTBALL PERFORMANCE II – NEW GOALS FOR SUCCESS
TRAINING FOR DISTANCE RUNNING
KNEE PAIN – PREVENTION AND TREATMENT
HYDRATION – FOR OPTIMAL SPORTS PERFORMANCE
TRAINING FOR TENNIS
RUNNING INJURIES – PREVENTION AND TREATMENT

The above reports are available at a cost of £29.99 each from Peak Performance (S/R), 33-41 Dallington Street, London, EC1V 0BB. Cheques should be made payable to Peak Performance.

Contributors

Andrew Hamilton BSc Hons, MRSC, ACSM is a member of the Royal Society of Chemistry, the American College of Sports Medicine and a consultant to the fitness industry, specialising in sport and performance nutrition

John Shepherd MA is a specialist health, sport and fitness writer and a former international long jumper

James Marshall MSc, CSCS, ACSM/HFI, runs Excelsior, a sports training company

Nick Grantham is a strength and conditioning coach who has worked with elite athletes for the past 10 years. He now heads up the strength and conditioning team at GENR8 Fitness

Alison McConnell is currently professor of applied physiology at Brunel University. Her research interests are in respiratory limitations to exercise performance

Andy Lane is professor of sport and learning at the University of Wolverhampton

Ulrik Larsen BPhtyMAPA is an APA sports physiotherapist and clinical Pilates consultant specialising in rehabilitation of sports injury

Jim Petruzzi is a performance coach, specialising in sports science and sports psychology, who works with several professional football clubs and international teams

David Joyce BPhty (hons), MPhty (Sports), CSCS is a sports physiotherapist at Blackburn Rovers FC. He has previously worked in Olympic sports and in professional rugby union. He teaches on the postgraduate masters in sports physiotherapy at the University of Bath, UK

CONTENTS

From player to athlete

Once upon a time, plenty of natural talent laced with a splash of dazzling skill was all that was needed to propel a footballer to the top. But in the 21st Century, the beautiful game, while still beautiful, demands that its participants are not just football players, but athletes too, possessing oodles of strength, speed, power and stamina!

In this special report on football, we look at the very latest scientific findings on football conditioning for any footballer seeking that winning edge, whatever the level of competition. The information inside explains how to put together the most advanced conditioning programme possible and also how footballers can develop performance-enhancing speed, strength and injury resistance. In addition, we lift the lid on how the world's best coaches prepare their teams for tournament football and manage that all-important post-match recovery, which is so essential for all footballers that play regularly.

The world's greatest footballer Pelé was once quoted as saying: "If you fail to prepare, you must prepare to fail." Even back then, Pele realised just how important training and conditioning is for footballing success. The good news is that 21st Century sports science is showing exactly how footballers should condition themselves for maximum performance, so read this report and prepare for success!

Andrew Hamilton BSc Hons MRSC

Stay on the ball – a scientific approach to football conditioning

At a Glance

- The physical requirements of playing football are outlined;
- The role of testing physical performance in players is discussed;
- Training protocols to improve performance and prevent in-season detraining are suggested.

Pre match warm-up drills and exercises are a commonplace sight in football but are these drills making the footballers better at what they do, or are coaches merely replicating past practice or advocating what they did as a player years ago? More generally, do the technical training and exercise routines reduce the risk of injury and enhance the players' performance on the field, and can they be made better? *James Marshall* investigates

Football players have to perform repeated sprints throughout the match. Fitter players will be able to perform these sprints for longer. A less fit player may be faster, but won't be able to produce that speed when it counts – for example during the last 10 minutes of each half or in injury time.

Research on professional women football players in the USA compared their performance in matches to that of good players (but not professional or internationals) in the Danish and Swedish leagues and found that the work rate was much higher in the professional players, who covered 33% more distance in their hardest five minutes of a match than the 'good' players (1).

However, it was interesting to see that following this burst, the next five minutes resulted in a 17% below average work rate, showing that it is impossible to maintain the absolute top work rates. The professionals also ran at top speeds for 28% longer over the match than the 'good' players, covering 1.68km compared to 1.33km. The overall distance covered was between 9-11km with over 1,300 changes in activity in the match – an average of one change every 4 seconds!

There was also a difference in activity levels between the positions for both groups, with defenders performing fewer sprints than midfielders and attackers and also fewer intervals of high intensity running overall. Fatigue had an effect on both groups, with the professionals running 25-27% less at high intensity in the last 15 minutes of the game compared to the previous five 15-minute intervals. The 'good' players performed less work in the last 15 minutes of both halves compared to the previous 30 minutes, highlighting the difference between activity levels of merely good amateur players and professionals.

'Some researchers are now trying to integrate skill work into the fitness tests to try and separate the different levels of ability more accurately'

Testing

Having assessed the levels of activity required in football, how do we know if players are fit enough to play at the highest level? Any test has to be able to measure a fitness parameter that is used in football, and also to distinguish between good and very good players. These fitness tests may be useful to see if the player is fit enough but lacks skill, or is skilful in training but lacks the ability to produce that consistently throughout the game.

Some researchers are now trying to integrate skill work into the fitness tests to try and separate the different levels of ability more accurately. The advantage of this is that it becomes more specific to football; the disadvantage is that when you are testing more than one variable at once, it is harder to discern which is the weakest point that needs to be trained – skill or fitness.

One group of Serbian researchers used a zigzag run test without a ball and then one when dribbling a ball [3]. The course was series of four 5-metre sections set out at 100-degree angles (*see figure 1 overleaf*). The smaller the gap between the two times indicated a higher level of skill and was known as the 'skill index'. This allows the testers to identify the quick players with the ball, and then see whether less quick players need to work on speed, or skill level.

Training speed or agility

It's quite common to see football coaches do generic speed or agility work using various pieces of equipment on the ground as aids to their training. However, whether this works or not is debatable; it looks good, it's easy to do, but is it transferable to the sport of football itself?

The problem is that most agility tests identify how quick a player moves around obstacles or between two or three

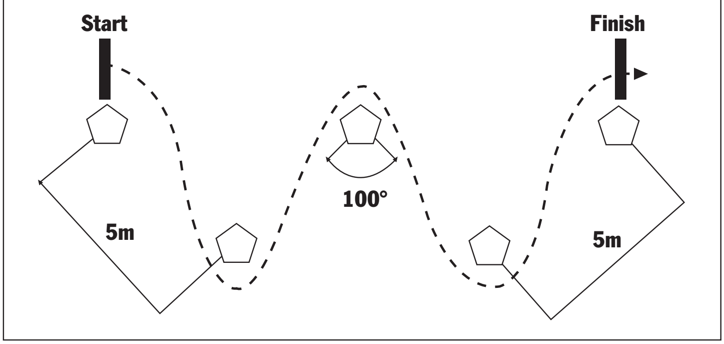
Small-sided games

Small-sided games are often used in training as an efficient way of working on fitness and simultaneously. These consist of games of two versus two, three versus three and so on in a half or quarter-sized pitch that requires all players to work almost continuously throughout the duration of the session. The coach can adjust the game to make it more accurately replicate the demands of matches themselves. But, do they actually allow for maximal bursts of activity in a limited space?

A study compared the training activity profiles of elite women football players and also their domestic and international matches [2]. While the work-to-rest ratios were very similar, the composition of the activities was different. Matches usually had a period of up to four seconds of high intensity activity (defined as sprinting, striding or high intensity running) followed by 44-64 seconds of low intensity activity (defined as standing, walking or jogging). This equated to work:rest ratios of 1:13 for attackers, 1:10 for midfielders, and 1:15 for defenders.

In international matches, however, there were more episodes of repeated sprints than in domestic competition and training. The average player had performed 4.8 repeated sprints in international games, with each sprint averaging 2.1 seconds and with 5.8 seconds of active recovery between the sprints. This type of repeated sprint activity wasn't found in the small-sided games in training, so clearly they were not helping to prepare the players as well for international matches as for domestic matches.

Figure 1:
Schematic representation of the 'zigzag test'



different cones. They don't identify how a player reacts to a stimulus that actually occurs in the game. A good tennis player therefore may do well on a football agility test, but that doesn't mean he can play football!

To illustrate this, researchers looked at speed and agility for six random intermittent dynamic type sports: football, field hockey, rugby, basketball, tennis and netball [4]. They tested players before and after three training protocols using the **T-Test**, a 15-metre sprint, a **countermovement jump** and a dynamic balance test.

The training protocols used were based on either programmed agility movements, random agility movements in the form of small-sided games or a control group with no conditioning. The programmed group was further split into two subgroups, with one subgroup using specialised equipment while the other didn't (*see box 1*). The trials ran over six weeks with training being split into two separate 60-minute sessions a week, including a 15-minute warm up.

The subjects involved in this study were untrained, so the results may not be transferable to trained athletes. Both training groups improved their performance over the six weeks, with the programmed group improving more than the random group. There was no difference within the programmed group between subjects who used equipment and those who didn't.

Box 1: Training protocols for week 1 drills in agility movement study – random vs programmed with and without equipment (4)

Programmed with equipment

6 x 6 inch hurdles:

- Walk throughs – walk over the hurdles one leg going over each hurdle while the supporting leg is placed to the side of the hurdle; repeat on other side
- Run throughs – same but running
- Lateral run throughs – same but going sideways
- Bunny hops

Ladder drills:

- Lateral bunny hops
- Fast foot ladder
- One foot per square run – go through the ladder placing one foot in each square
- Miss a square run – same but longer strides missing a square in between
- Hopscotch
- Bunny hops
- Lateral two feet per square run – going sideways place two feet in each square

Programmed without equipment

7-metre length:

- Walk, high knees
- Run, high knees
- Lateral, high knees (running sideways with knees coming level with your hips)
- Bunny hops
- Lateral bunny hops

5-metre length:

- Fast feet run
- Burning coal run
- Bunny hops
- Lateral fast feet

Random agility

- Two 20-minute matches
- 5-minute rest interval
- Rotate goalkeeper every 4 minutes
- Ball to be kept on the ground
- No player to enter goalkeeper area (5m radius from centre of goal)

The important findings are that the use of equipment makes no difference in improving agility; it is the quality and design of the drills that are more important. This has financial implications for small clubs because most of the specialised equipment is quite expensive.

Table 1: Training schedule for Texas A & M football team

	Monday	Tuesday	Wednesday	Thursday	Friday
Summer (10 weeks)	L S C	A	L S C	A	L C
In-season (15 weeks)	L C	C	L C	OFF	OFF
Spring (12 weeks)	L S	OFF	L S A	L A C	OFF
L= Lifting; S = Sprinting; C = Cardiovascular Conditioning; A= Agility; OFF= no training					

As well as the subjects being untrained (where any type of training will normally lead to an improvement) another limitation of this study was that the tests themselves were programmed tests – *ie* the subjects knew exactly where to go and in what order, so programmed conditioning may well be more suitable for doing better at these tests. Moreover, the group who played the games were also improving their ball skills and game awareness concurrently, and this was not measured.

One study that did look at trained professional football players used either strength or strength and plyometric training plan to improve sprint and jump performance over seven weeks(5). One group of players performed the strength-only sessions, which consisted of half squats performed at 4-6RM (the maximum amount of weight that could be lifted safely either four, five or six times) for three to five sets. The other group completed the same strength sessions but also performed various plyometric exercises such as leg bounds and hurdle jumps.

Both groups improved their leg strength and their sprint and jump performances. The rationale behind the study was that strength training has been shown to improve high force, but not necessarily high velocity. The plyometrics were designed as part of a power programme to help improve force production at speed, which translates into linear sprint speed and vertical jump ability. The authors concluded that players who were also doing football specific training sessions gained no further benefits by performing additional plyometric work – possibly because the football training sessions were already specific enough to aid in increasing the rate of force development.

Pre-season conditioning

Most studies done on football players conditioning are short in nature, normally six to eight weeks, because there's only limited time available to implement new tests and protocols out of season. However, the longer-term effects of training plans and protocols will differ as players continue to adapt. Similarly, if some maintenance work is not done each week, the effects of a pre-season training programme may not last beyond Christmas.

Footballers often talk about being 'match fit' but that maybe should read 'match fat' as evidence shows that just training and playing football may result in greater body fat levels at the end of the season than at the beginning (6)! The same trend has also been demonstrated in rugby league players who recorded increased fat and reduced aerobic and muscular power at the end of the season compared to the beginning (7).

A study carried out at Texas A&M University looked at a female varsity football team and measures of VO_2max, body mass and body fat % through a one-year cycle (8). Despite their season only being 15 weeks long, the players' average VO_2max decreased from just over 49mls/kg/min to 44.9mls/kg/min while body fat increased from 15.7% to 18.8 %!

The difference in the training schedule from pre-season to in-season to off-season can be seen in table 1. The main difference was the elimination of the high-intensity speed sessions during the season and also the reduction of weightlifting volume by 35%, with no increase in load. The emphasis during the season was on maintaining the cardiovascular workouts (presumably to maintain VO_2max and keep body fat in check) but these did not have the desired effect.

Maybe the coaches believed that matches and cardiovascular training sessions would be enough to maintain fitness. However, as we saw in the study of small-sided games (2), while matches and cardiovascular training can have many benefits, the necessary high-intensity work to maintain peak performance may be missing. By dropping the volume of weight

Jargon buster

T-Test
An agility test that requires an athlete to run forward, sideways and backwards on a set course in as quick a time as possible

Countermovement jump
Where the jumper starts from an upright standing position, makes a preliminary downward movement by flexing at the knees and hips, then immediately extends the knees and hips again to jump vertically up off the ground

‘Footballers often talk about being “match fit” but that maybe should read “match fat”’

lifting and eliminating the high-intensity speed workouts, the players effectively became detrained as the season went on.

Although there are no comparable studies in elite footballers, extrapolating these results to a typical European season (which lasts over twice as long) suggests that in-season detraining may be even more of a problem. Indeed, this effect has been observed in a longer season in junior reserve team players (10 to 14 year olds) who gained fat and were slower at the end of the season than the start [8]. Caution is needed when looking at data in this age group as maturation levels play a big part in changing physiology, but the decline in performance can be linked to lack of an in-season training plan.

Take home message

So how do you plan your training programme? Time is a factor and part-time clubs obviously have less. I would recommend the warm-up as the ideal place to work on the technical aspects of agility, rather than the standard jog around the pitch. Also, the agility drills must replicate the movement patterns of football, and not just be comprised of equipment obstacle courses that distract from the purpose of training. Here are some tips:

- A combination of programmed and unprogrammed agility sessions, leading into small-sided games will give players a sound aerobic base and incorporate skill work;
- These should be combined with higher intensity quality work for speed and also anaerobic power;
- Weight training should be conducted in the off-season with squats being a key lift, to develop lower body power and speed;
- In-season work should also incorporate shorter sessions of weight training and sprints, but with high levels of intensity.

Coaches and researchers often have a particular approach, which they firmly believe in and will often go to great lengths to prove or justify these beliefs. However, it seems that all aspects of training can work to some extent, but also have their flaws, and that detraining is a common factor during the season. It is therefore important to vary the types of training to prevent staleness and also to maintain intensity and quality work throughout the season. This will ensure that the players are as fit at the end of the season as they were at the beginning.

References

1. JSCR, 22 (2), 341-349 (2008)
2. JSCR, 22 (2) 543-552 (2008)
3. JSCR 22 (4), 1046-1050 (2008)
4. JSCR, 21 (4), 1093-1100 (2007)
5. JSCR 22 (3), 773-780 (2008)
6. JSCR, 21 (1), 48-51 (2007)
7. JSCR, 22(4), 1308-1314 (2008)
8. JSCR 19 (2), 400-408 (2005)

From footballer to athlete: the science of muscular conditioning

At a Glance

- Explains the muscular requirements of strength and conditioning for footballers;
- Shows how recent advances in exercise boichemistry have provided us with a better understanding of how footballers should train

The training demands on top soccer players can undermine their athletic fitness. *David Joyce* explains why, and how to train to win.

In the run-up to a major tournament such as the World or European Cup, the focus of attention is inevitably drawn to the most popular game on the planet and its glamorous top tier of players. However, these tournaments also showcase the increasing tendency of managers to seek out true athletes for their squads.

Modern soccer requires its most successful players to be athletic 'allrounders', with excellent muscular endurance, so they can sprint, jump, shoot and tackle for the full 90 or even 120 minutes; and excellent strength,in order to be able to perform at a high level and avoid injury.

Success as a professional soccer player is predicated upon a vast array of physical, technical and tactical abilities. Optimal physical attributes do vary by player position (a goalkeeper needs less muscular endurance than a midfield player, for instance), but all need excellent baseline muscular and cardiovascular endurance; the ability to accelerate rapidly and jump well is a distinct advantage. Muscular endurance, trunk and lower limb strength and power will all figure prominently in how far any soccer player can go at elite level.

The type of training required to achieve muscular strength is, however, quite different from that needed for endurance. In fact, many studies have concluded that they may be mutually exclusive: that if both training regimes are undertaken concurrently, endurance training actually 'interferes' with the strength gains of resistance training[1]. This theory of concurrent training was first published in scientific literature by Dr Robert Hickson in 1980, and three decades on it remains a controversial subject.

To this day, the holy grail of sports conditioning is to be able to understand the interference effect, and manipulate training variables to minimise (if not negate) its influence. But clinicians, too, have responsibilities to get it right on this issue, particularly in end-stage rehabilitation, when the player is off the plinth and very nearly back on the pitch. I believe it's important not to pigeonhole the different player support roles, and that all of us should be seeking sound knowledge of applied exercise physiology. How else can we claim to have looked after the 'whole athlete'? This article aims to extend our horizons in applying physiological principles to total athletic performance management.

Endurance training in soccer

During an average game, elite-level soccer players run distances of eight to 12km, at close to the lactate threshold. It is said that VO2 max is the single most important factor in determining success in sports such as soccer, rugby and hockey; researchers have certainly been able to demonstrate a correlation between average VO2 max and final league positions in a professional European league[2]. As a consequence, a high priority is placed on endurance training, both preseason and throughout the competitive period. Typically this involves game-related running; but a common training approach, particularly during pre-season conditioning, is to use repetitive straight-line runs at more than 90% of maximum heart rate (MHR) for three to seven minutes. Such high intensity work at the 'anaerobic threshold' has long been used as an effective training method for increasing VO2max. But only recently has science enabled a molecular-level understanding of why this might be.

Molecular adaptations to endurance exercise

The broad aim of endurance training is to improve the athlete's capacity to fuel repeated muscular contractions. Specifically the aims are to:

- increase maximal oxygen uptake
- (VO2max)
- improve the skeletal muscles' ability to
- metabolise this oxygen into energy.

In other words, endurance training seeks to improve the body's ability both to supply and use oxygen.

Muscles that are called upon to work for extended periods of time have to be fuelled by large amounts of ATP (adenosine triphosphate: the chemical compound that provides energy for all cellular processes, including muscle contraction).

When muscles have to work at high intensity over extended periods, we are able to see an increase in an enzyme called AMP-activated protein kinase (AMPK). AMPK is thought to be responsible for increasing mitochondrial mass within the muscle – a key adaptation brought about by endurance training, as it is the mitochondria that are the 'power stations' of the cell. The greater the mitochondrial density within a skeletal muscle cell, the greater its potential to produce energy through aerobic metabolism. So the activation of AMPK would seem to be a key molecular aim of endurance training.

Given that AMPK levels are linked to metabolic stress, it seems reasonable to assume that strategies that increase these levels will stimulate an AMPK-mediated increase in mitochondrial mass: hence, the training approach that favours high-intensity drills at close to VO2max.

Resistance training in soccer

In soccer, strength and power are just as important as muscular

Table 1: Characteristics of endurance and resistance training		
	Endurance	Resistance
Load	Low	High
Duration	Long	Short

endurance. While speed endurance may not be critical – after all, the average run lasts for two to four seconds – the ability to out-sprint and out-jump an opponent obviously is. When the player increases their muscle force generation (and hence propulsion), their ability to accelerate, jump and change direction also improves. Helgerud et al[3] demonstrated that an eight-week strength training programme not only improved squat strength (from 116kg to 176kg) but also reduced sprint times over 10m and 20m and increased jump height by 3cm. Three centimetres may not sound much, but the value of being able to out-jump the opposing centre-back to head the winning goal in the WorldCup Final is immeasurable!

Despite this knowledge and the growing appreciation of the role of strength training in football, there is still some way to go before it is considered part of the fabric of a soccer training regime – which it already is in the other football codes.

Molecular adaptations to resistance training

The broad aim of strength training is to increase the capacity of skeletal muscle to perform high-intensity, high-load contractions during a short period of time. Improvements in strength occur primarily as a result of increases in neuro muscular efficiency and muscle cell hypertrophy.The acute response to strength training is a marked increase in protein synthesis, which can last for up to 36 hours. Perhaps the most crucial component in the complicated pathway that leads to protein synthes is(and hence muscle hypertrophy) after resistance training is the production of an enzyme called 'mammalian target of Rapamycin complex –1' (mTORC1). So the goal of resistance training may in fact ultimately be to activate mTORC1.

Concurrent training

There is not enough training time in the season to follow a linear periodised model that develops the different aspects of fitness one by one.Instead, in most cases a non-linear periodised model is used, meaning that strength and endurance improvements are sought concurrently. Difficulties invariably arise.

Training's 'specificity' principle states that specific exercise elicits specific physiological adaptations to produce specific training effects. As can be seen from Table 1(above), the training methodologies used to make strength gains are very different from those used for endurance gains.

And indeed many of the adaptations being sought by doing endurance training are different, and at times, opposed to those of strength training, as Table 2 (below) shows.

The specificity principle underlies the 'interference effect' hypothesis. Hickson was unequivocal when he stated that 'simultaneously training for strength and endurance will result in a reduced capacity to develop strength'[1]. In the last 30 years many studies have sought to prove or disprove this statement and to examine the mechanisms behind an interference effect, yet for every study that finds in favour of Hickson there exists another that challenges the effect.

As ever, many of these studies differ in their design and outcome measures, making it hard to compare results, but the balance of opinion seems to rest with the view that large volumes of endurance-type training are indeed detrimental to strength gains.

Table 2: Summary of adaptations from endurance and resistance training

	Endurance	Resistance
Aerobic capacity	↑	↓ (potentially)
Mitochondrial mass	↑	↓
Muscle fibre size	-	↑
Oxidative enzyme activity	↑	↓

Why the interference effect might be true

Both acute and chronic hypotheses have been proposed to explain the interference effect. The acute hypothesis proposes that endurance training results in neuromuscular fatigue, which undermines the athlete's ability to perform their strength training work optimally. The central plank of the chronichy pothesisis that the muscle is subjected to metabolic andmorphologic conflict by the differing and sometimes contradictory demands of the programmes. As a result, the muscle is unable to adapt satisfactorily to either form of training.

Burgeoning studies of cellular metabolism during concurrent training provide new clues to the mechanism behind the interference effect. And it is indeed becoming clear that at a molecular level, the divergent training demands are creating a sub-optimal cellular environment for anabolic responses.Of particular concern is the suggestion that AMPK can block the activation of mTORC1, adversely affecting resistance training-induced increases in protein synthesis and there by muscle hypertrophy[4]. It may be that the acute blockage of Mtorc1 by AMPK, when repeated often enough, will set up a longer-term inability for skeletal muscle to maximise the gains from strength training (though this is not yet proven).

This appears to be a one-way blockage though: mTORC1 does not seem to block AMPK, so the resistance work does not limit endurance adaptations.This is borne out by studies that have failed to show limitations in the development of aerobic power during concurrent training. In fact, explosive-strength training enhances neuromuscular efficiency and running economy, and reduces 5,000m running time[5]. This finding adds weight to the argument for soccer players participating in strength training.

Impact of nutrition

The availability of fuel for endurance and resistance exercise can have profound effects on subsequent muscular adaptations. It appears that AMPK production is amplified when activated in the face of low muscle glycogen, but switches off when muscle glycogen levels return to normal[6]. This is the theory of 'train low-compete high'(train in a fasted state but race with high muscle glycogen stores), which has gained popularity in recent years and is supported by a growing number of scientific studies in trained and untrained subjects alike.

Given that AMPK can interrupt protein synthesis, however, it is reasonable to suggest that it may be advantageous to turn it off prior to resistance training, as would happen for instance, by ingesting carbohydrates and raising muscle glycogen levels after endurance exercise. It's really important to note, however, that this notion remains a theoretical model only; no study investigating this in elite, concurrently training athletes has yet been published.

On the other hand mTORC1 is optimally activated in a cellular environment rich in amino-acids, so nutrients are vital to maximise protein synthesis during strength training. It seems reasonable to propose, therefore, that players should consume protein prior to and during their resistance training session. Additionally it has been shown with rats that mTORC1 levels remain elevated for up to 16 hours post exercise[7]; this may point to a benefit of conducting strength training sessions late in the afternoon, so that protein synthesis can continue for the rest of the day and night, giving at least 12 hours of elevated mTORC1 levels before endurance training-mediated increases in AMPK switch it off.

As nutrition and the timing of training sessions can both therefore influence the molecular level response, they should be factored in whenever you plan conditioning programmes in soccer. This knowledge may help with any advice we give to soccer-playing clients in our care. It may even help our appointment scheduling: perhaps we should plan any sessions with an endurance bias for morning appointments, leaving the strength sessions to the afternoon, and reminding clients to ensure they have had a protein-rich meal before they turn up.

Conclusion

Concurrent training has attracted controversy among sports scientists for 30 years, focused on the potential for the effects of one type of training to interfere with beneficial adaptations for another type. Despite this, concurrent training is widely practised in professional soccer, against a competitive and commercial background that simply does not permit more extensive periodised training.

From recent research, it appears that there is some molecular level support for the interference effect, and that strength is the fitness component most likely to end up suffering. However, this same molecular level understanding also enables us to see how nutrient support and scheduling of training sessions could help us negate the influence of the interference effect.

References

1. Hickson, RC. Interference of strength development by simultaneously training for strength and endurance. Eur.J.Appl. Physiol. Occup.Physiol. 45:255-263,1980.

2. Apor,P. Successful formulae forfitness training. In Reilly, T et al. (Eds), Science and Football. London: E & FN Spon:95-107, 1988.

3. Helgerud,J,Kemiet al.Pre-season concurrent strength and endurance development in elite soccer players. In Hoff, Jetal(eds).Football (soccer):New Developments in Physical Training Research. Trondheim: NTNU 55-66, 2002.

4. Inoki,K,Zhu,Tetal. TSC2 mediate scellular energy response to control cell growth and survival. Cell 115:577-590, 2003.

5. Paavolainen, L, Hakkinen, K et al. Explosive-strength training improves 5-km running time by improving running economy and muscle power. J. Appl. Physiol. 86:1527-1533, 1999.

6. Barr,K and McGee,S. Optimising training adaptations by manipulating glycogen.Eur.J. Sp. Sci. 8: 97-106, 2008.

7. Kubica,N, Bolster, DR etal. Resistance exercise increases muscle protein synthesis and translation of eukaryoticinitiation factor2 Bespsilon mRNAin amammalian target of rapamycin-dependent manner. J. Biol. Chem. 280: 7570-7580.

Football – why and how effective pre-season training is a must

At a Glance

- The energy requirements of football are outlined;
The principles of pre-season training are discussed, particularly the importance of skills-based fitness training;
- Examples are given of these principles applied in practice.

Effective pre-season football training is not just about running around the football pitch in order to shed those off-season pounds. According to *Jim Petruzzi*, a much more scientific approach is needed, which combines energy systems training with skill development

'I wouldn't say pre-seasons are a lot easier now but they're a lot better,' says the Villa striker. 'All I can remember is you didn't get to see a ball for four or five days. As soon as you reported back for training it was straight into running morning and afternoon. I think if you asked a lot of older players, they would say that's exactly what it was like. The difference nowadays is that you see the ball right away, the first day. Yes, we still do running but it's not so intense, pounding the roads for a couple of hours. It's a hell of a lot different.'
Kevin Philips, Aston Villa striker, 2006

Sports science and modern technology has had a major effect on football training over the past 15 years. Many teams have become much more analytical about their players' work rate in games, and also in training, by introducing tools such as game analysis and heart rate monitors, in order to gain an accurate

Jargonbuster
Alactic
the energy pathway which permits athletes to work at very high intensity for over 10-15 seconds without lactic acid production or the use of oxygen

understanding of the physical demands of players in games.

The structure and training methods in football throughout the season have also changed significantly and the period of pre-season training has seen some of the biggest and most significant changes, due to the importance of ensuring that players starting the season are in the best possible shape, and the need to maintain their fitness throughout the season.

Gone are the days when players would report to pre-season training and told they would not see a ball for two weeks. Small-sided games and ball-related exercises now comprise a major part of training within the modern professional game. A perfect example of this was the preparation that the Korean team (widely acknowledged to be one of the best prepared teams in the tournament) adopted in preparation for the 2002 World Cup finals.

In a review, Verheijen described how initially the Korean players could not maintain their desired pace for the full 90 minutes(1). Players made high-intensity runs less frequently and there were fewer 'explosive actions' as the second half progressed.

After a systematic training programme, they were able to maintain a higher tempo for the entire match and the recovery between explosive efforts was dramatically improved.

The energy requirements of footballers

Football incorporates periods of high-intensity efforts interspersed with periods of lower-intensity exercise. The physiological demands of football require players to be competent in several aspects of fitness, which include aerobic and anaerobic power, muscle strength, flexibility and agility.

Overall, the game of football is essentially aerobic with intermittent anaerobic and alactic bursts of energy. Outfield players average heart rates of about 160bpm during football games and operate at 75-80% of their maximum oxygen uptake (VO2max), which is comparable to marathon running. However, football is not characterised by steady heart rates of 160bpm, which are sustained for 90 minutes of play; heart rates are continually fluctuating depending on the nature of the activity the player is performing.

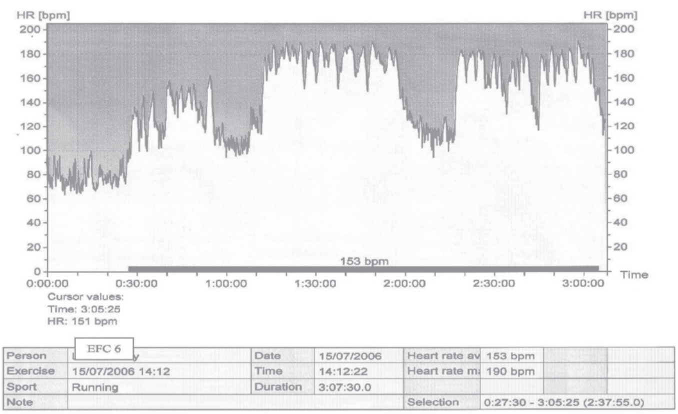
Figure 1 below illustrates an actual heart rate plot from a professional footballer using a heart rate monitor taken during a pre-season game; notice the continuously varying heart rate but with high average peak values.

At the professional level, the contemporary game of football seems to be more demanding than suggested in much of the early literature(2), which therefore suggests a more systematic approach to training is needed(3).

A comparison of the work rates of English Premier League players over two seasons (1998-1999 and 1999-2000) with previous observations of top English League players before 1992 shows that today's players cover approximately 1.5kms more ground in a game than their earlier counterparts(4) – a difference that is apparent for all the playing positions.

The data for the 1997-98 season shows that compared with the 1991-92 season, there is also evidence of a faster tempo to the game, including more movement of the ball and shorter breaks in play. This is probably partly due to changes in the rules, such as the omission of the back pass and also advances

Figure 1: Actual heart rate plot of professional footballer



'A successful pre-season programme is one that incorporates all of the necessary components to enable players to maximise their performance as soon as the season commences'

in sports science and player conditioning.

However, despite the high aerobic demands necessary to sustain work output for 90 minutes, games are often decided on the quality of explosive efforts, which depend on anaerobic and alactic bursts of energy; for example, to get to the ball first, leap above an opponent, spring into a goal-scoring position or to close down an opponent and deny them space to pass or shoot at goal.

The simulation of the exercise intensity corresponding to match play has enabled sport scientists to study a number of aspects of play under laboratory conditions. Observations highlight the value of exercising with the ball where possible, notably using activity drills in small groups. Small-sided games have particular advantages for young players, both in providing a physiological training stimulus and a suitable medium for skills work. While complementary training may be necessary in specific cases, integrating fitness training into a holistic process is generally advisable.

Principles of pre-season training

A successful pre-season programme is one that incorporates all of the necessary components to enable players to maximise their performance as soon as the season commences, and to be able to sustain peak physical condition throughout the season. These fitness components often vary with the individual player, the positional role in the team and the team's style of play. Other considerations include the physical demands of the game, the current level of fitness of a particular player and what the team is striving to achieve. To meet these requirements, a well-designed pre-season training programme that addresses the specific demands of each footballer is a must. Because of this, it is worth considering physical and physiological tests at the start of your pre-season schedule to see how the players are doing, and to evaluate their preparation plans. These tests give information on the levels of endurance, speed, muscular endurance, strength, coordination, technical, and tactical elements during the preparation period.

A pre-season preparation period covers the period from the beginning of team training until the first official match. The length of these training periods may differ from one country to another. During this training period, physical conditioning should be composed mainly of games and exercises with a ball. The frequency and number of training sessions should be increased gradually as the season approaches[5].

Paul Aigbogun, coach of the San Francisco Seals team, speaks of some of his favourite practices demonstrating how the ball can be incorporated into training for physiological benefits: 'Some of my favourite practices are crossing and finishing, keep ball, building up to a small-sided game, starting at 1 v 1, building up to 2 v 2, 3 v 3, 4 v 4, probably up to a maximum of 8 v 8. Another one of my favourite practices is attacking team play, 11 v 6'.

Adapting these games to meet the physiological demands of football is important. Football is played by two teams of 11 players performing in an area of approximately 100m by 60m. However, during training, it is common practice to reduce both the number of players on the pitch and the size of the pitch, which has the effect of increasing the proportion of anaerobic/ explosive work required. These small-sided games are one of the most common drills used by coaches in football training; whereas in the past small-sided games were mainly used to develop the technical tactical abilities of the players, they are now being employed by amateur and professional teams as an effective tool to improve physiological aspects of the game[6].

Changing approach to conditioning

Although it's true that footballers cover large distances during a match, it's important to note that football players are continuously alternating between anaerobic and aerobic activity, which allows recovery to take place. As a consequence, football is characterised by one dominant energy system in the body (aerobic) but with the two other energy systems (anaerobic alactic and anaerobic lactic) that enable higher-intensity outputs to play a vital role. Training all three energy systems,

Jargonbuster

Anaerobic lactic
Short duration (1-2 minutes) high-intensity energy pathway involving the breakdown of glycogen (glycolysis) in the absence of oxygen, with the formation of ATP plus lactic acid

therefore, is important.

Traditionally, footballers have used interval training to develop aerobic fitness. However, the use of small-sided games has recently been recommended as an ideal training method for improving fitness and competitive performance in football, because match-specific small-sided games can effectively improve the fitness of the cardiovascular system while mimicking match-specific skill requirements[7,8]. Other advantages include increased player motivation, training the capacity to perform skilled movements under pressure and a reduced rate of training injuries.

Scientific research has established that five-a¬side football drills on a pitch measuring 50m x 40m can produce heart rate responses within the intensity range previously shown to be effective for improving aerobic fitness and football performance (performing running interval training at 90 to 95% of maximal heart rate)[9].

Examples of principles in practice

Pre-season anaerobic training – One approach is to work on general anaerobic conditioning using quality interval training, which can be performed by performing football-related activities. In practice, that means alternating maximum speed sprints with very light jogging or walking. Workouts should last about 20-30 minutes and consist of 7-10 second sprints and 30-50 seconds of low-intensity jogging or walking, giving an aerobic/anaerobic training ratio of 5:1. For example, you could play 1 v 1, where one player is defending a goal on the edge of the 18-yard line. The other player sprints at full pace from the other 18-yard line, receives the ball on the halfway line and sprints towards the goal aiming to get a shot on target. He then jogs backs and repeats the same drill.

An example of this was a training drill that Bansgo conducted with Zambrotta while he was assistant coach at Juventus. The drill was for Zambrotta to play the ball from the edge of his own box to a midfielder, sprint and then receive the ball inside the opposite half and run with the ball, cutting back inside and striking it with his left leg. The aerobic/anaerobic training ratio was 5:1 – ie very specific to football.

Pre-season speed training – Here's an example of a speed drill that combines skill and fitness training. Divide the players into two equal groups, placing them both in a single line formation, and have the two players at the front of the two groups facing each other at a distance of about 20 metres apart. Player A (the player at the front of the line) from group one passes the ball to the other player A (the player at the front of the line in group two) and sprints to the other side to the back of group two. Player A from group two receives the ball, controls and passes the ball then sprints to the back of group one. Each player repeats this with the emphasis being on speed. After passing the ball, it should take about 3 seconds for the player to sprint 20 metres, with a short rest before performing the exercise again.

Pre-season aerobic training – Examples include drills lasting 2-3 minutes with a work/rest ratio of 1:1 working at low intensity or continuous low-intensity work over a period of 20 minutes. Alternatively you could play a small-sided game such as 4 v 4, though if you wanted to work solely on the aerobic system, these games would need to be played at low intensity to keep aerobic activity to a minimum.

As a rule of thumb, training should involve regular use of the ball wherever possible as this will not only help develop the specific muscles involved in match play, but also improve technical and tactical skills and help keep players interested. This is where small-sided games offer an advantage and many coaches such as Marcello Lippi, formerly at Juventus, and winner of the 2006 World Cup with Italy, are big believers in the positive effects of small-sided games.

Summary

Small-sided games and football-related activities, as highlighted, have a number of benefits. Footballers love

Summary of energy systems in football:

1 Anaerobic alactic, high intensity. Duration up to 15 seconds; used in explosive efforts and short sprints, kicking, tackling etc;
2 Anaerobic lactic, moderate-high intensity. Duration of 15-120 seconds; used in longer sprints and sustained high-intensity efforts (heart rate around 90% of maximum);
3 Aerobic moderate to low intensity 120 seconds plus used while jogging, walking, recovery between harder efforts etc.

Aerobic activities	Anaerobic activities
Walking	Most tackling and contact situations
Walking backwards	Jumping
Jogging	Accelerating and changing direction quickly
Running at speeds less than ¾ maximum pace	Running at speeds greater than ¾ maximum pace

Constructing a football-specific pre-season training session

The following is a guide you can use to help you plan your own pre-season training sessions. As well as simple running drills, you can also incorporate the relevant work/rest/intensity combinations into football-specific drills

Speed

Exercise (secs)	*Rest*	*Intensity*	*Repetitions*
2-10	5 times exercise duration	Maximal	2-10

Building speed/endurance

Exercise (secs)	*Rest*	*Intensity*	*Repetitions*
20-40	5 times exercise duration	Almost maximal	2-10

Maintaining speed/endurance

Exercise (secs)	*Rest*	*Intensity*	*Repetitions*
30-90	30-90 seconds	Almost maximal	2-10

Aerobic high intensity

Exercise (mins)	*Rest*	*Intensity*	*Repetitions*
2-5	Same as exercise duration	90%+ of heart rate maximum	4-6

Aerobic low intensity

Exercise (mins)	*Rest*	*Intensity*	*Repetitions*
8-10	1-2 minutes	70-80% of heart rate maximum	2-4

nothing more than to play football, and while the physiological aspect of football is one of the most important factors in players performing at their best, incorporating functional activity, small-sided games, and football-specific activity is bound to make sessions more enjoyable for the players while improving their physical fitness to meet the demands of the game.

References

1. Verheijen Conditioning for Soccer 2003; 1/275-276

2. Insight – The FA Coaches Association Journal 2004; 2(7):56-57

3. Journal of Human Movement Studies 1976; 2:87-97

4. J Sports Sci Med 2001; 6:63-70

5. Acta Physiol Scand Suppl 1994; 619:1-155

6. Br J Sports Med 2002; 36(3):218-221

7. Balsom, PD. Precision Football. Kempele, Finland. Polar Electro Oy 1999

8. Sports Coach 2002; 24(4):18-20

9. Journal of Sports Sciences 2000; 18:885-892

Short and sweet – why all footballers should consider 40m sprinting!

At a Glance

- The relevance and potential benefits of 40m sprinting are discussed;
- Recent research on improving 40m sprint times is presented;
- Tips for testing 40m sprint times are given;
- A sample 40m sprint training programme is outlined.

Many team sports athletes will go through a battery of fitness tests throughout their career. One of the most widely used is the 40m sprint (the 40-yard dash in the USA), which is used to test speed. *James Marshall* explains how footballers can benefit from 40m sprint training

While it's true that there are other speed tests that are relatively easy to administer and which provide immediate feedback to coaches and athletes, the 40m test is so prevalent in sporting circles that athletes may benefit from training plans that improve their 40m sprinting, as well as their linear speed, to assist their sporting performance. Indeed, in the USA, whole training programmes, websites and camps are devoted to 'improving your 40'.

This data is especially relevant to sports such as football, where players are not only required to run bursts of similar distances during the game, but also need to have high top speeds and good acceleration, eg being first to a ball or racing back to get into defensive position; 40m sprinting can also be relevant as a measure of power and leg speed[1,2].

Jargonbuster

Postactivation potentiation
An increase in the contractile property of muscle after a series of previous contractions due to a combination of chemical, neuromuscular and mechanical changes in the muscle[13]

Running, jumping or squatting?

In order to improve running speed over 40m shouldn't you just practise running 40m? Inevitably, practising any skill that is going to be tested will result in improvements in untrained subjects as a learning effect takes place. However, developing strength through weight training exercises such as the squat, or power through exercises such as plyometrics or jump squats has also been advocated as an alternative to just running.

As usual, research is not 100% clear on the answer, mainly due to the design of the studies and the use of 'recreationally trained' or 'untrained' subjects (such as university students) who are usually male, instead of well trained athletes. The training effect demonstrated in these studies may therefore not be especially relevant for those who are better trained or are female.

The NFL Combine

The National Football League holds a scouting combine in Indianapolis each year in which the top 300 college players are invited to perform a battery of physical and skill related tests. This six-day event is an opportunity for the 32 professional teams to assess the capabilities of players at each position. The college draft takes place two months later in which teams select players by rounds. The earlier a player is selected, the more money he will make. The 40yd dash (36.9m) is one of the physical tests, alongside vertical jump, how many times a player can bench press 100kg and others.

Players across all positions have to perform the same tests, so 159kg offensive linemen and 81kg defensive backs all do the 40yd dash, but are compared by position. The results of all these tests provide a high correlation with draft position only for running backs, wide receivers and defensive backs – strangely enough, exactly the positions that frequently have to cover 40yds in the game at top speed[11]!

The 40yd dash times receive immense coverage in the US media, mainly because it is an easy to understand figure; every fan wants to know what their favourite player can 'do the 40 in'. The fastest time at this year's combine was by 79.5kg Yamon Figurs who ran the 40yds in 4.30 seconds. Figurs was drafted by the Baltimore Ravens in the third round and was the 74th player taken overall, coming from a small college, with limited prospects. His position was definitely augmented by his 40yd time.

What is clear, however, is that running the 40m requires acceleration over the first 15m, which is improved by forward body lean and short but quick strides with minimal ground contact time and with a large force[3]. From 15m to 40m, stride length increases, with the fully extended rear leg pushing off the track with the toes and the leg driving forward with a high knee action. Squatting and jumping exercises that reproduce either a quick ground contact time or allow the triple extension of the hip, knee and ankle are most commonly used. These include jump squats, cleans and bounding drills.

Decreasing the ground contact time without enhancing the ability to increase force proportionately will result in slower linear speed because the acceleration produced will be less. Developing power with resistance training is usually achieved by either using heavy weights (70-90% 1RM) and low velocity or lighter weights (30-50% 1RM) and high-velocity movements. Both have been found to be effective when using squat, hip extension and hip flexion movements in improving 20m acceleration time[4].

Improving maximal leg strength may prove to be crucial in improving speed in untrained subjects, but less so in experienced athletes. This is due to the fact that a large increase is needed in leg strength before a corresponding increase in speed is seen. A large strength increase is easier to achieve in untrained subjects than those who have been training for 10 or more years.

In trained subjects, squatting immediately before sprinting may produce an acute effect over 40m due to postactivation potentiation (PAP)[5]. One set of three heavy squats at 90% 1RM were effective in reducing 40m sprint time in college American football players compared with three squat jumps with a 30% 1RM load. A four-minute rest period was enforced between the exercise and the sprint. However, this is not recommended for untrained subjects as the squats would have an unduly fatiguing effect and reduce the ability to produce power.

The recovery phase

Most studies have looked at training the drive phase of the sprint action; however, training the recovery phase could be just as important. One study using untrained subjects improved 40yd times over eight weeks by using elastic bands to improve hip flexor strength for the recovery phase[6]. The subjects tied the elastic band around their ankles and then reproduced the high knee lift against the resistance of the band. The subjects improved hip flexor strength by 12% and decreased their 40yd time by 9%.

The idea of reproducing this action under load is sound, but it is unlikely to work in trained subjects due to the limitations of using elastic bands. Unlike using free weights or cables, which require a large initial force to overcome inertia, bands have little inertia at the beginning of the movement, but resistance increases towards the end of range. This results in early deceleration, which is counterproductive in most athletic movements.

Sprint training protocols

As the 40m is a very specific running test, and most training time is limited, the running drills need to be very effective. Running a series of 40m sprints, with 'walk back recovery,' which is common in team environments, may not produce the best results. Instead, carefully managed rest times that allow recovery of the phosphocreatine energy system should be used. This will then help the athlete run at their top speed for each sprint in the training session. Rather than run the same set of drills in each session, it may be best to include some over-speed and uphill sessions as well as normal sessions.

Incline or running with resistance is designed to increase ground contact time and reduce stride length, which may be useful in the initial 15m of acceleration. Downhill running or overspeed training is designed to increase stride length and reduce ground contact time, important in the 15-40m phase of the sprint. When using inclines, declines, resisted or overspeed training methods, it is important to observe running mechanics.

Testing 'the 40'

While testing the 40 is theoretically quick and easy to administer, experience shows that it can't always be done. One major problem is the weather. Indoor facilities that have a 50m space in a straight line (you have to allow at least 10m for safe deceleration at the end) are rare. Outdoors, the pitch surface has to be dry to allow foot purchase and should be consistent between tests to establish reliability.

Wind is also a factor, with tail, head or cross winds all affecting the times. If you are just conducting one test to establish who is quickest on your team, then wind is not a problem because the conditions are the same for everyone. But, if you are using the data to monitor progress over time or comparing with players from other parts of the country, then conditions become important.

Equipment used could be handheld stopwatches or electronic light gates. If using handheld times, then up to three testers should be used and an average between the three scores recorded(12) . If using electronic gates, make sure you have spare batteries, as they can become depleted quite quickly. Mark out the distance with an accurate tape measure and ensure you get metres and yards correct – I have seen the two confused and some very fast scores recorded!

Allow the players sufficient time to warm up, providing a general and then specific warm up with speed drills. Then allow each player three attempts to run their quickest score, with rest time between each attempt. The starting position is important, from a two-point or three-point stationary start; on the line or 75cm behind the first electronic gate. The times recorded will be different for each protocol, but the consistency between tests is crucial – everyone must follow the same protocol. There's no evidence that subjects competing against each other over 40yds run faster than when running against the clock (or vice versa), so whichever method is easier for you to administer should be used(12).

Jargonbuster

Phosphocreatine energy system
Generates ATP for immediate efforts of activity from two to seven seconds in duration

Too much incline or resistance will result in severely altered running styles and poor posture, which then has a detrimental effect when the resistance is removed. The same is true for decline or overspeed training (being towed).

Two recent studies had different views on this. The first used a protocol of towing (over-speed sprints), pushing (resisted sprints) and normal sprints and compared the three groups over 22m[7]. The subjects were untrained college students and the sprint sessions were conducted three times a week for six weeks and consisted of sprinting 22m five times.

All three groups improved their times at their own protocol (ie the resisted group got better at running against resistance) but the transference to flat speed was greatest in the normal sprint group and then by the overspeed group. The short-term nature of this study indicates that the adaptations to the training were neuromuscular in nature; the subjects became more efficient at their drills. This may not have transference to sport specificity, but if you are trying to get good at a one-off 40m test, then training at that speed for six weeks may help. However, in the longer term, you are unlikely to get better results by just doing that.

The second study combined uphill, flat and downhill running into the same session to provide resisted, tempo and overspeed stimulation to the subjects and compared that to just uphill, flat or downhill sessions (without resistance or towing)[8].

The researchers designed and built a wooden platform that had a 20m flat portion, a 20m incline at 3 degrees, a 10m flat portion at the top, a 20m decline at 3 degrees and then a flat 10m at the end. The combined uphill/downhill group ran this 80m total six times with 10 minutes' rest between sprints, three times a week for six weeks. The other groups ran the same total distance, but in shorter bursts using the same platform, so they ran 12 sets of 40m combining the flat and either the down or the up portion of the platform.

At the end of the six weeks training, the subjects were tested over 35m and the combined uphill/ downhill group showed a 3.4% increase in top speed with the downhill group showing a

Sample 40m sprint training programme for football

Concentrating on four areas: technique, strength, sprinting, plyometric training (energy system conditioning is assumed to be done as part of the team training sessions thought the use of small-sided games).

A – Off-season

Technical drills to be done for 10 minutes as part of football team training warm-ups.

Strength (two sessions per week)
Squats 4 sets of 3 reps @ 90% 1RM 2 mins rest between sets
Jump squats 4 sets of 5 reps @ 30% 1RM 2 mins rest between sets
Cable leg drive 4 sets of 5 reps @ 30% 1RM 2 mins rest between sets

Plyometrics (two sessions per week)
Double-leg bounds 10m; progress to 20m
Tuck jumps continuous 2 sets of 10 reps
Single-leg bounds for distance 10m; progress to 20m
Single-leg bounds for speed 10m; progress to 20m

Sprints (two sessions per week)
Session 1
Alternate each week between resisted sprints towing a 10kg weight or an uphill run of 40m at 3 degrees. 4 resisted/uphill sprints, 3 mins rest between reps. 4 flat 40m sprints at full speed, 5 mins rest between reps.

Session 2
4 downhill sprints for 40m at 3-degree decline, 3 mins rest between reps.
4 flat 40m sprints at full speed, 5 mins rest between reps.

Sample week for a player who does two team sessions in the off season; player does two sprint sessions, two plyometric sessions and two strength sessions each week

	Sun	**Mon**	**Tues**	**Wed**	**Thurs**	**Friday**	**Sat**
Session1	Rest	Sprint1	Plyo1	Rest	Plyo2	Rest	Strength2
Session2	Rest	Rest	Team	Strength1	Team	Sprint2	Rest

B – In-season

Sample week for in-season training; only one strength, plyometric and sprint session per week in order to avoid fatigue (because of the high number of matches being played)

	Sun	**Mon**	**Tues**	**Wed**	**Thurs**	**Friday**	**Sat**
Session1	Rest	Sprint	Rest	Match	Rest	Plyo	Match
Session2		Strength	Team		Team	Rest	

smaller 1.1% increase. The flat and uphill training groups made no significant changes to running speed after six weeks of training.

The key factor distinguishing between the downhill only group and the combined uphill/downhill group is that the latter had their neuromuscular system overloaded, then unloaded and then assisted. This loading and unloading in the same session could be the difference and is worth trying in training.

Other benefits of practising 'the 40'

Regular sprint training can lead to better sprint times, but could it also be used as a training tool in itself leading to other physiological improvements. Plyometrics are often used as an effective training method to help reduce ground contact time for sprinters and jumpers. A Croatian study compared a sprint training protocol with a plyometric protocol over 10 weeks and looked at the effects on drop jumps, countermovement jumps, squat jumps and squat strength as well as 20m sprint time and 20yd shuttle runs[9].

Both groups improved their jumps but the sprint group also improved their isometric squat strength and their speed and agility scores. This study showed that sprinting could be used as a training tool that has similar or better effects than plyometrics. The same researchers also analysed anthropometric characteristics of the two groups and found that the only significant change was a 6.1% reduction in body fat in the sprint group[10].

Summary

Assumptions may be have to be made in designing training protocols for well trained footballers due to the paucity of research using trained subjects. However, it does appear that once a well developed strength base is in place with sound sprint mechanics, the use of different sprint speeds and drills followed by normal mechanics at top speed is more effective than running just flat speed drills.

In less trained subjects the most effective way to improve

40m speed over the short term (circa six weeks) is to practise the test and coach the running style well. This will be effective once, but for those athletes who are tested regularly, a solid strength base needs to be developed in combination with power exercises either in the gym or using plyometrics.

It's worth commenting on the use of time spent on sprint drills. Most coaches who have limited access to their players will not allow players to spend even 10 minutes doing nothing in their training session; taking up a whole evening doing six maximal sprints over 40m with 10 minutes' recovery will not therefore go down well. Try doing that on a rainy night in January and your players won't like it much either! Doing 20 sets of 40m sprints with 'walk back recovery' may look busier and the players will be tired, but it won't help their

Working on lower body strength and power in the gym, however, will have the two-fold effect of improving both sprint speed and overall conditioning.

References

1. JSCResearch 2006; 20(3):500-505
2. JSCR 2005; 19(2):326-331
3. Journal of Sports Science and Medicine 2003; 2:
4. Journal of Sports Science 2002; 20:981-990
5. JSCR 2005; 19(4):893-897
6. JSCR 2005; 19(3):615-621
7.JSCR 2006; 20(4):833-837
8. JSCR 2006; 20(3):767-777
9. JSCR 2007; 21(2):543-549
10. Kinesiology 2005; 37(1):32-39
11. JSCR 2003; 17(1):6-11
12. JSCR 2007; 21(2):385-388
13. Exercise and Sports Science Review 2002; 30:138-143

Accelerating performance – how footballers can make a quick getaway

At a Glance

- The optimum biomechanical techniques for maximising acceleration areoutlined;
- Recent research on the efficacy of different types of muscular conditioningfor enhancing acceleration in athletes is discussed;
- The benefits or otherwise of other training techniques such as weightedsled and over-speed work are considered.

Acceleration is crucial to winning performance in football. *John Shepherd* analyses what makes for a quick getaway from a technical point of view and identifies the best training methods to develop this crucial aspect of sport performance

Forget top speed. Athletes that can increase their speed (ie accelerate) more rapidly than their rivals can gain an incredible and often unassailable performance advantage. The most obvious example is the 100m sprinter, who might not attain the highest top speed, but reaches the finish line first because he or she is able to attain their top speed before the other competitors. The same is true in racket and field sports; rugby players and footballers may breach the defence with a searing burst of pace that leaves the opposition for dead, while a racket sport player may accelerate to retrieve a shot that his opponent 'thought' was a winner.

What makes for great acceleration technique?

In order to study this, researchers from New Zealand studied the ground reaction forces (GRF) involved in the acceleration sprint phase[1]. Thirty-six athletes performed maximal-effort sprints from which video and GRF data were collected at the 16-metre mark. The team discovered that the faster accelerating athletes displayed less vertical impulse in their acceleration phase ie more force was directed horizontally, thus pushing them forward. The quicker accelerators also had faster ground contact times.

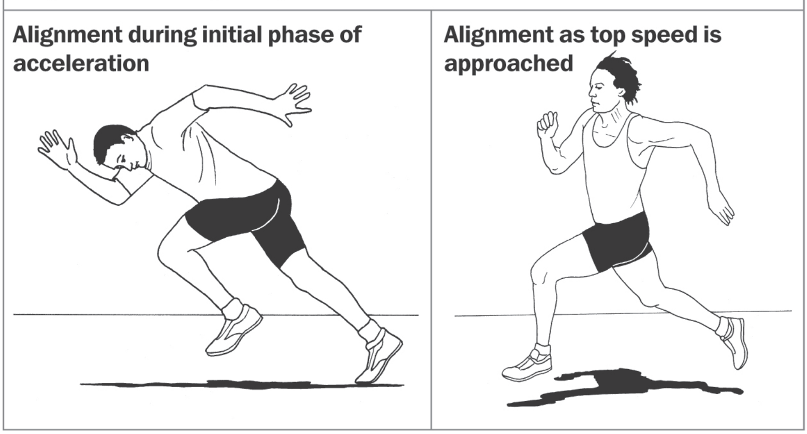
Although acceleration requires greater foot/ground contact times when compared to maximum speed sprinting (to impart sufficient force to overcome inertia), the research indicates that better acceleration derives from quicker ground contacts.

Acceleration and sprinting

In sprinting, a low body position is desirable when leaving the blocks because it enables the athlete to maximise their acceleration. This phase of the race is often described as the part when the sprinter is sprinting with their legs 'behind their body' and contrasts with the main 'flat-out' part when work is done 'in front of the body'.

The arms should be pumped vigorously backwards and forwards as the athlete drives from the blocks to gain momentum. Coaches vary in the way they teach the leg

Figure 1: Body alignment during acceleration



movement; some argue for a 'driving back' movement of the legs, while others advocate bringing the thighs to the chest in a piston like manner. In both cases however, the body should remain inclined, until around the 15-metre mark, when the sprinter's torso moves into an increasingly upright position (see figure 1).

In football however, it's obviously far more difficult to execute such a precise accelerative technique. Players will often be off balance and/or may have a ball at their feet. Additionally they may be playing on a soft and slippery surface, which will significantly hamper power generation. Nevertheless, footballers and their coaches can learn much from the techniques harnessed by sprinters for maximum acceleration – notably the low body position and centre of gravity that enables the legs to supply optimum propulsive drive from static position.

However, football coaches should also develop accelerative practices that involve turns. An example of an accelerative practice for involves two players standing 2m apart. On a command, they turn through 180 degrees and sprint 5m. As a variation, the drill can be performed with 90-degree turns, with players turning in opposite directions.

Training for increased acceleration

It's often argued that the most specific sports improvements are derived from training practices that closely replicate the movement patterns of the sport in question. This would mean, for example, that plyometric muscular action exercises (such as hopping and bounding) should have a greater relevance to the majority of sports than the more usual concentric/eccentric type of muscular action. However, when it comes to conditioning acceleration, research indicates that it's not so simple.

Concentric training and acceleration

Researchers from Canada investigated the relationship between sprint start performance (five-metre time) concentric

Jargonbuster

Plyometric muscular contraction
Powerful muscular contraction that results from a concentric muscular contraction immediately following an eccentric muscular contraction in the same muscle/ muscles

Concentric muscular contraction
Shortening of a muscle as it contracts, for example, during the curling phase of a biceps curl

muscle strength and power variables[2]. Thirty male athletes performed six 10m sprints from a standing start. Sprint times were recorded, as were the force-time characteristics of the first ground contact (using a recessed force plate).

Three to six days later the subjects completed three loaded concentric jump squats, using a traditional and split-squat technique, with a range of external loads from 30-70% of one repetition maximum (1RM). These exercises require the performer to bend their legs to jump, pause and then jump. In doing this they invoke an almost purely concentric muscular contraction, rather than a plyometric one.

The results showed that athletes who were better at moving the weights during the squat jumps were the best 10m accelerators. This led the researchers to conclude that concentric (not plyometric) force development was critical to sprint start performance and accordingly that maximal concentric jump power was related to sprint acceleration.

To further clarify; the first step from a stationary start (or near stationary position for a footballer) requires a concentric muscular action. This contrasts to the subsequent sprinting strides that profit from the increased plyometric power opportunities provided, which occurs when the eccentric priming of the subsequent concentric contraction increases power potential, in the muscles of the calves, thighs and hips. Think of it like stretching out a spring to its full extent (the eccentric contraction) and then letting it go. A lot more power is released in the split second the spring recoils (the concentric contraction).

Acceleration and leg stiffness

Most sprint coaches recommend a programme of plyometric exercises, such as hopping and bounding to develop explosive ability (including acceleration) and enhance leg stiffness. Basically the stiffer a footballer's legs are, the better able they will be at generating power from the running/playing surface. To provide an analogy, carbon fibre legs will be much stiffer and therefore propulsive than pipe-cleaner legs!

Plyometric training and acceleration

A team of researchers from New South Wales (Australia) examined the effect of heavy versus light-load 'jump squats' (the plyometric exercise) over an eight-week training programme on electromyography (EMG) and various other physical performance measures(3).

Twenty six athletic men with varying levels of resistance training experience performed sessions of jump squats with either 30% of 1RM (the JS30 group – nine members), or 80% 1RM (the JS80 group – 10 members), or controls (the C group – seven members). All the subjects performed an agility test, 20m sprint and jump squats at 30%, 55% and 80% of their 1RMs before and after training. Peak velocity, peak power, maximum jump height (JH), and average EMG activity for the concentric phase were calculated for the jumps.

The researchers discovered that there were significant increases in peak power and velocity in the 30%, 55%, and 80% jump squat performances of the JS30 group. This group also significantly improved their 1RM scores and crucially, showed improvements in their 20m sprint times. In contrast, while the JS80 jump squat group significantly increased both peak power and velocity in the 55% and 80% 1RM jump squat and significantly increased their 1RMs, their 20m times were much slower. This investigation indicates that training with light-load plyometric jump squats resulted in increased movement velocity capabilities. In contrast, the heavier load did not benefit sprint acceleration, which could be as a consequence of the slower ground contacts and reactive forces that lifting such a load requires.

Jargonbuster

Eccentric muscular contraction
Lengthening of a muscle as it contracts, for example, during the lowering phase of a biceps curl

Electromyography (EMG)
A measure of the electrical activity in muscles, the more there is the greater the level of muscle fibre recruitment

However, a team of French researchers discovered that leg stiffness as measured via a hopping test was not directly proportional to accelerative ability, although it was to flat out speed[4]. The acceleration and maximal running velocity developed by eleven subjects over a 40 metre sprint was measured by radar. Leg power was measured by a treadmill test and a hopping test. Each subject performed maximal sprint accelerations on a treadmill equipped with force and speed transducers, which were used to calculate forward power. The hopping test was performed on a force platform. Leg stiffness was calculated using the flight and contact times of the hopping test – ie the greater the hop height and the quicker the ground contact, the stiffer the performer's legs.

What did the researchers find? Treadmill forward leg power was correlated to both the initial acceleration and maximal running velocity during track sprinting. However, leg stiffness calculated from hopping was significantly correlated with maximal velocity but not with acceleration. These findings were corroborated by another French team whose very similar research is particularly interesting in that it involved 19 regional to national level 100m sprinters – rather than non-elite performers[5]. These athletes had best times ranging from 10.72 to 12.87 seconds. The 100m sprint was divided into a 0-30m acceleration phase, a 30-60m secondary acceleration to maximum speed phase and a 60-100m speed maintenance phase. This team discovered that their hopping test was the best predictor of the last two phases of the 100m race and that sprinters who had the greatest leg stiffness produced the highest acceleration between the first and the second phases – not the first.

So why is leg stiffness less important for acceleration? The answer is as indicated previously more than likely a response to the fact that concentric muscular strength expression is a key acceleration determinant, while plyometric power – which is enhanced by greater leg stiffness – becomes more relevant to the sprint athlete when they can use a fast eccentric pre-stretching muscular contraction to enhance the power output of the subsequent concentric contraction.

Weighted sleds and acceleration

Athletes from numerous sports tow weighted sleds (or car tyres) loaded with weights over distances from 5-40m in an attempt to improve their acceleration. Variations in standing starts are used, for example, three-point and sprint starts. Achieving a low driving position is particularly important when towing if the athlete is to get in the best position to overcome inertia. The added load will force the athlete to drive hard through their legs and pump vigorously with their arms.

A team of Greek researchers looked specifically at the validity of towing methods as a way of improving both acceleration and sprint speed[6]. Eleven students trained using 5kg weighted sleds (the RS group) and 11 without (the US group). Both followed sprint-training programmes, which consisted of 4 x 20m and 4 x 50m maximal effort runs. These were performed three times a week for eight weeks. Before and after the training programmes the subjects performed a 50-metre sprint test. The students' running velocity was measured over 0-20m, 20-40m, 20-50m and 40-50m. In addition stride length and stride frequency were evaluated at the third stride in acceleration and between 42-47m during the maximum speed phase.

The researchers discovered that the RS group improved their running velocity over the 0-20m phase ie their acceleration improved. However, this acceleration improvement had no effect on their flat out speed. This contrasted with the US group who improved their running velocity over the 20-40m, 40-50m, and 20-50m run sections. This led the researchers to draw the obvious conclusions that, 'Sprint training with a 5kg sled for eight weeks improved acceleration, but un-resisted sprint training improved performance in the maximum speed phase of non-elite athletes. It appears that each phase of sprint run demands a specific training approach.'

However, if sleds are used as a means of improving acceleration, what is the optimum load to tow for maximum training adaptation? Australian researchers from Sydney considered just this[7]. Twenty male field sports players completed a series of sprints without resistance and with loads equating to 12.6 and 32.2% of body mass. The team discovered that stride length was significantly reduced by approximately 10 and 24% for each load respectively. Stride frequency also decreased, but not to the same extent as stride length. In addition sled towing increased ground contact time, trunk lean, and hip flexion. Upper body results showed an increase in shoulder range of motion with added resistance. Crucially it was discovered that the heavier load generally resulted in a greater disruption to normal acceleration kinematics (sprinting technique) compared with the lighter load. In short, towing heavier weight sleds is unlikely to specifically benefit acceleration.

Over-speed acceleration training

Over-speed training refers to a training condition when an athlete is 'forced' into greater limb and body speeds by use of external devices/factors. These include elastic-chord towing devices and downhill runs.

Californian researchers looked at the use of elastic-chord towing devices for improving acceleration in nine collegiate sprinters who ran two 20-metre maximal sprints (MSs) and towed sprints (TSs)[8]. In particular, they measured selected kinematics of the acceleration phase of sprinting, which were recorded on high-speed video. One complete stride at the 15-metre point on the fastest trial was digitised for computer analysis.

The team discovered that there were significant differences for horizontal velocity of the centre of mass (CoM), stride length (SL), and horizontal distance from the CoM of the foot, to the CoM of the body for the MSs group compared to the TSs group. However, these differences mitigated against improved acceleration as they were contrary to optimum sprint acceleration requirements; it turned out that due to the pull of the elastic chord, the TSs group was unable to 'drive their legs' as effectively as they would without such assistance. The increased forward momentum imparted by the over-speed method prevented them from getting their body and their feet into the required optimum driving position, which meant that the desired leg drive and 'pushing back' of the track surface was disrupted.

Summary

Increased acceleration requires a structured approach and the use of specific drills, practices and conditioning. Developing powerful concentric leg strength is crucial, as is using weighted sleds with a relatively light load (5kg). However, plyometric drills (and increased leg stiffness) are increasingly important as strides get longer, and ground contact times reduce as top speeds are approached. Acceleration and top speed running practices and conditioning methods need to be blended into a coherent training plan if an a footballer is going to reach his or her full speed potential. Over-speed methods do not seem to offer real benefit, nor do heavy weight squat jumps or heavy load weighted sleds.

'Scientists discovered that towing heavier loads generally resulted in a greater disruption to normal acceleration kinematics (sprinting technique) compared with lighter loads'

References

1. J Appl Biomech 2005; 21(1):31-43
2. Eur J Appl Physiol 2004; 91(1):46-52. Epub2003 Sep 24
3. J Strength Cond Res 2002; 16(1):75-82 7. Strength Cond Res 2003; 17(4):760-7
4. Med Sci Sports Exerc 2001; 33(2):326-33
5. J Sports Med Phys Fitness 2002; 42(3):274-81
6. J Sports Med Phys Fitness 2005; 45(3):284-90
7. Strength Cond Res 2003; 17(4):760-78. J Strength Co nd Res 2003; 17(1):72-5

Deceleration – slow down faster for better performance!

At a Glance

- The importance of deceleration in sport is outlined;
- The role of eccentric muscle contraction in deceleration is explained;
- Examples of conditioning exercises and resistance drills to improve deceleration and reduce injury risk are given.

Improving your ability to slow down and stop rapidly might seem totally at odds with the goal of improving sports performance. But as *John Shepherd* explains, specific deceleration training drills will not only improve speed around the football pitch, but can also reduce the risk of injury

Athletes and coaches invariably strive for maximum acceleration and absolute speed, increased endurance and greater dynamic agility – not the ability to slow down! But think of a footballer landing from a header and then turning to sprint into an open position, or a tennis player scampering to the net in order to retrieve a drop shot then stopping, turning and sprinting to the service line to get to a lob; it's obvious that the ability to slow the body down as quickly as possible in order to make another movement or movements is critical to performance.

Eccentric muscular action

Muscles contract in different ways to produce and control movement. Key to stopping the body when decelerating from a sprint or landing from a jump is the eccentric contraction. An

Jargonbuster

Drop (or depth) jump
Jumps performed from a platform (40-100cm high). The athlete steps off and reacts to the ground on landing to perform a jump (or series of jumps)

Anterior cruciate ligament (ACL)
One of four ligaments that support the knee joint

Electromyographic (EMG)
Measure of electrical activity in muscles. The more activity, the greater the level of muscular stimulation

eccentric contraction occurs when a muscle lengthens under load to control movement. A concentric contraction (which forms the basis of the majority of sports movements) occurs when a muscle shortens to produce movement.

Examples of eccentric contraction include:

- The lowering phase of a biceps curl, when the biceps muscle elongates while under tension (from the weight);
- Hamstring muscle lengthening that happens when sprinting (as it contracts during the return phase of the running action). This occurs when the foot leaves the running surface, travels up toward the butt and is then extended to a position in front of the body in preparation for the next stride. The hamstring muscle controls the acceleration of the lower leg, controlling and pulling the lower leg back down toward the running surface. Most hamstring (and muscle) strains occur during this eccentric muscular phase, which helps explains the value of specific eccentric muscular training (more later).

If an athlete's muscles are not sufficiently eccentrically conditioned then the muscle fibres will be unable to optimally dissipate and control the force of the landing. These forces are considerable. For example, when landing from a **drop jump** (box height 80-100cm), the ankle joints can be subject to a load six to eight times that of the athlete's body weight and a figure skater landing from a jump will have to absorb five to eight times their body weight[1].

Increasing eccentric strength will guard against injury

As indicated, developing specific eccentric strength can guard against injury. A number of studies have been conducted to consider the way men and women land in response to a jump with specific reference to **anterior cruciate ligament (ACL)** injury. The findings often indicate that women lack specific eccentric muscle strength, which is a contributory factor to their increased injury risk.

For example, researchers from North Carolina considered landing preparation as a factor in potential ACL injury[3].

Muscle fibre and eccentric muscle action and injury

Researchers from Tennessee wanted to find out specifically where eccentric forces were dissipated on landing from a jump[2]. Specifically, they considered the eccentric forces that the lower limbs were subjected to from a drop jump landing performed from three different heights: 32, 62 and 103cm. Three different landing techniques were used – soft, normal and stiff. These reflected the amount of knee flexion (bend) that the subjects used on landing.

Nine active males participated in the study. The researchers discovered that the mean eccentric work for the ankle muscles was 0.52, 0.74, and 0.87 joules per kilo of body weight and 0.94, 1.31, and 2.15 joules per kilo for the hip extensors (hip flexors), at 0.32, 0.62, and 1.03m, respectively. However, the average eccentric work performed by the knee extensors (quadriceps) for all the three drop heights was 1.21, 1.63, and 2.26 joules per kilo – a far higher figure than for the ankles and hip extensors. This led the researchers to conclude that the quadriceps muscles were key to energy absorbance capacity on landing, whatever the type of landing. Improving their eccentric force absorption while developing specific strength is therefore very important. This can be achieved in a number of ways – see later in the article.

Three-dimensional video and **electromyographic (EMG)** data were collected for 36 recreational athletes (17 men and 19 women) as they decelerated during landing. Specifically, the team looked at knee and hip angular motion patterns during the flight phase before ground contact.

They discovered that these motions, plus quadriceps and hamstring activation patterns were different between the men and women. For example, compared to men, women tended to display:

- Decreased knee and hip flexion (in this instance, lowering movements that could absorb some of the impact forces);
- Increased internal rotation of the knee, increasing detrimental impact forces transmitted through the knee;
- Increased hamstring activation before landing, with decreased hamstring activation after landing. Hamstring strength on landing has been identified as being important for stabilising the impact.

The researchers concluded that lower extremity motion patterns during landing of the stop-jump task are pre-programmed before landing, and that female subjects prepared for landing in a way that increased anterior cruciate ligament loading during their landings thus increasing the risk for non-contact ACL injury.

Conditioning deceleration

What are the best methods to condition deceleration and that all-important crucial eccentric contraction? Researchers in Stockholm looked at two weights-based training methodologies[4]. Fifteen men participated in a five-week study involving 12 workouts. Eight workouts were performed using concentric/eccentric leg extensions on a weights stack machine, while seven used a flywheel machine, which provided variable resistance and crucially, eccentric muscle overload. In this device, a large rotating wheel generates magnetic tension and

Deceleration agility practices

There are numerous dynamic drills using cones and designated running patterns and speeds that can be designed to enhance deceleration. Here are a couple of good examples for footballers:

1) The compass drill

Five cones are needed; one is placed in the 'centre' of the compass and the others at its four points, 10m apart. To a command, the player sprints to each compass point, returning to the middle each time. They can do this by running around the cones or by touching the top of each. The player should practice the drill using clockwise and anti-clockwise turns. Times can be taken to identify improvement. A useful extra tip for players wishing to improve deceleration is to try and maintain a low centre of gravity and make the 'braking' movements from the balls of the feet.

2) Backward running into forward sprint

This simple drill requires the player to run backwards over 15m. Movement should be generated from the balls of the feet and the arms coordinated with the legs (*ie* opposite arm to leg). The chest should be elevated and the athlete should look straight ahead. On completing the 15m (marked by a cone), the player then immediately breaks and transfers into a forward sprint. This is a demanding drill and should be progressed to gradually. Perform four times with a 30-second recovery in between.

provides extremely accurate control over the resistance generated – both eccentrically and concentrically.

For the study, both groups had to overcome comparable resistance using a similar muscular action. The key difference was that the flywheel machine allowed its users to experience greater eccentric loading.

The team tested for maximal **isometric** force across numerous angles and hypertrophy (muscle growth) in all four regions of the participants' quadriceps. It was discovered that the flywheel trainers were able to exert more isometric force at all angles compared to the weight stack group. This could be attributed to the fact that eccentric strength is involved in holding and resisting muscular forces.

Although both groups experienced quadriceps muscle strength increases that were deemed not to be statistically significant, the flywheel group's muscles displayed greater hypertrophy across all four regions. This led the researchers to conclude that more robust muscular adaptations occur following flywheel than weight stack resistance exercise, supporting the idea that eccentric overload offers a potent stimuli essential to optimise the benefits of resistance exercise.

Practicalities of eccentric weight training to enhance deceleration

To 'lift' eccentrically, an athlete needs two spotters and/or specifically constructed equipment. These eccentric lifts often use super-maximal loadings of 105-125% of the athlete's normal one repetition maximum (1RM). This is because muscles are able to withstand greater eccentric than concentric loading due to increased fast-twitch muscle fibre and **motor unit** recruitment.

Using the bench press as an example, the bar should be loaded and the athlete assisted in lifting it into the ready position. The athlete should then lower the weight to a five count with the spotters on hand. At the bottom of the lift the spotters assist the athlete to return the bar to the stands. Note:

Thoughts of an expert

Tudor Bompa is one of the world's foremost conditioning authorities and is an advocate of weight training for the maximisation of all aspects of sports performance, including eccentric training methods for a variety of sports abilities, including deceleration (*see table 1*). Bompa believes that for weight training, these methods should only be used by mature athletes going through a training phase designed to develop maximum strength. Doing this will significantly stimulate the neuromuscular system and allow increased power output from fast-twitch fibres. This increased output that can then be used to enhance sports performance through subsequent training phases.

Bompa also believes that the strength developed at certain percentages of 1RM has a direct transference into specific sports abilities. For example (and in the light of this article), he believes that landing (and reactive) power is enhanced by loads between >105 (super-maximal eccentric training) and 80% (maximum/ heavy concentric/eccentric weights) and deceleration between 90-60% of 1RM (heavy to medium concentric/eccentric weights).

Jargonbuster

Isometric
a static contraction where no movement occurs

Motor units
A bundle of muscles fibres that share a neural (electrical) activation pathway

the athlete only assists the return of the bar; they should not try to 'press it back up'.

Plyometric training to enhance deceleration

Plyometric exercises are crucial when conditioning for dynamic deceleration. A plyometric exercise evokes a specific combination of muscular actions that enhances the athlete's ability to absorb landing forces and (if required) produce dynamic stopping, jumping and cutting movements.

When an athlete lands from a jump, to leap into another, the muscles are 'stretched under load' (the eccentric contraction); in other words, the muscle fibres lengthen as they absorb the impact. This process also stores energy. The stronger the athlete's muscles are eccentrically, the greater control they can exert during landing. Therefore, the strain that is placed on the knee and ankle joints is lower, and more power is available for the subsequent concentric contraction.

You can think of an eccentric contraction from a jump landing as a bit like cocking the trigger on a gun; it prepares the muscles to fire with much enhanced concentric power when the

Table 1: Relationship between weight lifted (as a percentage of 1RM) and the development of different types of 'sports strength', including deceleration

Percentage of 1RM	**>105**	**100**	**90**	**80**	**70**	**60**	**50**	**40**
Type of strength								
Landing/reactive power	■	■	■					
Throwing power		■	■	■	■			
Take-off power		■	■	■				
Deceleration			■	■	■	■		
Acceleration				■	■	■	■	■

Table adapted from Bompa: 'Periodisation Of Strength' 2005; p67

'hammer' is released, or, in the athletic example, the athlete leaps into a jump (or similar dynamic movement).

Conclusions

This article outlines the importance of specific conditioning for deceleration. Football coaches and players should incorporate specific drills and practices into a carefully balanced training plan designed to get the most from these abilities and reduce injury risks. The drills outlines above will improve eccentric strength in the relevant muscles.

> *'You can think of an eccentric contraction from a jump landing as a bit like cocking the trigger on a gun'*

Drop jumps

The height of the drop should be between 40-100cm. The higher the drop is, the greater the strength component; the lower the drop, the greater the speed component. To perform the exercise the player stands on a suitable platform and steps off. On landing they react to the ground as quickly as possible to leap either upward or forward. Their arms should be used to enhance the power of the jump *ie* swung backward prior to landing and forward as vigorously as possible, just prior to, on and after landing. It is crucial that the player reacts to the ground as quickly as possible to maximise the plyometric action. They should not overly flex their knees on landing.

Do: 4 x 6 jumps (recovery of 30 seconds between jumps and 1 minute between sets)

Eccentric drop jumps

For this variation, when landing from the jump, the athlete attempts to 'block' their landing – *ie* attempt to land without significantly bending the knees, although there should be a slight bend at the knees. This is the plyometric equivalent of eccentric weight training – as described previously.

Do: 4 x 6 jumps (recovery as above)

Performing jumps such as these can provide the conditioning needed in female players to help reduce ACL injury. However, the coach and player should analyse the jump and deceleration patterns required for football. and devise specific training programmes and practices accordingly. For example, if a sport requires more vertical as opposed to horizontal jumping then relevant practices should be implemented in training. The same goes for single- versus double-leg landings and the quantity of jumps.

Double- and single-leg hop jump and react drill ('line bounce')

This drill deliberately creates multiple dynamic deceleration requirements in a short space of time. For the double-leg version, the player stands behind a line on a suitable training surface such as a running track. He or she then jumps using a low trajectory over the line to a position approximately 60-90cm in front of it, and then immediately jumps back to the starting position reacting as quickly as possible. The drill is then continued in this back and forward manner. The arms should be swung backwards and forwards to assist speed and balance. It is crucial to be as dynamic as possible. The single-leg option is performed in much the same way and is a more advanced option. Obviously, the player hops to and fro over the line.

Do: 3 x 20 seconds (for double-leg version) 3 x 10 seconds
(for single-leg version)

References

1. Tudor Bompa et al. Periodisation Training for Sports (second edition); Human Kinetics 2005
2. Med Sci Sports Exerc 2000; 32(4): 812-9
3. Am J Sports Med 2007; 35(2): 235-41. Epub 2006 Nov 7
4. Eur J Appl Physiol 2008; 102(3): 271-81. Epub 2007 Oct 10

Plyometric training: footballer's friend or foe?

At a Glance

- The energy expenditure and movement demands of football are considered;
- The potential benefits of plyometrics for football training are discussed;
- Recent research on the relative merits of weight training and plyometric training is presented and recommendations made.

Plyometric type training exercises for power and speed are used with great effect in a number of sports. But how useful are they for footballers? *John Shepherd* looks at the recent research and comes up with some surprising conclusions…

Football is a high-intensity intermittent sport. Although players can cover up to 11km in a game, most of this is done in short, sharp bursts lasting seconds, and this performance therefore relies on anaerobic energy, speed and power. Plyometric (jumping) exercises to develop power are used by sportsmen and sportswomen from myriad sports with success. But can they be applied to football and combined with traditional approaches?

A plyometric exercise involves the combination of two muscle contractions coming together to enhance muscular power outputs and therefore speed and power (*see box 1*). Footballers need to posses agility, speed and strength (*see box 2*) and plyometrics are a great way to condition these outcomes. Firstly, let's take a look at some research that has examined the inclusion of these types of exercises into football training.

Swiss researchers examined the effect of surface type (grass or sand) on residual muscle soreness, vertical jump and sprint performance in 37 footballers [(2)]. Why residual muscle soreness? Well, if a player suffers from soreness or gets injured and has to be rehabbed back to full fitness, the knowledge of the best surfaces on which to train will be of great benefit to football conditioners, physiotherapists and managers.

Eighteen players followed a four-week plyometric training programme on grass, while 19 followed the same programme on sand. Pre and post-intervention programme, the players were tested on 10m and 20m sprint performance, squat jump and **counter movement jump** ability. Muscle soreness was tested using a questionnaire. The results showed that both interventions improved sprint speed and squat jump performance similarly. However, it was discovered that the footballers performing plyometrics on sand improved their counter movement jump more than those who jumped from the grass. It was additionally discovered that the players who performed their jumps from sand reported less muscle soreness.

In the world of sports conditioning, specificity is seen as key in terms of conditioning drills and practice, and maybe, therefore, jumping from sand could be seen as less relevant than jumping from grass. However, it's not always that simple. To perform a squat jump requires the generation of force from a stationary position, primarily using a concentric muscle contraction in the ankles, thighs and hip muscles. But the

Box 1: Understanding plyometrics

A plyometric exercise is used to develop power and speed and involves the combination of two muscle contractions Specifically this occurs when a **concentric** muscle contraction immediately follows an **eccentric** one. It's a bit like stretching a spring to its fullest extent (the eccentric contraction) and then letting it go. Large levels of energy are released in the split second the spring contracts (the concentric contraction) and this specific muscular sequence is also known as the 'stretch shortening cycle'. There are numerous exercises that can be used to develop a player's plyometric power, such as hops and bounds, **drop jumps** and agility practices.

Jargonbuster

Anaerobic
Energy system for high intensity exercise that doesn't require oxygen

Concentric muscle contraction
When muscles shorten under load – eg the lifting phase of a biceps curl

Eccentric muscle contraction
When muscles lengthen under load – eg when stopping from running and landing from a jump or the lowering phase of a biceps curl

Drop jump
Jump performed immediately on landing after stepping from a box or platform (recommended box height 30-75cms)

Counter movement jump
Jump performed with eccentric to concentric movement (knee bend and jump)

Box 2: The demands of football

In 2003 researchers from Britain looked at the specific movement and energy expenditure patterns of Premiership players (1). In all, 55 players from 12 teams – all internationals with an average of 36 caps for their respective countries – were observed around the pitch using a player cam. It was discovered that the players spent about 40% of their time on the pitch performing 'purposeful movements' – that's time spent running at various speeds and performing football specific movements and skills.

When this purposeful movement was further analysed it was discovered that strikers, midfielders and defenders spent 48.7% of their time moving directly forward, 20.6% not moving in any direction at all and 30.7% performing football specific movements and skills. Table 1 breaks this information down further into movement types:

The researchers then went even further and looked at the specifics of the 'other' movements, such as turns and even the degrees through which the players rotated, including how many were made to the left and to the right. In all it was determined that 726 turns were made by all player groups across a match with 69% of these being between 0 and 90 degrees. All outfield players made an average of 111 on-ball movements.

Position-specific movements of Premiership players (% of time)			
Movement	Striker	Mid-fielder	Defender
Standing	5.3	2.1	6.3
Walking	14.1	12.8	15.8
Jogging	24.7	28.3	31.5
Running	11.1	14.6	7.6
Sprinting	5.5	6.4	2.5
Skipping	8.3	9.1	12.3
Shuffling	9.5	7.9	10.5
Other	21.5	18.8	13.6

As you'll see from the table it was discovered, for example, that strikers made more 'other' movements than mid-fielders or defenders. And more of their turns were between 270 and 360 degrees, reflecting the spins and turns they need to make to shake off defenders and free up space up front.

By contrast, defenders made more backward runs and feet forward dives. Strikers not surprisingly (because of the feet first antics of the defenders!) had to absorb the most physical punishment. They also performed the highest intensity activity, for example, stopping and swerving. Midfielders did the most running with around 11km per match compared to the 10km of strikers and defenders, and also made the most forward runs and passes.

These results (and similar research) indicate specific training demands. For example, a striker needs to be physically strong and powerful and the training should reflect this. More specifically, they will also need to maximise their turning ability. Plyometric training would therefore appear to be a key training ingredient both for strikers and other players.

'Heavy strength training leads to significant gains in strength and power-related measurements in professional soccer players'

counter movement jump utilises the eccentric/concentric stretch shortening cycle interaction and jumping from the softer surface will slow this down. Basically the sand will 'damp' the explosive capability of the muscles, which explains the reduced adaptation to this training method of the players in that group.

However jumping from sand requires greater strength and this probably explains why the players who performed their plyometrics from this surface improved this jump more significantly. It was as if they were performing their jumps with added resistance, which overloaded their muscles to a greater extent than the grass, producing a resultant increase in strength.

What are the lessons here for football conditioners? Varying the surface from which players perform their plyometrics training could yield physiological and performance benefits, and reduce residual muscular soreness, allowing a player to complete more high-intensity training. However, everything else being equal, it's probably still better that players train on hard dry grass, running tracks or sprung sports hall floors when

Box 3: Maximum strength training

The inclusion of heavy load, low-repetition weight training is increasingly recommended for sportsmen and women in power sports. In many ways this recommendation comes from the work of Tudor Bompa – one of the world's foremost conditioning experts [4]. Bompa believes that optimum performance is not possible unless an athlete follows what he calls an 'MxS' of maximum strength training phase. He argues that this phase enables the athlete to recruit larger numbers of their fast twitch (speed and power) producing muscle fibres.

This type of training should be performed as dynamically as possible given the heavy load, but with adherence to strict exercise form. Long recoveries (3-6 minutes) should be taken between sets of 1-4 repetitions to enable the athlete to apply maximum effort to each lift. It should be noted that the intensity of this training is very high; footballers (and all other athletes) should progress systematically to being able to handle such loads over time using a properly constructed training programme, which allows gradual progression to these high intensities.

performing plyometrics. This is because the harder surfaces will help develop a 'quick fire stretch shortening cycle', which will translate into improved on-pitch performance.

Weight training

For comprehensive football conditioning, weight training and plyometrics can be combined. But what kind of weight training protocol works best for footballers? Researchers from Norway examined weight training protocols used by professional football teams [3]. Specifically they wanted to find out whether there was a strong relationship between maximal strength, sprint and vertical jump performance among elite players.

Seventeen international players, with an average age of 25, participated in the survey. They were tested for maximum half-squat, vertical jump and sprint performance over 30m and using a 10m-shuttle run. It was discovered that half squat performance was a key determinant of all test performances and it was also noted that this did not compromise anaerobic endurance as measured by the shuttle run. The researchers concluded that '*elite soccer players should focus on maximal strength training, with emphasis on maximal mobilisation of concentric movements*' *(see box 3*).

Power combination training

Power combination training combines plyometric and weight training exercises into the same workout. The exercises are usually paired and must work the same muscle groups. Typical examples include the squat jump and half squat, and the split jump and the single leg press. Loadings on the weights exercises must be in excess of 70% of one repetition maximum (1RM). This is to ensure that the exercise targets large numbers of fast twitch fibres (a lighter weight would tend to emphasise slow twitch fibres – which have an endurance role and are consequentially much less likely to contribute to power, speed and strength development).

Power combination workouts have been shown to enhance the power outputs of fast twitch muscle fibres within the workout and over a training period. This is believed to occur as a result of 'potentiation', which is essentially heightened neuromuscular activity in the relevant muscles. The net effect is that an athlete is able to recruit larger numbers of fast twitch muscle fibres without conscious effort, thus boosting their power output.

However, there is some research which argues that this method of training may be less beneficial for football players. Norwegian researchers looked at power combination training methods and their effects on professional players [5]. Six players were assigned to a heavy weight training group, who also completed 6-8 specific football sessions a week, whilst 8 players performed plyometrics as well as the heavy strength work and the football sessions. A control group just performed the 6-8 weekly soccer sessions.

The pre- and post-intervention tests used by the researchers included maximum half squat, counter-movement jumps and peak power in half squat with 20kg, 35kg, and 50kg loads (basically the players' speeds of movement were measured during the half squat with these weights and their power outputs measured). In terms of sprint speed, acceleration, flat out speed and 40m times were tested.

The result showed that there were no significant differences between the footballers who had performed the power combination training or the heavy squats only. As a result of these findings, the researchers decided to create just one intervention group with players performing heavy weights and plyometrics. Again, a control group just performed a comparable number of weekly football sessions. The power combination training footballers showed improvements across all tests, except the counter movement jump. These improvements were deemed to be significant for the half squat 1RM and sergeant jump for example. However, non-significant differences were seen on the half squat power tests with 20kg and 35kg loads and all of the sprint tests.

This led the researchers to conclude that, *'there are no significant performance-enhancing effects of combining strength and plyometric training in professional soccer players concurrently* *performing 6-8 soccer sessions a week compared to strength training alone. However, heavy strength training leads to significant gains in strength and power-related measurements in professional soccer players'*.

How can these findings be reconciled with the fact that much other research indicates that power combination training works? Simon Thadani is the conditioning coach at Ipswich Town FC, and believes that football conditioners must be conscious of the training that players are doing with the football coaches and that this must all be assessed and added to the overall training load on the players.

He provides the following real life scenario: '*One of the football coaches took away several of the defenders for half an hour to concentrate on heading. I watched the session and observed that each player ended up doing 150 plus headers. I therefore decided that the players had done enough and did not need to do the afternoon session, nor plyometrics the next day*.'

Basically, what Simon is noting is that the football sessions were conditioning the jump performance of the players without them having to do a specific jumping workout. This might explain the findings of the Norwegian researchers above; a crucial consideration for football conditioners (indeed conditioners of all high intensity intermittent sports) is that the physiological demands of the sport itself (both through training and competition) cannot be overlooked as a contributor to the overall training and conditioning load.

Conclusion

Developing the maximum power capabilities of footballers is crucial for maximum playing performance. Although plyometric exercises tick all the right boxes in this respect, it would appear that heavy weight exercises, notably the half squat, are perhaps even more effective as part of a properly constructed training programme.

Plyometric exercises, as specific training units, may be more beneficial in pre-season and from an injury prevention perspective (in terms of mastering improved technique and strengthening relevant muscles) in a controlled environment. And, finally, when plyometrics are used, conditioning coaches should also be mindful of the surface on which they are performed, in terms of training response and potential muscle soreness.

References

1) Journal of Sports Science and Medicine (2007) 6, 63-70

2) Br J Sports Med. 2008 Jan;42(1):42-6. Epub 2007 May 25

3) Br J Sports Med. 2004 Jun;38(3):285-8.

4) Periodization Training for Sports, 2nd edition: Bompa Et al, Human Kinetics, 2005

5) J Strength Cond Res. 2008 May;22(3):773-80.

Get ready: preparing for major tournament football

At a Glance

This article:
- Discuss the physiological and logistical challenges of World Cup football preparation;
- Look at the strategies be employed by national coaches.

The World Cup is as much a battle of attrition as it is a tactical war, and the team that suffers the fewest injuries and is able to minimise performance loss over this period will greatly increase their winning chances. *David Joyce* explains , using the 2010 World Cup tournament in South Africa as an example.

Tapering and peaking for the World Cup

There's a dearth of research directly assessing tapering in preparation for a tournament where multiple peaking is required. Because of this, it's not really known which is the best way to taper for team sports tournaments; the physical preparation of players for major tournaments has evolved more through trial and error than any specific experimental research. It should be noted, however, that the principles that will be employed by the teams are derived from training practices that have been proven to be effective in individual sports.

One of the main worries for national coaches is that the World Cup is scheduled at the end of a very long club season. National federations tend to opt for one of two strategies in a tournament year:

- To advance their domestic club seasons so that the earlier fitness allows more time for recovery for the national players;
- To delay the commencement of the season and so their national squad players go straight from the club season to the tournament

‘The physical preparation of players for major tournaments has evolved more through trial and error rather than any specific experimental research’

in competitive shape.

Both strategies have their advantages and disadvantages and there is very little in the way of scientific evidence to support one strategy over the other, although the earlier finish is much more common around the world.

Again, there’s little evidence to say what the optimum length of break between club season and the tournament should be. Some coaches believe that an ideal approach to peaking for the World Cup involves commencing around six weeks before the first game because this gives sufficient time for:

- Recovery from the rigours of the domestic season, allowing the medical staff time to rehabilitate injuries and for the players to rest both physically and psychologically;
- Rebuilding focusing on both aerobic and anaerobic

Box 1: Injuries and load monitoring

Football fans hold their collective breath when a key player for their national team is injured playing club football. The closer to the tournament we get, the greater the significance an injury has. Four weeks off for a hamstring is not ideal at any stage of a season, but when there are only six weeks to go before the tournament, it can be disastrous. This explains why players are likely to be more conservative in their return from injury schedules at this stage of the season, and is particularly the case if their club is not challenging for silverware or battling relegation. The majority of the top teams, however, will have players who will be in contention for major club honours right up to the last day of the season.

While injuries due to impacts etc are very difficult to prevent, intrinsic injuries related to overload can be significantly reduced with planning and appropriate intervention. For example, players in the Australian national team have each are issued with GPS watches so that the sports medicine/sports science team can keep tabs on their training and playing loads. The Aussies are not the only country aware of the importance of load monitoring. The English team are very proactive when it comes to monitoring the playing health of their list. However, because the players are not centrally contracted (as in cricket, for example) the national federation can only have so much influence and are ultimately reliant on the management team at club level until the end of the season.

Box 2: Altitude and ball movement

Altitude will affect not just the players' performance, but also the way the ball moves through the air. To understand these effects, we need to have a quick look at the science of fluid mechanics. The ball will travel further and up to 5% faster at altitude but by the same token, players will struggle to generate the same amount of 'spin' compared to sea level because the air at altitude is thinner and therefore the 'Magnus effect' will be less.

The Magnus effect explains how a football can swerve towards goal after it is struck with spin. As a spinning ball flies through the air, it attracts particles of air to its surface. These particles will create friction forces more on one side of the ball (the side that's spinning toward the direction of ball flight) compared to the other and it is these unequal friction forces that cause the ball to swing. This is the same reason why bowlers try to shine only one side of the ball in cricket. However, with thinner air at altitude, the friction forces are reduced and, as a result, the ball does not swing as much in the air.

conditioning (the exact distribution of this emphasis will depend on the status of the individual athlete and the demands of their position). The aim for many coaches will be to ensure that the loading is sufficient to improve players' fitness but not overtrain them. This is a tricky balancing act to achieve because it's all too easy to stray into overtraining; monitoring of the training status of the players is therefore paramount in this period. This is also a major period of tactical training, as coaches attempt to mould a team from a disparate collection of players who may well have been plying their trade in all corners of the globe;

- Pre-tournament tapering, of which low-volume but high-intensity warm up matches are vital components. The coaches will be hoping that this tapering period will induce a period of supercompensation in time for the tournament itself.

In practical terms, most players will have a short break of a week or so following the conclusion of their domestic campaign before converging on their homeland for their national team's preparation camp. There will be a period of approximately one month between the end of most European leagues and the kick-off of the tournament. During this time, most nations will play between three and six friendly games against opposition that did not make the finals in South Africa or are in different groups. in 2010, for example, New Zealand scheduled four matches in the space of 16 days, all against teams that qualified for South Africa but were in different groups. Two of these were played at altitude in South Africa, one at altitude in Austria and the other in Australia.

Altitude

One of the key factors that teams have to consider is the effect of altitude on their players and indeed, on the game (*see box 2, page 79)*. The World Cup in South Africa is a case in point as there is huge variance in the altitude of the stadiums. Spain, for example, will play Switzerland in Durban at the Moses Mabhida stadium which is located almost on the beach (26 feet above sea level) and then five days later will be playing Honduras at Ellis Park, Johannesburg which is 5,562 feet higher!

The effect of altitude on the players' physiology is the other area that needs to be considered. In terms of the Earth's topography, 5,500ft is considered 'moderate altitude' (Bolivia's national stadium stands at more than double that at 11,932ft!) and yet significant physiological challenges will still be issued at this level.

Only a small change in the blood's oxygen carrying capacity (more technically known as haemoglobin percentage saturation) occurs below 10,000ft but even the relatively small drop seen at 5,500ft can significantly curtail intense aerobic activity. Although short-term activities such as sprinting are not significantly affected at altitude, the reduction in oxygen transport is likely to have an effect on repeated bouts of intense exercise. Clearly, football is a sport involving such repeated bouts, with the average wide midfielder in the English Premier League completing in excess of 60 high intensity sprinting efforts (faster than seven metres per second) every match. This tells us that even moderate altitude is energy sapping. Other short-term effects of exposure to altitude can include:

- Increased heart rate;
- Nausea;
- Sleeplessness and lethargy;
- Headaches;
- Decreased maximum oxygen uptake (VO_2max).

All these combined can lead to performance loss and as a result, a period of acclimatisation may be required.

Conclusion

It's not just the altitude of a venue that can give coaches and sports scientists headaches as they attempt to juggle all the variables that make up the complicated jigsaw that is a major tournament preparation schedule. There is a need for recovery following the club football season to be blended with a conditioning programme, an acclimatisation schedule and tactical training in order to produce a squad of players capable of performing at their maximum. All this plate spinning is necessary just to get the team at an optimal level for kick-off in their first match. In the following article, we'll explore some of the recovery strategies that teams need to employ to allow them to produce the goods over the course of the biggest sporting event on the planet.

World Cup football: why rapid recovery matters

At a Glance

This article:
- Examines the physical and mental stresses of playing elite tournament football;
- Looks at the likely strategies the World Cup teams will employ to overcome these stresses;
- Makes practical recommendations applicable to players participating in football tournaments generally.

The 2010 FIFA World Cup is nearly upon us. What inter-match recovery strategies are likely to be employed by the 32 teams during the tournament and what can other sportsmen and women learn from the world's best professionals? *David Joyce* investigates

In the previous article, I argued that the team that wins the World Cup is often the one that minimises total performance decrements the most. Obviously, several variables interact to amount to a total team performance with avoidance of injury and suspensions to key players critical to team success. A key variable is recovery – the process of restoring the body to a rested level in preparation for the next round of competition or training. Optimal recovery strategies involve both physical and psychological approaches. Before we discuss these strategies, let's examine the stresses the players will undergo in a little more detail.

Pre-tournament stresses

The first thing that many teams will have to recover from is the flight from their country to the host nation and the adjustment to a new time zone is something that needs to be completed as soon as possible. Obviously, no team will fly in from afar just before their first game and so jet lag (*see box 1*) shouldn't affect the players within the tournament proper, although it can hamper training in the period beforehand if not overcome efficiently.

Altitude acclimatisation is another consideration although this was covered in the previous article so I won't go into great detail about it here. Suffice to say that some teams choose to spend time at altitude prior to the tournament and some teams use special apparatus to try to overcome the effects of altitude more rapidly!

In-tournament stresses

Each player is likely to be stressed differently and as such, there cannot be a perfect recovery recipe that suits everyone. It's essential, therefore, that any recovery strategy is individualised to the player and also according to the load that the player has encountered during a particular game (*see box 2*). For instance,

Box 1: Jet lag

Jet lag is a form of travel fatigue and occurs when passengers have to cross multiple time zones. Symptoms occur when there is a mismatch in the 'body-clock time' and the new local time. Symptoms of jet lag include:

- Tiredness and irritability;
- Poor concentration and decision making;
- Headaches;
- Inability to sleep/waking in the night;
- Decreased mental and physical performance;
- Loss of appetite.

The following guidelines can help overcome jet lag symptoms in elite athletes:

- Pre-flight adjustment of activity (eating and sleeping) times in accordance with those at the destination;
- Try to arrange for arrival time to be in the late afternoon/evening;
- Avoid alcohol and caffeine on the flight but drink plenty of water, sports drinks or fruit juice;
- Shower and brief period of light exercise upon arrival[1].

Box 2: factors affecting individual recovery strategies

- Distances run during the game – An elite midfielder may cover almost 14km during a game, whereas a centre back is likely to traverse only around 11.5km;
- Number of sprints during the game – An elite left back in the English Premier League would average well over 100 sprints (running faster than 7m/s) during a game, while a right back tends to do much less sprinting, averaging less than 50;
- Number of decelerations – Body load is much greater (due to the eccentric stress placed on the lower limbs) when the number of decelerations (stop-start, changes of direction, etc) are high;
- Emotional stress – It is vital to remember that we are dealing with human beings, not robots. For example, the emotional stress of striker who has just scored the goal that takes his team into the next round is likely to be quite different to that experienced by a full back who scored an own goal to gift a win to their opposition;
- Injury – If a player has sustained an injury, they may not necessarily be able to complete the same recovery programme as their team-mates;
- Age – An older player's body takes longer to recover following a game;
- Environmental stress – The physiological stress of playing in unaccustomed weather or at altitude can affect players in different ways.

high intensity running (faster than 5.5metres/sec [m/s]) distance is much greater when both teams play an open counter-attacking game, whereas the physical load in terms of high intensity running during a more cagey, tight game will be substantially lower.

Physiological aspects

Many of the studies on recovery strategies have been performed on untrained populations and there are limited studies on elite footballers. As such, it's difficult to be certain that all of the effects of intense competition published in studies actually apply to World Cup players. However, there are three physiological aspects of intense competition that most definitely are relevant to elite footballers:

Box 3: Fuelling and refuelling guidelines

Timing	Type of intake
Pre-match meal (2 hrs before game)	Mixed meal with low to moderate glycaemic (GI) carbohydrate and a moderate amount of protein.
Immediately pre-match (within 10mins)	Medium to high GI carbohydrate snack
Half time	Medium to high GI sports drink or carbohydrate snack
Immediately post-match	High GI carbohydrate and protein (4:1) carbohydrate/protein, supplying 1.5g of carbohydrate per kilo of bodyweight

Dehydration

The intermittently intense nature of the game of soccer has been shown to elicit sweat losses of between 1,500-3,750mls during a 90-minute match in warm climates(2). Performance decrements have been shown to occur at dehydration rates of less than 2%(3), so it is necessary to replenish fluids during and after the match, well as after training.

Glycogen depletion

Glycogen is stored mainly in the muscles and in the liver and is the primary fuel source during a football match. In fact, it is thought that the development of fatigue during a match is related to the depletion of glycogen(4). This depletion produces a reduction in work rate seen in the latter stages of the game, as demonstrated by a reduction in running distance and fewer episodes of high intensity running. As long ago as 1973, Swedish research showed that players with low initial glycogen content covered 25% less distance during a match compared with players with high glycogen levels. It is therefore crucial to ensure that players start a match with high glycogen reserves and top up at half time.

Muscle damage

The most common injury 'complaint' in football is muscle soreness as a result of direct contact. These contact injuries don't necessarily make it onto the injury lists that are published in the media or in official reports because they may not be severe enough to stop a player from playing in the following match. They are, however, enough to reduce subsequent training performance.

The structural damage that occurs can be quantified by the presence of increased biochemical markers of damage in the blood – in particular, creatine kinase (CK). The presence of elevated CK concentrations following a football match can only partially be accounted for by the high levels of **eccentric loading** encountered by muscles. Direct trauma to the muscles is the other major contributor, and significant performance decrements have been demonstrated when CK levels are elevated. As such, efforts to reduce the effects of muscle damage have been a focus of recent recovery strategy studies [5].

Jargonbuster

Eccentric loading
When muscles lengthen under load – for example, the quadriceps during the landing phase when running

Recovery strategies

With these factors in mind, it becomes easy to see why an 'off-the-peg' recovery strategy just isn't feasible. There are two 'non-negotiables', though, when it comes to match recovery

Box 4: Strategies to enhance sleep

- Maintain a dark room. Light promotes wakefulness through the inhibition of melatonin secretion (sleep hormone) as well as stimulation of the sympathetic nervous system;
- Avoid caffeinated drinks such as tea, coffee and cola in the afternoon and evening;
- Try to maintain the same bedtime routine regardless of circumstances;
- Keep the room cool; the ideal temperature for sleeping varies from person to person, but keeping covered in a slightly cooler room is preferable to being too warm;
- Avoid naps during the day if they interfere with the ability to sleep at night.

and these need to be followed irrespective of the individual. These two factors are:

1. Nutrition (see box 3)

a) Re-hydration – Precisely what each team will use to achieve this will almost certainly be determined by the sponsorship deals that each national federation has in place, but in general, a carbohydrate and electrolyte blend sports drink will be the most commonly used drink. It's likely that players' hydration status will be monitored daily by most national sport science teams, with fines likely to be issued to players found to be dehydrated!

b) Glycogen resynthesis – High pre-event muscle glycogen levels are essential for optimal performance in sports that entail high levels of sustained, high intensity work and the restoration of muscle glycogen levels post-exercise is crucial for rapid recovery. The greatest depletion in muscle glycogen occurs in the first half of the match, so a rapidly releasing carbohydrate-energy drink is recommended during the interval. Following the match, 75-90g of CHO should be ingested immediately within two hours of the final whistle[6] and then at regular intervals up to five hours afterwards (although this will obviously depend on the time the game finishes). As players frequently have difficulty eating immediately following a match, a carbohydrate-rich drink is often used as this allows for rehydration as well.

2. Sleep

Adequate sleep is vital for both physiological and psychological restoration. While high quality sleep studies involving elite athletes are few, in general sleep deprivation has been shown to have the following effects:

- Impaired immune function with increased incidence of illness;
- Delayed reaction times and impaired decision making capacity;
- Perception of increased exertion with repetition of effort;

- Decreased growth hormone synthesis, impairing muscular repair;
- Increased cortisol (stress hormone) release;
- Delayed glycogen store replenishment.

As a result, all nations have to make arrangements to optimise the sleeping environment whilst in their camp during the tournament. Many players will have difficulty getting to sleep at a reasonable time following an evening game because of the mental and emotional stress generated by the match. This is not so much of an issue in the short term; the players will be used to dealing with this when playing evening games for their club. Where it does become an issue is when a player starts to accumulate a 'sleep debt'. Box 4 lists some strategies that can enhance sleep quality/quantity.

'It's likely that players' hydration status will be monitored daily by most national sport science teams, with fines likely to be issued to players found to be dehydrated!'

Other recovery strategies

Myriad other strategies have been proposed to help footballers recover following matches. The most common of these include:

- **Ice baths** – Cold-water immersion produces pain relieving effects and may be beneficial in reducing the muscle damage following a match. Contrast therapy may also be used. This usually involves a 20-30 minute programme of movement in warm water (37-43°C) for 3-4 minutes, followed by immersion in cold water (12-15°C) for 30-60 seconds. Cold water immersion has been shown to enhance CK clearance in rugby players compared to passive recovery(5). Ice baths may also enhance sleep, another important feature of the recovery process.
- **Massage** – Massage is one of the most commonly used recovery methods in elite football. The evidence does indicate that massage is effective in reducing perceptions of muscle soreness although the benefits for muscle function and athletic performance are less clear. However, massage can be very relaxing, which is very important in reducing psychological stress. It is possible, though, that vigorous post-match massage could add to muscular trauma, so its application should be under the

strict supervision of the sports medicine team.

● **Pool recovery sessions** – Hydrostatic pressure (from immersion in water) may be beneficial in reducing the symptoms of muscle damage and general fatigue following a match and the evidence suggests that the temperature of the water is not particularly important. An example of a typical pool recovery programme is shown in box 5.

Inter-match training

World cup draws are generally scheduled such that, at least in the group stages, there are either five or six days between matches. The aim is to ensure that players are as fresh as possible for the next match, and so the emphasis of these days is therefore on recovery from the previous match, including injury treatment as well as tactical sessions. Most teams will schedule a single training session each day (although management staff reserve the right to schedule double sessions dependent on previous performance!).

Obviously, each team's recovery protocols will vary dependent on the philosophy of the management and sport science staff. However, it's likely that the majority of the teams

Box 5: typical pool recovery programme

- Walk forwards/backwards/sideways 5 x 10m (each direction) in waist deep water;
- Swim 4 lengths (variety of strokes);
- Aqua jogging (low intensity) – two lengths;
- Walking lunges with upper body stretches (rotations/side bends etc) – two widths;
- High knee lift and heel flick jogging – two widths;
- Sideways lunges – two widths;
- Aqua volleyball game two x 5-minute halves;
- Five minutes of static stretching of major muscle groups (unless contraindicated).

will follow a more or less similar schedule along the lines of:

- Day 1: Recovery protocol (hydrotherapy, stretching, massage, active recovery, ice baths, injury treatment) and game analysis;
- Day 2: Light small-sided game drills and opposition analysis;
- Day 3: Team shape, set piece drills and specific individual role training;
- Day 4: Final team preparations and specific individual role training.

It is important to consider the fact that there will be significant media and sponsorship obligations placed upon the players and programmes will need to take this into account. There will also need to be time allocated to individual relaxation strategies such as massage, meditation and yoga.

Playing partnerships are usually much less familiar in a national squad than in the club environment simply because so much more time is spent with club team-mates. Additionally, it is not uncommon for the style of play a footballer may encounter when playing for their country to be completely different to that they routinely use when playing for their club. Given these facts, a significant proportion of time spent in national team training will involve consolidating team shape and tactical formations.

Another consideration is that fitness coaches will need to maintain the fitness of the entire squad. A player may not be used at all throughout the group stages but an injury to a team-mate may mean that they are called upon to start later in the tournament. It is essential, therefore, that the fringe players maintain their fitness levels. The key is to ensure that the training load these players undergo is sufficient to keep them 'match fit' yet rested enough to be able to make a performance impact if called upon. High intensity training can be achieved through the use of small-sided games (3-, 4- and 5-a-side) and this has been shown to be a very effective method of maintaining match fitness[7].

'Fitness coaches will need to maintain the fitness of the entire squad. A player may not be used at all throughout the group stages but an injury to a team-mate may mean that they are called upon to start later in the tournament'

Conclusion

The effectiveness of the recovery strategies employed by the various sports science teams at the World Cup are major determinants in how well teams perform. The key factors that need to be considered are individualised strategies for glycogen and fluid restoration following matches and training sessions, as well as sleep. This is in addition to recovery from the psychological and emotional stresses that inevitably occur during such a high-stakes event. In fact, these measures are not too different to those that passionate fans may need to employ during the month long tournament!

References

1. European J Sport Sci, 2007, 7(1), 1-7

2. Sports Medicine, 1986, 3, 50-60

3. J Strength Conditioning Research, 2008, 22(5), 1394-1401

4. Maughan, R. & Gleeson, M. 'The Biochemical Basis of Sports Performance'. Oxford University Press, 2004

5. British J Sports M, 2006, 40, 260-263

6. Sports Medicine, 2003, 33(2), 117-144

7. Int J Sports Med, 2009, 30, 636-642

Notes