STRENGTH TRAINING

Julio Tous is a Fitness Training Consultant with FC Barcelona. In this article he looks at the various new technologies being applied to strength training.

1. Introduction

Until very recently, professional football clubs in Spain often placed too little emphasis on strength and power training. A reason for this fact could be the long-held belief that strength training reduces speed and technique by promoting 'bulky' muscles. Another factor is that professional teams usually have only one conditioning coach (sometimes without a full-time contract), with a strength coach being an exception.

During the second half of the 2003-2004 season, a project was developed at F.C. Barcelona. The three main objectives of this project were to:

1) Prevent injuries via optimum conditioning;

2) Develop specific strength and power;

3) Hasten the return to play of injured players after following the physiotherapist's rehabilitation programme.

To achieve these objectives, the use of different technologies related to strength and power training was introduced:

-Flywheel technology (YoYo Technology Inc., Stockholm, Sweden)

-VersaPulley (Heartrate Inc., California, USA)

-Whole-body vibrations (self-made unit)

-MuscleLabTM (Langesund, Norway)

Traditional weight training was almost eliminated from the training schedule. It was still used, but just for purposes of assessing strength and power. This fact helped to reduce the duration of training sessions and increase the motivation of players.

The aim of this article is to present this experience of top level football. In the process the scientific background to each training intervention is explained.

2. Eccentric training: the key for injury prevention

It is well known that eccentric muscle actions generate greater force at a lower level of activation and subject muscles to more severe damage than do concentric actions. Thus, it is accepted that muscle injuries often occur while the contracted muscle is suddenly overstretched beyond its limits. Unfamiliar eccentric exercise frequently results in muscle damage, the symptoms of which include loss of strength, experience of pain and muscle tenderness. Following complete recovery, a repeated bout of the same exercise results in minimal symptoms of muscle damage and has been referred to as the “repeated bouts effect”. The exact mechanism of this adaptation is not well defined but it seems there could be neural, mechanical and cellular adaptations. It is apparent, however, that if the tissue’s threshold for failure of force production increases and the attenuation of loads is enhanced, a protective effect can occur. Those are the main reasons why nowadays eccentric training is accepted as the preferred model to prevent muscle injuries.

On the other hand, eccentric training has been shown to be successful in rehabilitation from chronic tendinosis. Both randomised and non-randomised studies have indicated very good short-term clinical results after performing eccentric training in both achilles and patellar tendinopathies.

Unfortunately, the mechanisms behind the positive effects of eccentric exercises as treatment for tendon injuries are not well known. Possible explanations are:

1. Increase in tensile strength in the tendon;

2. Effect of stretching in lengthening the muscle-tendon unit and reducing ankle joint motion;

3. Alteration in pain perception from the tendon.

2.1. Flywheel (Yoyo) technology

The working principle of this device is based on setting a flywheel into rotational motion by concentric muscle action and then decelerating the motion by eccentric muscle action. By performing the eccentric action over a smaller angular displacement, and hence with a greater muscle torque than that for concentric action, an eccentric overload is accomplished.

Research on this device has been done over the last decade. Askling et al (2003) reported that hamstring injury was prevented in Sweden Premier League players after training with this technology. One group of players performed 16 sessions of specific hamstrings exercise during pre-season (4 sets of 8 repetitions). Another group did not perform any additional specific hamstrings exercise, serving as a control. By the end of the season, the flywheel group suffered three hamstrings injuries and the control group ten. Moreover, the first hamstring injury in the training group appeared only after 4 months of completing the training programme. Furthermore, players in the flywheel group increased significantly not only their muscle strength but also their running speed over 30 m. Any experienced coach will know how difficult it is to increase sprinting speed in already well-trained players.

Figure 1. Leg curl flywheel machine employed by Askling et al., (2003).

The experience garnered over 5 months last season is that players who undertook regular training once or twice a week did not suffer any further injury in the hamstring muscle group. It cannot be concluded that this training was the key factor in injury prevention, but the available evidence is supportive.

We could take advantage of the design of the Flywheel Multigym (see Figure 2) because our players were not familiar with half-squat exercises. With this unit we avoided referred discomfort in the back while squatting heavy loads but still have very high levels of force that could reach 2500 N among the F.C. Barcelona players. It was possible also to monitor training intensity via a rotary encoder and a force sensor connected to the “Musclelab” that also provides biofeedback in real time. Another feature of this device is that it can be used to assess strength and power of both legs.

Figure 2. Leg press in the Flywheel MultiGym: force levels are unlimited for the legs, without stress in the upper body.

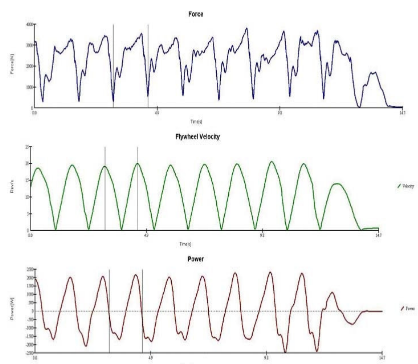


Figure 3. Monitoring training intensity with Yoyo Multigym in real time helps to increase motivation and performance.

2.2. Versa Pulley

Similar in concept to YoYo technology, variable inertia and unlimited three-dimensional movements are presented by using a cone instead of a wheel. In this way it is possible to incorporate more complex specific movements. The intensity of the portable unit is much lower than the flywheel. An overload of 250 to 900 N (depending on the intensity level) is obtained compared to over 900 N in the YoYo machine while performing at maximum speed with the arms. However, a difference between the two machines is that Versa Pulley provides high eccentric velocities at moderate to low forces while Yoyo provides high forces at moderate to low eccentric velocities. Both training concepts are needed to cover the force-velocity spectrum. The possibilities of exercises with Versa Pulley are almost unlimited, as with other pulley, but the difference is in the eccentric overloading that can be obtained. Important exercises for football players are: backward kick with hip extension to prevent hamstring strains, crosses behind the leg to focus on hip adductors, leg rotations to prevent injuries to the anterior cruciate ligament (ACL).

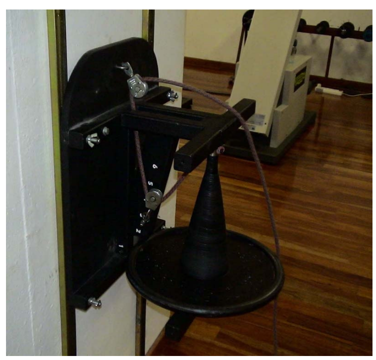


Figure 4. Left: Portable VersaPulley. Right: exercise for arm extensors.

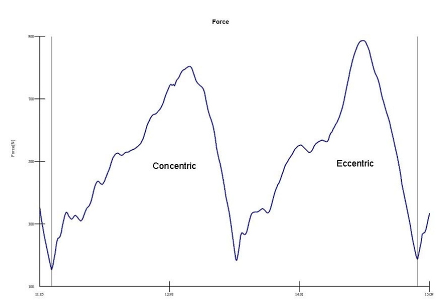
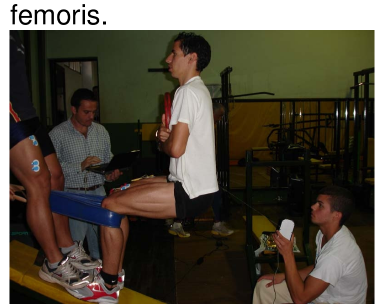


Figure 5. Force values of one repetition while performing arm pulls with the VersaPulley. While peak values are similar 800 N (conc) vs. 886 N (ecc), RFD (Rate of Force Development) during the last 300 ms up to the peak force of each movement presents large differences: 498 N (conc) vs 1112 N (ecc).

2.3. Tirante musculador (eccentric brace)

A very cheap device which can be used to perform eccentric training is a brace called Tirante MusculadorTM. Focus on problematic muscles such as rectus femoris or biceps femoris can be achieved by exercises that entail active tension stretching. Hip extension to induce the required tension is illustrated in Figure 6.

Figure 6. Eccentric exercise for the quadriceps with “Tirante musculadorTM” (blue brace) that allows hip extension and so extra involvement of rectus femoris.



With free weights and exercises such as the squat or leg press, it is not possible to perform a hip extension as shown in Figure 6. The action of hip extension is needed in order to accomplish the biarticular function of rectus femoris. Electromyographic studies have found similar activity in vasti muscles when comparing this exercise with a half-squat of 150 kg but rectus femoris is activated much more. Besides, this muscle is injured disproportionately compared to the three monoarticular vasti muscles of the quadriceps.

3. Whole-body vibrations

In the past five years we have been working with this training method. We decided to build a home-made vibration platform that could fit our needs at the Physical Education Institute in Barcelona. Building the device from scratch was very important in order to understand how these platforms really work. This is not a new training method; it has been used in Russia for more than 40 years. However, until the 1990s there was little published on whole-body vibration as a training method for athletes.

Training using whole-body vibration consists of applying mechanical vibrations to the body via platforms, cables or dumbells. We use a vibration amplitude of 4 mm and a frequency that goes from 26 Hz (for recovery) to 35 Hz (for strengthening). These sinusoidal vibrations provoke a fast and short change in muscle length that is detected by the muscle spindles, which subsequently innervate the efferent nerve fibres of the host muscle. In this way, an increase in muscle activity is usually observed with values higher than those recorded during voluntary muscular activity. This method may induce improvements in strength and power performance similar to those observed with regular strength training.
In a study of Italian professional players by Bosco et al (2001), 17 players followed a training programme during pre-season performing 5 sets of 90º squat (60 s exercise with 60 s rest in between). After one month (5 sessions per week) players significantly increased their jumping ability and flexibility of the leg flexors. Unfortunately, this study did not include a control group to determine if the increases in performance were related to whole-body vibration training or to other training elements performed during that pre-season.

On the other hand, Sannicandro (2003) found an increase in sway control of the lower limb in 20 regional football players compared to a control group. These results suggest whole-body vibration training is an effective method to improve the control of equilibrium and hence prevent the occurrence of injuries.

More relevant for football-specific demands is the study of Berschin et al (2003). They included a whole-body vibration programme during the pre-season training of 24 professional rugby players (6 weeks; 3 sessions per week). Exercises consisted of performing over the platform 5x3´ squats with loads increasing every week up to 70% of 1RM. Another group performed regular weight training (5x12 reps at 70% of 1RM performed explosively). After 6 weeks the players training with whole-body vibrations improved their performance in either jumping, speed and agility tests significantly more than the group doing regular weight-training. Besides, the players reported that they felt more powerful and stable while performing changes of direction.

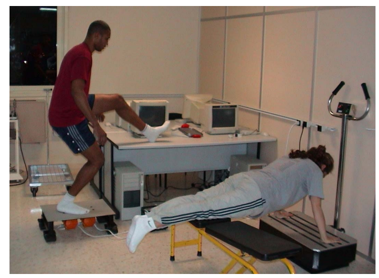


Figure 7. Different exercises with different vibration platforms

We could take advantage of different features of our self-made vibration platform. With this platform we can adjust vibration frequency with 0.1 Hz accuracy. This is an important factor because optimum frequencies are in different ranges for each muscle (see Figure 8). Also, the small portable vibration platform provides a more unstable environment than a big commercial platform. A wider range of exercises can be performed, such as the “decline squat” (see Figure 9). Good clinical results have been found in chronic patellar tendinopathy patients after performing eccentric squats on a 25º decline board. Another very useful exercise is hip extension over the platform to accomplish an eccentric action of the quadriceps (see Figure 10).

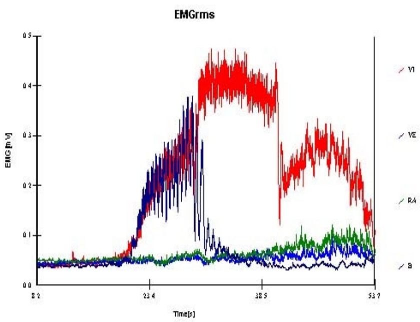


Figure 8. Increase of vibration frequency of one hertz per second can show the optimum frequency for different muscles. In this example vastus medialis reached maximum EMG activity between 30 and 35 Hz while gastrocnemius medialis reached it between 25 and 30 Hz.

Figure 9. Left: decline squat with vibrations. Right: side step with vibrations.

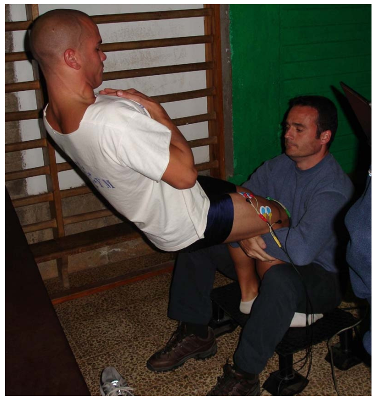


Figure 10. Eccentric exercise for the quadriceps on the vibration platform.

4. Musclelab

Musclelab is one of the most complete systems to be found for evaluating muscle behavior. It is a light-weight portable device that can be easily transported to the training ground. Several research groups have reported good reliability for the apparatus. One of the most interesting characteristics of this device is on-line biofeedback. This facility helps to increase motivation and even power performance. With this portable “lab”, a wide variety of dynamic and isometric muscle tests can be conducted. To perform them we need to use different sensors such as linear encoder, EMG sensors, infrared lights contact mat, force sensor, goniometers, and so on. In order to know how the muscular strength expresses itself the following tests are recommended for use:

-Strength, speed and power can be assessed with four to five different loads (usually 20, 40, 60 and 80% of 1RM). It is possible to address the following questions: What is the optimal load each player should lift in each exercise (and according to the time of the season) based on his training objective?; Does the player have a proper muscle performance at that time?; Does the player have any imbalance in muscles or limbs that need to be corrected?; Did the training programme produce the expected adaptations? (see Figure 11)

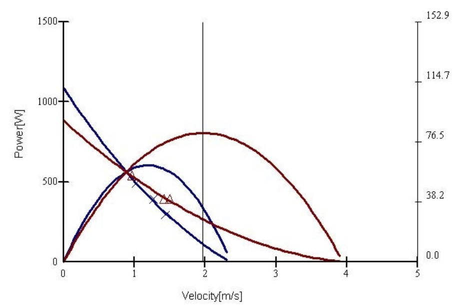


Figure 11. Force-velocity and power curves before and after 5 weeks of training at the optimal training load (45% 1RM = 40 kg).

-Muscle endurance. After this protocol already described, we can identify when a set or work-out should finish to avoid overtraining or any undesirable adaptations. It is also possible to establish how the player responds to muscle fatigue over time (see example from an international striker in Figure 12).

Figure 12. One set of bench press at the optimal training load (in this case 40 kg or 45% of 1RM) Outstanding athletes like Patrick Kluivert

(permission for use of image provided) can perform from 5 to 7 reps above the maximum power (red line), when fatigue starts (2 reps under the target power) the set should be finished to avoid undesired adaptations.

-Electromiography (EMG) synchronized with power output. With this test it is possible to address the following questions: What exercises elicit the greatest activity in each muscle in each player? What is the optimum frequency to work-out on the vibration platform? The player receives bio-feedback in real time while exercising and so can change the way the exercise is executed, if necessary (see example in Figure 13).

Figure 13. Above: EMG biofeedback while doing leg curl on the YoYo (MuscleLab is over the table). Down: Lateral foot rotation mainly affects biceps femoris (left) while medial rotation mainly affects semimembranosus (right).

-Jump tests. How much does each player jump in different situations? Both flight and contact times are recorded.

5. Discussion and Conclusions

The first question to ask is whether enough scientific evidence is available to support the inclusion of strength training programmes in football?

Findings from the Icelandic League indicate a significant relationship between average jump height of the players and team success. The same trend was found for leg extension power, body composition, body fat and the lowest number of days lost to injury per team. Despite the fact that the Iceland football league is not fully professional, these data suggest that optimum conditioning and injury prevention programmes should be a priority in contemporary football training (Arnason et al., 2004). Controlled intervention programmes with top level players are rare. Injury prevention studies have mainly used non-professional football players with injury reduction percentages between 43% and 87%. Top-level players were studied by Askling et al. (2003) who found that hamstring injuries were reduced by 70% compared to a control group.

It is unrealistic to attempt a controlled experiment in top players such as those at F.C. Barcelona. A comparison of injury rate (the main objective of the intervention) could be done between September-January and February-June periods. Compared with the first five months of the season, injury rate was reduced by 38% (in all the players). The incidence of injury was 40% less in the players who had done training compared to those who did not perform any specific programme. Days off due to injury were reduced even more, being less in those players who have done the training programme. Many variables could have affected the results such as fewer matches (out of UEFA and Spanish cup in late February) or an impressive winning series (9 consecutive victories and 17 matches undefeated in the second half of the Spanish League). Nevertheless, these statistics support the use of a training programme to prevent injury. Unfortunately, it was not possible to continue this project and confirm its success over several years.

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Further Reading

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Biography

Julio Tous is a Lecturer at the Ramon Llull University (Barcelona) as well as fitness training consultant with FC Barcelona and other professional teams as well as elite players. He completed his doctorate in the area of muscle strength development in 2001.

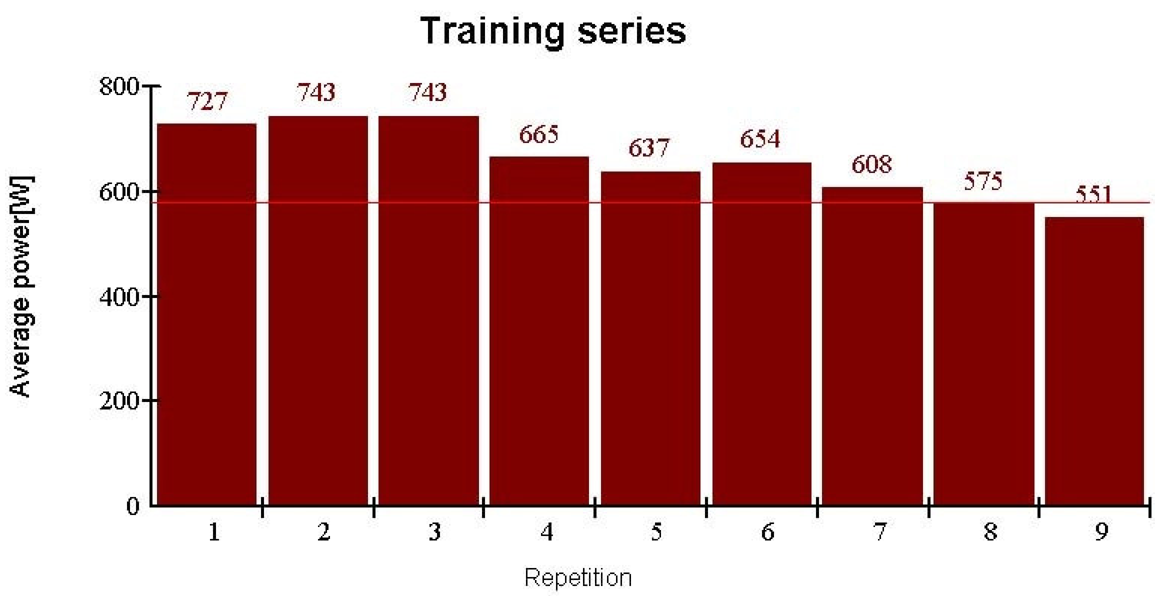

Figure 12