

Strength and conditioning for sprint hurdles

By Paul Read



Introduction

The male sprint hurdles is a highly dynamic Olympic event with distinct technical requirements due to the need to execute a succession of jumps interspersed with sprints. Competition event distances are set at 110m (outdoor) and 60m (indoor). Hurdle height is set at 1.067m (for males) with the distance to the first hurdle 13.72m from the start. For the 110m hurdles event, a further nine hurdles are placed at 9.14m intervals and the current world record, (at the time of writing), is 12.87s, set by Dayron Robles of Cuba.

The aim of this article is to provide a needs analysis of the event relating to the biomechanical and physiological aspects, injury considerations, suitability of fitness tests and training approaches to assist strength and conditioning (S&C) professionals in optimising performance with their athletes.

Needs analysis

Elite hurdlers adopt a stride pattern of eight strides to the first hurdle, although some exceptional athletes have been shown to use seven.⁷⁷ Following clearance of the first hurdle, typically three strides are used between hurdles, with the fourth used to negotiate the hurdle, and the race is completed with six strides to the finish.⁷⁷

During the acceleration phase, EMG analysis of the sprint start suggests the rear leg exerts 61% of the force.¹⁸ In the same study, a large contribution of the erector spinae, vastus lateralis and gastrocnemius was reported. As the acceleration phase progresses there is an increasing contribution from the gluteus maximus, rectus femoris, vastus lateralis, vastus medialis, biceps femoris and gastrocnemius.¹⁸

The gluteus maximus and vastus medialis appear to be the most active while the foot is on the ground, whereas the biceps femoris, vastus lateralis and rectus femoris are most active when the foot is off the ground.¹⁸ This may be as a result of the increased need to stabilise the knee joint while the foot is on the ground, resulting in an increased recruitment of the glutes (providing external rotation of femur and hip extension), while the vastus medialis will play a prominent role in knee stability.

At this point it should be considered that the mechanics of sprint hurdle starts may differ due to the added demand of negotiating the first hurdle after 13.72m. Subsequently, the time available in which to accelerate is reduced; the requirement to produce significant concentric force is paramount. This highlights the importance of maximum strength demonstrated by the strong correlation ($r=0.94$) between 1rm squat and 10m sprint times.⁸⁵



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Energy system demands

Anaerobic production of ATP from phosphocreatine has been shown to dominate in the high hurdles,^{81, 77} with anaerobic metabolism exceeding 90%.⁷⁷ Through the use of mathematical equations, contributions were identified as 95% anaerobic to 5% aerobic in the 60m event and 91.2% to 8.8% in the 110m. However, Astrand and Rodahl,³ reported an approximate anaerobic-aerobic ratio of 85% at 10 seconds of maximal work.

Injury incidence

Specific data relating to injuries in the sprint hurdles is scarce; however, D'Souza²⁴ reported a large proportion of injuries were sustained during training over a season-long period (see Table 1 for the anatomical regions injured). Also sprints and sprint hurdles displayed the highest injury rate of all the events analysed, with 12 out of the 18 hurdle subjects experiencing an injury. Confirming this, Watson and Di Martino⁷⁹ studied 257 track and field high school athletes, with half the total number of injuries occurring in sprinters.

The most common injuries included posterior tibial syndrome, ankle injuries and patellar tendonitis. A consideration for the S&C coach is providing a detailed assessment due to inhibition of the gluteus maximus and gluteus medius, key hip extensors and hip abductors respectively following ankle injuries.^{14, 34}

The role of the hamstrings

A key concern has long been the reduction of hamstring strain injuries.⁸⁷ Silent at toe off, the hamstrings become active during late swing phase when the hip is highly flexed and the knee is extending, remaining active through the terminal swing and the early and mid-stance phases.⁸⁷ This suggests the hamstrings function eccentrically to control hip flexion and knee extension during swing phase and concentrically as a hip extensor during the stance phase. It has also been shown that peak stretch occurs late in the swing phase due to hip flexion,⁷³ with a majority of hamstring strains occurring in the biceps femoris.²⁰ Interestingly, stretch in the biceps femoris has been shown to be significantly greater during swing phase than in the other hamstring muscles.⁷²

Effective programme design needs to consider the hamstrings, and in particular the biceps femoris. Due to the kinematics during sprints, eccentrically strong hamstrings with optimal length tension relationships may provide a suitable environment for injury prevention.¹² Exercises such as nordics and stiff-legged deadlifts should be considered a key component of any prehab and performance programme in addition to rotational movements to fully recruit the biceps femoris.⁶⁷

Further to this, the velocity of hurdle clearance depends on the speed of the lead leg during the take-off phase with the knee swing of the lead leg amounting to more than 13m/s-1, while the speed of the foot of the lead leg is 18.2m/s-1, more than double the horizontal velocity of the centre of mass during take-off.¹⁷ As such,

the inclusion of high velocity eccentric training for the hamstrings is also suggested.

Fitness testing

Power – countermovement jump (CMJ) and squat jump (SJ), power clean

As identified above, a key aspect of the sprint hurdles is the start and acceleration phase. Evidence exists of strong correlations between countermovement jump (CMJ) and sprint performance ($r = 0.88$ and $r = 0.86$),⁵³ velocity out of the blocks,⁶² and 10m sprint time from a start block.⁶¹ The use of a single leg (CMJ) to determine power ratios and imbalances between the two legs may also be apparent. It is worth noting that Bracic *et al*¹¹ identified elite sprinters who demonstrated that lower bilateral deficits in CMJ produced higher peak forces ($r = 0.63$). Additionally a higher total impulse of force on the blocks was shown.

Bilateral deficits also tend to be higher in elite sprinters compared to team sport athletes.⁹ This is an important consideration with regards to the identification and correction of strength imbalances between limbs, as in addition to performance decrements, it has been reported that a discrepancy >15% is an important injury predictor.²¹ Subsequently effective programme design should incorporate the use of unilateral exercises, including split squats, lunges, step ups, single leg Romanian deadlifts and unilateral plyometrics.

Assessing performance in the squat jump versus the CMJ is a good determinant of the athlete's ability to utilise the mechanisms of the stretch shortening cycle (SSC) and their elastic potential, switching rapidly from an eccentric to concentric contraction. The ability to optimise the use of the SSC in the CMJ has been defined as the Eccentric Utilisation Ratio.⁶⁰ Athletes should be able to jump higher in the CMJ versus the squat jump or non-countermovement jump as has been previously established.⁸² If a difference in jump height is not evident, it provides the S&C coach with a clear 'window of opportunity' to enhance the stretch shortening cycle (SSC) and rate of force development (RFD) abilities of the athlete.

The use of Olympic lifts to enhance RFD is now common practice. Channel and Barfield¹⁵ provided support for their inclusion as part of an effective S&C programme in their analysis of traditional lifts (squats) versus Olympic lifts. A significantly higher correlation was noted between power clean and VJ ($r=0.75$) versus the squat and VJ ($r=0.42$). Additionally, Hortobagyi *et al*⁴⁷ noted that athletes displaying the highest power clean also scored highly in jumping and sprinting tests.

Lower body strength – 1RM squat

Chaouachi *et al*¹⁶ examined the relationship between one rep maximum squat, t-test, sprints and five-jump test in professional basketball players. Significant correlations with sprint performance were noted ($r=0.63$); however, agility was not observed, indicating the importance of developing strength to enhance the athletes' ability to overcome inertia. Also resistance training has been

Region	Shin	Back	Ankle	Knee	H/string	Foot	Thigh	Hip	Shoulder	Elbow
% Injury occurrence	25	8.3	16.7	16.7	8.3	8.3	8.3	16.7	8.3	0

Table 1. Anatomical injury locations as reported by D'Souza²⁴

Physical characteristic	Test	Rest period
Anthropometry	Height/weight/body fat	n/a
Flexibility/movement screen	Overhead squat	n/a
Power	SJ, CMJ, S/L CMJ, Power clean (if technique appropriate), RSI (various heights)	5 mins
Strength	1RM squat / bench press/ pull up	
Speed/acceleration	5,10,150 metres	

Table 2. A suggested testing battery for sprint hurdles athletes

shown to improve initial acceleration in sprinting,²² with maximum strength correlating highly ($r=0.86$) with elite sprint performance.⁸⁹

Reactive strength index (RSI)

Short contact time in the landing phase is a key determinant of successful hurdling,¹⁷ completing an efficient transition from hurdle clearance to running between the hurdles.

On the basis of these findings the ability to effectively switch from an eccentric to concentric contraction is an essential requirement, suggesting the use of plyometrics and the development of SSC capabilities.

The ability of the muscular system to promote stiffness, neutralising ground reaction forces is essential, allowing the SSC properties of the tendon to work efficiently with ground contact times following hurdle clearance reported at 0.08s.¹⁷ This provides justification for the measure of RSI as a means to quantify SSC performance,³¹ categorised by the interaction of jump height divided by ground contact time.⁵⁹ The use of drop or depth jumps from various heights using a contact mat can determine the athlete's ability to switch effectively from an eccentric to concentric contraction with measures of ground contact time and jump height recorded.

Upper body strength 1RM bench press / pull up

The upper body has been identified as a key component in sprinting – in particular, the shoulder complex, primarily the pecs and deltoids.⁴¹ The arm swing, however, remains controversial with suggestions of no direct contribution to forward movement or horizontal propulsive forces.⁴² This may be due to the simultaneous forward-backward action of contralateral arms, cancelling out the effect.⁹⁰

In spite of this, two important roles have been identified; first to counteract the momentary momentum of the legs, controlling the rotation of the trunk,^{41,55} with angular momentum balance of the arms reducing torso rotations.⁶⁴ In the sprint hurdles, event this is probably a key function as the lead arm is contralateral to the lead leg during hurdle clearance.

The second role involves the enhancement of vertical propulsive forces, accounting for up to 10% of the upward lift.⁴¹ The arms have a mechanical advantage in vertical propulsion as there is a synchronised upward and downward movement, ensuring no cancellation of propulsive force. This mechanism is also probably present in the take-off phase prior to hurdle clearance: however, this is speculative due to the lack of research available. Efficient sprinters display a mechanical model where the arm swing originating from the shoulder with

a flexion and extension action (at the shoulder and elbow), corresponds to the flexion and extension taking place at the ipsilateral shoulder and hip.⁹⁰

When testing upper body strength, it is common to include upper body pushing/pressing. Empirical evidence supporting this with sprinters has been reported as the bench press scores of former 100m world record holders were consistently 1.90-2.14 times body weight.³³ A case could also be argued for testing antagonist strength, utilising upper body pulling to ensure joint health and optimal power production.⁴ Additionally, the contribution of the posterior oblique sling system⁷⁵ consisting of the gluteus maximus and contralateral latissimus dorsi, (connected via the thoracolumbar fascia linkage), is highly active in running actions.

Flexibility and ROM

If a sprint hurdler is unable to adequately flex their lead leg to their trunk when clearing a hurdle, they will have to go higher over the barrier to ensure a proper clearance.⁵⁴ This requires greater energy expenditure in addition to longer airtimes and disruption of hurdle mechanics.

A simple movement screen can be utilised to identify flexibility and movement deficiencies. One such example is the overhead squat test.⁴³ This allows a total body assessment of movement to guide stretching and strengthening prescription.

It may or may not be within the remit of the S&C professional to perform range of movement tests to identify joint restrictions and manual muscle tests to assess weakness. It is beyond the scope of this article to discuss specific details of such tests; however the reader is encouraged to view the work of Kendall *et al*⁴⁸ for more information.

Speed/acceleration

As stated above, the requirement for high levels of acceleration is a fundamental aspect of sprint hurdle performance. As such, test distances to assess first step quickness and reaction time (5m) and acceleration (10m) are recommended. Measurement of first step quickness over 5m is indicated due to the specific event demands dictated by the short time available in which to accelerate prior to negotiation of the first hurdle.

Although this approach may provide important information, potential measurement error is likely to increase as even with timing gates, the error associated with a 10m sprint is between 1% or 0.02s²³ and 2% or 0.04s.²⁹ As such, the use of timing gates is essential. Additionally, measurement of peak speed is also suggested; however, to the knowledge of the author

Phase / emphasis	Session 1	Load	Reps / sets	Session 2	Load	Reps / sets
Base Conditioning	HC & jerk Overhead SQ DB BP Lunge BB roll out	70%1rm 70%1rm >70%1rm >70%1rm	5x3 4x6-8 4x6 4x6 3x10	Hang snatch Front SQ Nordics DB row Cable anti-rotations	70%1rm >70%1rm BW >70%1rm >70%1rm	5x3 4x6-8 3x6-8 4x6 3x10e/s
STR	SQ snatch Bench step up* B/O row Stiff legged D/L	80-85%1rm >85%1rm >85%1rm >85%1rm	5x3 4x4e/l 4x4 4x4	SQ clean Back SQ* BP SN grip D/L	80-85%1rm 85%1rm >85%1rm >85%1rm	5x3 4x4 4x4 4x4
P/SPD - STR	PW clean & jerk Back squat* BP* MB back toss	80%1rm 90%1rm 90%1rm Explosive	5x3^ 3x3 3x3 5x3	PW snatch/split Split squat* B/O row SG Clean/snatch pulls	80%1rm 90%1rm 90%1rm >80%1rm	5x3^ 3x3 3x3 5x3

Table 3. Periodised plan for sprint hurdles

*Indicates opportunities to insert complexes. ^Suggested use of cluster sets

there is currently no hurdle specific test for peak speed or speed endurance. A suggested testing battery is detailed in Table 2.

Training for performance enhancement

Strength training

A key factor in determining hurdling performance is sprinting speed.⁵⁶ Thus, it should be considered that the ability to run at maximal speed requires high levels of force production.⁶ It is worth noting that it has been indicated that force applied to the ground is the most important determinant of running speed, resulting in a greater displacement of the athlete's body and an increased stride length.⁸⁰ Further to this, significant correlations ($r=0.77 - 0.94$) have been reported between peak power and maximum strength.¹ With this in mind it should be noted that gains in strength may only be maintained for two weeks.⁴⁷ As such, including strength sessions and strength maintenance exercises in each phase of training may be advisable.

Complex training

Differing neural adaptations can be expected from heavy and light loads in training. One such training strategy is to combine the two methods. This phenomenon of combination training has been attributed to enhancing post activation potentiation (PAP). This involves the completion of an exercise under load, for example a heavy back squat, followed by an empirically similar exercise that emphasises speed of movement such as a CMJ jump.

There is a large body of research pertaining to PAP – for a review see Ebben.²⁶ The exact mechanisms of PAP have not been established; however, enhanced neuromuscular drive⁴⁴ increased phosphorylation of myosin regulatory light chains and an increased cross bridge attachment rate⁶⁸ are plausible explanations.

The benefits of complex training are clearly evident. Adams *et al*² measured the CMJ of three groups after a training intervention with increases in the heavy squat group (3.3cm) and plyometric and light load group (3.81cm). In contrast, the combined group of squats and plyometrics increased by 10.67cm. In support, Eduardo *et al*²⁷ performed complex training with high school basketball players twice a week. Increases in squat strength, CMJ height and medicine ball throw performance were evident, whereas the resistance training-only group reduced their previous levels.

Additionally, further increases in CMJ height (4%)

post PAP intervention have been reported.³⁶ However, females only achieved increases of (0.42%). The authors suggested that the males may have displayed less neural inhibition, higher nervous system activation and a better ability to deal with fatigue.

Complex training does not always show a positive effect, and in some instances performance decrements.⁸⁹ However, loads up to 70% 1rm were used for three reps, which may not have provided sufficient intensity stimulus as has been suggested previously.⁴⁰

With various discrepancies in the research, coaches are advised to perform testing and monitoring when implementing complex training on an athlete-specific basis. Greater results may also be achieved once a suitable training age has been established.⁴⁴

Rate of force development (RFD)

Success in sprinting and the sprint hurdles requires force generation in a rapid manner. Rate of force development (RFD) has been defined as the change in force development divided by the change in time.⁷² Optimal production of rapid force requires neuromuscular activation,⁷¹ and is a representation of the athlete's ability to accelerate. This suggests the inclusion of ballistic or explosive exercises to enhance acceleration and running velocity. Various types of jumps, sprints and plyometrics can be utilised to enhance this quality, but there is also a strong argument for the inclusion of weight-lifting movements.

The use of Olympic lifts has been indicated in the enhancement of RFD.⁴⁶ This is supported by McBride *et al*⁵⁸ in a comparison of power lifters, Olympic lifters and sprinters, with the Olympic lifting group displaying the highest levels of peak force and power outputs. Such evidence gains further momentum as Garhammer³⁷ reported that Olympic lifts displayed significantly higher power outputs than the traditional lifts, namely the squat, deadlift and bench press.

Olympic lifts are also adaptable in their application, as indicated by the use of squat cleans/squat snatches to allow greater loading in strength phases, whereas, power clean/power snatch variations can be used to target strength-speed performance. Additionally, pulling from different heights (box or hang positions) can assist the S&C professional to avoid monotony with their athletes.

Cluster training

Manipulation of the structure of the training set is often overlooked, with people opting instead for traditional

	Phase 1 eccentric jumping	Phase 2 low intensity fast plyometrics	Phase 3 hurdle jumping	Phase 4 depth jumping
Emphasis	Optimal landing mechanics	Short GCT Legs like stiff springs Stay on balls of the feet	Short GCT Some degree of jump height	Short GCT Max jump height
Sample exercises	Jump and stick Jump up to box Single leg jump and stick	Ankling S/L ankling	Hurdle jumps	Depth jumps Multiple depth jumps

Table 4. Suggested progressive model for fast SSC training plyometrics. Flanagan and Comyns³¹

approaches completing all the required reps in sequence. More recently, an intra-repetition rest (IRR) methodology termed the rest-pause set,³¹ or cluster set,³⁷ has been suggested as an effective method for enhancing RFD and power output.

IRR may improve the quality of each repetition, theorised by the fact that partial recovery between reps, increases peak power, barbell velocity and displacement with reductions in fatigue.³⁸ The effect is a subsequent increase in the power output of the set.⁵² As such, cluster training may be particularly suitable with Olympic lifts where RFD is paramount.

Reductions in RFD and peak power have been shown with 5-9 maximal contractions.⁷⁴ Thus, utilising low reps and clusters to promote power in peaking phases, enhancing RFD may improve sprint performance. IRR allows partial replenishment of phosphocreatine (PCr), whereas traditional sets result in subsequent depletion.

Careful consideration of the goals of each training phase is needed, as clusters may not be suitable for strength gains as opposed to traditional set structure.⁶⁹

Intention of velocity

A key aspect in training sprint athletes is to coach explosive concentric contractions. Behm and Sale⁷ used two groups incorporating either a ballistic or isometric action over 16 weeks of training. The principle stimulus for the high velocity response was the attempt to perform ballistic actions. The type of contraction was shown to be of lesser importance, whereas the intention to move the weight quickly provided the greatest contributing factor. Training applications may include utilising a slow eccentric tempo, such as in a squat followed by an explosive concentric contraction to enhance RFD. Athletes may need verbal cues to provide the correct stimulation during such lifts.

The training considerations discussed in this review may assist in the design of suitable periodised training programmes for enhancing sprint hurdle performance. See Table 3 for an outline incorporating many of the aspects reviewed above.

Plyometrics

In elite athletes, ground contact times (GCT) have been established at 0.08s.¹⁷ This suggests sprint athletes must be able to switch rapidly from an eccentric to concentric contraction, minimising the amortisation phase utilising the properties of the SSC. Eccentric/concentric coupling has been shown to produce more powerful contractions than a purely concentric action.⁵⁰ This may be due to an enhanced ability to store and utilise elastic energy during the concentric phase as a result of the prior eccentric action.⁴⁹ Additionally, increased propulsive force as a result of efficient SSC mechanics aids in a reduction of the metabolic cost of movement,⁸ with estimates of approximately 60% of the total mechanical energy recovered in economical sprinting.⁷⁶

A number of theories have been proposed to explain the underlying mechanisms of the SSC. Examples include the contribution of elastic strain energy,⁶⁰ involuntary nervous processes, such as GTO inhibition and myotatic stretch reflex,¹⁰ increased active range of movement,⁷ length tension characteristics,²⁸ pre-activity tension⁵¹ and enhanced co-ordination due to the involvement of the pre-stretch.⁸

When designing plyometric programmes, it is essential to consider the specifics of the ground contact used in the sport/event. Two categories of SSC have been categorised⁷⁰: slow SSC (>250milliseconds) or fast SSC (<250milliseconds). In the case of sprint hurdles it



could be argued that both are evident, as contact time when landing from a hurdle is approximately 0.08s.¹⁷ However, the start/acceleration phase utilises slow SSC mechanics with the force exerted by the front leg during the push off applied for >250 milliseconds in elite sprinters.⁶⁴

Training slow or fast SSC requires different approaches. A progressive model of development for fast SSC abilities is suggested (Table 4), based on the work of Flanagan and Comyns.³¹ Examples of slow SSC include vertical jumps (emphasising acceleration), whereas exercises such as depth jumps (classified as fast SSC) are more suitable for top speed sprinting.⁵⁸

In a training setting, jump mats can be used as a feedback mechanism and motivational tool to provide information as to the jump height and RSI emphasising short GCT. Additionally it should be considered that technique drills for acceleration and speed development would be utilised; however these may fall under the remit of the technical coaches at high levels of performance.

Monitoring by foot contacts'

Typically, plyometric training is monitored by totalling number of foot contacts. General recommendations ensure that elite athletes are limited to 140 contacts, whereas less experienced athletes reduce the total number of contacts to <100.⁴ This may be an oversimplification, as the intensity of the exercises selected will dictate the appropriate number of contacts due to the eccentric demand placed on the musculotendinous unit, ie, depth jump (high eccentric demand) versus jump to box (low eccentric demand). It has also been suggested that athletes should not perform plyometrics unless they can squat 1.5 – 2.5 times their bodyweight.⁴⁵ Such an approach will delay the development of effective SSC mechanics; low and medium intensity plyometrics, such as jump and stick and ankling should be incorporated during developmental phases.³¹ Therefore, S&C coaches should quantify the intensity of the drills provided using a grading approach as suggested by Ebben *et al*,²⁵ considering; double versus single leg contact, jump height, use of added resistance and the integration of overhead targets.

Regarding effective prescription of programme variables, it should be considered that SSC function is significantly affected by fatigue, with reductions in flight time ($p < 0.001$) and peak force ($p < 0.01$) and increased GCT ($p < 0.05$) recorded 15 seconds following the completion of a drop jump,¹⁹ suggesting that the efficiency of the SSC mechanism was reduced. Subsequently, a training prescription of two to three sessions a week of < 10 reps/sets with a work to rest ratio of 1:5 in a non-fatigued state is recommended.²⁵

Summary

The sprint hurdles is an explosive event, requiring the development of a number of specific qualities such as maximal strength, reactive strength, effective SSC mechanics, power and RFD. These components of fitness should be incorporated as part of a periodised plan, implemented concurrently to the technical and speed development work on the track.

There are also a number of methods and techniques in the toolbox of the S&C professional such as Olympic lifts, plyometrics, complexes and cluster training to enhance performance and maximise the time available developing their athletes.

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