Clinical Commentary/Current Concept Review

Implementing Velocity-Based Training to Optimize Return to Sprint After Anterior Cruciate Ligament Reconstruction in Soccer Players: A Clinical Commentary

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After anterior cruciate ligament reconstruction (ACLR), return to sprint is poorly documented in the literature. In soccer, return to sprint is an essential component of return to play and performance after ACLR. The characteristics of running in soccer are specific (velocity differences, nonlinear, intensity). It is important to address these particularities, such as curvilinear running, acceleration, deceleration, changes of direction, and variations in velocity, in the patient's rehabilitation program. Force, velocity, and acceleration capacities are key elements to sprint performance. Velocity-based training (VBT) has gained much interest in recent years and may have a role to play in optimizing return to play and return to sprint after ACLR. Force, velocity, and acceleration can be assessed using force-velocity-power and acceleration-speed profiles, which should inform rehabilitation. The purpose of this commentary is to describe a velocity-based return to sprint program which can be used during ACLR rehabilitation.

INTRODUCTION

Anterior cruciate ligament (ACL) tear is a severe injury for soccer players with both physical and socio-psychological impacts. Most athletes who sustain this injury go through a surgical reconstruction of the ligament, an ACL reconstruction (ACLR).[1] ACLR has many consequences: the player will be away from competition for a long period of time (usually between 8 and 12 months), only 55% of athletes will return to competition, and re-injury rates can be as high as 20-40%.[2] The physical impacts of the ACL tear and reconstruction on the injured limb including joint degeneration, neuromuscular and sensorimotor deficits are potential reasons for athletes not being able to return to their previous level of performance.[3] These adverse effects may be addressed through an appropriate rehabilitation and return to sport program to enable the athlete to return to performance while limiting the impact on future knee health. Looking at the increase in research in the field of return to sport after ACLR over the last ten years, velocity-based training (VBT) has gained a substantial interest. Muscle strengthening is important for return to sport, but often the strengthening methods used are not sufficient in view of the muscle persistent strength deficits reported at six months and one and two years postoperatively.[4] VBT may help to overcome some of the suboptimal effects of more traditional strength training and address the physiological capacities required for sprint performance.

For soccer players, sport performance results from a combination of physical, physiological, psychological,

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technical, tactical, and nutritional parameters.[5] Among physical and physiological parameters, a player's ability to sprint repeatedly with short periods of recovery is crucial. Four percent of the total distances covered by field players during a game are executed in sprint runs (above 23 km/h).[6] These very high intensity runs represent 10 to 15% of the effective playing time and are fundamental efforts that can lead to goal actions.[7,8] However, the details regarding the introduction of sprint and its management during post ACLR rehabilitation in soccer players has rarely been explored.

The purpose of this commentary is to describe a velocity-based return to sprint program which can be used during ACLR rehabilitation. Several concepts will be presented in this paper: the specificity of sprint in soccer after ACL reconstruction, the use of VBT in the return to sport continuum after ACLR, the relationship between force-velocity-power and acceleration-speed and how to assess them to individualize/optimize rehabilitation. Finally, the importance of sprint work progression will be discussed.

REQUIREMENTS FOR SPRINT PERFORMANCE IN SOCCER

Soccer players play in a complex environment with multiple stimuli that requires numerous athletic and cognitive abilities.[9] Multi-directional speed ability is an important skill, defined as the proficiency and ability of an individual to accelerate, decelerate and rapidly change direction (side-cutting), while maintaining high speed in all directions within a specific sport scenario.[10] For instance, a striker may have to overcome an opponent to create an advantage for the team. Acceleration, deceleration and top speed have been defined as key performance indicators.[11]

Acceleration is thought to have a strong metabolic demand, compared to deceleration, which elicits a higher mechanical demand especially at the knee joint (higher loading rates and greater Ground Reaction Forces [GRFs]).[12,13] On the other hand, deceleration (braking) plays a central role in sport performance: being skilled in braking allows an athlete to rapidly reduce the momentum of the entire body mass and redirect it in the necessary direction.[14] In soccer, decelerations and re-accelerations are more frequent than accelerations.[15] Great technical skill is required to optimize the braking phase by attenuation of loading forces as efficiently as possible. It is accomplished by manipulation of the body's center of mass and allowing braking forces to be produced by muscle and other connective tissues.[16]

The ability to sprint efficiently is paramount for soccer players.[17] Variation of as little as 0.04s over a 20m sprint time resulted in a variation in distance covered of almost 30cm.[18] Sprint time is not the only determinant of running performance in soccer.[18] Acceleration abilities are also crucial and related to athletes' horizontal net force production capacities. Multiple acceleration patterns exist in soccer.[19] Players accelerate from a range of different speeds, including a standing start to sub-maximal speeds.[17] It is not possible to reach the same level of acceleration at all speeds: peak acceleration decreases as the speed increases until it reaches zero at maximum speed.[19]

Another characteristic of sprint in soccer, the curvilinear sprint, is not often described in the literature. While linear sprint demonstrates similar mechanical behavior (kinematic, kinetic and spatio-temporal) in both legs, in curvilinear sprint each leg has a different role.[20] The inside leg plays a fundamental role of stabilizer in the frontal plane (with an eversion-adduction strategy) as well as in propulsion. It also has significantly longer ground contact times than the outside leg. The outside leg plays a greater role in control of movement in the horizontal plane.[21] During the curvilinear sprint, lateral forces are constantly redirected to the body which requires the body to be in a constantly inclined position, with the hip of the inside leg in adduction and internal rotation and the ankle in eversion, and a considerable mechanical impact on the knee.[21]

FORCE-VELOCITY AND ACCELERATION-SPEED PROFILES

In muscle physiology, the force-velocity (F-V) relationship indicates that the slower a skeletal muscle shortens, the greater the force it can generate, and vice versa. This relationship is a fundamental principle of skeletal muscle physiology that was based on Hill's ground-breaking studies in isolated frog muscles[22] and originally used to develop theories of skeletal muscle contraction mechanisms.[23] This work was a precursor and undoubtedly laid the foundations for current research into the force-velocity profile. The force-velocity profile provides a complete and meaningful understanding of the individual mechanical determinants of linear sprint performance.

Power can be considered, from a mechanical point of view, as the product of force and velocity. In sprint, the power developed to move forward is the product of horizontal force and running speed. There is a close relationship between these two components, which are oriented in opposite directions at maximum acceleration. This is represented by the F-V relationship. The athlete's F-V profile is represented by a slope. (Figure 1) This slope indicates the relative importance of strength and speed in determining maximum power (Pmax). The F-V profile gives an indication of the athlete's ability to generate and apply high levels of ground reaction force in the horizontal direction as a function of running speed.

In the process of return to sprint after an ACL injury, assessing the athlete's force-velocity capacity is important, especially if a pre-injury evaluation has been carried out (during pre-season for example). This would allow stakeholders to see if the athlete has regained his or her ability to produce force and to compare them with athletes playing in the same position. An accessible and inexpensive approach to obtain the F-V profile during a linear sprint test on the field has been proposed.[24] This method only requires measuring the athlete's velocity during a sprint (using split time, laser timing, or radar guns). The F-V profile provides valuable information about the mechanical limits

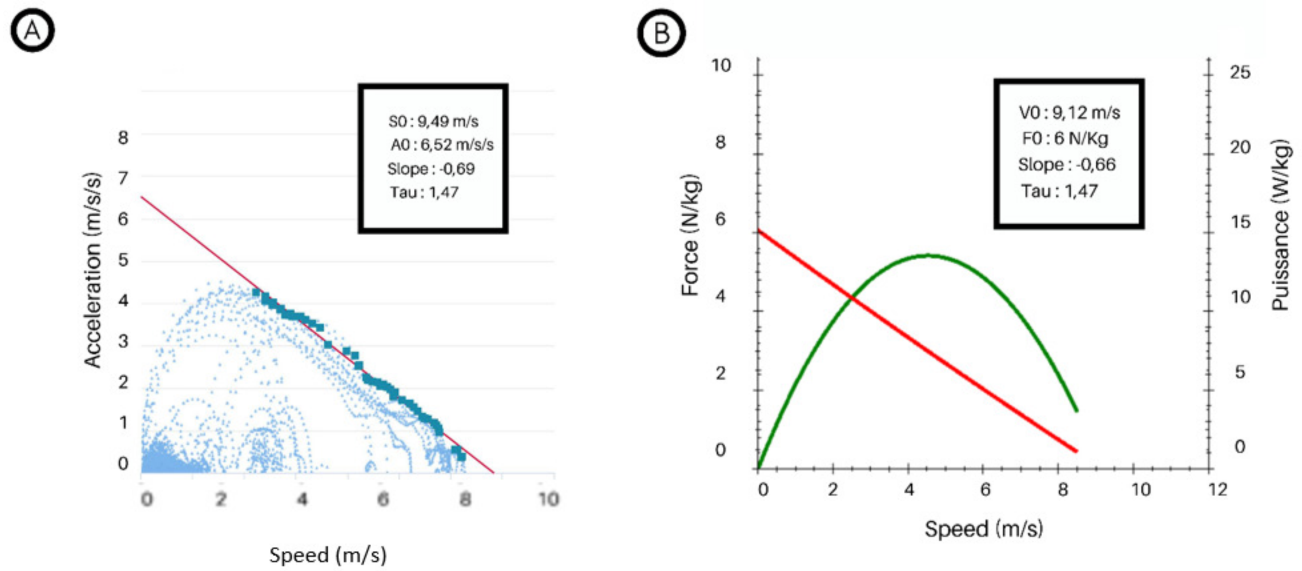

Figure 1. Comparison of acceleration-velocity (A) and force-velocity-power (B) profiles achieved during a single sprint field rehabilitation session.

S0 : Maximal theoretical speed, A0: Maximal theoretical acceleration,V0: maximal theoretical velocity, F0 : maximal theoretical force, Tau: time constant computed by S0/A0 or V0/F0

of the player's neuromuscular system, allowing the creation of tailored programs to optimize sprint performance.[25]

Monitoring soccer players acceleration qualities should only be done relative to the starting speed. A method to evaluate the individual limits of specific acceleration capacities, over all the speed ranges between 3m/s and an athlete's maximum speed, has been tested using Global Positioning System (GPS) data.[26] There is a quasi-linear and individual relationship between maximal acceleration for a given speed. This relationship has been described as the player's acceleration-speed profile. It is done by recording time, speed, and acceleration data; collected by a GPS (Vector Pro©, Catapult, Melbourne, Australia ; GPEXE©, Exelio SLR , Reana del Rojale, Italy; Apex Athele Series©, Statsport, Newry, United Kingdom) worn by the soccer player.[26] In order to cover the whole speed spectrum of the player, the data collection must be done over several training sessions.[26] The modelling of the acceleration-velocity profile can be achieved either by using a software specific to the GPS used or by importing the raw spatio-temporal data into a dedicated spreadsheet.[26] This method allows to record data while the player is in an ecological environment and not in a laboratory controlled test situation. The variables obtained are the theoretical maximum acceleration peak (A0), the theoretical maximum speed (S0), the profile slope (AS) and the time constant (Tau). The individual acceleration-velocity profile of fourteen elite soccer players was studied from pre-season to the end of the season.[27] Some stability in the team average values was observed, while the individual A0 values underwent changes in contrast to the S0 values.[27] These findings indicate that, from a performance and injury perspective, it may be appropriate to make frequent assessments of players' acceleration-velocity profiles to monitor changes in sprint performance throughout the season as well as to establish pre-injury reference values.

Figure 1 compares the acceleration-velocity profile (A) and the force-velocity profile (B) of the same player, measured with a GPS unit (GPEXE©, Exelio SLR, Italy). Data were collected during a single outdoor training session consisting of a sequence of exercises including ball games and changes of direction with and without the ball and 5 linear sprints of 30m. The instruction given for the assessment of the force-velocity profile was: "Accelerate as hard and as long as possible". While the instruction for the rest of the session was: "Play as usual". Profile A was modelled by the application published by GPEXE© (Exelio SLR , Reana del Rojale, Italy), while profile B was modelled by the software Mookystalker© (version 3.0.15, MTraining, Ecole-Valentin, France). The two profiles modelled as a result of this single session are close and in line with the conceptual equivalence described by Morin et al.[26]

With regard to return to sprint after ACLR clinicians and strength and conditioning staff can tailor their interventions using force-velocity-power and acceleration-velocity profiles. These profiles allow them to target specific deficits within mechanical determinants of sprint performance during the rehabilitation process. Different training methods can address some of those deficits. Velocity based training is one of them.

VELOCITY-BASED TRAINING

To accelerate, the player must be able to produce high levels of horizontal force over distances that are typically between 5 and 20m.[28,29] For the soccer player, it is a necessity to regain explosive force production capabilities after ACLR. Resistance training is effective to recover a neuromuscular phenotype that is compatible with this objective.[30] The Percentage Based Training (PBT) method leads the individual to muscle failure.[31] PBT simply relates to the weight

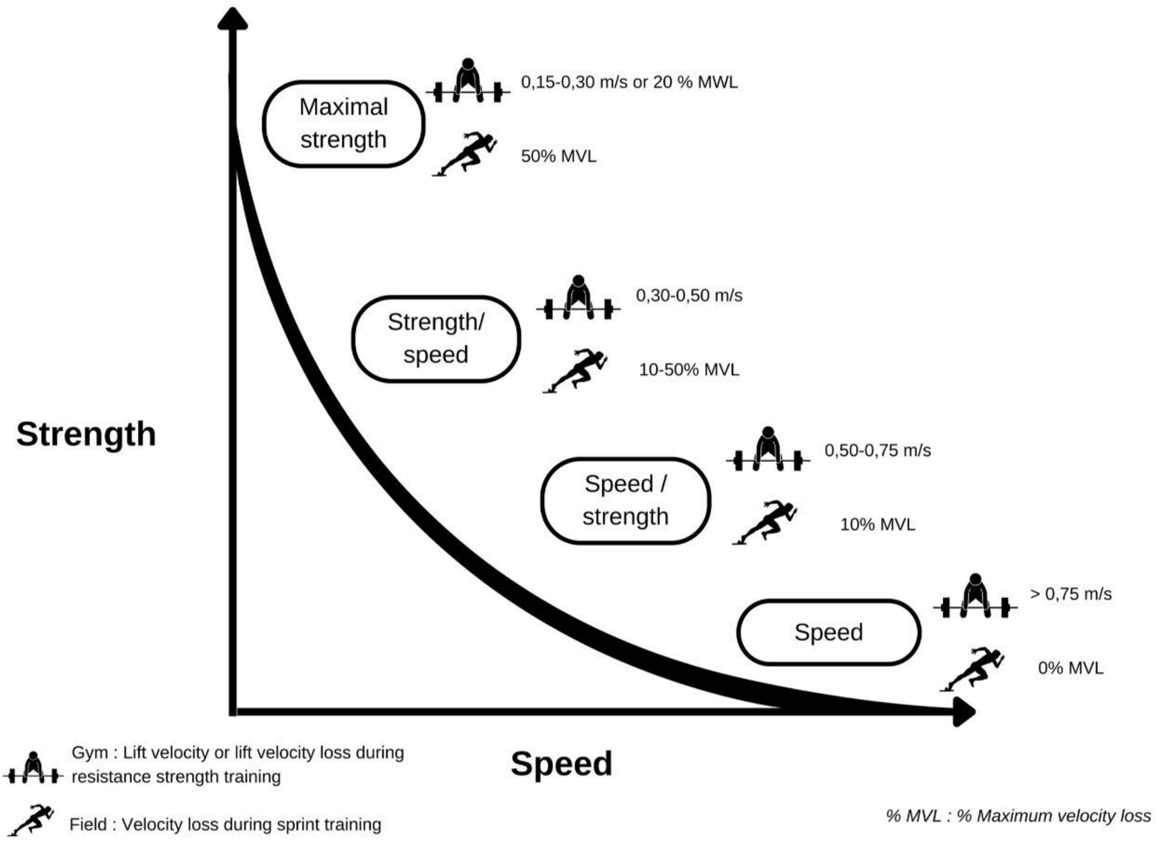

Figure 2. Specific strength development relative to speed of movement.

the person can lift in a given exercise in relation to their maximum capacity. For example – if a person is performing bench press with 100kg, and his known 1RM (1 rep maximum) is 110kg, then the percentage is 90%. This results in a significant reduction in the fast type IIx fibers that are essential for explosive force production.[32,33]

Alternative training methods that may avoid these problems exist. Velocity-based training (VBT) is one method to consider. It involves measuring the movement velocity for a specific load during each repetition (Figure 2).[34] The heavier the load to be moved, the lower the velocity, until velocity becomes minimal when the 1-RM is reached.[35] The movement velocity of a barbell can be measured when performing non-specific sprint strength training exercises. The inertial load of a whole system (player mass + additional load) can also be measured in the case of specific sprint exercises. In either case, the maximum voluntary velocity is of paramount importance (Table 1).[36]

VELOCITY-BASED TRAINING AND DEVELOPMENT OF SPRINT-SPECIFIC STRENGTH QUALITIES

When a player is coming back from an ACLR and is able to sprint, it is crucial to incorporate sprint specific training, such as sled resisted sprint or uphill sprint in sessions.[37] Several authors have shown that the capacity to produce horizontal force is diminished when returning to sport, so an appropriate stimulus must be offered to correct this deficit.[38-40] With VBT, similar to PBT training, intensity needs to be individualized.[41] This can be achieved by practitioners using a "sprint velocity based training" in order to offer a training intensity that corresponds to the player's real needs.[25] The basic idea is to select a specific additional load that leads to a specific reduction in maximum speed, which differs according to the desired adaptations (e.g : technical competency, speed–strength, power and strength–speed) (Figure 3)[42] This can be done by establishing a load-velocity profile. Creating the profile requires knowing the coefficient of friction between the sled and the ground,[42] the maximum speed of the player with no additional load and then with four additional loads. Morin et al. has created a spreadsheet to calculate the profile from this data (Appendix 1; https://jbmorin.net/downloads-📊📈/).[37] The acceleration intention must be maximal in each trial in order to obtain a linear regression coefficient that is close to one.[37] The profile created makes it possible to know the load ranges that correspond to the specific training zones and allows practitioners to define the appropriate load to achieve the targeted adaptations (Figure 4).[42] It has been shown that resisted sprint sessions increase the theoretical maximal force production (F0) and ground force application efficiency (RFmax) more than conventional sprint sessions,[37] without altering sprint kinematics.[25] F0 and RFmax are strongly correlated with a player's acceleration capabilities.[43,44] The ideal load for op-

LOWER BODY MAXIMUM STRENGTH PROGRAM					
Warm-up	**Exercise**	**Sets**	**Time**	**Tempo**	**Rest**
	Tempo run	8	30 sec	explosive	30 sec
	Mobility circuit	1			
Session instructions : stop each set when the loss of speed reaches 10% from first repetition speed	**Exercise**	**Sets**	**VBT velocity range**	**Tempo**	**Rest between sets**
	Trap bar deadlift	4	0.4-0.5 m/s	explosive	3 min or more if needed
	Lateal dumbell lunge	4	0.4-0.5 m/s	explosive	3 min or more if needed
	Deadlift	4	0.4-0.5 m/s	explosive	3 min or more if needed
	Hip thrust	4	0.4-0.5 m/s	explosive	3 min or more if needed
	Squat	4	0.4-0.5 m/s	explosive	3 min or more if needed
	Single romanian deadlift	4	0.4-0.5 m/s	explosive	3 min or more if needed

Table 1. Velocity-based strength program training

m/s; meter per second, s; second, min; minutes.

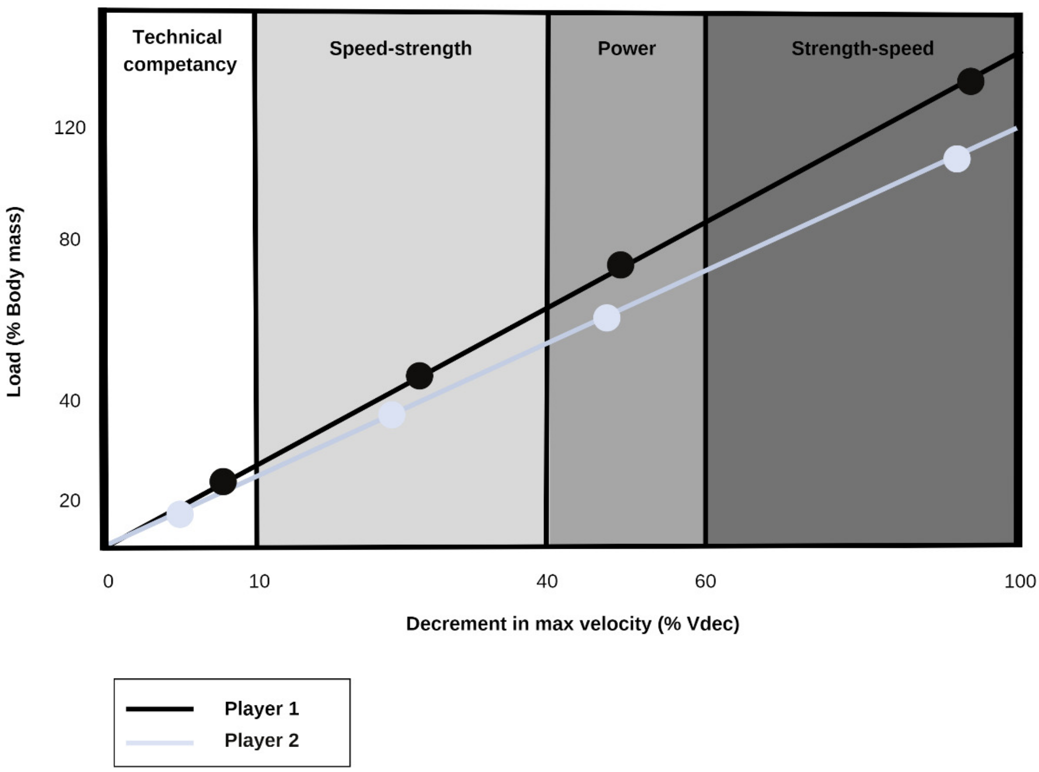

Figure 3. Example of individual load velocity profile of two different players and corresponding specific training zones.[42]

timizing the development of the maximum propulsive qualities is that which reduces the maximum speed by 50%.[25]

Figure 4. Velocity based specific training zone with Vitruve Linear Encoder© (Vitruve, Madrid, Spain) Device during squatting

PROGRESSION FROM HIGH INTENSITY RUNNING TO REINTRODUCTION OF SPRINT IN REHABILITATION.

The reintroduction of sprint is an important step in the final phase of ACLR rehabilitation. Sprint re-introduction must be preceded by a purposive progression in intensity of running activities. The literature highlights proposed three-stage evolution starting from the beginning of return to running.[45,46] These three stages are described Table 1. Each stage requires an increase in force capacities. The first stage sets a speed between 50 and 70% of the player's maximum speed (MS) corresponding to high-speed running. This requires muscular and functional capacities greater than 70% of quadriceps and hamstring limb symmetry index (LSI).[45,46] The second stage consists of increasing to 75% or 85% MS.[45,46] This is described as very high speed running. To get there, capacities higher than 85% LSI are recommended. The last stage is the re-introduction of above 90% MS which requires capacities close to 100% LSI (Table 2).[45,46]

For return-to-sprint process, it is essential to focus on the work:rest ratio. It should be low at the beginning to guarantee quality work at each introduction of a higher intensity level, work : rest ratio of 1:4 seems to be a good pace to start, generating a high level of energy resynthesis, so that the cardiovascular aspect is not a limiting factor in the quality of high-intensity work.[47] An intensity plateau and volume is set up during a minimum of seven field sessions per each stage. This is accomplished by increasing the volume of running at the targeted intensity as well as using interval training, with temporal parameters depending on the intensity required, from a 2:1 ratio of work time over rest time at small intensities, up to a 1:2 ratio at high intensities.[45,47]The duration and number of rehabilitation sessions per phase will depend on the athlete's ability to adapt and the rapidity of improvement. The total running volume, the distances suggested for each repetition and the work/recovery ratio will vary depending on the level of the athlete and the sport.[45,47] For example (Figure 5), for elite soccer players values shoulg be higher than: 4500m for total distance, 800m for high speed running (between 20-25km/h), 300m for sprint and 300m acceleration and deceleration (higher than 3m/s/s).[48]

Welling et al. have studied sprint performance post ACLR.[47] A strong correlation exists between peak speed, performance in repeated sprint and return to play rate. Return to sprint and repeated sprint performance are essential steps towards return to performance in soccer.[45] Only one on-field test that assesses sprint performance after ACLR is described in the literature.[47,49] It consists of 12 sprint of 40 m with maximal acceleration.[50] However, there are obstacles to the use of this test in clinical practice. Indeed, the muscular and articular demands of this test require several progressive sessions (volume and intensity) of maximum-intensity rehabilitation prior to its first performance to avoid the risk of muscular damage during the test. A simpler test to objectify sprint performance and monitor athletes during the return to performance process may needed.

CONCLUSION

After ACL reconstruction, muscular and physical abilities must be developed to allow return to play to be optimized. Return to play involves the development of strength, speed and acceleration capacities while taking into account the demands of soccer including acceleration, deceleration, changes of direction, and velocity of running (sprinting). Velocity-based training may be proven efficient in redeveloping sprint skills following ACLR and this commentary provides some recommendations by the authors on how it may be used and further investigated. Velocity-based training methods may help clinicians to improve sprint performance after ACLR in soccer players. Return to sprinting should be gradually carried out and tailored to the athlete's assessed capacity (force-velocity and force-acceleration profiles) in order to avoid overload that may jeopardize the return to play.

Print rehabilitation phase	Pre-requisites	Training aim	Exercise prescription
Phase 1 reintroduction of HSR	LSI>70%, return to undermaximal linear running	55-70% maximal speed, stride, bounce and dynamic placement quality	CMJ one-leg repeated plyometrics on one leg at 20cm skills in gym in frequency, axis, lateral, front-back, push-brake at moderate intensity 50-100m straight line at target speed in a running session with aerobic capacity
Phase 2 reintroduction of VHSR	LSI>85%	75-85% MS, efficacity and qualities of strides during acceleration	drop jump one-leg repeated plyometrics on one leg at 20cm in all axes skills on the pitch , axis, lateral, front-back, push-brake at sustained intensity 50-100m straight line at target speed in a running session with aerobic capacity
Phase 3 reintroduction of sprint in control situation	LSI near 100% RSI-mod CMJ one-leg near 100% to training group value >3N/kg of BW of concentric Q strength in isokinetism >1,8N/kg on concentric H strength >2,2N/kg on eccentric hamstring strength	>90% MS, efficient of postural control	repeated plyometrics on one leg at 30cm in all axes skills on the pitch , all type of movement at high intensity specific sprint and acceleration work
Phase 4 sprint with chaos situation	"	near 100% MS, Maintain quality and intensity despite the environment and complex tasks	skills on the pitch , all type of movement at maximal intensity specific sprint and acceleration work specific football skills with chaos environement

Table 2. Progression sprint recovery during rehabilitation after ACLR[46]

LSI; Limb Symmetry Index, MS; maximal speed, HSR; high speed running, VSHR; very high-speed running, BW; body weight, Q; quadriceps, H; hamstring, RSI-mod; reactive strength index – modified.

Figure 5. Specific high-speed running (between 20-25km/h) training with an elite soccer player after ACLR

COI STATEMENT

The authors declare no conflict of interest

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SUPPLEMENTARY MATERIALS

Appendix 1

Download: https://ijspt.scholasticahq.com/article/92704-implementing-velocity-based-training-to-optimize-return-to-sprint-after-anterior-cruciate-ligament-reconstruction-in-soccer-players-a-clinical-commen/attachment/193644.docx