WHY IS REACTIVE STRENGTH IMPORTANT AFTER ACL RECONSTRUCTION AND HOW TO REDEVELOP IT

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WHAT IS REACTIVE STRENGTH?

Reactive strength, also known as plyometric or elastic strength, is the ability of an athlete to rapidly and efficiently transfer force, primarily using the stretch shortening cycle (SSC), during tasks involving short ground contact times such as hopping, sprinting or change of direction. All reactive strength exercises consist of three phases:

- **Eccentric Phase (Stretching)** In this phase, musculotendinous structures undergo a lengthening eliciting the stretch component of the SSC during which the body stores elastic energy.
- **Amortization Phase (Transition):** This is the brief, critical transition phase between the eccentric and concentric phases. It represents the time between the end of the eccentric phase and the beginning of the concentric phase. The goal is to minimize the duration of this phase to utilize the stored elastic energy effectively.
- **Concentric Phase (Shortening):** In this phase, the stored energy is released as the musculotendinous structures contract and shorten to produce force and movement. The greater the eccentric component and the more developed the plyometric capacity of the athlete, the higher the force production during this phase.

WHY IS REACTIVE STRENGTH IMPORTANT AFTER ACLR?

Ongoing asymmetries in reactive strength are among the most persistent functional deficits after ACL reconstruction. Kotsifaki et al[1] demonstrated greater asymmetries during drop jumps in male athletes after ACLR at the time to return to sport (77%LSI in RSI), despite having achieved symmetry in horizontal hop distance(97%LSI) (Figure 1 and 2) and strength tests (95%LSI). This research also highlighted the reduction in work done at the knee during the eccentric phase of the test (compensated at the hip) and reduced work at the ankle during the concentric phase (also compensated at the hip) (Figure 3 and 4).

Similar differences were identified by King et al[2] when comparing drop jump and horizontal jump performance (Figure 5). In addition, biomechanical deficits were found in knee extension moments in the sagittal plane and at the knee and ankle in the frontal plane.

1. Eccentric (Stretching)

2. Amortization (Transition)

3. Concentric (Shortening)

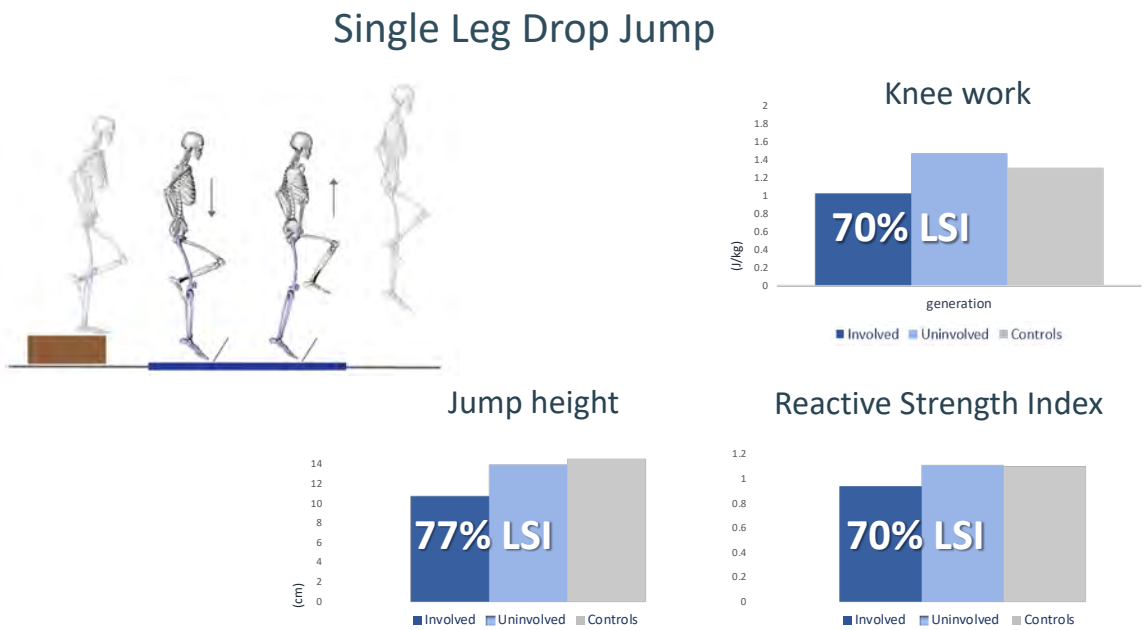


Figure 1

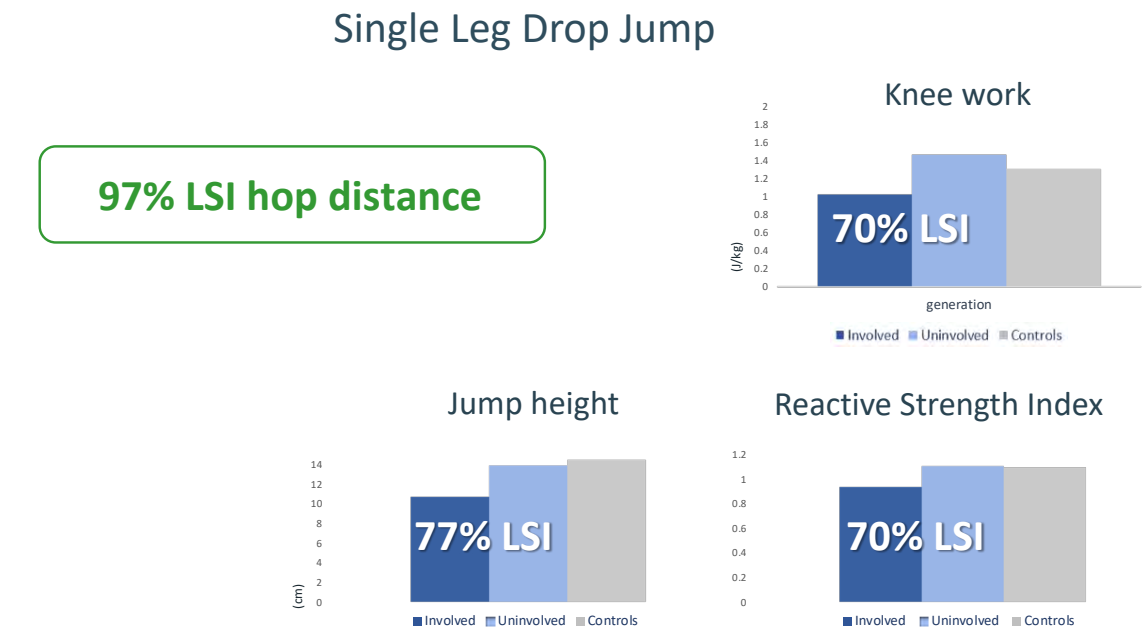
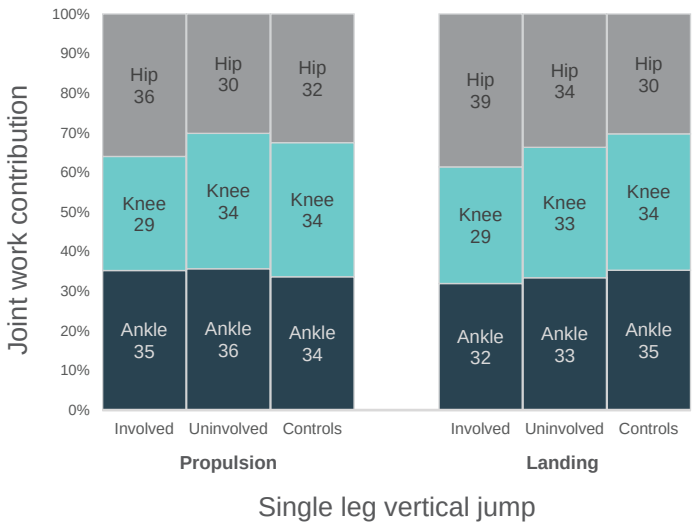
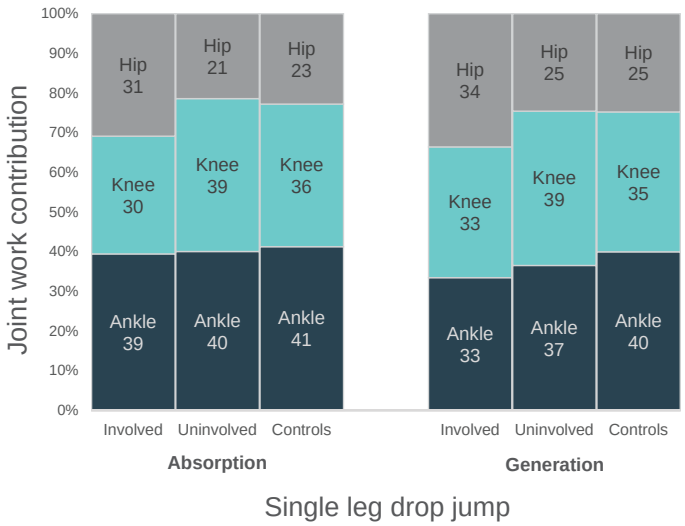


Figure 2





Figures 3 and 4

Read et al demonstrated lower-level performances and greater asymmetry in 10-second hop performances in soccer players who were in the later stages of rehabilitation after ACLR versus matched control participants. Some of these differences may be attributed to residual deficits in knee-extension and reactive strength as indicated by their predictive associations and the observed between-limbs differences in Single Leg Drop Jump Reactive Strength Index and isokinetic quadriceps peak torque[5].

Therefore plyometric exercises must be selected and coached that can improve reactive strength performance but can also target and resolve joint specific biomechanical deficits.

HOW TO ASSESS REACTIVE STRENGTH?

Reactive Strength Index (RSI), is a metric used to express the reactive strength or plyometric ability of an athlete, primarily during drop jump tests. RSI is calculated by dividing jump height (or jump performance) by the ground contact time:

RSI = Jump Height (in meters) / Contact Time (in seconds)

There are a number valid and reliable tests used to measure reactive strength including drop jumps, repeated jumps, rebound jump, and the 10-5 test[3]. As outlined in the testing article in this edition, in Aspetar we use the double and single leg drop jump during our rehabilitation pathway pathway to measure RSI.

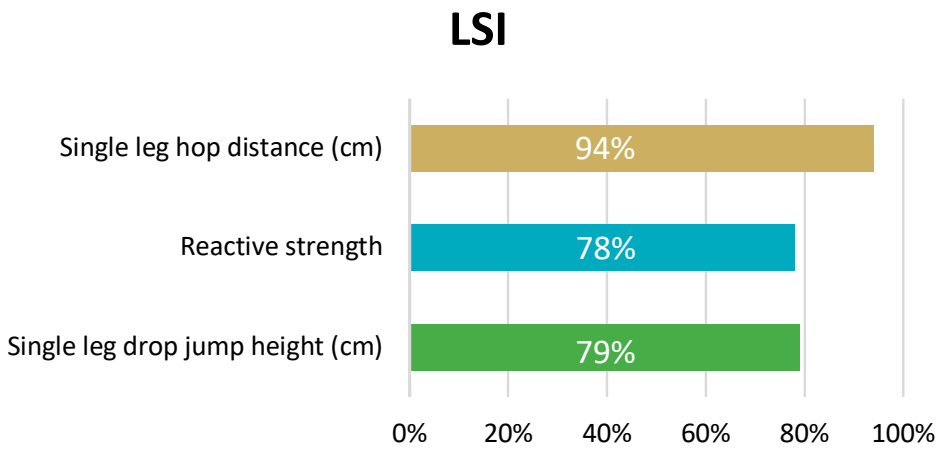


Figure 5

A higher RSI value indicates a higher level of reactive strength, reflecting a well-developed SSC allowing the athlete to be more explosive during short ground contact tasks. There is some variation across sports in reactive strength ability. Field sports such as football, rugby, AFL and court sports such as volleyball, basketball and handball would have lower levels of RSI (good scores would be 1.5 – 2.0) compared to track and field athletes (especially sprinters and jumping disciplines who may have RSI > 2.0 even in the lower-level athletes). It is important to recall that RSI is a ratio and to therefore not only interpret the RSI value, but also its component parts (is there a longer ground contact time on one side vs less jump height despite same ground contact time) to understand how best to tailor your exercise intervention.

Read et al demonstrated that RSI was the only variable to change significantly on the involved limb of 26 football players with ACLR versus 25 matched control participants, across the 2 measured time points in 32 & 42 weeks post ACLR, but improvements in RSI were not reflective of changes in drop jump ground reaction force characteristics and SSC function. Thus, RSI should not be the only metric recorded, and assessment of ground reaction force variables could be considered as an important component of future return-to-play criteria, providing a more comprehensive evaluation of readiness to reperform[6].

KEY FACTORS TO CONSIDER WHEN DEVELOPING REACTIVE STRENGTH DURING ACL REHABILITATION

The following critical monitoring factors emphasize the importance of assessing an athlete's readiness for plyometric rehabilitation and addressing any underlying issues to ensure safe and effective training.

1. **Pain / swelling:** A fundamental principle in ACLR rehabilitation is to ensure that plyometric exercises are entirely pain-free. Experiencing pain during these exercises is a clear contra-indication for higher intensity activities. Additionally it's vital to avoid any post-exercise (following day) swelling. This principle emphasizes the importance of a gradual, safe progression minimizes the risk of setbacks or complications.
2. **Muscle Strength:** a good strength base of the lower limb muscles (especially the quadriceps and calf muscles) are important for developing reactive strength and progressing pain free to higher level exercises. Approximately 30% of single leg drop jump asymmetry is explained by quadriceps asymmetry so ongoing resolution of strength deficits will improve reactive strength performance[4].
3. **Tendon Stiffness:** Tendons act like springs, storing and releasing energy during quick movements. Stiffer tendons can enhance the efficiency of force production. Heavy eccentric exercises, in particular targeting the calf and Achilles complex can greatly improve this quality throughout the rehabilitation process.
4. **Short ground contact time:** It's vital to gradually reduce ground contact time. This principle aims to enhance the ability to rapidly load and unload the lower limbs, promoting better shock absorption and control.
5. **Heel always off ground:** By focusing on this aspect, athletes can improve ankle stability, reduce excessive stress on the knee joint, and enhance neuromuscular control.
6. **Knee extended when doing ankle targeted exercises:** Ensuring the knee remains extended while performing ankle targeted exercises is essential. This principle helps isolate and strengthen the ankle joint without involving the knee. It promotes targeted strengthening - stiffness and better functional outcomes
7. **Volume vs. Intensity:** Developing good technique early in rehabilitation and the capacity to maintain it (increasing volume) is essential to developing load tolerance in the knee ahead of running and higher intensity plyometrics. As competency improves the volume and frequency of training will need to be reduced and intensity increased to ensure that the required demands are placed on the nervous system to maximize performance.
8. **Direction:** It is important to target reactive strength with plyometric exercises in multiple directions and planes of movement to optimize athletic performance - vertical for steady state running and sprinting, horizontal for acceleration and lateral for change of direction.

THE ASPETAR REACTIVE STRENGTH CURRICULUM

The Aspetar reactive strength curriculum is a structured and systematic program designed to develop an athlete's reactive strength after an ACLR. It typically includes a series of exercises with gradual progressions aimed at improving an athlete's ability to quickly and efficiently transfer force during movements that involve the stretch-shortening cycle.

All of the exercises below require full weight bearing ability of the athlete and full knee extension, are performed with the heel(s) off the ground, an upright posture and active ankle dorsiflexion. Hands are always maintained on hips to minimize upper limb and trunk compensations.

See next pages for exercises

CONCLUSION

Reactive strength is an essential component of the rehabilitation process for athletes who have undergone ACLR. It plays a pivotal role in restoring athletic performance and ensuring the long-term success of an athlete's return to sport. Following ACLR, athletes often experience a decline in power, agility, and speed making it crucial to rebuild their ability to generate force quickly and efficiently. Plyometric exercises are also a key component of every effective ACL prevention program. A logical progression of exercises with appropriate focus on technique as well as gradually increasing volume or intensity should see all athletes restore their reactive strength ability giving themselves an important component of physical competency to optimize their athletic performance in minimize their re-injury risk on return to sport.

References

1. *Kotsifaki A, Van Rossom S, Whiteley R, et al. Single leg vertical jump performance identifies knee function deficits at return to sport after ACL reconstruction in male athletes. Br J Sports Med. May 2022;56(9):490-498. doi:10.1136/bjsports-2021-104692*
2. *King E, Richter C, Franklyn-Miller A, et al. Whole-body biomechanical differences between limbs exist 9 months after ACL reconstruction across jump/landing tasks. Scandinavian journal of medicine & science in sports. Dec 2018;28(12):2567-2578. doi:10.1111/sms.13259*
3. *Comyns TM, Flanagan EP, Fleming S, Fitzgerald E, Harper DJ. Interday Reliability and Usefulness of a Reactive Strength Index Derived From 2 Maximal Rebound Jump Tests. Int J Sports Physiol Perform. Aug 29 2019:1200-1204. doi:10.1123/ijspp.2018-0829*
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5. *Read PJ, Davies WT, Bishop C, McAuliffe S, Wilson MG, Turner AN. Residual Deficits in Reactive Strength After Anterior Cruciate Ligament Reconstruction in Soccer Players. J Athl Train. 2023 May 1;58(5):423-429. doi: 10.4085/0169-20. PMID: 37523420.*
6. *Read PJ, Pedley JS, Eirug I, Sideris V, Oliver JL. Impaired Stretch-Shortening Cycle Function Persists Despite Improvements in Reactive Strength After Anterior Cruciate Ligament Reconstruction. J Strength Cond Res. 2022 May 1;36(5):1238-1244. doi: 10.1519/JSC.0000000000004208. Epub 2022 Jan 5. PMID: 35482544.*

1. Toe Taps

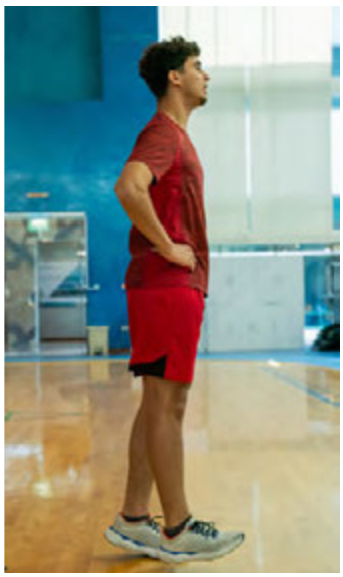
Toe taps are the foundation exercise of reactive strength development. It is essential that reactive strength rehabilitation intensity, should only be increased when the execution of the preceding exercise is mastered and performed correctly. This exercise shall begin as early as possible and when the athlete is able to fully weight-bear and to maintain full extension in his knee with a balanced posture, heels off the ground and active ankle dorsiflexion.

Suggested starting dose: 3-4 sets X 20-30 taps

2. Alternate pogos

Progression of the toe taps is alternate leg pogos with similar coaching cues/criteria (maintain knee extension, heel off the ground, active dorsiflexion) with a period when both feet are off the ground.

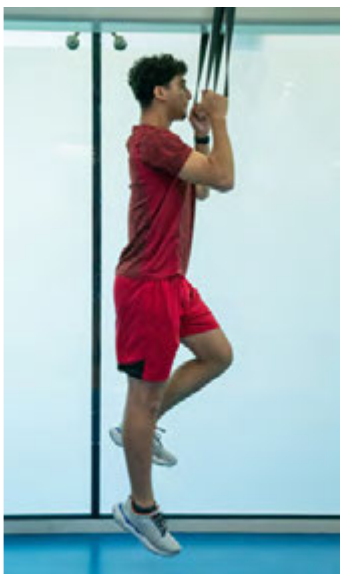
Suggested starting dose: 3-4 sets X 20-30 pogos



3. SL pogos banded

Using a band to reduce body weight when transitioning from alternate leg pogos to single leg can assist with a smooth painfree trainsistion.

Suggested starting dose: 3-4 sets X 15-20 pogos



4. SL pogos

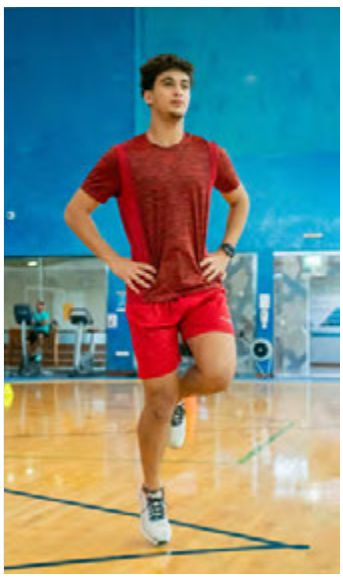
This exercise is a progression by removing the assistance of the band. Maintanence of full or close to full knee extension, when trying to minimize ground contact time and emphasizing a quick and explosive push-off with heel off the ground are essential.

Suggested starting dose :3-4 sets X 15-20 pogos

5. Line Hopping

Standing before the line on one leg with heel off the ground, knee slightly bent and good body posture with the chest erect, hopping in front of the line and explosively pushing off to hop back to the starting point. Stay close to the line without touching it. The backward component of the hop is an increased biomechanical challenge on ankle stiffness.

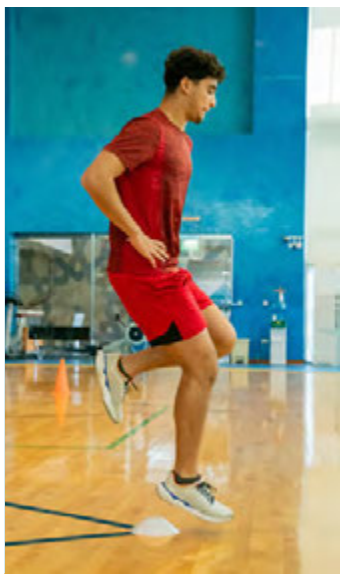
Suggested starting dose: 3-4 sets X 15-20 hops



6. Cone Hopping

Standing before the cone on one leg with the heel off the ground, knee slightly bent and good upright chest posture, hopping in front of the cone and explosively pushing back to the starting point. Stay close to the cone without stepping on it. The slight increase in jump height required to cross the cone vs the line previously increases the plyometric ability required.

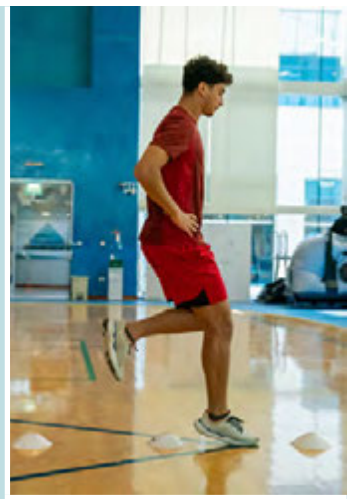
Suggested starting dose: 3-4 sets X 10-15 hops



7. 2 cones hopping forward – 1 cone hopping backwards

Standing before the first cone on one leg with heel off the ground, knee slightly bent, and good erect chest posture, hopping over two cones then explosively pushing backwards over one cone, before repeating the sequence for 4-5 cones. ('Two forward, one back'). Focusing also on hopping with same speed and explosiveness forward and backwards.

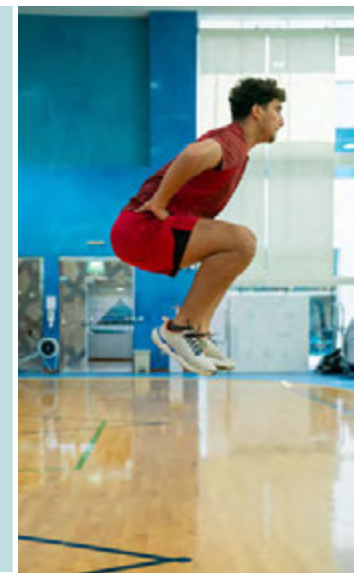
Suggested starting dose: 3-4 sets X 9-12 hops



8. DL Tuck jumps

One of the highest intensity plyometric exercises, that involves explosively jumping off both feet and bringing knees up towards chest, tucking them in. Extending legs back out as preparing to land with proper alignment, and explosively go into the next jump, repeating the same motion.

Suggested starting dose: 3-4 sets X 6-8 jumps



9. SL Tuck jumps

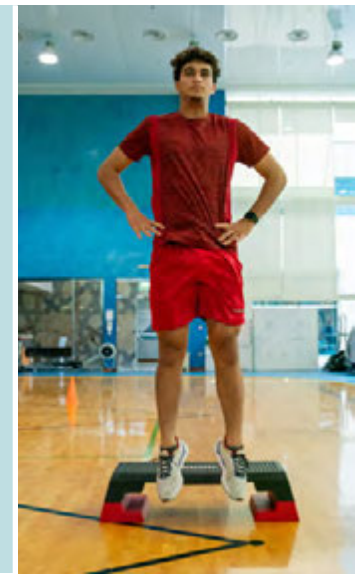
The highest intensity plyometric exercise, involves explosively jumping off one foot and bringing knee up towards the chest and then tucking it in. Extending the leg in preparation to land with proper alignment and explosively going to the next jump, repeating the motion.

Suggested starting dose: 3-4 sets X 4-6 jumps

10. DL Drop Jump

Prior to reactive strength testing or as an exercise progression, both legs drop simultaneously from a certain height (30cm) and with as short a ground contact as possible push off as quickly and jump as maximally as possible.

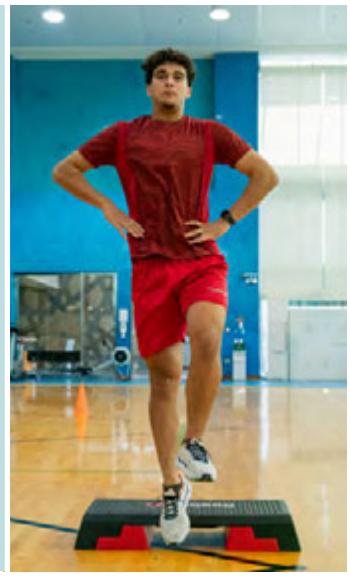
Suggested dose: 3-4 sets of 4-6 jumps



11. SL Drop jump

Progressing from the previous exercise to single leg from a certain height (15cm) maintaining that short ground contact time and maximal push off.

Suggested dose: 3-4 sets of 3-4 jumps



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