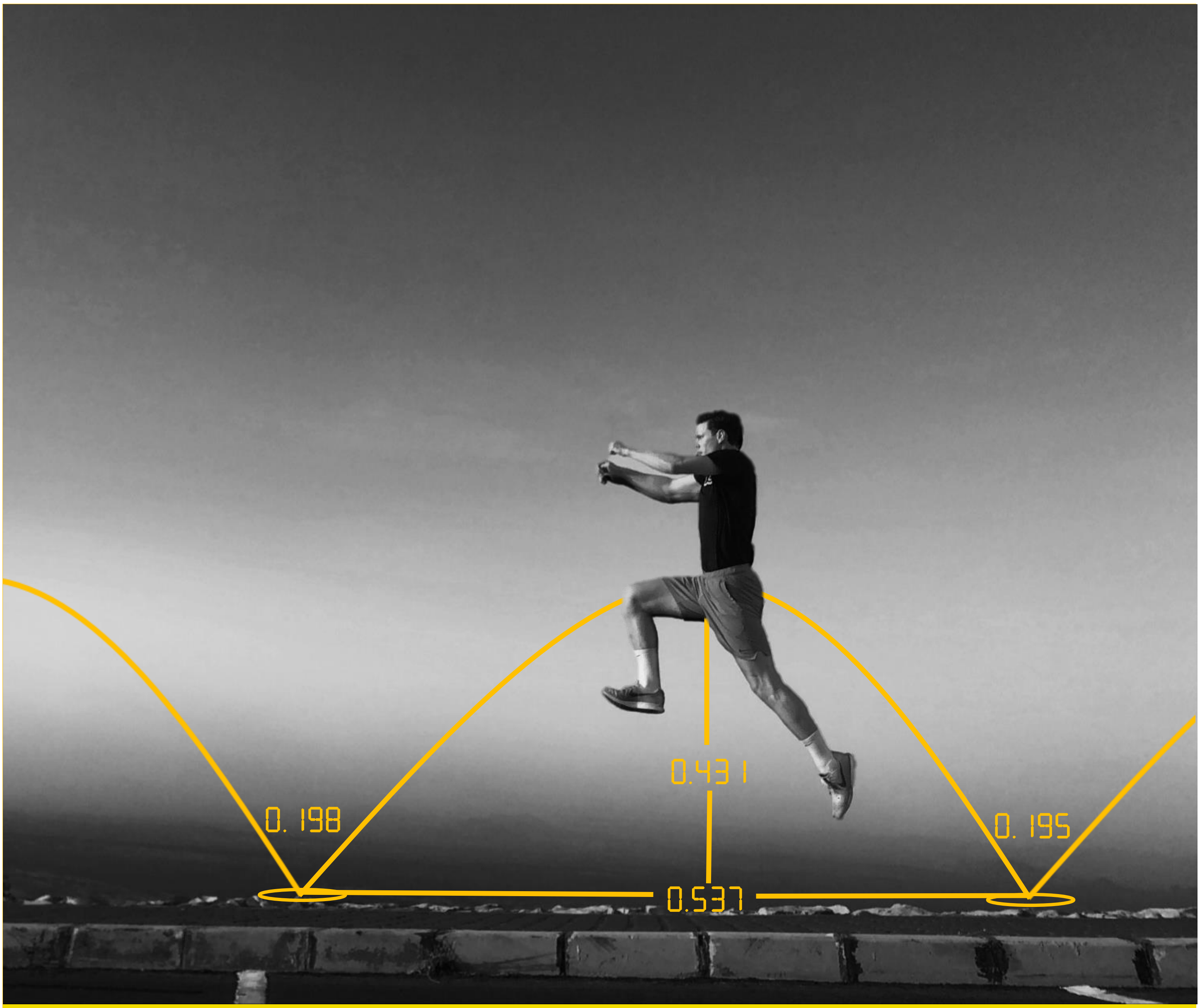

Reactive Strength Ratio & Output Manual

Understanding the fundamentals of RSRatio and RSOutput

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1.0 The Reason for New Metrics

1.1 Introduction to Reactive Strength

The Reactive Strength Index (RSI) is a measurement of reactive strength using a plyometric landing which provides an easy to calculate value. RSI identifies an athlete's ability to produce force over short Ground Contact times (GCT) that leads into a Flight Time (FT) and/or Jump Height (JH) through singular or continuous movements. We can use RSI as a way of determining a person's plyometric ability to produce force over the quickest GCT and identify how certain exercises and movements lead to greater RSI outputs. However, noticeable limitations are present with the method to truly identify reactive strength. If we break down the term reactive strength, we can gain a better understanding of a) what the term means; and b) what is required to utilise reactive strength in given movements.

Reactive - Acting in response to a stimulus rather than absorbing/controlling it.

Strength - The capacity of an object or substance to withstand great force or pressure.

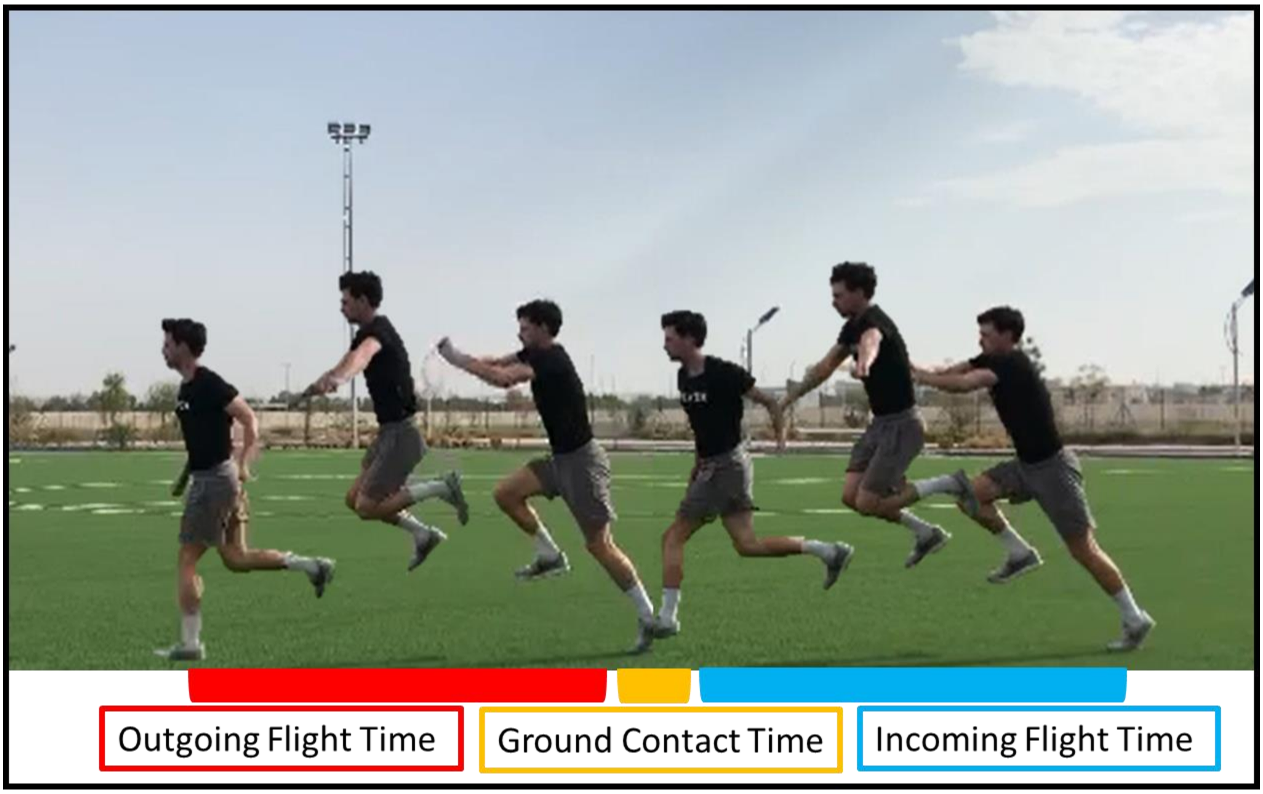
Reactive Strength - Ability to withstand eccentric loading from a stimulus and reproduce with maximal concentric force into subsequent take-off.

By breaking down and understanding the definition, it is easier to understand why RSI might not be the best measure of reactive strength as it does not consider the person's ability to be reactive to a specific incoming landing. Although it can be argued that quicker GCT shows an athlete is able to utilise reactive strength better, this may not be enough as it does not consider the approach variation into the landing of differing movements. The approach into a landing will vary in plyometric movements based on variables such as FTs, fall height and speed; thus the levels of reactive strength needed to reproduce force will differ even if RSI values are the same. Furthermore, this helps reiterate that exercises such as countermovement and box jumps are not plyometric movements as they do not have distinct landing-takeoff mechanics required as part of a reactive strength movement.

This is by no means a criticism of RSI, which is highly useful as a monitoring and tracking tool for coaches and athletes; however, the value has a strong focus towards the performance outcome rather than the process. With the value having been adapted to account for CMJ with the RSI-Mod equation, the use of RSI is less of a reactive strength measure and more towards an impulse measure. Thus, we believe that when looking to measure lower limb stiffness and reactive strength in plyometric movements with distinct landing-takeoff mechanics, there is a more appropriate calculation to use. With athletes utilising reactive strength to respond to and reproduce force into consequent movements, a calculation should not only consider the performance output (outgoing RSI) but also the approach into the landing (incoming RSI) to fully encompass the term reactive strength. This will also consider the importance of reactive strength to overcome increased approach loadings that RSI may not consider in varying plyometric movements.

1.2 Terminology

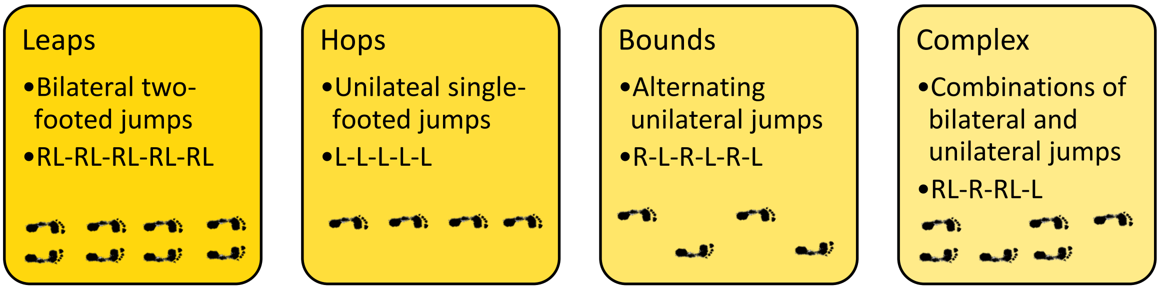
Outgoing RSI (Traditional RSI)	The ability to produce a maximal flight time (FT) from a minimal ground contact time (GCT)
Incoming RSI	The measurement of an incoming FT with the landing GCT
Reactive Strength Ratio (RSRatio)	The relationship between the incoming RSI and outgoing RSI to measure plyometric momentum
Reactive Strength Output (RSOutput)	The measure of reactive strength and neuromuscular strain an athlete has used to accomplish a plyometric task



2.0 Reactive Strength Ratio

2.1 What is RSRatio?

The Reactive Strength Ratio (RSRatio) is a measurement of exercise momentum considering the incoming and outgoing flight phases and the influence on the ground contact. The RSI test is effective at testing vertical angular momentum movements (on the spot, up and down) by assessing the relationship between GCT and jump height. Due to the large variations of plyometrics the RSI test has its limitations especially when assessing the large array of horizontal based movements used frequently in coaching.



Ground impulse in plyometric movements are split by two incoming momentum influence: 1) Falling 2) Limb Velocity. The most common influence comes from utilising gravity during falls that can be achieved through dropping from altitudes such as depth jumps, hops, leaps or bounds for height. The other method used to spike ground reaction force is created due to the velocity of a limb striking the ground, these are typically seen in movements at speed like sprinting or horizontally focused unilateral plyometrics where an emphasis may be placed on stride frequency and maintaining velocity.

The spectrum of plyometrics range from on the spot, to movements for height, distance, speed or changes in direction, these can also all be further influenced by carrying velocity into a movement or doing them from a static start. The development of the use of these more locomotive versions of plyometrics is constantly growing throughout sport and coaches are realising that the training method has evolved past just falling from platforms.

Due to the complexity of these open-chain movements, they become difficult to measure when testing on devices like force plates, jump-mats or even when using Velocity Based Training (VBT) technologies. Most of these devices focus primarily on measuring ground contacts and the following takeoff to calculate things like reactive strength but miss the critical influencing factor of the incoming flight of the previous movement to truly understand how to measure specific plyometric movements.

2.2 Measuring RSRatio

RSRatio*= (Outgoing RSI) / (Incoming RSI)*

Incoming RSI: Flight time - 0.35 / 0.17 GCT = 2.05
Outgoing RSI: Flight time - 0.37 / 0.17 GCT = 2.17

RSRatio: 2.17 / 2.05 = **1.059**

When testing to measure RSRatio, both the FTs (flight time) before and after a landing should be calculated, whilst monitoring GCT (Ground Contact Time). With both FTs, incoming momentum can be used to assess its influence on GCT and the outgoing takeoff FT. Both FTs are individually divided by the GCT giving 2 initial scores. The outgoing RSI is then divided by the incoming RSI to give a ratio of 1 based on the impact of incoming vs outgoing capacities.

2.3 Understanding RSRatio

Losing Momentum RSR < 1	Maintaining Momentum RSR = 1	Gaining Momentum RSR > 1
Greater incoming flight time where the athlete struggles to handle the eccentric force and create an equal or larger outgoing flight time.	**Both flight times are equal and the athlete has been able to utilise the incoming energy to propel themselves equally during the outgoing flight.**	**Incoming flight time is managed well and they're able to handle the force to propel themselves out of the takeoff creating a larger outgoing flight time.**

Training Bandwidths

Due to the natural complexity of human locomotion the likelihood of a perfect RSRatio of 1 is very low. For this reason, we suggest the use of bandwidth zones for athletes to train within. This is to gain a greater perspective as to what adaptations may be happening whilst using a specific movement. These bandwidths also allow the coach/athlete to measure and gain greater insight into the training load/volume of a given movement and the sets, reps and capacity to monitor fatigue. These bandwidths are suggested to stay within the 10 percentiles of the ratio of 1. Athletes are advised to stay within 0.90-1.10, this is used as a monitoring tool to ensure the movements being used aren't overloading the athlete eccentrically or equally not challenging the athlete with a large enough incoming FT and therefore having to create their own impulse for greater outgoing takeoffs. These bandwidths nevertheless can be used to train athletes at either ends of the plyometric spectrum, whether that's for spiking eccentric impulse or focusing more towards the concentric output.

Optimal Ratio of 1

An RSRatio of 1 as stated previously is a maintenance of momentum, where both incoming and outgoing FTs are identical. This optimal ratio of 1 can be a sign of locomotive rhythm for the athlete in a given exercise. Rhythm can be the foundation of Force-Velocity acquisition, showing that an athlete's competencies at a given movement in time are handled with efficient locomotive properties. The athlete's ability to pre-activate the joint musculature before contact, initiates a well-timed stiffening effect at the joint, which critically couples the energy of the incoming flight to be utilised during the outgoing takeoff. This in essence is smooth graceful movement with rhythm even during dynamic high-speed movement.

3.0 Reactive Strength Output

3.1 What is RSOutput?

RSOutput was created in an attempt to identify the work performed during a plyometric movement which RSI fails to do. RSI works as a performance metric identifying the end result, however with large variations in approach to plyometric landings, RSI fails to determine the neuromuscular strain and effort experienced during movements. The introduction of RSRatio has provided a useful tool for measuring plyometric momentum based upon incoming:outgoing RSI values, yet it does not provide us with a performance output value in which we can distinguish differences between movements and exercise effort. RSOutput is a measure of reactive strength that considers the body's ability to tolerate incoming load as well as then producing an output measure (Outgoing RSI). To achieve the value, it is important to evenly account for both incoming and outgoing RSI values by taking the average of the two. This ensures that both the approach and execution are accounted for in the value, before dividing this by the RSRatio which is used to account for the increased neuromuscular loading experienced in greater approach FTs.

3.2 Measuring RSOutput

***RSOutput** = ((Outgoing RSI + Incoming RSI) / 2) / (RSRatio)*

Incoming RSI: Flight time - 0.35 / 0.17 GCT = 2.05
Outgoing RSI: Flight time - 0.37 / 0.17 GCT = 2.17
RSRatio: 2.17 / 2.05 = 1.059

RSOutput: ((2.17 + 2.05) / 2) / 1.059 = **1.99**

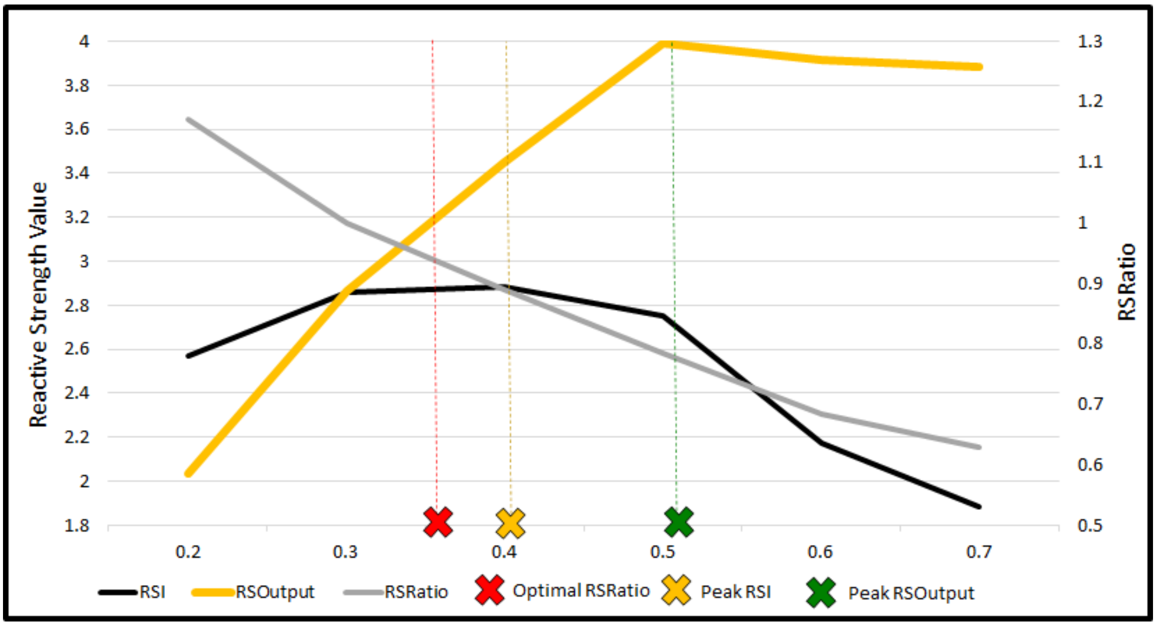
When creating a method to calculate reactive strength it was important to understand the impact of the approach into the movement and account for incoming RSI, this allows us to consider the athletes ability to eccentrically absorb the landing forces from the incoming FT and then reproduce it. By taking an average value of both incoming and outgoing RSI we can account for the mean workload needed to complete the plyometric movement. This means that a lower incoming RSI will reduce the mean compared to outgoing RSI, whereas a higher incoming RSI will increase the mean. When an exercise has an RSRatio of 1 then incoming RSI will not affect mean RSI due to a balance of incoming and outgoing momentum. By using this mean value, large incoming RSI values which lead to smaller outgoing RSI values aren't solely dependent upon the output value and will account for the increased loading of the approach. By only collecting the mean of incoming and outgoing RSI, values may be equal in two plyometric movements even though one may have a much larger incoming RSI leading to increased loading to overcome. Therefore, we divide the value by RSRatio to account for the greater neurological stimulus attained from increased incoming FT or drop heights. By dividing the average by the RSRatio we can account for this increased loading of plyometric movements where RSRatio <1 and generate a reactive strength value which reflects the demands of the movement. The example below highlights this case using two drop jumps.

Height (m)	Fall Time (s)	GCT (s)	FT (s)	Out-RSI	In-RSI	RSRatio	RSOutput
0.3	0.495	0.185	0.550	2.972	2.675	1.110	2.543
0.6	0.700	0.198	0.590	2.980	3.533	0.754	4.318

Note; As you can see the RSI for both 0.3 & 0.6m are relatively similar, however this does not account for the differences in eccentric loading that the neuromuscular system is exposed to. RSOutput provides a value that explains the work performed to overcome greater eccentric loading in various drop jumps which RSI fails to do. This provides a value that can objectively show the level of reactive strength and neuromuscular strain an athlete has used to accomplish said tasks.

3.3 What can the data tell us?

RSOutput has a prime use within drop jump profiling to identify peak reactive strength in an athlete as well as the optimal drop jump height to obtain this. By testing an athlete over multiple drop heights, we can see an exponential trend to peak reactive strength which then plateaus and drops off, thus showing that increasing drop heights will have a diminishing return after the optimal height. An example of a drop jump profile can be seen below.



Note; By identifying values such as RSR=1, Peak RSI and optimal RSOutput, we can start to plan training intensities when it comes to drop jumps as well as indications for locomotive plyometrics. Similar to resistance training, we can target more eccentric stimuli by manipulating drop jump height or focus more on output and technique work.