REACTIVE STRENGTH INDEX-MODIFIED IN DIFFERENT PLYOMETRIC TASKS

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The Reactive Strength Index-Modified (RSI_{mod}) is a reliable method of measuring the explosiveness of an athlete during a range of plyometric exercises. The purpose of the current study was to measure the between-limb differences in RSI_{mod} across three different plyometric tasks. Eleven recreationally active participants performed countermovement jumps, stop jumps and single-leg jumps. The study found no significant differences in RSI_{mod} between dominant and non-dominant limbs across all three tasks ($p>0.05$), but did find RSI_{mod} to be higher in the stop jump than a countermovement jump and single leg stop jump for both dominant and non-dominant limbs. These findings show RSI_{mod} may not be an indicator of limb asymmetry, but may be useful for the coach when looking to develop explosive performance in an athlete or performer.

KEY WORDS: limb asymmetry, jump performance, ground reaction force.

INTRODUCTION: Plyometric exercise training is thought to be essential for the development and improvement of the Stretch-Shortening Cycle (Ebben & Petushek, 2010) and can therefore improve performance measures such as vertical jump height (Lloyd, Oliver, Hughes & Williams, 2012). The measure of Reactive Strength Index (RSI) is primarily used in plyometric activities and is said to be a measurement of an athlete's "explosiveness" (Flanagan & Comyns, 2008). It is calculated by dividing jump height by contact time. The reliability of RSI was highlighted by Flanagan, Ebben and Jensen (2008), who found no significant difference between 3 trials of depth jump ($p>0.05$). Ebben and Petushek (2010) introduced a modified RSI (RSI_{mod}), making RSI applicable to all forms of plyometric exercise, including the countermovement jump (CMJ), by replacing 'contact time' with 'time to take-off'. Ebben and Petushek (2010) also highlighted the reliability of RSI_{mod} due to there being no significant difference between 3 trials ($p>0.05$) and found differences in RSI_{mod} between various plyometric exercises ($p \leq 0.001$).

There is a lack of research comparing RSI_{mod} to other variables of jump performance, such as peak ground reaction force (GRF), although Suchomel, Bailey, Sole, Grazer and Beckham (2015) found significant correlations between RSI_{mod} and peak force during a CMJ in both male ($p=0.003$, $r= 0.37$) and female ($p<0.001$, $r= 0.50$) athletes. It may however be noted that these relationships are only considered to be of moderate strength, therefore using peak GRF to predict RSI_{mod} may be invalid.

Limb asymmetries in GRF variables are currently inconclusive in detecting functional performance differences between limbs, whether that be injured vs. non-injured or dominant vs. non-dominant. Benjanuvatra, Lay, Alderson and Blanksby (2013) reported variations in GRF between single and double-legged CMJ. It was reported that limbs were capable of superior force production during the single-leg jumps, and suggested this could be due to asymmetric neural drive, as opposed to strength imbalances. The purpose of the current study was to compare asymmetries in RSI_{mod} between dominant and non-dominant limbs in various plyometric tasks. This will inform coaches on the temporal and kinetic demands of commonly used plyometric tasks. Single-leg RSI_{mod} was also correlated with single-leg peak GRF to compare with the findings of Suchomel et al. (2015). It was hypothesised that RSI_{mod} asymmetries would be greater in the stop-jump tasks compared to CMJ and single-leg jumps. It was also hypothesised that there would be significant correlations between RSI_{mod} and peak vertical GRF across all tasks.

METHODS: Eleven participants (Mean±SD; age = 20.4±1.5 years, height = 1.74±0.07 m, body mass = 80.1±12.9 kg) volunteered to act as participants for the current study. This research received university ethical approval and all participants provided informed consent prior to participation. Participants were injury free at the time of testing and for 6 months prior. Participants were recreationally active in a range of sports, including both individual and team. All participants carried out a standardised warm-up and were familiarised with the testing protocol prior to data collection. The participants then carried out four jumps; 1) a CMJ, 2) a stop jump (SJ) which involved three steps before landing on both legs prior to the jump, 3) a single-leg stop jump on the dominant leg (DLJ) and 4) a single-leg stop jump on the non-dominant leg (NLJ). The dominant leg was defined as the 'plant leg' used when kicking a ball for distance. Jumps were performed in a randomised order, with three-minute rest periods between each jump to minimise fatigue (Baechle & Earle, 2008). Each jump was repeated three times and an average value of each variable was used in data analysis.
Peak vertical GRF, time to take-off, and flight time for each leg was recorded using 2 side-by-side 0.91 x 0.63 m force platforms (Kistler, Switzerland) sampling at 1000Hz. Jump height was calculated using a standard flight time equation (Flanagan et al., 2008), and time to take-off was determined as the time difference between the beginning of the eccentric phase (identified by a reduction in vertical GRF from standing) and take-off. RSI_{mod} was calculated by jump height / time to take-off (Ebben & Petushek, 2010). Limb asymmetry was determined by the difference between legs for peak vertical GRF and RSI_{mod} for each of the jumps.
Statistical Analysis: Statistical analysis was carried out using SPSS (version 22.0). A two-way repeated-measures ANOVA was used to determine the differences between jumps for both dominant and non-dominant limbs. A dependent *t*-test was applied to investigate limb asymmetry for each jump. Pearson's Product Moment Correlation Coefficient was also used to show the relationship between RSI_{mod} and peak GRF for each limb. Alpha level was set at $p<0.05$. Cohen's *d* effect sizes were also used to determine magnitude of differences. Interpretation of effect size was based on the scale for effect size classification of Hopkins (2000): < 0.04 = trivial, 0.041 to 0.249 = small, 0.25 to 0.549 = medium, 0.55 to 0.799 = large, and >0.8 = very large.

RESULTS: Significant differences in RSI_{mod} were found between CMJ and SJ ($p=0.002$, $d=1.75$), and SJ and DLJ ($p<0.001$, $d=1.74$) for the dominant limb (Figure 1; Table 1). Similarly, significant differences in RSI_{mod} were found between CMJ and SJ ($p<0.001$, $d=1.66$), and SJ and NLJ ($p<0.001$, $d=1.67$) for the non-dominant limb (Figure 1; Table 1). There was no significant difference between CMJ and DLJ ($p=1.00$, $d=0.09$) for the dominant leg, and CMJ and NLJ ($p=1.00$, $d=0.22$) for the non-dominant limb.

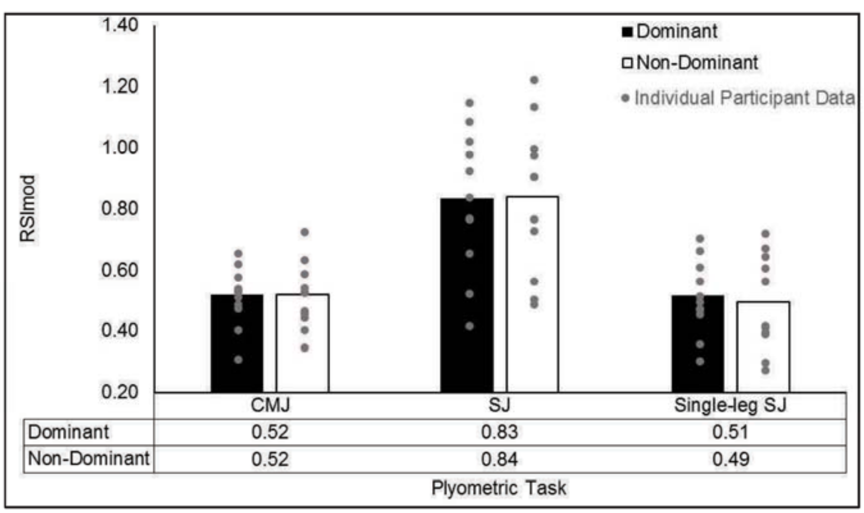

Figure 1: RSI_{mod} (Mean±SD) for dominant and non-dominant limbs in each jump.

Table 1: RSI_{mod} (Mean±SD) for dominant and non-dominant limbs in each jump.

	CMJ	Stop Jump	Single leg Stop Jump
Dominant	$0.52{\pm}0.10^{b}$	$0.83{\pm}0.23^{ac}$	$0.52{\pm}0.12^{b}$
Non-Dominant	$0.52{\pm}0.11^{b}$	$0.84{\pm}0.25^{ac}$	$0.49{\pm}0.16^{b}$
Between limb Cohen's d	0.02	0.02	0.14

[a] Significantly different (p<0.05) from CMJ
[b] Significantly different (p<0.05) from SJ
[c] Significantly different (p<0.05) from matched Single leg Jump

Table 2: Vertical GRF (Mean±SD) for dominant and non-dominant limbs in each jump.

	CMJ	Stop Jump	Single leg Stop Jump
Dominant ($N{\cdot}kg^{-1}$)	$12.15{\pm}1.22^{c}$	$13.24{\pm}1.95^{c}$	$22.73{\pm}2.62^{ab}$
Non-Dominant ($N{\cdot}kg^{-1}$)	$12.16{\pm}1.29^{c}$	$14.32{\pm}3.10^{c}$	$22.96{\pm}2.27^{ab}$
Between limb Cohen's d	0.01	0.42	0.09

[a] Significantly different (p<0.05) from CMJ
[b] Significantly different (p<0.05) from SJ
[c] Significantly different (p<0.05) from matched Single leg Stop Jump

There was also no significant between-limb difference in RSI_{mod} in the CMJ ($p=0.931$, $d=0.02$), SJ ($p=0.850$, $d=0.02$) and the single leg jumps ($p=0.558$, $d=0.14$). When RSI_{mod} was correlated with peak GRF for each limb in each condition, CMJ for the dominant limb ($r= 0.69$, $p= 0.020$) and both single-leg jumps (DLJ: $r= 0.70$, $p= 0.018$; NLJ: $r= 0.80$, $p= 0.003$) were found to be significant. No between-limb differences in peak GRF were found across all conditions (Table 2).

DISCUSSION: As hypothesised RSI_{mod} was significantly greater in the SJ than the other conditions for both the dominant and non-dominant limbs. This could be explained by the amount of contact time taken in the SJ compared to the CMJ (Ebben & Petushek, 2010), as well as the greater amount of GRF production during a bilateral jump, as opposed to unilateral plyometric tasks. This may indicate that the SJ is a more explosive type of movement, and coaches may want to make use of this form of plyometric exercise when looking to enhance performance variables such as speed and power. The main purpose of the current study was to use RSI_{mod} to determine limb asymmetry in plyometric tasks. However, the non-significant between-limb difference, along with small effect size, shows that limb dominance did not affect RSI_{mod} values. This could possibly be explained by the limited number of participants, however the small effect sizes showed that the non-significant differences may not be explained by a type II error of sample size. Suchomel et al. (2015) found a moderate relationship between RSI_{mod} and peak force during a CMJ and it was therefore noted that peak GRF may be an invalid predictor of RSI_{mod}. The current findings may support this notion, although significant relationships were found for the CMJ in the dominant limb, and in the single-leg jumps for both limbs. It may also be noted that Suchomel et al. (2015) used Division I collegiate athletes in their study, whereas this current study used recreationally-active participants from a range of sporting backgrounds.

The results of the current study found that peak GRF in the single leg jumps was significantly greater than the single-limb GRFs during the CMJ. This supports the findings of Benjavunatra et al. (2013), who stated that the legs were capable of producing more force in single-leg jumps when compared to bilateral jumps. It may be recommended for future studies with similar protocols to include a unilateral CMJ condition, to establish the true effect of limb dominance on force production. Benjavunatra et al. (2013) also recommended that when testing for limb asymmetries in force characteristics, such as impulse, it would be advised to use single-leg jumps as opposed to double-leg jumps. As no asymmetry was found for RSI_{mod} between limbs, coaches and researchers may not definitively be able to use the measure to assess asymmetry. RSI_{mod} was significantly lower in DLJ and NLJ than both limbs in the SJ (Figure 1; Table 1). This shows that the participants were less able to produce enough force to reach similar jump heights as in the SJ, as time to take-off was similar across the conditions. This may have future implications on plyometric exercise training for athletes that use single-leg take-offs, such as runners or long jumpers, as unilateral tasks may be more beneficial to the development of reactive strength in the athlete than conventional plyometric jumps. Compared with SJ, the CMJ produced relatively low RSI_{mod} values, which may be explained by the longer time to take-off (Ebben & Petushek, 2010). Suchomel et al. (2015) compared RSI_{mod} differences between males and females but did not include unilateral data, which may be more applicable to most team sports and some individual sports. Future studies comparing males and females may also be advised to measure the between-limb differences, as this may be different amongst genders.

CONCLUSION: The current study found that RSI_{mod} may not be a suitable method to investigate lower-limb asymmetry across several plyometric tasks. RSI_{mod} does however differ amongst the jumps carried out in this study. Dominant and non-dominant limbs display similar RSI_{mod} values during CMJ and single leg jumps and were higher in SJ. This may be useful for a coach when looking to use plyometric training to develop the stretch shortening cycle of an athlete. The suggestions in previous studies that peak GRF in plyometric tasks may be an invalid predictor of RSI_{mod} are supported and strengthened by the findings of the current study. Unilateral jumping tasks may be beneficial for increasing the explosiveness of limbs, as this study found a higher unilateral peak GRF coupled with similar contact times. Future studies should measure RSI_{mod} in athletes of different sporting activities, such as team sports vs. individual sports, as well as looking to establish RSI_{mod} limb asymmetries in males and females separately.

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