THE USE OF REACTIVE STRENGTH INDEX-MODIFIED AS AN EXPLOSIVE PERFORMANCE MEASUREMENT IN MALE AND FEMALE ATHLETES

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This study examined the reliability of reactive strength index-modified (RSImod), relationships between RSImod and force-time variables, and difference in RSImod between male and female collegiate athletes. 106 Division I collegiate athletes performed unloaded and loaded countermovement jumps. Intraclass correlation coefficients and coefficients of variation were used to establish the reliability of RSImod. Correlations were calculated between RSImod and rate of force development, peak force, and peak power. RSImod appears to be a reliable performance measurement in male and female athletes. Furthermore, RSImod has moderate to very large relationships with rate of force development, peak force, and peak power. Statistically significant differences in RSImod existed between males and females during both unloaded and loaded CMJs.

KEYWORDS: reliability, correlations, explosiveness, performance characteristics, countermovement jump

INTRODUCTION: The performance characteristics of athletes can be measured in a number of ways. Previous research has identified the reactive strength index as a variable that can be used to assess an athlete's reactive strength (Flanagan, Ebben, & Jensen, 2008) and performance in training (McClymont, 2003). The reactive strength index is a variable of interest that indicates how high an athlete jumps relative to their ground contact time during a depth jump (Flanagan & Comyns, 2008). However, because athlete testing protocols do not always include depth jumps, reactive strength index may not always be a viable option to use as a performance measure. A recent study indicated that reactive strength index-modified (RSImod), or jump height divided by the time to takeoff of various plyometric exercises, could provide sport scientists with an alternative method of assessing reactive strength during several different plyometric exercises (Ebben & Petushek, 2010). RSImod assessed using the countermovement jump (CMJ) is of particular interest, given that the CMJ is commonly used in athlete performance monitoring (Robbins, 2011; Sporis, Vuleta, Vuleta, & Milanovic, 2010).

Although previous research has assessed the relative measures of reliability of RSImod using for a subject group mixed with both males and females (Ebben & Petushek, 2010), no previous research has assessed absolute measures of reliability of RSImod or for male and female athletes separately. In order to determine if RSImod is a viable performance measurement for both male and female athletes, separate analyses should be completed. Furthermore, no previous research has evaluated relationships between RSImod and other common variables derived from the force-time record of a CMJ. Therefore, the primary purpose of this study was to assess the intrasession reliability of RSImod using relative and absolute measures during both unloaded and loaded CMJs in male and female Division I athletes. A secondary purpose of this study was to examine the correlational relationships between RSImod and force-time characteristics of the CMJ. A tertiary purpose of this study was to compare the differences in RSImod between male and female athletes during unloaded and loaded CMJs.

METHODS: One hundred six collegiate male (n = 61; height: 180.4 ± 6.9 cm, body mass: 82.6 ± 10.4 kg) and female (n = 45; height: 168.8 ± 7.4 cm, body mass: 67.0 ± 9.7 kg) athletes participated in this study, as part of an ongoing athlete monitoring program. Male athletes participated in baseball, tennis, and soccer, while female athletes participated in volleyball,

tennis, and soccer. This retrospective study was approved by the East Tennessee State University Institutional Review Board.

Prior to participation, each athlete completed the same standardized warm-up which consisted of 25 jumping jacks, a set of five repetitions of mid-thigh pulls with a 20 kg barbell, and three sets of five repetitions of mid-thigh pulls with 40 kg for women and 60 kg for men. As a specific warm-up, athletes performed two submaximal CMJs (perceived 50% and 75% maximum effort) with a near weightless PVC pipe (< 1kg). One minute following the warm-up jumps, each athlete completed two maximum effort CMJs with 30 seconds of rest in between each jump. One minute following the unloaded CMJs, each athlete began performing warm-up CMJ repetitions with a 20 kg barbell. Again, each athlete performed warm-up jumps at their perceived 50% and 75% maximum effort. Identical to the unloaded CMJs, each athlete completed two maximum effort CMJs with 30 seconds of rest in between each jump with the 20 kg barbell. Each CMJ was completed with the athlete's hands on the PVC pipe or barbell while it rested on their upper back, similar to a back squat. In addition, each jump was performed on a force plate (91 cm x 91 cm, Rice Lake Weighing Systems, Rice Lake, WI, USA) sampling at 1000 Hz. Data were analyzed using a custom LabVIEW program (2010 Version, National Instruments Co., Austin, TX, USA). A digital low-pass Butterworth filter with a cutoff frequency of 10 Hz was used to remove electrical noise from the signal. RSImod was calculated by dividing the jump height by the time to takeoff (Ebben & Petushek, 2010). Briefly, time to takeoff was calculated from the force-time record as the length of time between onset of the eccentric phase or countermovement, to the onset of the flight phase.

Intraclass correlation coefficient measures and coefficients of variation were used to establish the relative and absolute reliability of RSImod, respectively. It should be noted that this study used typical error expressed as a coefficient of variation percentage (Hopkins, 2014). Pearson's zero order, product-moment correlations (r) were calculated between RSImod and rate of force development, peak force, and peak power. Correlation values of 0.0, 0.1, 0.3, 0.5, 0.7, 0.9, and 1.0 were interpreted as trivial, small, moderate, large, very large, nearly perfect, and perfect according to Hopkins (2014). Finally, two independent sample t-tests were used to assess differences in RSImod between male and female athletes during both unloaded and loaded CMJ conditions. In addition, effect sizes (*d*) and confidence intervals (CI) were calculated. Levene's test for equality of variances was used between groups and revealed no statistically significant differences, thus equal variances were assumed. All data analyses were completed using SPSS 21 (IBM, New York, NY, USA) and statistical significance for all analyses was set at $p \leq 0.05$.

RESULTS: Reliability statistics and descriptive RSImod data for male and female athletes during the unloaded and loaded CMJ conditions are displayed in Tables 1 and 2, respectively.

Regarding male athletes, statistically significant correlations between RSImod and RFD ($p < 0.001$, r = 0.56), peak force ($p = 0.003$, r = 0.37), and peak power ($p < 0.001$, r = 0.47) existed during the unloaded condition. In addition, statistically significant correlations between RSImod and RFD ($p < 0.001$, r = 0.56), peak force ($p < 0.001$, r = 0.50), and peak power ($p < 0.001$, r = 0.56) existed during the loaded condition. Similar results were found in female athletes. Statistically significant correlations between RSImod and RFD ($p < 0.001$, r = 0.66), peak force ($p < 0.001$, r = 0.50), and peak power ($p < 0.001$, r = 0.69) existed during the unloaded condition. In addition, statistically significant correlations existed between RSImod and RFD ($p < 0.001$, r = 0.69), peak force ($p < 0.001$, r = 0.59), and peak power ($p < 0.001$, r = 0.78) during the loaded condition.

Statistically significant sex differences in RSImod existed. Males produced statistically greater RSImod values as compared to females during both the unloaded (t = 6.823, $p < 0.001$, d = 1.41, CI = 0.08 – 0.15) and loaded (t = 8.597, $p < 0.001$, d = 1.69, CI = 0.08 – 0.13) CMJs.

Table 1: Reliability statistics of RSImod during unloaded and loaded countermovement jumps.

Sex and CMJ Condition	ICC (CI)	CV% (CI)
Males Unloaded	0.96 (0.93 – 0.97)	7.6% (5.5 – 12.5)
Males Loaded	0.96 (0.93 – 0.98)	7.5% (5.4 – 12.3)
Females Unloaded	0.96 (0.93 – 0.98)	9.3% (6.7 – 15.4)
Females Loaded	0.98 (0.96 – 0.99)	8.0% (5.8 – 13.2)

Notes: ICC = intraclass correlation coefficient; CV % = coefficient of variation percentage; CI = 95% confidence intervals

Table 2. Descriptive male (n = 61) and female (n=45) RSImod data (M ± SD).

CMJ Condition	Reactive Strength Index-Modified ($m \cdot s^{-1}$)	
	Males	Females
*Unloaded	0.41 ± 0.09	0.29 ± 0.08
*Loaded	0.29 ± 0.07	0.18 ± 0.06

*Notes: * = Statistically significant difference between males and females, $p < 0.001$*

DISCUSSION: This study examined the intrasession reliability of RSImod, relationships between RSImod and other force-time characteristics, and compared RSImod values between male and female Division I collegiate athletes during both unloaded and loaded CMJs. The main findings of this study were threefold. First, RSImod was found to be a reliable performance measure in both male and female athletes during both unloaded and loaded conditions. Second, moderate to very large correlational relationships existed between RSImod and other force-time characteristics during both CMJ conditions. Finally, statistically significant differences in RSImod existed between male and female athletes during both CMJ conditions.

Both relative and absolute measures of reliability were used to determine the reliability of RSImod during both unloaded and loaded CMJ conditions. Intraclass correlation coefficients indicated that RSImod is a reliable performance measurement between two trials of a maximal CMJ. The ICC values of the current study were similar to those found in previous research (Ebben & Petushek, 2010). A unique aspect of this study was the examination of the absolute reliability of RSImod. The CV values for men and women during both unloaded and loaded conditions are relatively small, further indicating that RSImod is a reliable performance measurement. It should be noted that team differences in RSImod may have contributed to a higher CV value. Future research may consider investigating the differences in RSImod values between separate teams.

Statistically significant correlational relationships existed between RSImod and RFD, peak force, and peak power in both men and women during both CMJ conditions. In male and female athletes, large correlations existed between RSImod and RFD during both unloaded and loaded CMJs. Rate of force development is often viewed as an explosive characteristic of athletes (Young, 1995). Prior to the current study, RSImod was noted as being a potential measure of explosiveness (Ebben & Petushek, 2010). The data from the current study support this notion. The ability of an athlete to develop force quickly, both eccentrically and concentrically, may influence the jump height of an athlete (Dowling & Vamos, 1993), which would explain the strong correlational relationship between RFD and RSImod.

Moderate to Large and Large correlations existed between RSImod and peak force for men and women, respectively. In addition, Small to Moderate and Large to Very Large correlations existed between RSImod and peak power. It appears that there are stronger relationships between RSImod, peak force, and peak power in women as compared to men. From a practical standpoint, this may indicate that RSImod values may be a better indicator of peak force and peak power production ability in female athletes as compared to male athletes. However, because this is the first study to examine the correlational relationships between these variables, it is difficult to make conclusive statements with regard to these relationships.

Statistically significant differences in RSImod existed between male and female athletes during both the unloaded and loaded CMJ conditions. Specifically, the RSImod values for men during the unloaded and loaded CMJ conditions were 34.3% and 46.8% greater than the RSImod values of the women, respectively. These findings are in contrast with previous research that did not find statistically significant differences in RSImod values between male and female subjects (Ebben & Petushek, 2010), but in agreement with others (Ebben, Flanagan, & Jensen, 2009). The RSImod values in the current study for men and women were lower than those reported in previous studies (Ebben, et al., 2009; Ebben & Petushek, 2010). However, it should be noted that the previous studies used an arm swing during their CMJs, which could have contributed to a higher jump height (Lees, Vanrenterghem, & Clercq, 2004), thus increasing the RSImod value. The current findings follow the trend of many performance variables that indicate that men typically produce higher values than women. With regard to RSImod, it is likely that differences in strength between men and women, specifically eccentric strength, will allow men to perform a more rapid countermovement and be able to transition more effectively to an explosive propulsive phase, ultimately allowing for a greater jump height and decreased time to takeoff.

CONCLUSION: Reactive strength index-modified appears to be a reliable performance measure for both male and female Division I collegiate athletes. Based on the large relationship with RFD, RSImod may be described and used as a measure of explosiveness. Stronger relationships between RSImod, peak force, and peak power existed in female athletes as compared to male athletes; however, further evidence regarding these relationships is needed before conclusive statements can be made. Male athletes produced greater RSImod values as compared to female athletes. Future researchers may wish to repeat this study with different populations as well as investigate more into the RSImod relationship differences between males and females.

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