Using Reactive Strength Index-Modified as an Explosive Performance Measurement Tool in Division I Athletes

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Abstract

Suchomel, TJ, Bailey, CA, Sole, CJ, Grazer, JL, and Beckham, GK. Using reactive strength index-modified as an explosive performance measurement tool in Division I athletes. *J Strength Cond Res* 29(4): 899–904, 2015—The purposes of this study included examining the reliability of reactive strength index-modified (RSImod), the relationships between RSImod and force-time variables, and the differences in RSImod between male and female collegiate athletes. One hundred six Division I collegiate athletes performed unloaded and loaded countermovement jumps (CMJs). Intraclass correlation coefficients and typical error expressed as a coefficient of variation were used to establish the relative and absolute reliability of RSImod, respectively. Pearson zero-order product-moment correlation coefficients were used to examine the relationships between RSImod and rate of force development, peak force (PF), and peak power (PP) during unloaded and loaded jumping conditions. Finally, independent samples *t*-tests were used to examine the sex differences in RSImod between male and female athletes. Intraclass correlation coefficient values for RSImod ranged from 0.96 to 0.98, and typical error values ranged from 7.5 to 9.3% during all jumping conditions. Statistically significant correlations existed between RSImod and all force-time variables examined for male and female athletes during both jumping conditions ($p \leq 0.05$). Statistically significant differences in RSImod existed between male and female athletes during both unloaded and loaded CMJs ($p < 0.001$). Reactive strength index-modified seems to be a reliable performance measurement in male and female athletes. Reactive strength index-modified may be described and used as a measure of explosiveness. Stronger relationships between RSImod, PF, and PP existed in female athletes as compared with that in male athletes; however, further evidence investigating these relationships is needed before conclusive statements can be made. Male athletes produced greater RSImod values as compared with that produced by female athletes.

Key Words countermovement jump, athlete monitoring, stretch-shortening cycle, reliability, validity, rate of force development

Introduction

The monitoring of various performance characteristics of athletes is a crucial component to the overall training process. The performance characteristics of athletes can be measured in a variety of ways. Thus, it is important as practitioners to identify variables of interest that provide reliable assessments of an athlete's performance. Previous research has identified the reactive strength index as a variable that can be used to assess an athlete's reactive strength (6) and performance in training (13). This variable may be of interest because it shows how high an athlete jumps relative to his or her ground contact time during a depth jump (5,6). Although the reactive strength index may provide valuable information to practitioners, it should be noted that athlete testing and monitoring protocols do not always include depth jumps, nor do all athletes have the strength to justify the use of depth jumps (15), and thus, reactive strength index may not always be a viable option as a performance measure. Therefore, another assessment of an athlete's reactive strength may be warranted.

A recent study has indicated that reactive strength index-modified (RSImod) may provide sport scientists with an alternative method of assessing reactive strength during several different plyometric exercises (4). The calculation of RSImod is altered from the original reactive strength index equation by substituting time to takeoff for ground contact time, which allows the assessment of more plyometric exercises that begin from the ground, such as the countermovement jump (CMJ), instead of the depth jump. Assessment of RSImod during a CMJ is of particular interest

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given that the CMJ is commonly used in athlete performance monitoring (16,17).

To provide sport coaches with information about the reactive strength of their athletes, sport scientists must choose a performance variable that is both reliable and valid. Although previous research has assessed the relative measures of reliability of RSImod using a subject group mixed with both men and women (4), no previous study has assessed the relative and absolute reliability of RSImod for male and female athletes separately. To determine if RSImod is a viable performance measurement for both male and female athletes, separate analyses are warranted, given the differences as to how each sex uses the stretch-shortening cycle in different jumps (1,10). Further, no previous research has evaluated the relationships between RSImod and other commonly assessed performance variables derived from the force-time record of a CMJ. Thus, it is necessary to assess the validity of RSImod as a performance measurement of lower body explosiveness. Therefore, the primary purpose of this study was to assess the intrasession reliability of RSImod using both 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 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. It was hypothesized that RSImod would be determined to be a reliable and valid performance measurement and that differences in RSImod would exist between male and female athletes.

Methods

Experimental Approach to the Problem

To test our hypotheses, Division I collegiate athletes completed unloaded and loaded CMJs as part of an ongoing long-term athlete-monitoring program. Intraclass correlation coefficients and typical error were used to evaluate relative and absolute reliability, respectively. Pearson zero-order product-moment correlation coefficients were used to evaluate the relationships between RSImod and rate of force development (RFD), peak force (PF), and peak power (PP) measured during both unloaded and loaded jumping conditions. To compare the differences between sexes, 2 independent samples *t*-tests were used.

Subjects

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, whereas female athletes participated in tennis, soccer, and volleyball. All athletes were between 18 and 23 years old. The athletes were currently in the preseason phase of their training during their participation in this study. All athletes read and signed a written informed consent form before participation. This retrospective study was approved by the East Tennessee State University Institutional Review Board.

Procedures

Each subject attended 1 testing session. Before participation, every athlete completed a standardized warm-up that consisted of 25 jumping jacks, 1 set of 5 midthigh pull repetitions with a 20-kg barbell, and 3 sets of 5 midthigh pull repetitions with 40 kg for women and 60 kg for men. As a specific warm-up, all athletes then completed a warm-up CMJ at 50 and 75% of their perceived maximum effort with a near weightless (<1 kg) polyvinyl chloride pipe. After 1 minute of rest, each athlete performed 2, single maximum effort CMJs with 30 seconds of rest between each jump. One minute after the unloaded CMJs, each athlete performed warm-up CMJs with a 20-kg barbell. Similar to the unloaded condition, each athlete performed warm-up jumps at his or her perceived 50 and 75% maximum effort. After the warm-up repetitions, each athlete completed 2, single maximum effort CMJs with 30 seconds of rest between each jump with the 20-kg barbell. All CMJs were performed while the athletes held the PVC pipe or barbell resting on their upper trapezius muscles behind their neck near the seventh cervical vertebrae, similar to a high-bar back squat position (Figure 1). This was done in an effort to isolate the performance of the lower extremities, standardize jumping conditions, and to eliminate the use of an arm swing, which may greatly affect jump height and other force-time variables during a CMJ (11). All the CMJs were performed on a force platform (91 cm × 91 cm, Rice Lake Weighing Systems, Rice Lake, WI, USA) sampling at 1,000 Hz.

Figure 1. Position of the polyvinyl chloride pipe (left) and barbell (right) during the unloaded and loaded countermovement jump conditions, respectively.

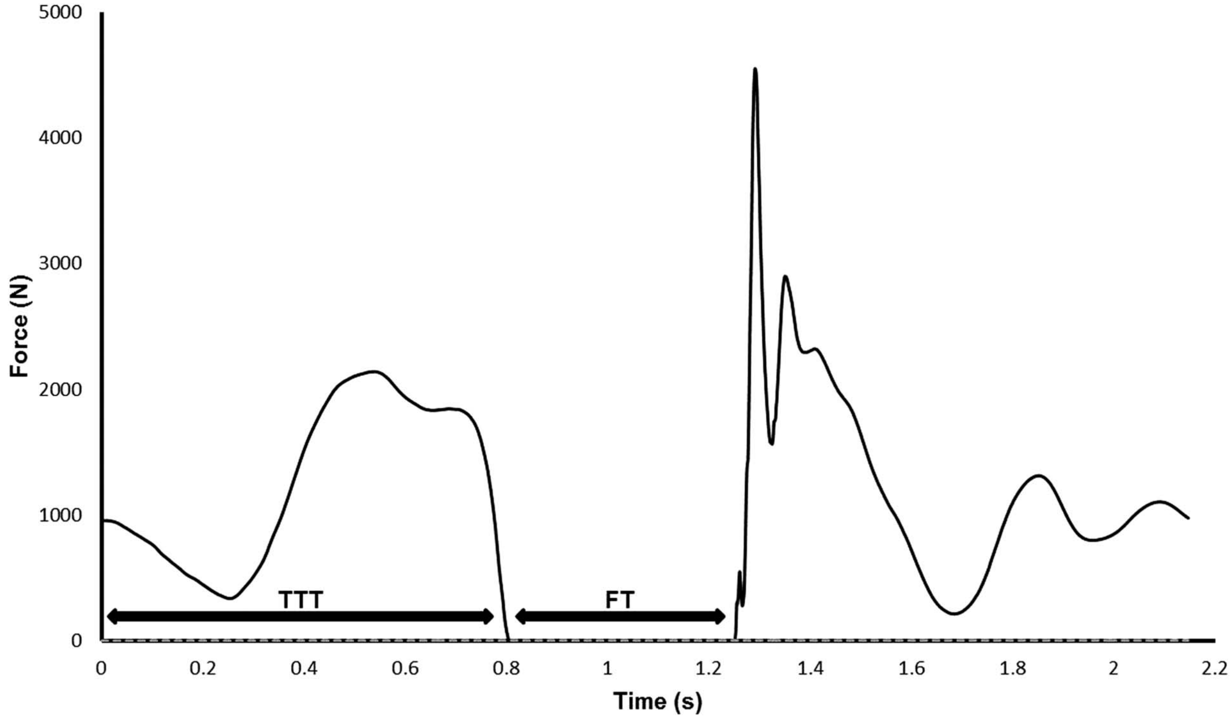

Figure 2. Force-time record of a countermovement jump indicating TTT and the FT used to calculated jump height. TTT = time to takeoff; FT = flight time.

Statistical Analyses

All CMJ data were collected and analyzed using a customized LabVIEW program (2010 Version, National Instruments Co., Austin, TX, USA). In addition, voltage data obtained from the force platform were filtered using a digital low-pass Butterworth filter with a cutoff frequency of 10 Hz to remove noise from the signal. As previously mentioned, the RSImod value for each athlete was calculated by dividing the jump height by the time to takeoff. Briefly, jump height was calculated based on the flight time of the center of mass using previously established methods (12). Time to takeoff was calculated from the force-time record as the length of time between onset of the countermovement to the point of takeoff (4) (Figure 2). This study used a threshold of 7.5 N to determine the onset of the countermovement. Rate of force development was calculated as the change in force divided by the change in time during the countermovement-stretching phase as defined in previous research (9,12,14). Peak force and PP were then calculated as the greatest value of force and power, respectively, which occurred during the concentric phase of each CMJ. Reactive strength index-modified, RFD, PF, and PP values produced during each jump in the unloaded and loaded jumping conditions were used for analysis of reliability, and then averaged for further statistical analyses.

Table 1. Reliability statistics of RSImod during unloaded and loaded CMJs.*

Sex and CMJ condition	ICC (CI)	TE% (CI)
Men unloaded	0.96 (0.93–0.97)	7.6 (5.5–12.5)
Men loaded	0.96 (0.93–0.98)	7.5 (5.4–12.3)
Women unloaded	0.96 (0.93–0.98)	9.3 (6.7–15.4)
Women loaded	0.98 (0.96–0.99)	8.0 (5.8–13.2)

*RSImod = reactive strength index-modified; CMJ = countermovement jump; ICC = intraclass correlation coefficient; TE = typical error expressed as a coefficient of variation percentage; CI = 95% confidence intervals.

Intraclass correlation coefficient measures and typical error were used to establish the relative and absolute reliability of RSImod, respectively. It should be noted that this

Table 2. Descriptive countermovement jump data of male ($n = 61$) and female ($n = 45$) athletes during the unloaded jumping condition (mean ± *SD*).*

Performance variable	Athletes: Men	Athletes: Women
RSImod†	0.41 ± 0.09	0.29 ± 0.08
JH (m)	0.35 ± 0.06	0.25 ± 0.06
RFD ($N \cdot s^{-1}$)	5,338.9 ± 1,818.9	3,760.2 ± 1,470.2
PF (N)	1,914.8 ± 231.0	1,444.2 ± 225.4
PP (W)	4,562.7 ± 823.3	2,950.0 ± 692.2

*RSImod = reactive strength index-modified; JH = jump height; RFD = rate of force development; PF = peak force; PP = peak power.
†Statistically significant difference between male and female athletes, $p < 0.001$.

study used typical error expressed as a coefficient of variation percentage (8). Pearson's zero-order, product-moment correlations (r) were calculated between RSImod and RFD, PF, and PP during the unloaded and loaded CMJ conditions. 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 based on a previously established scale by Hopkins (8). Finally, 2 independent sample t-tests were used to assess the differences in RSImod between male and female athletes during both unloaded and loaded CMJ conditions. In addition, effect sizes (d) and 95% confidence intervals (CI) were calculated for mean differences for all pairwise comparisons. Effect sizes were interpreted as trivial, small, moderate, large, very large, and nearly perfect when Cohen's d was 0.0, 0.2, 0.6, 1.2, 2.0, and 4.0, respectively, according to a scale developed by Hopkins (8). Levene's test for equality of variances was used between groups and revealed no statistically significant differences; thus, equal variances were assumed. All statistical 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 for RSImod in male and female athletes during the unloaded and loaded CMJ conditions are displayed in Table 1. Intraclass correlation coefficient measures for jump height, RFD, PF, and PP ranged from 0.92 to 0.99 and from 0.93 to 0.99 during the unloaded and loaded jumping conditions for both male and female athletes, respectively. The typical errors for jump height, RFD, PF, and PP in male athletes were in the range 5.1–5.4%, 12.0–12.3%, 1.4–2.6%, and 2.7–2.9%, respectively, during the unloaded and loaded jumping conditions. The typical errors for jump height, RFD, PF, and PP in female athletes were in the range 4.1–4.7%, 13.5–14.7%, 1.9–4.4%, and 2.7–4.4%, respectively, during the unloaded and loaded jumping conditions.

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

Descriptive CMJ data for male and female athletes during the unloaded and loaded jumping conditions are displayed in Tables 2 and 3, respectively. Statistically significant sex differences in RSImod existed. Male athletes produced statistically greater RSImod values as compared with that produced by female athletes 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 3. Descriptive countermovement jump data of male ($n = 61$) and female ($n = 45$) athletes during the loaded jumping condition (mean ± *SD*).*

Performance variable	Athletes: Men	Athletes: Women
RSImod†	0.29 ± 0.07	0.18 ± 0.06
JH (m)	0.28 ± 0.05	0.18 ± 0.05
RFD ($N \cdot s^{-1}$)	4,272.4 ± 1,392.7	2,766.6 ± 1,175.3
PF (N)	2,063.1 ± 228.4	1,586.5 ± 230.6
PP (W)	4,606.2 ± 801.7	2,958.0 ± 688.2

*RSImod = reactive strength index-modified; JH = jump height; RFD = rate of force development; PF = peak force; PP = peak power.
†Statistically significant difference between male and female athletes, $p < 0.001$.

Discussion

This study examined the intrasession reliability of RSImod, evaluated 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. There were 3 primary findings in this study. First, RSImod was found to be a reliable performance measure in both male and female athletes during both unloaded and loaded jumping conditions. Second, moderate to very large 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 the unloaded and loaded jumping conditions.

This study used both relative and absolute measures of reliability to determine the reliability of RSImod during the unloaded and loaded CMJ conditions. Intraclass correlation coefficients indicated that RSImod is a reliable performance measurement between 2 maximal effort CMJ trials. The intraclass correlation coefficient values of this study were similar to those previously reported by Ebben and Petushek (4). A unique aspect of the study was the examination of the absolute reliability of RSImod. The typical error values for male and female athletes were 7.6 and 9.3% were during the unloaded condition and 7.5 and 8.0% during the loaded condition, respectively. From a practical standpoint, previous research has indicated that a true change in performance in test-retest situations would require a 1.5 × typical error change (7). Based on the current typical error data, it is suggested that a change in RSImod of approximately 11–14% would be required to demonstrate a true change in performance. Sport scientists and practitioners should take this into account when monitoring the RSImod of athletes.

Statistically significant correlations existed between RSImod and RFD, PF, and PP in both male and female athletes 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 performance characteristic of athletes (19). Before this study, RSImod had also been suggested as being a potential measure of explosiveness (4). Based on the strong correlations between RSImod and RFD during both unloaded and loaded jumping conditions ($r = 0.56$ and $r = 0.56$ for men; $r = 0.66$ and $r = 0.69$ for women), the results of this 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 (2), which would explain the strong relationship between RSImod and RFD.

Moderate to large and large correlations existed between RSImod and PF for male and female athletes, respectively. In addition, small to moderate and large to very large correlations existed between RSImod and PP for male and female athletes, respectively. This is the first study that has examined the correlational relationships between these variables; this makes it difficult to make conclusive statements regarding these relationships. However, the findings of this study indicate that male and female athletes who produce greater force during CMJs may also possess greater reactive strength capabilities. In contrast, the sample of male athletes within this study did not express large relationships between their reactive strength characteristics and PP production, whereas the female athletes did. It is unclear at this point as to what the strength of these relationships mean from a practical standpoint, and thus, further research is needed.

Statistically significant differences in RSImod values existed between male and female athletes during both the unloaded and loaded CMJ conditions. Specifically, the RSImod values for men were 34.3 and 46.8% greater than the RSImod values for the women during the unloaded and loaded CMJ conditions, respectively. The differences between male and female athletes are practically significant because large effect sizes were present. The current findings are in contrast with previous research that did not find statistically significant differences in RSImod values between male and female subjects (4), but are in agreement with another study (3). The RSImod values in this study for men and women were lower than those reported in previous studies (3,4). However, it should be noted that the previous studies used an arm swing during the CMJs, which could have contributed to a higher jump height (11), thus increasing the RSImod value. Another obvious distinction between this study and the previous studies is the sample size. The sample size of this study is more than twice that of the previously discussed studies, which contributes to the strength of the current results. In addition, it should be noted that the subjects within this study were more homogeneous with regard to competitive level (Division I) as compared with in previous studies. However, with respect to sport participation, our subjects were less homogeneous with athletes participating in 6 different strength-power sports. Future research may consider examining RSImod differences between sports because it is currently unknown whether or not differences in RSImod exist between teams and athletes that compete in different sports.

The current findings indicate that male athletes produced greater magnitudes of all of the performance variables as compared with the values female athletes produced. However, it should be noted that statistical comparisons were only made between the RSImod values between sexes because of the focus of this study. 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, which may allow for a greater jump height and decreased time to takeoff. Future research may consider examining the relationships between RSImod and eccentric strength in male and female athletes.

Based on the strong relationships that existed with RFD within this study, RSImod may be described and used as a measure of explosiveness during athlete monitoring. Combining the current findings with those of the previous research that has labeled RSImod as a measurement of reactive strength (4), an indicator of an athlete's performance in training (13), and stretch-shortening cycle use (18), makes RSImod an appealing variable for use in assessing an athlete's performance characteristics and monitoring the training process. Thus, it is suggested that further research should examine RSImod values between and within athletic teams and also determine how RSImod changes in response to various training stimuli (e.g., high volume, low intensity vs. low volume, high intensity).

Practical Applications

Reactive strength index-modified seems to be a reliable performance measure for both male and female Division I collegiate athletes. Sport scientists who use CMJs to monitor their athletes' performance and training should consider using RSImod as an explosive stretch-shortening cycle measurement. Male and female athletes produce different RSImod values, but moderate to very large relationships existed between RSImod, RFD, PF, and PP for both sexes. It seems that RSImod can provide valuable information regarding the explosive performance characteristics of athletes upon which this information can be used to prescribe specific training stimuli to enhance an athlete's performance capabilities.

Although the assessment of RSImod requires the use of a force platform, practitioners may consider using portable force platforms during field testing. By doing this, practitioners may be able to assess the performance characteristics of athletes to a greater extent as compared with simply using a contact mat. More extensive information, not limited to reactive strength characteristics, can be collected and given back to the sport coach and athlete during field testing. This highlights the need to use better technologies for the assessment of athletes and training outcomes.

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