REACTIVE STRENGTH INDEX-MODIFIED: A COMPARISON BETWEEN SIX U.S. COLLEGIATE ATHLETIC TEAMS

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The purpose of this study was to compare reactive strength index-modified (RSImod) between six U.S. collegiate sport teams. One hundred six athletes performed maximum effort countermovement jumps during unloaded and loaded conditions. RSImod measures for each team were compared using one-way ANOVAs, and Bonferroni *post hoc* tests where warranted. Statistically significant differences in RSImod values existed between teams during both unloaded (< 1kg) and loaded (20kg) conditions. The greatest RSImod values during both conditions were produced by men's soccer and followed in order by baseball, women's volleyball, men's tennis, women's soccer, and women's tennis. The data indicate that athletes from different sports possess different reactive strength characteristics.

KEYWORDS: countermovement jump, performance characteristics, team comparison

INTRODUCTION: Specific muscular performance characteristics of athletes, across various disciplines, are important to consider when designing and implementing training and monitoring programs. Moreover, these muscular performance characteristics may determine whether or not an individual or team is successful in their respective sport/event. Several studies have indicated that differences in muscular performance characteristics exist between starters and non-starters and between professionals and amateurs (Jajtner et al., 2013; le Gall, Carling, Williams, & Reilly, 2010; Massuca, Fragoso, & Teles, 2014). Further research has shown differences between player positions within American football (Iguchi et al., 2011; Robbins, 2011), Gaelic football (Cullen et al., 2013), soccer (Sporis, Jukic, Ostojic, & Milanovic, 2009), handball (Sporis, Vuleta, Vuleta, & Milanovic, 2010), and lacrosse (Hoffman et al., 2009). Despite the above research, only one study has examined differences in muscular performance characteristics between teams (Sato et al., 2012) and found statistical differences in isometric strength measures.

In strength-power sports, the "explosive" characteristics of an athlete are viewed as vital components to their success (Young, 1995). A measure that could be used to indicate an athlete's explosiveness during several jumping exercises is reactive strength index-modified (RSImod) (Ebben & Petushek, 2010). RSImod may provide sport scientists and coaches with an indication of an athlete's reactive strength (Ebben & Petushek, 2010; Flanagan, Ebben, & Jensen, 2008) and potentially their performance in training (McClymont, 2003). Further understanding of the reactive strength abilities of athletes participating within a given sport, and between other sports, is integral to improving a coach's ability to prescribe and monitor training for their athletes. Therefore, the purpose of this study was to compare the RSImod values between six U.S. collegiate sport teams during unloaded and loaded CMJs.

METHODS: Subjects for this study included 106 collegiate athletes from various sports in a National Collegiate Athletic Association (NCAA) Division I institution, including baseball (n = 29; height = 182.1 ± 6.2 cm, body mass 88.0 ± 9.0 kg), men's tennis (n = 7; height = 176.9 ± 9.0 cm, body mass = 74.7 ± 9.5 kg), men's soccer (n = 25; height = 179.5 ± 6.8 cm, body mass = 78.5 ± 9.2 kg), women's tennis (n = 11; height = 167.6 ± 5.6 cm, body mass = 68.6 ± 12.7 kg), women's soccer (n = 22; height = 166.1 ± 6.2 cm, body mass = 63.9 ± 8.1 kg), and women's volleyball (n = 12; height = 174.3 ± 8.2 cm, body mass = 70.8 ± 7.8 kg). Subjects ranged in age from 18-23.

This retrospective study was approved by the East Tennessee State University Institutional Review Board and all data were collected as part of an ongoing athlete monitoring program. Each athlete completed the same standardized warm-up prior to performing maximum effort CMJs without arm swings and holding a bar. The warm-up consisted of 25 jumping jacks, one set of five repetitions of mid-thigh pulls with a 20 kg bar, 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 (50% and 75% of perceived maximum effort) with a low mass (< 1kg) 5.5 cm diameter PVC pipe. After resting for one minute, athletes completed two maximum effort CMJs with 30 seconds of recovery in between each jump with the PVC pipe. Afterward, each athlete performed a warm-up CMJ at 50% and 75% of their perceived maximum effort with a 20 kg barbell. Each athlete completed two maximum effort CMJs with 30 seconds of rest between each jump with the 20 kg barbell. All CMJs were performed on a force plate (91 cm x 91 cm, Rice Lake Weighing Systems, Rich Lake, WI, USA) sampling at 1000 Hz. Jumps were collected and analyzed using a custom LabVIEW program (2010 Version, National Instruments Co., Austin, TX, USA) and a digital low-pass Butterworth filter with a cutoff frequency of 10 Hz was used to remove electrical noise from the vertical force signal. Using the procedures detailed by Ebben & Petushek (2010), RSImod was calculated by dividing the jump height by the time to takeoff of each jump. 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.

To determine the internal consistency of RSImod within each team, intraclass correlation coefficients were calculated and ranged 0.91 – 0.96 and 0.94 – 0.98 for the unloaded and loaded jumping conditions, respectively. Additional analysis was conducted by examining coefficient of variation (CV) percentage from each team. These values are interpreted in the discussion section. Because the number of subjects was different for each team, Levene's test was used to identify the homogeneity of variances before the statistical analysis. Two one-way ANOVAs were used to identify the differences of RSImod between each team. When necessary, *post hoc* analyses were conducted using the Bonferroni technique. In addition, calculations of effect size (*d*) and 95% confidence intervals (CI) for the difference between means were calculated. Effect sizes were interpreted using the scale developed by Hopkins (2014). 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: The Levene's test revealed no statistically significant differences in homogeneity of variance between teams and thus, equal variances were assumed. Descriptive RSImod data for each team are displayed in Table 1.

Table 1: Reactive strength index-modified values ($m \cdot s^{-1}$) of each sport team (Mean ± SD)

Variables	M Soccer	W Soccer	M Tennis	W Tennis	M Baseball	W Volleyball
*RSImod0kg	0.44 ± 0.09	0.28 ± 0.06	0.30 ± 0.07	0.23 ± 0.05	0.41 ± 0.08	0.38 ± 0.07
*RSImod20kg	0.30 ± 0.06	0.16 ± 0.04	0.22 ± 0.07	0.14 ± 0.04	0.30 ± 0.06	0.24 ± 0.08

*Notes: *Statistically significant difference between teams, p < 0.05; RSImod0kg = reactive strength index-modified during unloaded jumps; RSImod20kg = reactive strength index-modified during loaded jumps with 20kg*

Statistically significant differences existed between teams during both the unloaded ($F_{(5,100)}$ = 21.634, $p < 0.001$) and loaded ($F_{(5,100)}$ = 28.128, $p < 0.001$) jumping conditions. During the unloaded jumping condition, the RSImod values of the men's soccer team were statistically greater than men's tennis ($p = 0.001$, $d = 1.74$, CI = 0.04 – 0.23), women's tennis ($p < 0.001$, $d = 2.88$, CI = 0.13 – 0.29), and women's soccer ($p < 0.001$, $d = 2.09$, CI = 0.10 – 0.23). The RSImod values of the baseball team were statistically greater than those of the men's tennis ($p = 0.014$, $d = 1.46$, CI = 0.01 – 0.20), women's tennis ($p < 0.001$, $d = 2.70$, CI = 0.10 – 0.26), and women's soccer (p < 0.001, d = 1.84, CI = 0.07 – 0.19) teams. The RSImod values of the women's volleyball team were statistically greater than the women's tennis (p < 0.001, d = 2.47, CI = 0.06 – 0.24) and women's soccer (p = 0.004, d = 1.53, CI = 0.02 – 0.18). Similar findings existed during the loaded jumping condition. The RSImod values of the men's soccer team were statistically greater than men's tennis (p = 0.009, d = 1.23, CI = 0.01 – 0.15), women's tennis (p < 0.001, d = 3.14, CI = 0.10 – 0.22), and women's soccer (p < 0.001, d = 2.75, CI = 0.09 – 0.18). Baseball RSImod values were statistically greater than those of the men's tennis (p = 0.011, d = 1.23, CI = 0.01 – 0.15), women's tennis (p < 0.001, d = 3.14, CI = 0.10 – 0.21) and women's soccer (p < 0.001, d = 2.75, CI = 0.09 – 0.18) teams. Finally, the RSImod values of the women's volleyball team were statistically greater than both the women's tennis (p < 0.001, d = 2.16, CI = 0.04 – 0.18) and women's soccer teams (p < 0.001, d = 1.77, CI = 0.03 – 0.15). No other statistically significant differences existed between teams during either jumping condition.

DISCUSSION: The purpose of this study was to compare the differences in RSImod during CMJs between six NCAA Division I U.S. collegiate sport teams. Differences in RSImod existed between sport teams during both the unloaded and loaded jumping conditions. The current study indicates that the greatest RSImod values were produced by men's soccer followed in order by baseball, women's volleyball, men's tennis, women's soccer, and women's tennis during the unloaded jumping condition. Specifically, the RSImod values of the men's soccer team were 7.1%, 14.6%, 37.8%, 44.4%, and 62.7% greater than the baseball, women's volleyball, men's tennis, women's soccer, and women's tennis teams, respectively. The greatest RSImod values during the loaded jumping condition were produced by the men's soccer and baseball teams and were followed in order by women's volleyball, men's tennis, women's soccer, and women's tennis. Specifically, the RSImod of men's soccer and baseball was 22.2%, 30.8%, 60.9%, and 72.7% greater than the women's volleyball, men's tennis, women's soccer, and women's tennis teams, respectively. Based on the large to very large effect sizes and percent differences information, it is clear that sizeable differences in RSImod exist between different sport teams. Furthermore, the differences in RSImod became greater during the loaded jumping condition, indicating that differences in strength may have contributed to the results of this study. The RSImod values reported in this study are lower than those previously reported (Ebben, Flanagan, & Jensen, 2009; Ebben & Petushek, 2010) during the unloaded CMJ. However, it should be noted that the previous studies used an arm swing during the CMJs, which may have contributed to a higher CMJ height and RSImod value.

For unloaded RSImod data, the greatest CV was displayed by men's tennis with 9.9%, followed by women's tennis with 9.4%, men's soccer with 9.1%, baseball with 7.6%, and women's volleyball and women's soccer with 7.4%. For loaded RSImod data, the greatest CV was displayed by women's tennis with 8.5%, followed by women's volleyball with 8.3%, baseball with 7.5%, men's soccer with 7.2%, women's soccer with 6.9%, and men's tennis with 4.7%. The CV values displayed above are relatively small, indicating only minimal differences exist in the ability to use the stretch-shortening cycle for maximum CMJ jump height within teams. Possible explanations for increased CV may include differences in muscular strength (Sato, et al., 2012), the nature of each sport, and positional differences within each sport.

Some limitations exist in the current study. First, the sample of athletes examined in the current study ranged from Freshmen to Senior. It is likely that the training volume experienced at the collegiate level exceeds that which each athlete experienced in high school. Thus, athletes who have participated in a structured strength training program for a longer period of time may produce greater values of RSImod compared to those who have little experience in a similar setting. This may be reflected in the team's overall RSImod outcome. A similar rationale can be used to address position differences within each sport. Previous research has indicated that differences in muscular performance characteristics exist between players of different positions (Cullen, et al., 2013; Hoffman, et al., 2009; Iguchi, et al., 2011; Robbins, 2011; Sporis, et al., 2009; Sporis, et al., 2010). Certain positions in sports may exhibit lower or higher values of RSImod, thus altering the team's average RSImod. Because no data currently exist on RSImod differences between different positions within teams, it is impossible to determine if positional differences altered the results of this study.

CONCLUSION: The collegiate athletes studied from different sports exhibit varying reactive strength characteristics. It is unclear exactly why these differences exist, but it does provide some direction for the understanding of RSImod. Being aware of differences in RSImod between sports may help direct the creation of training and monitoring programs more effectively for a given sport. The origin of the variability of RSImod within some teams is unclear and thus, further research is warranted to improve our understanding of this measure of explosive muscular performance. Specifically, future research should consider investigating differences in RSImod in individuals with different strength levels and positions within each sport.

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