A Comparison of Reactive Strength Index-Modified Between Six U.S. Collegiate Athletic Teams

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Abstract

Suchomel, TJ, Sole, CJ, Bailey, CA, Grazer, JL, and Beckham, GK. A comparison of reactive strength index-modified between six U.S. collegiate athletic teams. *J Strength Cond Res* 29(5): 1310–1316, 2015—The purpose of this study was to examine the differences in reactive strength index-modified (RSImod), jump height (JH), and time to takeoff (TTT) between 6 U.S. collegiate sport teams. One hundred six male and female Division I collegiate athletes performed unloaded (<1 kg) and loaded (20 kg) countermovement jumps as part of an ongoing athlete monitoring program. Reactive strength index-modified, JH, and TTT values for each team were compared using 1-way analysis of variance. Statistically significant differences in RSImod ($p < 0.001$), JH ($p < 0.001$), and TTT ($p = 0.003$) existed between teams during the unloaded jumping condition. Similarly, statistically significant differences in RSImod ($p < 0.001$), JH ($p < 0.001$), and TTT ($p = 0.028$) existed between teams during the loaded jumping condition. Men's soccer and baseball produced the greatest RSImod values during both the unloaded and loaded jumping conditions followed by women's volleyball, men's tennis, women's soccer, and women's tennis. The greatest JH during unloaded and loaded jumping conditions was produced by men's baseball followed by men's soccer, women's volleyball, men's tennis, women's soccer, and women's tennis. Men's soccer produced shorter TTT compared with men's baseball (12.7%) and women's soccer (13.3%) during the unloaded and loaded jumping conditions, respectively. Collegiate sport teams exhibit varying reactive strength characteristics during unloaded and loaded jumping conditions. Understanding the differences in RSImod between sports may help direct the creation of training and monitoring programs more effectively for various sports.

Key Words countermovement jump, athlete monitoring, stretch-shortening cycle, performance characteristics, team comparison

Introduction

Specific performance characteristics of athletes, across various disciplines and sports, are important to consider when designing, implementing, and monitoring training programs. Moreover, the performance characteristics exhibited by an individual athlete or a team may determine whether that individual or team is successful in his or her or their respective sport or event. Several studies have indicated that differences in muscular performances exist between starters and nonstarters and between professional and amateur athletes (12,14,17). Additional research has displayed that differences in performance characteristics exist between different player positions within American football (11,19), Gaelic football (4), soccer (21), handball (22), lacrosse (9), and baseball (2). Surprisingly, only 1 study has examined the differences in muscular performance characteristics between teams (20) and found statistical differences in isometric strength measures.

Within strength-power sports, the "explosive" characteristics of an athlete are often viewed as vital components to his or her success (26). A measure that could be used to indicate an athlete's explosiveness during several jumping exercises is reactive strength index-modified (RSImod) (7,23). Magnitudes of RSImod are calculated by dividing an athlete's jump height (JH) by his or her time to takeoff (TTT) (7,23), typically using a plyometric exercise that begins from the ground, such as the countermovement jump (CMJ). By monitoring RSImod, sport scientists and coaches could be provided with an indication of an athlete's or a team's reactive strength (7,8,23), explosiveness (23), ability to use the stretch-shortening cycle (24), and potentially the athlete's or the team's performance in training (18).

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Furthermore, assessing RSImod during a CMJ may be of particular interest given that CMJs are commonly used in testing batteries of athletes (19,22).

Further understanding of the reactive strength abilities of athletes participating within a given sport, and between sports, is integral to improving a coach's ability to prescribe and monitor training for his or her athletes. Although only 1 study has examined performance characteristics (i.e., isometric strength) between teams (20), no previous research has examined the reactive strength characteristics between collegiate athletic teams. Therefore, the purpose of this study was to compare the RSImod, JH, and TTT values between 6 U.S. collegiate sport teams during unloaded and loaded CMJs. Based on the differing performance requirements and training methods of various sports, it was hypothesized that meaningful differences in RSImod, JH, and TTT would exist among sports teams.

Methods

Experimental Approach to the Problem

To examine the differences in RSImod, JH, and TTT between Division I National Collegiate Athletic Association (NCAA) sport teams, athletes completed unloaded and loaded CMJs as part of an ongoing athlete monitoring program. To compare the differences in RSImod, JH, and TTT between teams, a series of 1-way analysis of variance were used.

Subjects

This study included 106 male and female Division I NCAA athletes. The male athletes participated in baseball ($n = 29$; height = 182.1 ± 6.2 cm, body mass 88.0 ± 9.0 kg), tennis ($n = 7$; height = 176.9 ± 9.0 cm, body mass = 74.7 ± 9.5 kg), and soccer ($n = 25$; height = 179.5 ± 6.8 cm, body mass = 78.5 ± 9.2 kg), whereas the female athletes participated in tennis ($n = 11$; height = 167.6 ± 5.6 cm, body mass = 68.6 ± 12.7 kg), soccer ($n = 22$; height = 166.1 ± 6.2 cm, body mass = 63.9 ± 8.1 kg), and volleyball ($n = 12$; height = 174.3 ± 8.2 cm, body mass = 70.8 ± 7.8 kg). All athletes were between 18 and 23 years old. Each athlete was in the preseason phase of training during his or her 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's Institutional Review Board.

Procedures

Each athlete participated in 1 testing session as part of an ongoing athlete monitoring program. Before CMJ testing, each athlete completed a standardized warm-up that consisted of 25 jumping jacks, 1 set of 5 midthigh clean pull repetitions with a 20-kg barbell, and 3 sets of 5 midthigh clean pull repetitions with 40-kg barbell for women and 60-kg barbell for men. After the general warm-up, each athlete performed a warm-up CMJ at 50 and 75% of his or her perceived maximum effort with a near weightless polyvinyl chloride pipe (<1 kg) across his or her shoulders as part of a specific warm-up. 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 at 50 and 75% of his or her perceived maximum effort. Following 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 of the CMJs were performed on a force platform (91 × 91 cm; Rice Lake Weighing Systems, Rice Lake, WI, USA) sampling at 1,000 Hz.

Data Analysis

The CMJ data were collected and analyzed using a customized LabVIEW program (2010 Version; National Instruments, Co., Austin, TX, USA). 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 any noise from the signal. As mentioned above, the RSImod value for each CMJ was calculated by dividing the JH by the TTT. Jump height was calculated based on the flight time of the center of mass using previously established methods (16). Time to takeoff was calculated from the force-time record as the length of time between the onset of the countermovement and the point of takeoff (7). The current study used a threshold of 7.5 newtons to determine the onset of the countermovement. The 2 maximal jumps performed during each jumping condition were used to calculate the intraclass correlation coefficient values for each variable. The average RSImod, JH, and TTT were taken from the 2 CMJs performed in each jumping condition and used for further statistical analyses.

Statistical Analyses

Intraclass correlation coefficients were used to determine the test-retest reliability of RSImod, JH, and TTT within each team for the unloaded and loaded jumping conditions. The values are displayed in Table 1. Additional analysis of within-team variation of RSImod was conducted by examining coefficient of variation (CV) percentage for each team. These CV percentages are interpreted in the discussion section. To examine the homogeneity of variances before further statistical analyses could be completed, Levene's test was used. A series of 1-way analysis of variance were used to examine the differences in RSImod, JH, and TTT between each team. When necessary, post hoc analyses were completed using the Bonferroni technique. Cohen's d effect sizes and 95% confidence intervals (CIs) were calculated for the difference between means. 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, based on the scale by Hopkins (10). All statistical analyses were completed using SPSS 21 (IBM, New York, NY, USA), and statistical significance for all analyses was set at $p \leq 0.05$.

Table 1. Reliability statistics of each team for reactive strength index-modified, jump height, and time to takeoff during the unloaded and loaded jumping conditions.*

	Jumping condition					
	Unloaded			Loaded		
Team	RSImod ($m \cdot s^{-1}$)	JH (m)	TTT (s)	RSImod ($m \cdot s^{-1}$)	JH (m)	TTT (s)
M baseball	0.94	0.95	0.83	0.95	0.93	0.88
M tennis	0.92	0.91	0.89	0.98	0.99	0.97
M soccer	0.95	0.98	0.88	0.94	0.97	0.94
W tennis	0.96	0.98	0.91	0.94	0.99	0.89
W soccer	0.93	0.95	0.80	0.96	0.95	0.92
W volleyball	0.93	0.95	0.87	0.96	0.96	0.91

*RSImod = reactive strength index-modified; JH = jump height; TTT = time to takeoff; M = men; W = women.

Results

No statistically significant differences in the homogeneity of variance existed among teams within the Levene's test, and thus, equal variances were assumed. Descriptive RSImod, JH, and TTT data for each team during the unloaded and loaded jumping conditions are displayed in Tables 2 and 3, respectively.

Unloaded Jumping Condition

Statistically significant differences in RSImod existed among teams during the unloaded jumping condition ($F_{(5,100)}$ = 21.634; $p < 0.001$). The RSImod values of the men's soccer team were statistically greater than those of the 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) teams. The RSImod values of men's 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 those of 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) teams. No other statistically significant differences in RSImod existed among teams ($p > 0.05$).

Similar to RSImod, statistically significant differences in JH existed among teams during the unloaded jumping condition ($F_{(5,100)}$ = 34.782; $p < 0.001$). The JHs produced by men's baseball were statistically greater than those produced by men's tennis ($p < 0.001$; $d = 2.00$; CI = 0.04–0.16), women's tennis ($p < 0.001$; $d = 3.75$; CI = 0.12–0.22), and women's soccer ($p < 0.001$; $d = 3.15$; CI = 0.09–0.17). In addition, the JHs produced by men's soccer were statistically greater than those produced by men's tennis ($p = 0.001$; $d = 1.45$; CI = 0.02–0.15), women's tennis ($p < 0.001$; $d = 2.94$; CI = 0.10–0.20), and women's soccer ($p < 0.001$; $d = 2.32$; CI = 0.07–0.16). Finally, women's volleyball produced statistically greater JHs as compared with both women's tennis ($p < 0.001$; $d = 3.25$; CI = 0.07–0.19) and women's soccer ($p < 0.001$; $d = 2.54$; CI = 0.04–0.15). No other statistically significant differences in JH existed among teams ($p > 0.05$).

Statistically significant differences in TTT also existed among the teams examined during the unloaded jumping condition ($F_{(5,100)}$ = 3.847; $p = 0.003$). Men's soccer produced statistically shorter TTT as compared with men's baseball

Table 2. Descriptive team data during the unloaded jumping condition.*

	Performance variable (mean ± *SD*)		
Team	RSImod ($m \cdot s^{-1}$)†	JH (m)†	TTT (s)‡
M baseball	0.41 ± 0.08	0.37 ± 0.05	0.92 ± 0.08
M tennis	0.30 ± 0.07	0.27 ± 0.05	0.90 ± 0.10
M soccer	0.44 ± 0.09	0.35 ± 0.06	0.81 ± 0.10
W tennis	0.23 ± 0.05	0.20 ± 0.04	0.91 ± 0.14
W soccer	0.28 ± 0.06	0.24 ± 0.03	0.88 ± 0.09
W volleyball	0.38 ± 0.07	0.33 ± 0.04	0.90 ± 0.10

*RSImod = reactive strength index-modified; JH = jump height; TTT = time to takeoff; M = men; W = women.
†Statistically significant difference between teams ($p < 0.001$).
‡Statistically significant difference between teams ($p < 0.01$).

TABLE 3. Descriptive team data during the loaded jumping condition.*

Team	Performance variable (mean ± *SD*)		
	RSImod ($m \cdot s^{-1}$)†	JH (m)†	TTT (s)‡
M baseball	0.30 ± 0.06	0.29 ± 0.04	1.01 ± 0.10
M tennis	0.22 ± 0.07	0.21 ± 0.04	1.01 ± 0.17
M soccer	0.30 ± 0.06	0.27 ± 0.04	0.91 ± 0.10
W tennis	0.14 ± 0.04	0.14 ± 0.03	1.02 ± 0.17
W soccer	0.16 ± 0.04	0.17 ± 0.02	1.04 ± 0.14
W volleyball	0.24 ± 0.08	0.25 ± 0.07	1.03 ± 0.19

*RSImod = reactive strength index-modified; JH = jump height; TTT = time to takeoff; M = men; W = women.
†Statistically significant difference between teams ($p < 0.001$).
‡Statistically significant difference between teams ($p \leq 0.05$).

($p = 0.001$; $d = 1.21$; CI = −0.19 to −0.03). No other statistically significant differences in TTT existed among teams ($p > 0.05$).

Loaded Jumping Condition

Statistically significant differences in RSImod existed among teams during the loaded jumping condition ($F_{(5,100)} = 28.128$; $p < 0.001$). The RSImod values of the men's soccer team were statistically greater than those of 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) teams. 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). 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) teams. No other statistically significant differences in RSImod existed among teams ($p > 0.05$).

Similar to RSImod, statistically significant differences in JH existed among teams for the loaded jumping condition ($F_{(5,100)} = 48.218$; $p < 0.001$). The JHs produced by men's baseball were statistically greater than those produced by men's tennis ($p < 0.001$; $d = 2.00$; CI = 0.04–0.13), women's tennis ($p < 0.001$; $d = 4.24$; CI = 0.11–0.19), women's soccer ($p < 0.001$; $d = 3.79$; CI = 0.09–0.16), and women's volleyball ($p = 0.010$; $d = 0.70$; CI = 0.01–0.08). In addition, the JHs produced by men's soccer were statistically greater than those produced by men's tennis ($p = 0.003$; $d = 1.50$; CI = 0.01–0.11), women's tennis ($p < 0.001$; $d = 3.68$; CI = 0.09–0.17), and women's soccer ($p < 0.001$; $d = 3.16$; CI = 0.08–0.14). Women's volleyball produced statistically greater JHs as compared with both women's tennis ($p < 0.001$; $d = 2.04$; CI = 0.06–0.15) and women's soccer ($p < 0.001$; $d = 1.55$; CI = 0.04–0.12). Finally, men's tennis produced statistically greater JHs as compared with women's tennis ($p = 0.005$; $d = 1.98$; CI = 0.01–0.12). No other statistically significant differences in JH existed among teams ($p > 0.05$).

Statistically significant differences in TTT also existed among the teams examined during the loaded jumping condition ($F_{(5,100)} = 2.629$; $p = 0.028$). Post hoc analysis indicated that men's soccer produced a TTT that was statistically shorter than that of women's soccer ($p = 0.027$; $d = 1.07$; CI = −0.25 to −0.01). However, no other statistically significant differences in TTT existed among teams ($p > 0.05$).

Team RSImod Coefficient of Variation

For unloaded RSImod, the greatest CV was displayed by women's tennis with 24.1%, followed in order by men's tennis with 23.2%, women's soccer with 21.1%, men's soccer with 20.5%, women's volleyball with 19.6%, and men's baseball with 18.9%. For the loaded jumping condition RSImod data, the greatest CV was displayed by men's tennis with 31.0%, followed in order by women's volleyball with 25.6%, women's tennis with 25.3%, women's soccer with 22.5%, men's soccer with 20.5%, and men's baseball with 19.8%.

DISCUSSION

The purpose of this study was to examine RSImod, JH, and TTT between 6 NCAA Division I teams during unloaded and loaded CMJs. The results of the current study indicate that statistically significant differences in RSImod, JH, and TTT exist among the examined sport teams during both unloaded and loaded jumping conditions.

The results of the current study indicate that the greatest RSImod values during the unloaded jumping condition were produced by the men's soccer team and were followed in order by men's baseball, women's volleyball, men's tennis, women's soccer, and women's tennis. Specifically, men's soccer produced RSImod values that were 7.1, 14.6, 37.8, 44.4, and 62.7% greater than those produced by the men's 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. The RSImod values of men's soccer and baseball were 22.2%, 30.8, 60.9, and 72.7% greater than those produced by the women's volleyball, men's tennis, women's soccer, and women's tennis teams, respectively. Large to very large effect sizes indicate that sizable differences in RSImod exist among different sport teams in both unloaded and loaded jumping conditions. The differences in RSImod among teams became greater during the loaded jumping condition, possibly suggesting that differences in strength may have contributed to the differences observed in this study. This notion is supported by the study by Beckham et al. (3), who indicated that strong relationships existed between isometric midthigh pull strength and RSImod. It should be noted that the RSImod values reported in this study are lower than those reported previously (6,7) but similar to another study (23) during the unloaded CMJ. However, 2 of the previous studies (6,7) used an arm swing during the CMJs, which may have contributed to a higher CMJ height (15) and potentially a greater RSImod value.

The current study indicated that statistically significant differences in JH among teams existed during the unloaded and loaded jumping conditions. The greatest JHs during the unloaded jumping conditions were produced by men's baseball team, which was followed in order by men's soccer, women's volleyball, men's tennis, women's soccer, and women's tennis teams. More specifically, the JH produced by the men's baseball team was 5.6, 11.4, 31.3, 42.6, and 59.6% greater than those produced by the men's soccer, women's volleyball, men's tennis, women's soccer, and women's tennis teams, respectively. Similar findings existed during the loaded jumping condition with the greatest JHs being produced by the men's baseball team followed in order by men's soccer, women's volleyball, men's tennis, women's soccer, and women's tennis teams. During the loaded jumping condition, the JHs produced by men's baseball team were enhanced to be 7.1, 14.8, 32.0, 52.2, and 69.8% greater than those produced by the men's soccer, women's volleyball, men's tennis, women's soccer, and women's tennis teams, respectively. Based on the percent differences and present effect sizes, it is clear that the differences that existed were sizable. Furthermore, it appears that the differences among teams increased during the loaded jumping condition, suggesting that muscular strength may have been a limiting factor. In fact, previous research has indicated that the strength of an athlete is strongly related to his or her sprinting and vertical jumping ability (25). Although not included in this analysis, research that investigates the relationship between muscular strength and RSImod is warranted.

Statistically significant differences in TTT existed among the teams examined within this study. The men's soccer team produced a TTT that was 12.7% shorter than that produced by the men's baseball team during the unloaded jumping condition. In addition, men's soccer produced a TTT that was 13.3% shorter than that produced by the women's soccer team during the loaded jumping condition. Few statistically significant pairwise differences in TTT existed among sport teams in this study. This is similar to previous findings that indicated that ground contact time was similar between genders during depth jumps (1,13) and TTT was similar between genders during CMJs (5). To enhance their RSImod value, an athlete must decrease his or her TTT or increase his or her JH or both, while maintaining the other variable. This was shown in the current investigation as the men's soccer team produced statistically shorter TTT than baseball team, resulting in larger RSImod values, even though baseball players jumped higher. Previous research has indicated that a moderate correlation ($r = -0.33$) existed between TTT and JH during CMJs (5). However, it should be noted that the previously mentioned study (5) defined TTT as the time between the onset of positive acceleration of the center of mass and takeoff, which is in contrast to the current study and other previous research (6,7,23). A shorter TTT period as displayed in previous research (5) would lead to an enhanced RSImod value, assuming the JH remained the same.

The calculated CVs of RSImod varied among the athletic teams ranged from 18.9 to 24.1% during the unloaded jumping condition and from 19.8 to 31.0% during the loaded jumping condition. The greatest CV percentages were produced by the women's tennis and men's tennis teams during the unloaded and loaded jumping conditions, respectively. Although the sample sizes of each tennis team were lower than those of the other teams examined, Levene's test for homogeneity of variance indicated that there was an equal distribution of the variance within each team. Possible explanations for increased CV may include differences in muscular strength, the nature of each sport, different methods of training, and positional differences within each sport (20). It is interesting that the CV percentage of every team, except men's soccer, increased during the loaded jumping condition, indicating that the strength levels of the athletes may have contributed to their reactive strength ability. Although not assessed in the current study, previous research has indicated that strong relationships existed between isometric midthigh pull strength and RSImod (3). As previously noted, the men's and women's tennis teams had some of the greatest CV percentage values in both the unloaded and loaded jumping conditions. It is possible that the limited vertical component displayed by tennis athletes during tennis matches may have contributed to a decreased RSImod value. However, further research is needed to support this contention.

Some limitations exist in the current study. First, the athletes examined within this study ranged from freshmen to senior. It is likely that the training volume experienced at the collegiate level exceeds that which the athletes experienced in high school (20). Thus, athletes with a greater training history may produce different values of RSImod, JH, and TTT as compared with those who have minimal experience in a similar setting. These results may then be reflected in the team's overall RSImod, JH, and TTT magnitudes. A similar rationale can be used to address position differences within each sport. Previous research has indicated that players of different positions within the same sport may exhibit different strength-power and physiological performance characteristics (4,9,11,19,21,22). A recent study by Bailey et al. (2) indicated that baseball position players and pitchers produced different RSImod values. Differences in RSImod between different positions in a sport such as baseball may alter a team's overall RSImod value. Therefore, it is suggested that future research should further examine the reactive strength characteristics of athletes that play different positions within the same sport.

Practical Applications

The current study indicates that athletes from different sport teams exhibit different reactive strength characteristics. It is unclear exactly why these differences exist, but this study does provide some direction for the understanding of RSImod. Being aware of the differences in RSImod, and the variables used to obtain it (i.e., JH and TTT), among sport teams may help direct the creation of athlete training and monitoring programs more effectively for various sports. For example, sport scientists and coaches may use the RSImod data to determine if more ballistic-type exercises (i.e., plyometrics, weightlifting movements) need to be added into an athlete's or a team's training program. Because RSImod can be used as a measure of explosiveness (23), the RSImod data of may also be used as an additional indicator of an individual's or a team's level of preparedness or fatigue. Although the ability to jump high may not be a prerequisite attribute for optimal performance in every sport, reactive strength is likely a desired attribute in any sport requiring agility, change of direction, and power production. Thus, monitoring RSImod is recommended for all sports. The origin of variability of RSImod within some teams remains unclear, and thus, further research is warranted to improve our understanding of this performance measure. It is suggested that future research should consider investigating differences not only in RSImod in individuals with varying strength levels and training experience but also in different positions within each sport.

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