

# Measuring Impulse-DSI and its Derivatives Via the Isometric Belt Squat: Assessing Relationships with Sprint Ability Among Division 1 Team Sport Athletes

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## ABSTRACT

The dynamic strength index (DSI) is a common athlete profiling tool that has traditionally been derived as the ratio between the peak force in the isometric mid-thigh pull (IMTP) and the countermovement jump (CMJ) to identify ballistic strength deficits. Recently, an impulse-based DSI (iDSI) has been proposed for the relevance of impulse metrics in explosive sports. Furthermore, the isometric belt squat (IBSq) may be a superior alternative to the IMTP for measuring lower-body force potential owing to its removal of the torso and upper limb involvement. This study assessed the reliability of two novel IBSq and CMJ 200ms impulse metrics. Furthermore, we assessed the individual relationships and predictive utility of the DSI derivatives and 40m sprint performance. 43 Division 1 team sport athletes (30 males and 13 females) were recruited. Reliability was assessed using the intraclass correlation coefficient (ICC) and the coefficient of variation (COV). The relationships between DSI and iDSI derivatives, 0-10m, 10-30m, and 30-40m split times were assessed using Pearson's correlation coefficient and stepwise regression. The IBSq and CMJ impulses

demonstrated acceptable reliability (ICC > .93, COV < 9.6%). IBSq and CMJ impulses explained up to 56% of the variance in 0-10m time ( $p < .002$ ) and up to 49% of the variance in 30-40m time ( $p < .0001$ ). The IBSq-derived iDSI score may be a reliable and accurate test for predicting sprint performance among Division 1 team sport athletes. Practitioners may monitor iDSI derivatives to enhance training decisions relevant to sprint speed.

**Keywords:** Dynamic strength index, countermovement jump, force plate, athlete profiling.

## INTRODUCTION

The practice of athlete profiling using force plate technology has become increasingly diverse within the fields of strength, conditioning, and performance training (1). With limited resources, coaches may struggle to balance the amount of actionable data that they can attain without distracting from the overall training goal and environment. Considering the vast number of metrics and analysis methods proposed, one may struggle to identify efficient test

batteries that contribute to both enhancing exercise prescription and predicting performance in the field of play.

A common athlete profiling technique that utilizes countermovement jump (CMJ) and isometric mid-thigh pull (IMTP) is the dynamic strength index (DSI). DSI is defined as the ratio between the CMJ concentric peak force (CMJ-P) and the IMTP peak force (IMTP-P)(2). Traditionally, athletes with a ratio  $>.80$  are recommended maximal strength training, while athletes with a ratio  $<.60$  are recommended ballistic training (2,3). A novel impulse-based dynamic strength index (iDSI) has been proposed in the last four years because of its relevance to explosive actions in sports (4). iDSI is the ratio of the concentric impulse generated during the countermovement jump to the isometric impulse generated during the IMTP. The fundamental difference between DSI and iDSI is that iDSI assumes that both test derivatives are performed with ballistic intent. Rather than comparing the maximal and dynamic peak forces, the iDSI is the ratio of the impulse during an explosive isometric muscle contraction and the impulse during an explosive high-velocity muscle contraction over a standardized contraction time.

Various methods have been used to measure lower-body isometric strength. For example, isometric barbell back squat (ISqT), isometric leg press, trap bar IMTP, barbell IMTP, and isometric belt squat (IBSq) have all been utilized (5). The setup and technical execution when performing an IMTP (strapping the hands, upper-body recruitment, system slack, and muscular inhibition) raises questions on the validity of measuring maximal lower-body strength. The IBSq may be a more valid test of explosive and maximal lower-body strength because it eliminates upper-limb and torso involvement from the test, which otherwise may prevent an athlete from exerting maximal effort through the lower body (5,6).

According to the spring-mass model, leg stiffness during upright sprinting determines the extent of vertical displacement of the center of mass; stiffer legs produce less displacement, allowing shorter ground contacts and higher velocities (7). At maximal velocity, this phase becomes increasingly quasi-isometric (8). In contrast, the acceleration phase involves greater hip and knee flexion and a higher reliance on concentric muscle actions (9). When an athlete performs any sporting movement, the total impulse applied to the ground determines

the resulting motion. In sprinting, each foot contact lasts roughly 40–200 ms (9), and changes in velocity depend on the horizontal impulse—the force applied over that brief contact period. As contact times shorten with increasing speed, the ability to reach peak force rapidly becomes a key determinant of sprint performance (10). Consequently, impulse and rate-of-force metrics measured over 100–300 ms in isometric tests may better reflect the force-time characteristics relevant to sprint performance beyond 5–10 m than peak force alone (11).

The traditional DSI has been utilized for its apparent diagnostic value and practicality. However, previous research on its determinants, CMJ-P and IMTP-P, has questioned its relevance to sports (12). The IMTP-P may explain up to 72% of the variance in the DSI score, suggesting limited additional value for CMJ-P (3). It has been demonstrated that the peak force in the IMTP is not associated with any dynamic jumping, change of direction, or sprint performance variables (12). Conversely, the peak rate of force development during the IMTP has been associated with pro-agility and 5-10m sprint times, and CMJ height (a direct result of concentric impulse) was more strongly associated with 20m sprint speed than CMJ-P (3,12,13). A favourable change in DSI or iDSI score over time does not necessarily indicate that an athlete has improved their performance in a sport-specific task. For instance, an apparent increase in DSI or iDSI may reflect reduced force output in the isometric test rather than a genuine improvement in concentric jump performance. Assessing the magnitude of individual determinants and their associations with other performance variables is valuable for the contextualization of scores (3,14).

The efficiency of data collection and utility of iDSI or DSI testing may be enhanced if the test derivatives are also related to key performance indicators. Therefore, the purpose of this study was to assess the relationship between DSI and iDSI derivatives and the different phases of 40m sprint performance. Specifically, the following hypotheses were that IBSq relative peak force (IBSq-P) and CMJ-P are significantly correlated with 0-10m sprint time, IBSq relative 200ms impulse (IBSq-I) and CMJ relative 200ms concentric impulse (CMJ-I) are significantly correlated with 0-10m, 10-30m, and 30-40m sprint time, IBSq-I and CMJ-I achieve acceptable reliability, and DSI and iDSI scores are moderately correlated with each other ( $r = .40 - .60$ ).

## METHODS

### *Experimental Approach to the Problem*

Three phases of sprint performance were collected: 0-10m, 10-30m, and 30-40m splits were chosen to describe acceleration ability, transitional acceleration ability, and maximum velocity running ability, respectively. Ground contact times in sprints range from roughly 200ms to less than 100ms (9). Previous research suggests that isometric impulse epochs  $\geq 200$ ms demonstrate greater test reliability (15,16). Previous research has generally reported isometric and dynamic impulse metrics as either inclusive of bodyweight or net impulse above the force of body weight (17,18). Instead, reporting metrics relative to body weight (impulse per kg) may be more relevant in identifying relationships with sprint performance, as sprinting is an expression of relative force production. For these reasons, IBSq relative 200ms impulse and CMJ relative 200ms concentric impulse were chosen as independent variables with which iDSI scores were calculated. Limited evidence has demonstrated moderate correlations between the DSI and iDSI scores, which seem to increase with increasing impulse epochs. The correlation between the DSI and iDSI score was used to quantify the uniqueness of the profiling metrics relative to each other (4,14).

### *Subjects*

The Institutional Review Board approval number for the current investigation was 2023\_073. The subjects were aged 18-23 years old and were currently enrolled at the University of San Francisco. Informed consent was obtained from all participants and their respective head coaches. To be eligible for inclusion in the study, each athlete must have had at least one semester of experience in the sports performance program at the University of San Francisco. Athletes could also not have sustained an injury within the last month that caused a loss of practice time. Athletes were currently practicing their sport at the end of pre-season. Familiarity with sprinting has been identified as a possible confounding variable in the relationship between DSI metrics and sprint ability (16,17,19). Therefore, participants were recruited from sports in which linear sprinting is a part of both competition and training (baseball, soccer, track, and field). Thirty male and 13 female NCAA Division 1 athletes were included in the final analysis.

### *Procedures*

Vald ForceDecks and Vald SmartSpeed (115 Breakfast Creek Road, Brisbane, Queensland 4006, Australia). were used to collect force-time and sprint variables, respectively. When using the ForceDecks software, it is important to manually adjust for the pre-tension force generated above body weight in any isometric test when time-dependent metrics are being measured (20). This was performed by manually calculating the relative IBSq-I and CMJ-I metrics from the raw data in Microsoft Excel. A custom-built steel platform and Spud Inc. weightlifting belt were used to perform the IBSq tests in conjunction with the ForceDecks system (Figure 1). The benefits of the SmartSpeed system are error-correction processing (ECP) and a contact mat for detecting the start of movement. ECP corrects for limbs crossing the gate before the center of mass and a contact mat corrects for variations in acceleration posture, improving the accuracy of comparisons between athletes (21).



**Figure 1.** Setup for the Isometric Belt Squat Test using VALD ForceDecks and Spud Inc. belt squat belt to collect isometric variables (original image by author).

Primary testing sessions were planned to occur within one week of the onset of the competitive season to control for seasonal changes in the force-velocity characteristics of sprint performance (22). The sprint times and force plate metrics were

collected on separate days. Testing occurred before practice or lifting sessions and never the day after exhaustive training, coordinated with the head coach. Under these conditions, countermovement jump height was used as a reliable indicator of major neuromuscular fatigue or detraining. Jump height reductions over time have been shown to reflect accumulated fatigue and training-load responses in team-sport athletes (23).

All subjects were familiarized with the force plate testing procedure at the time of data collection, which is part of the standard USF student-athlete monitoring protocol. On each occasion, the subjects were guided through a standardized warm-up progressing from lower-body calisthenic exercises to explosive ballistic exercises. The subjects first performed three maximal-effort CMJs with 30s of rest between trials. After five minutes of passive recovery, three IBSq reps were performed for 5s, each separated by two minutes of passive recovery. The IBSq was performed with feet shoulder-width apart and arms by the side with a closed fist in the neutral position. Knee angles were set between 120-140 degrees by a goniometer, and the best of each trial was taken for analysis.

Sprint times were collected within the same week of force plate testing and followed a standardized dynamic warm-up that progressed from various hops, skips, mechanical drills, intensive plyometrics, and accelerations with ascending efforts. Following the dynamic warm-up, the subjects were given a three-minute rest period. The starting position was a three-point stance with the dominant leg at 90° of knee flexion. The front hand was placed on a contact mat, which was aligned with the starting line. Subjects performed three maximal-effort 40-meter sprints with 0-10m, 10-30m, and 30-40m split times. Five minutes of recovery were provided between each sprint, and the best times for each split were taken for analysis.

### Statistical Analyses

Correlation and stepwise regression analyses were performed using SPSS (SPSS Statistics for Windows, Version 29.0.2.0). The statistical powers for the combined groups ( $n=43$ ), men's group ( $n=30$ ), and women's group ( $n=13$ ) regression analyses were found to be  $1-\beta = .99$ ,  $.95$ , and  $.73$ , respectively. The alpha level for significance was set at  $p \leq .05$ . The reliabilities of the novel IBSq-I and CMJ-I metrics were assessed using intraclass correlation with a threshold set at  $\geq .8$ , and the coefficient of variation

with a threshold set at  $< 10\%$ . The IBSq and CMJ independent variables were assessed for their relationship with each 40m split time via Pearson's correlation coefficient and stepwise regression. Evaluation of correlation coefficients between force plate and sprint variables were classified as:  $-0.1 - -0.29 =$  small,  $-0.30 - -0.49 =$  moderate,  $-0.50 - -0.69 =$  large,  $-0.70 - -0.89 =$  very large,  $-0.90 - -0.99 =$  nearly perfect,  $1.0 =$  perfect. The relationship between DSI and iDSI was assessed using Pearson's correlation coefficient. The assumptions of correlation and regression analysis (multicollinearity, linearity, and homoscedasticity) were assessed using the tolerance and variance inflation factor and scatter plots of the data.

## RESULTS

Descriptive statistics for IBSq-P, IBSq-I, CMJ-P, CMJ-I, DSI, iDSI, and 40m split times among men and women are presented in Table 1. The results of the reliability analysis of IBSq-I and CMJ-I are presented in Table 2. The correlations between the DSI and iDSI derivatives and 40m split times within each analysis group are presented in Table 3. The results of the multiple regression analysis for 0-10m, 10-30m, and 30-40m sprint times are presented in Tables 4, 5, and 6, respectively. No correlation was found between the DSI and iDSI scores.

### Correlations Between DSI, iDSI, and Sprint Performance

The IBSq-P showed moderate negative correlations with all three split times only in the combined group analysis of men and women ( $p = .003 - .038$ ). The IBSq-I showed moderate to large negative correlations with all three split times in the combined groups and men's analysis ( $p < .001 - .039$ ). The IBSq-I showed large to very large correlations with all three split times in the women's analysis group ( $p = .005 - .012$ ). CMJ-P showed moderate to large negative correlations with all three split times in the combined group analysis ( $p < .001$ ). CMJ-P showed moderate negative correlations with 0-10m and 30-40m time, but not 10-30m time, in the men's analysis group ( $p = .009 - .037$ ). CMJ-I showed large to very large negative correlations with all three split times in the combined groups and men's analysis group ( $p < .001 - .004$ ). CMJ-I showed a large negative correlation with 10-30m time, but not with 0-10 and 30-40m time in the women's analysis group ( $p=.044$ ).

**Table 1.** Descriptive Statistics for Men and Women

Variable	Men	Women
IBSq-P (n/kg)	78.13 (14.18)	64.99 (14.18)
IBSq-I (n*s/kg)	5.54 (1.14)	4.75 (.78)
CMJ-P (n/kg)	27.26 (2.55)	24.68 (1.79)
CMJ-I (n*s/kg)	4.66 (.31)	4.18 (.32)
DSI	.36 (.06)	.39 (.07)
iDSI	.87 (.18)	.90 (.14)
0-10m (s)	1.968 (.077)	2.143 (.119)
10-30m (s)	2.395 (.088)	2.640 (.163)
30-40m (s)	1.155 (.046)	1.232 (.112)

*IBSq-P = Relative isometric peak force. IBSq-I = Relative 200ms isometric impulse. CMJ-P = Relative dynamic concentric peak force. CMJ-I = Relative concentric 200ms impulse. Results are presented as mean (SD).*

**Table 2.** Reliability Analysis

Variable	ICC	COV
IBSq-I	.937 (.896 - .964)	9.6% (2% - 23%)
CMJ-I	.976 (.961 - .986)	2.5% (0% - 7%)

*IBSq-I = Relative 200ms isometric impulse. CMJ-I = Relative concentric 200ms impulse. ICC = Average measures intraclass correlation coefficient. COV = Mean coefficient of variation. Results are presented as ICC/COV (lower bound – upper bound).*

**Table 3.** Correlations between DSI, iDSI, and Derivatives With 40m Split Times

Variable	0-10m Time (s)	10-30m Time (s)	30-40m Time (s)
IBSq-P (n/kg)			
All (N = 43)	-.422**	-.443**	-.318*
Men (N = 30)	-.216	-.188	-.126
Women (N = 13)	-.238	-.347	-.255
IBSq-I (n*s/kg)			
All (N = 43)	.585**	-.533**	-.540**
Men (N = 30)	-.505**	-.379*	-.463*
Women (N = 13)	-.672*	-.725**	-.695**
CMJ-P (n/kg)			
All (N = 43)	-.599**	-.535**	-.481**
Men (N = 30)	-.470**	-.330	-.383*
Women (N = 13)	-.476	-.449	-.456
CMJ-I (n*s/kg)			
All (N = 43)	-.703**	-.753**	-.658**
Men (N = 30)	-.512**	-.654**	-.649**
Women (N = 13)	-.546	-.566*	-.544

*IBSq-P = Relative isometric peak force. IBSq-I = Relative 200ms isometric impulse. CMJ-P = Relative dynamic concentric peak force. CMJ-I = Relative concentric 200ms impulse. \*\* = Correlation is significant at the .01 level. \* = Correlation is significant at the .05 level.*

**Table 4.** Predicting 0-10m Sprint Time

Group	Predictors	R <sup>2</sup>	SE	F-Statistic	Pr > F
Combined	CMJ-I / IBSq-I	.564	.082	(2,40) 25.894	<.0001
Men	CMJ-I / IBSq-I	.371	.063	(2,27) 7.967	.002
Women	IBSq-I	.451	.092	(1,11) 9.040	.012

CMJ-I = Relative concentric 200ms impulse. IBSq-I = Relative 200ms isometric impulse.

**Table 5.** Predicting 10-30m Sprint Time

Group	Predictors	R <sup>2</sup>	SE	F-Statistic	Pr > F
Combined	CMJ-I	.566	.107	(1,41) 53.528	<.0001
Men	CMJ-I	.427	.068	(1,28) 20.878	<.0001
Women	IBSq-I	.526	.117	(1,11) 12.198	.005

CMJ-I = Relative concentric 200ms impulse. IBSq-I = Relative 200ms isometric impulse.

**Table 6.** Predicting 30-40m Sprint Time

Group	Predictors	R <sup>2</sup>	SE	F-Statistic	Pr > F
Combined	CMJ-I / IBSq-I	.491	.058	(2,40) 19.258	<.0001
Men	CMJ-I	.422	.036	(1,28) 20.419	<.0001
Women	IBSq-I	.483	.084	(1,11) 10.260	.008

CMJ-I = Relative concentric 200ms impulse. IBSq-I = Relative 200ms isometric impulse.

### Regression Analysis of DSI Derivatives and Sprint Performance

The two-predictor regression model of IBSq-I and CMJ-I explained 57% ( $p<.0001$ ) and 36% ( $p=.002$ ) of the variance in 0-10m time in the combined groups and men's group analysis, respectively. The two-predictor regression model of IBSq-I and CMJ-I also explained 49% of the variance in 30-40m time in the combined-groups analysis ( $p<.0001$ ). In the women's analysis, the single-predictor regression model of IBSq-I explained 45% ( $p=.012$ ), 53% ( $p=.005$ ), and 48% ( $p=.008$ ) of the variance at 0-10m, 10-30m, and 30-40m time, respectively. In the combined groups and men's group analysis, the single-predictor regression model of the CMJ-I explained 56% and 43% of the variance in 10-30m time, respectively ( $p<.0001$ ). CMJ-I also explained 42% of the variance in the 30-40m time in the men's group analysis ( $p<.0001$ ).

### DISCUSSION

For men and women individually, the hypothesis that IBSq-P would be significantly correlated with 0-10m time was not supported. IBSq-P was also not included in the final prediction model for any split time in either analysis group. The relative peak forces reported in the literature among similar athletic populations for the IMTP and ISqT range from ~21.9n/kg to 63.8n/kg (3,15,17,19). In the current study, the minimum peak force achieved by an athlete was 48.99n/kg, and the maximum

achieved was 100.11n/kg. This finding supports previous evidence that the IBSq test may be a more accurate reflection of maximal lower-body force production. This is possibly due to reductions in lower back moments, upper body loading, and apprehension to put maximal force into an immovable object (5,6). These factors may have contributed to the different findings in this study compared to previous correlational studies that utilized the IMTP or ISqT.

The hypothesis that IBSq-I would correlate with all three split times was true for all analysis groups. The correlation was stronger at every split for women ( $r = -.725$  to  $r = -.672$ ) than for men ( $r = -.379$  to  $r = -.505$ ). For women, the single-predictor model of IBSq-I best explained sprint performance at every split, which was unique compared to the men's and combined-groups analysis. The correlation between IBSq-P and IBSq-I in women approached significance ( $r = .494$ ,  $p = .086$ ), but not in men. Among male sprinters, the average IMTP-P reported in previous research was ~27 n/kg, and a significant correlation was observed with 0-5m sprint time (18). Conversely, an average IMTP relative peak force value of ~35n/kg for male basketball players demonstrated no correlation with 0-5m sprint time (17). It could be speculated that this lack of correlation was partly due to the athletes having relatively greater maximal isometric strength. From these results, one could hypothesize that the ability to produce maximal strength or impulse under zero-velocity conditions demonstrates a general/foundational force potential that may set

the stage for greater high-velocity force production. Furthermore, there may be a point of diminishing returns, where the dynamic peak force and impulse become better predictors of sprint speed. This notion is supported by the fact that the CMJ-I had a more significant correlation with all split times in men than in women, who were not as strong relative to their body weight.

For both men and women, CMJ-I had the strongest correlation with 10-30m time. The CMJ-I was also included in six of the nine prediction models (only excluded in the women's analysis for each split time). Previous research demonstrated that maximal strength measured by the IMTP may influence the type of jump strategy utilized by an athlete (3). For example, stronger athletes tend to have faster countermovements and greater eccentric braking forces (24). These increased braking forces also inflate CMJ-P. This is supported by the current results, where IBSq-P had a greater correlation with CMJ-P than with CMJ-I ( $r = .507$  vs.  $r = .369$ ). During the stance phase of sprinting, propulsive muscle contractions are primarily concentric or quasi-isometric (8). Therefore, this research could suggest that CMJ-I has a greater relationship with sprint time because it is less influenced by eccentric rate of force, jump strategy, and maximal strength level.

For 0-10m sprint time, the inclusion of IBSq-I in the prediction model was the only common denominator across all analysis groups. For the combined groups and men's analysis, IBSq-I and CMJ-I together explained 37-56% of the variance in the 0-10m sprint time. During a short sprint acceleration, the stretch-shortening cycle and its release of elastic energy or potentiation of motor unit recruitment cannot be utilized. This contrasts with what occurs during a CMJ test and precedes the measurement of the CMJ-I. It could be hypothesized that the inclusion of IBSq-I improves the model because it demonstrates the athlete's ability to ramp up forces quickly from a static position or without a contribution from an eccentric phase.

It was found that for the combined-groups analysis, IBSq-I was dropped from the prediction model only for the 10-30m time (CMJ-I alone explained 57% of the variance in the 10-30m time). This raises the question of why IBSq-I would be included for 0-10m time and again only for 30-40m time. One possible explanation for this is that as one approaches top speed, the knee joint becomes increasingly ridged to take greater advantage of the series elastic

component of the muscle-tendon unit (8). The knee extensor muscles act quasi-isometrically to spike the vertical ground reaction force quickly, while ground contact times are at their smallest (9,10).

Uniquely, for women, CMJ-I was not included in the final prediction model for any split time (IBSq-I alone explained 45-53% of the variance in split time). On average, women were about .08 to .25 seconds slower across each split time. Whether this difference was statistically significant was beyond the scope of this study. As discussed previously, it could be that for relatively less strong or fast individuals, IBSq-I is a more relevant predictor of sprint performance because it may represent a foundational component of general force production.

Recent research investigating impulse-based DSI has demonstrated moderate-to-large correlations with traditional DSI (4,14). These correlations ranged from  $r = .37$  to  $r = .94$  and increased as the epoch over which impulse was calculated increased. The current study was unique in that the DSI and iDSI scores were measured using the IBSq, with impulse reported relative to body mass (as opposed to net above body mass). There was no significant correlation between DSI and iDSI in the current study ( $r = .319$ ,  $p = .375$ ), suggesting that iDSI in the current study represents a unique profiling metric. Previous studies investigating DSI using the IMTP and ISqT found average DSI scores of .7, with the lowest score recorded being .45 (2,19,25). In the current study, the average DSI score was .37, and the lowest score recorded was .27. This can be attributed to the greater peak forces achieved with the IBSq, and therefore, it may not be appropriate to utilize the previously suggested thresholds of .60 - .80 for training prescriptions. Previous research on iDSI variables reported average iDSI scores of .77-.94, depending on the epoch length used to calculate iDSI (4,14). Generally, the shorter the epoch, the larger the iDSI value. The current study found an average iDSI of .88 and utilized an epoch of 200ms, which could be considered moderate relative to the 100ms and 300ms epochs used in previous studies.

Though each group received at least two familiarization sessions, groups had varying degrees of experience with either the force plate or sprint testing procedures. While proximity to the competitive season was controlled within a two-week timeframe, weather caused one testing session to be rescheduled. The final sample size

for women ( $n=13$ ) was smaller than anticipated, and a post-hoc power analysis revealed a power of .71 for women and .95 for men. It cannot be asserted that these limitations did not affect the study results. It was assumed that the relationships among the independent and dependent variables were linear. A curvilinear regression of IBSq-P and 0-10m time revealed an  $r$  of .188,  $p = .004$ . It could be hypothesized that for the variables discussed, there are thresholds of diminishing returns on sprint speed. The current investigation was cross-sectional, and it is unclear if prescribing specific exercises will reliably modulate changes in the current force plate metrics or if these longitudinal changes will coincide with predictable changes in sprint performance. Future research may aim to validate the practice of prescribing exercise based on the iDSI score.

## PRACTICAL APPLICATIONS

By completing just two tests, an explosive IBSq and CMJ, one can obtain reliable DSI and iDSI scores simultaneously, with which their derivatives may also be used to predict sprint ability. Furthermore, the IBSq-P, CMJ-P, IBSq-I, and CMJ-I may contribute contextual information for designing individualized training prescriptions. These findings help solve the problem of efficient and actionable data collection, where testing protocols are both prescriptive and predictive.

The relatively high maximal force expression demonstrated in the current study utilizing the IBSq compared to previous studies utilizing the IMTP suggests that the IBSq may also serve as a potent training stimulus beyond just an assessment of force production. The novel IBSq-I metric consistently demonstrated predictive utility for 0-10m sprint ability among male and female Division 1 athletes and may also be useful for predicting max-velocity sprint ability, which could be attributed to the quasi-isometric nature of max velocity sprinting. The IBSq-I also demonstrated good-to-excellent reliability in discriminating between athletes. Therefore, IBSq-I may be a useful metric to collect as part of an athlete profiling test battery in which sprint ability is relevant.

CMJ-I and IBSq-I did not demonstrate multicollinearity in the regression analysis, and each seemed to relate uniquely to sprint performance. With normative data, athletes can be percentile ranked in these metrics and compared with their

sprint ability among their peers. These comparisons can be used to identify training focuses. For example, assigning a focus on explosive, low-velocity force production versus explosive, high-velocity force production. Conversely, identifying outliers with comparatively high impulse metrics relative to their current sprint ability may indicate further investigation of kinematic sprint variables or other physical capacities. Assessing iDSI and traditional DSI together may also have advantages. A low DSI score alone suggests that athletes focus on ballistic activities. However, if the same athlete had a high iDSI score, it may indicate training accelerative strength (low-velocity rate of force development) or explosive eccentric strength (more related to peak force in the CMJ).

## ACKNOWLEDGEMENTS

I would like to extend my sincere gratitude to my dissertation committee, Dr. Joshua Dexheimer, Dr. Brian Serrano, and Dr. Eric LaMott, for empowering me to complete this research. I am especially grateful for their belief in the value of this project and their collective expertise, which was instrumental in its success.

## CONFLICTS OF INTEREST

The authors have declared that no competing interests exist, and the results of the present study do not constitute endorsement of any products by the authors or the IUSCA.

## FUNDING

The author declares no funding was received in order for this research to be completed.

## ETHICAL APPROVAL

The Institutional Review Board approval number for the current investigation was 2023\_073.

## DATES OF REFERENCE

Submission - 04/05/2025  
Acceptance - 08/12/2025  
Publication - 20/03/2026

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