Data Visualization for Dynamic Strength Index: A Qualitative Approach for Enhanced Interpretation and Decision-Making

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Abstract: Dynamic strength index (DSI) serves as an important metric for assessing the balance between athletes maximal and ballistic strength. However, its interpretation can be limited if the effects of both isometric and ballistic components are not considered. The aim of this study is to develop a qualitative approach for interpreting DSI through data visualization, providing strength and conditioning coaches' clearer insights that may guide more effective training recommendations. Thirty male college-level basketball athletes performed countermovement jumps (CMJ) and isometric mid-thigh pulls (IMTP) as a part of late-season testing. The peak IMTP force normalized to body mass was 39.02±3.57 N/kg, while peak CMJ force was 25.57±2.92 N/kg. The mean DSI was 0.66±0.09, where 2 athletes attained a DSI ≥0.80, 19 athletes between 0.60 and 0.80, and 9 athletes ≤0.60, corresponding to recommendations for maximal strength, concurrent, and ballistic training, respectively. T-score adjustments, used to categorize athletes based on maximal strength, resulted in the reclassification of 5 athletes from the concurrent training group to the maximal strength development group, and 5 athletes from the ballistic training group to the concurrent training group. Visualizing the DSI in a scatter plot, alongside T-score performance bands from the IMTP, allows for better evaluation of athletes' weaknesses and may guide more effective strength training recommendations.

1 INTRODUCTION

Basketball is defined by many high-intensity neuromuscular activities, such as sprinting, jumping, and rapid changes in direction, with frequent physical contacts between athletes (Stojanović et al., 2018, Petway et al., 2020, Wellm et al., 2024). Consequently, developing significant strength and power is essential for optimal athletic performance in basketball.

Assessing an athletes' strength capacity through targeted testing can provide valuable insights into neuromuscular function, enabling coaches to develop more personalized and effective training recommendations (McGuigan et al., 2013, Lockie et al., 2018, Morrison et al., 2022). Dynamic strength index (DSI) has been proposed as a promising method for balance evaluation between athletes maximal and ballistic strength capabilities (Sheppard et al., 2011, McMahon et al., 2017, Pleša et al., 2024). It is calculated as the ratio between an athlete's peak ballistic force (e.g., countermovement jump (CMJ), squat jump) and peak isometric force (e.g., isometric mid-thigh pull (IMTP), isometric squat) (Comfort et al., 2018). Generally, a low DSI (≤0.6) suggests a focus on ballistic training to improve power output, while a high DSI (≥0.8) indicates a need for maximal strength training. For intermediate DSI values (0.6 – 0.8), a concurrent training approach that incorporates both ballistic and strength training is recommended (Sheppard et al., 2011).

However, when interpreting DSI, many studies recommend considering the effects of both isometric and ballistic components. DSI alone should not be used to track training-induced progress, as simultaneously increasing both components may not significantly change DSI but would still indicate positive training adaptations (Bishop et al., 2023, Pleša et al., 2023, 2024). Additionally, for athletes with poor relative strength, prioritizing the development of maximal strength might be more beneficial than focusing solely on achieving a specific

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DSI value (Cormie et al., 2010, Suchomel et al., 2020). Therefore, it is essential for coaches to consider the broader context of different strength quality development when using DSI to guide training recommendations.

In sport science, decision support systems that incorporate data visualization are gaining increasing popularity due to their ability to simplify complex data and improve information delivery. By converting raw performance data into visually accessible formats, these systems allow for quicker, more comprehensive analysis and support better informed decision-making (McGuigan et al., 2013, Calder et al., 2015, Lockie et al., 2018, Torres-Ronda et al., 2024).

In addition, normalized scores like z-scores and t-scores are used to standardize data and create benchmarks, allowing for meaningful comparisons among individuals within a group (McGuigan et al., 2013, Lockie et al., 2018, Turner et al., 2019, McMahon et al., 2022). A z-score shows how many standard deviations a data point is from the group mean, which helps evaluate an individual's performance relative to the group norm. T-score is a transformed z-score, calculated by multiplying the z-score by 10 and adding 50, resulting in a more user-friendly format ranging from 0 to 100 (Turner et al., 2019, McMahon et al., 2022). By visualizing athletes' normalized score data, coaches can effectively assess each athletes' performance in comparison to their teammates and identify individual strengths and weaknesses (McGuigan et al., 2013, Lockie et al., 2018, Turner et al., 2019, McMahon et al., 2022).

The aim of this study is to develop a qualitative approach for interpreting DSI through data visualization, providing strength and conditioning coaches' clearer insights that may guide more effective training recommendations.

2 METHODS

2.1 Participants

This cross-sectional study involved thirty male college-level basketball athletes (age 19.5 ± 2.4 years; height 1.94 ± 0.08 m; body mass 87.2 ± 9.5 kg) who participated in a single testing session as part of their late-season evaluation. To ensure recovery, the testing was done one day after a rest day. Written informed consent was obtained from all participants prior to testing. The study was approved by the Research Ethics Committee of the Faculty of Biology and the Faculty of Geography and Earth Sciences at the University of Latvia (Nr. 18-29/30) and adhered to the ethical guidelines outlined in the World Medical Association's Declaration of Helsinki.

2.2 Testing

After arriving at the gym, each athlete completed a standardized warm-up consisting of activation exercises and dynamic lower body stretching.

Following a brief rest, athletes performed two sets of three maximal-effort countermovement jumps, with a 20-s rest between each jump and 3-min rest between sets. Athletes were instructed to place their hands on their hips and maintain this position throughout the entire movement. They were asked to perform a countermovement to a self-selected depth and then jump as high and as fast as possible.

To prevent potential post-activation performance enhancement effect of the IMTP on the CMJ (Blazevich et al. 2019), the IMTP test was conducted after the CMJ. IMTP was conducted with participants positioned at a knee joint angle of 125 – 145 degrees and a hip joint angle of 140 – 150 degrees, resulting in the barbell being positioned at approximately mid-thigh level. Once the bar height was established, athletes' hands were strapped to the bar using standard lifting straps. Before the main test, participants completed two warm-up pulls at 50% and 75% of their perceived maximum effort followed by three maximal effort IMTPs, with each trial separated by 1-min rest period. If peak force varied by >250 N, the trial was repeated. Athletes were instructed to pull the bar as hard as possible while also pushing their feet into the force plates for 3 – 5 s and received strong verbal encouragement throughout the test (Comfort et al., 2019).

All IMTP and CMJ were performed on dual force plates (MuscleLab, Ergotest Innovation AS, Norway) set at sampling rate of 1000 Hz and data was stored within the MuscleLab Professional Software, which enables immediate and reliable calculation of force-time variables. The best value from the test trials was used for subsequent data analysis. The DSI was calculated by dividing peak CMJ force by peak IMTP force. All athletes were familiar with the tests, having completed them in previous sessions, ensuring consistency and reducing variability in performance.

2.3 Statistical Analyses

Data are presented as mean ± SD. The normal distribution of IMTP and CMJ metrics was confirmed using the Shapiro-Wilk test. To establish benchmarks for the IMTP data, T-score performance bands using IMTP peak force normalized to body mass were created. These T-score bands were defined using 1 SD around the mean and assigned the following qualitative descriptions: ≤40 (poor), >40 – ≤60 (average), and >60 (good) (Robertson et al., 2017, McMahon et al., 2022).

The calculation of T-score performance bands was done using Microsoft Excel spreadsheet (McMahon et al., 2022). The plots have been created using Rstudio (R Core Team, 2020) and the ggplot2 (Wickham, 2016) and ggExtra (Attali & Baker, 2023) packages.

3 RESULTS

During the late season, the peak force for the college-level men's basketball athletes in the IMTP test was 3397.34 ± 454.82 N, while the peak force in the CMJ test was 2223.09 ± 296.16 N. When normalized to body mass, the peak IMTP force was 39.02 ± 3.57 N/kg and 25.57 ± 2.92 N/kg in the CMJ test.

The mean DSI across all athletes was 0.66 ± 0.09. Two athletes recorded a DSI ≥0.80, 19 athletes had a DSI between 0.60 and 0.80, and 9 athletes had a DSI ≤0.60, with corresponding training recommendations for maximal strength, concurrent, and ballistic training, respectively (Figure 1).

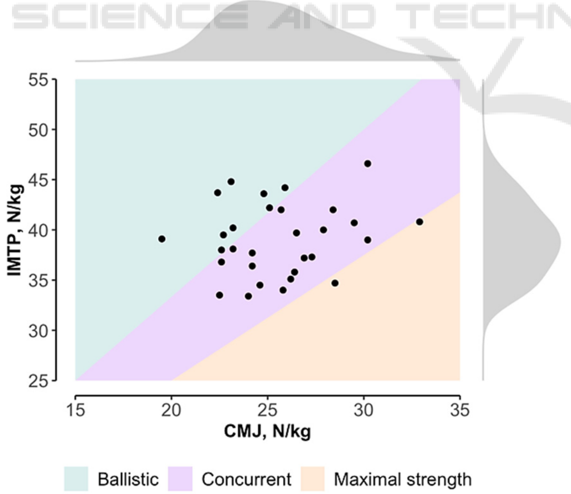

Figure 1: Visualization of ballistic and maximal strength with dynamic strength index recommendations shown as background colors.

Based on T-score performance bands, the following benchmarks for peak IMTP force normalized to body mass were established: poor maximal strength ≤35.45 N/kg, average maximal strength >35.45 – ≤42.60 N/kg, and good maximal strength >42.60 N/kg.

Table 1: T-score performance bands for IMTP peak force normalized to body mass.

Description	T-score	Peak IMTP force, N/kg
Good	>60	>42.60
Average	>40 – ≤60	>35.45 – ≤42.60
Poor	≤40	≤35.45

If an athletes' IMTP peak force normalized to body mass was classified as poor, the original DSI training recommendation was adjusted to prioritize enhancing maximal strength. For athletes with average IMTP peak force, recommendations were adjusted so that incorporating some degree of maximal strength training remained necessary (Figure 2).

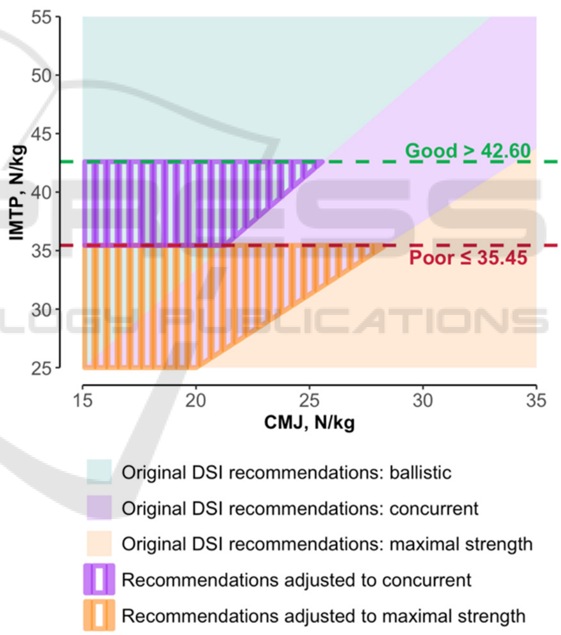

Figure 2: Dynamic strength index recommendation adjustment to maximal strength performance bands.

After considering the T-score based maximal strength performance band adjustments, a reassessment of the athletes' training recommendation group assignments was conducted. As a result, 5 additional athletes from the DSI-prescribed concurrent training group were moved to the group focused on maximal strength improvements, and 5 athletes from the ballistic training group to the concurrent training group (Figure 3).

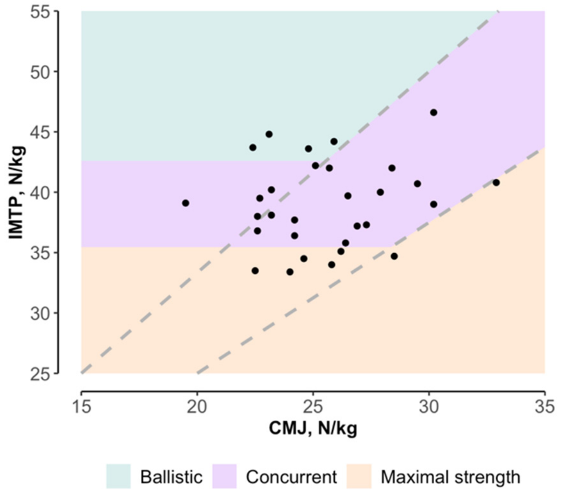

Figure 3: Visualization of ballistic and maximal strength with dynamic strength index recommendations adjusted for maximal strength performance bands.

4 DISCUSSION

The athletes of current study have higher peak IMTP forces compared to those reported in previous research on basketball players (Thomas et al., 2017; Pleša et al., 2024). However, peak CMJ force are similar to other studies with male basketball players (Thomas et al, 2017, Pleša et al., 2023, 2024).

The DSI values in previous research were higher than those recorded in this study (Thomas et al., 2017; Pleša et al., 2024). This discrepancy could be attributed to seasonal fluctuations in DSI (Pleša et al., 2023), as the current data were collected during the late season. Further, differences may be caused due to the fact that in the current research basketball player resistance training still emphasized maximal strength development, which may have helped to maintain maximal strength capacity. However, accumulated fatigue over the season might have contributed to lower peak CMJ force values, as CMJ has been shown to be sensitive to detecting fatigue over time (Wu etl al. 2019, Alba-Jiménez et al. 2022).

Given the association between maximal strength and power, traditional training periodization models emphasize the development of maximal strength before transitioning into power-oriented training (Taber et al., 2016, Stone et al., 2021). This strong foundation helps athletes' transition more effectively to high-velocity, power focused training. By employing T-score derived IMTP performance bands, this visualization assists in identifying athletes who have suboptimal maximal strength and may benefit from further strength development, even when the DSI indicates otherwise. For example, the current data of college-level basketball players shows that five athletes from the ballistic training group, initially assigned based on their DSI, could be reassigned to the concurrent training group, as they have not yet achieved good maximal strength. Additionally, five athletes in the concurrent training group exhibited poor maximal strength, suggesting that their primary focus should remain on maximal strength development. If ballistic training is included concurrently, the emphasis should still be on building a strong foundation of maximal strength to ensure balanced progress and optimal performance outcomes.

Preparing and visualizing athlete testing data is essential for clearly communicating insights to stakeholders and enhancing decision-making. By incorporating details on how peak IMTP force changes independently from peak CMJ force and adding maximal strength performance bands, this approach can help coaches to better identify weaknesses in both ballistic and maximal strength. This provides a clearer understanding than relying on numeric DSI data alone, leading to more informed and targeted training decisions.

However, it should be noted that to establish accurate benchmarks, a larger sample size than used in this study is necessary (Turner et al., 2019). Additionally, benchmarks should ideally be calculated when athletes are at peak performance, unaffected by the accumulated fatigue of the season. Therefore, further studies are needed to develop precise benchmarks that can be used to create accurate visualizations for basketball players, aiding in more informed training recommendations. Nevertheless, this approach holds promise, as it overcomes some of the limitations of relying just on a single numeric DSI value.

5 CONCLUSIONS

Visualizing the DSI in a scatter plot, alongside T-score performance bands from the IMTP, addresses some of the limitations of relying solely on the DSI value. This approach offers a more comprehensive evaluation of athletes' weaknesses and may guide more effective strength training recommendations.

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