Intro

Vertical jump performance is commonly used to assess lower-body athletic capability in sports that require force production, such as basketball, volleyball, and soccer. Jump height is often treated as a representative measure of overall neuromuscular performance, as it reflects lower-body production and responds consistently to training (Ma et al., 2025). However, identical jump heights can result from different mechanical strategies, limiting the extent to which jump height captures overall performance. This has led to growing interest in using force-plate metrics to better understand how jump performance is produced. Outcome measures alone may not show how force is applied during braking and propulsion, highlighting the need for phase-specific metrics in jump performance evaluation (Bishop et al., 2022).

Recent literature emphasizes separating the braking and propulsive phases of the countermovement jump, as each phase reflects distinct neuromuscular demands (McMahon et al., 2018). While force-based metrics capture an athlete's ability to generate and control force, temporal measures often reflect movement strategy rather than performance capacity (Dos'Santos et al., 2018). Despite this, applied studies directly comparing force- and time-based metrics across braking and propulsive phases in basketball populations remain limited, particularly when examining differences between male and female athletes. Addressing this gap may help clarify which metrics are most useful for evaluating jump performance and informing training and monitoring decisions.

Methods

To address the gap in the literature, five metrics would be used. The metrics chosen had to have a sufficient amount of data, which was checked prior to obtaining results. The first metric chosen was jump height (m), which served as the dependent variable. Jump height has a strong correlation with many athletic capabilities, especially those associated with basketball (Ma et al., 2025). Along with this, there was a large amount of data associated with this metric. Since the research question required a comparison between the braking phase and the propulsive phase, two of the same metrics were tracked for each. The metrics chosen were the force (N) and the length of time (s) for each phase. Force was known to have correlation with jump height, therefore it would serve as a metric to observe the differences between braking and propulsion phases (Jones et al. 2017). Meanwhile, the length of each phase was not seen as having much correlation, but would still allow for the comparison between phases (Beattie et al., 2020). These metrics all had at least 32000 measurements within the dataset, which would be sufficient.

To prepare the data to observe the metrics, the first step was to see if there were any null values, which came out to 0 for all five in the long format. There was also a check for any outliers using the interquartile range, which were removed from calculations and some visualizations. The interquartile range was calculated along with the means of each of the metrics to provide summary statistics. This allowed for the use of a t-test to compare the means between men's and women's basketball. Along with this, the p-value was obtained to see if there was a statistical significance between men’s and women’s basketball. Finally, scatterplots were made along with a line of best fit to observe the correlation of each metric with jump height. These statistical analyses would allow for the exploration into the research question.

Results

Across all athletes, having greater force was the strongest predictor of jump height, with both average braking force and average propulsive force showing moderate predictive relationships ($R^2 = 0.34$-0.48), while movement timing showed no significant correlation ($R^2 < 0.01$). This suggests that strength-focused training targeting maximal force generation will be more effective than speed-oriented approaches for improving athletes' jumping ability. The timing metrics did not differ significantly among male and female athletes ($p > 0.05$). However, there were differences in force production between male and female athletes, with the men’s basketball team producing significantly greater force across both force metrics when compared to the women’s basketball team ($p < 0.001$). This led the male athletes to produce higher jump heights which aligns with existing research demonstrating that sex-based physiological differences play an important role in vertical jump performance (Cormie et al., 2009; Hori et al., 2008).

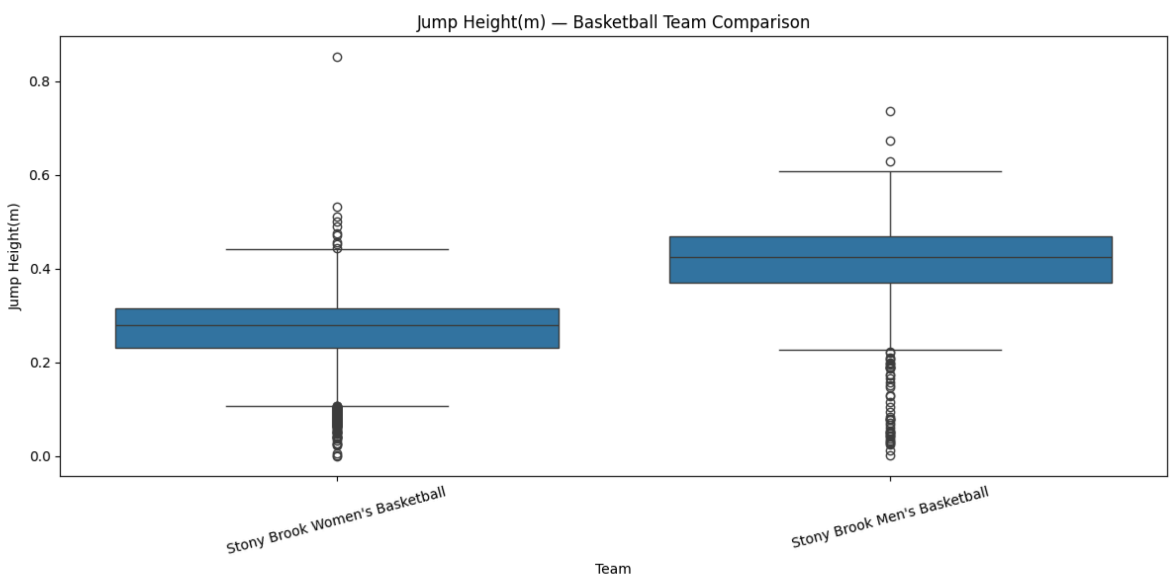

Figure 1. Difference in Jump height (m) between the women's and men’s basketball teams

Even though the literature emphasizes the importance of braking force and propulsive force in an athlete’s performance and injury risk (Dos’Santos et al., 2018; Harper & Kiely, 2018), neither propulsive force or propulsive phase duration significantly differed between the male and female athletes. Therefore, these metrics did not meaningfully contribute to our jump height analysis ($p > 0.05$). Our results suggest that force rather than time of movement had the better determining factor in greater jump height values.

Limitations

When interpreting the findings of this study, there are several limitation factors that should be looked at. First, the analysis relied on a large pre-existing dataset that was collected across multiple teams, seasons, and testing contexts. While we had substantial statistical data, the variability in testing conditions, athlete readiness, and data collection protocols were not fully controlled. These factors may have influenced the measured force and timing values and could not be fully controlled within the scope of the analysis. Second, while the selected metrics had a high number of total observations, not all athletes contributed data consistently across all the metrics or time points. As a result, some analyses relied on group leveled comparisons rather than fully individualized longitudinal trends. This limits the ability for us to draw conclusions about changes over time, particularly when assessing performance adaptations or fatigue related declines. Third, the use of group averages and initial recorded values as baselines brings in potential bias. Individual athletes may have entered the dataset at different stages of training or performance readiness, meaning that baseline value data may not represent true peak or habitual performance. Team level also may mask meaningful individual variability, especially in heterogeneous groups such as collegiate basketball teams.

Finally, this study focused on force plate derived metrics and did not account for contextual variables such as body mass, training load, playing position or even injury history. If these factors were included, it could've provided a more comprehensive understanding of how breaking and propulsive mechanics relate to just performance and injury risk. Future research would benefit from having standardized testing protocols, longitudinal athlete tracking, and integrating contextual information. Having these would strengthen our interpretations of whether differences in force production really contributes to changes in jump performance, which would strengthen the practical value of these metrics for athlete monitoring.

Discussion

This project examined the extent to which jump height is influenced by average braking force, average propulsive force, and the durations of the braking and propulsive phases in basketball athletes. Previously published studies were used to contextualize the findings and evaluate consistency with existing statistical evidence. The dataset, provided by administrators, consisted of fully de-identified player information, allowing for objective analysis and comparison across metrics reported in the literature. When comparing men's and women's basketball teams, the results revealed significant differences in jump height, average braking force, and average propulsive force between genders. These findings align with prior research documenting consistent differences in force production and jump performance between male and female athletes, with men generally demonstrating greater jump heights and higher force outputs. Such differences have been attributed to factors including greater body mass, increased muscle mass, and longer limb lengths, as discussed by Haag and Weyand (2025). In contrast, no significant differences were observed between men and women in braking phase duration or propulsive phase duration. The average timing of these phases differed by only thousandths of a second between groups, indicating minimal variation in movement strategy. Similar findings were reported by Sole et al. (2018), who observed comparable phase characteristics across athletes despite differences in jump performance. Taken together, the significant and non-significant relationships identified in this study suggest that average braking and propulsive force play a more substantial role in predicting jump height than phase timing alone. While the braking and propulsive phases remain important for understanding movement efficiency, their durations may not independently predict jump height (Bygate-Smith et al., 2025). Rather, higher force production appears to exert a greater influence on jump performance, with phase timing functioning to optimize the effective application of that force.

From a practical perspective, these findings suggest that coaches should prioritize training programs aimed at increasing lower-body force production while ensuring that braking and propulsive mechanics are properly coordinated to support increased strength and reduce injury risk (Harper et al., 2020). Additionally, understanding an athlete's phase timing may help guide individualized training interventions that enhance performance without compromising movement quality. This study also addressed a previously identified gap in jump height research related to inconsistencies in calculation methods. The lack of standardized formulas across studies has contributed to variability in reported jump height values. By standardizing metrics using group averages as a baseline for comparison, this analysis enabled a more consistent evaluation of jump height across individuals and teams. This approach allowed for clearer interpretation of performance differences without reliance on individualized baselines alone.