
Investigating the Reproducibility and Sensitivity of a New Pole Bending Machine : A Preliminary Study

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Résumé

Introduction

Pole vaulting involves complex energy transfers between the athlete and the pole to optimize performance (1). While prior research approximates energy balance during the support phase using Newtonian mechanics (2). The dynamics of energy transfer and recoil within the pole remain poorly understood. Warburton et al. (3) developed a pole bending machine to examine the energy involved in bending and the subsequent recoil, but only limited data were collected, and the device was not used in follow-up studies. This preliminary study aims to assess the reliability and sensitivity of a newly developed pole bending machine that dynamically measures the forces required to bend and recoil a pole.

Methods

Pole Bending Machine

The new machine builds upon Warburton's model, offering enhanced customization, including adjustable grip lengths and a secondary contact point simulating the lower arm. The system features a planting box-style frame and uses a rigid line connected to a brushless motor to pull the pole at a designated hooking point. A K-Pull dynamometer records force data and transmits it in real time via Bluetooth to the K-Force application (Kinvent, Montpellier, France).

Pole Bending Protocol

A single 4-meter pole with a flex index of 21.4 was tested in three configurations, with hooking points set at 0.1, 0.2, and 0.3 meters from the extremity. For each trial, the pole was bent until its chord was reduced by 30% (to 1.3 meters). Twelve trials were conducted per configuration, with at least 30 seconds of rest between them. The pulling mechanism, powered by a 7000W brushless motor, used a belt-driven system to wind a cable attached to the pole.

*Intervenant

Mechanical Parameters

Forces were recorded and averaged over 0.05 seconds when the pole chord was reduced by 0.1, 0.3, 0.5, and 1 meter. These values were labeled P1, P3, P5, and P10 for the pulling phase, and R1, R3, R5, and R10 for the recoil phase.

Statistical Analysis

Data were compiled and average values along with confidence intervals were calculated to assess reproducibility and random measurement noise. Sensitivity was evaluated through one-way ANOVA with repeated measures, comparing results from each gripping position.

Results and Discussion

Low standard deviations (SDs) were recorded across all trials, ranging from 0.07 to 0.16 kg in the pulling phase and from 0.09 to 0.29 kg in the recoiling phase. Recoil measurements exhibited slightly higher variability, particularly for R1 at a 0.1 m chord reduction, likely due to minor oscillations caused by the 0.15 kg force sensor.

Despite these variations, the narrow confidence intervals (± 0.14 to ± 0.32 kg during pulling) demonstrate good reproducibility, supporting the machine's capacity to test variables like grip length, hand spacing, and the use of a second forearm for pushing the pole. Future studies could explore differences across poles of varying stiffness, lengths, or manufacturers to better match pole characteristics to athlete technique and take-off speed.

As in Warburton's original study, the force required during the recoil phase was consistently lower than that needed to initiate bending. A marked difference was observed in R1, where the force gap reached 2.8 kg, compared to only 0.44 kg at R10. ANOVA testing revealed statistically significant differences ($p < 0.001$) across all hooking positions, except for R1 between 0.1 m and 0.2 m ($p = 0.091$), highlighting the machine's sensitivity to subtle technical or equipment changes.

Conclusion

This study assessed the reproducibility and sensitivity of force measurements from a newly developed pole bending machine. By mimicking a realistic planting box and upper hand grip configuration, the device enables dynamic, free-motion pole testing. Results showed consistent reproducibility with narrow confidence intervals, especially during the pulling phase. However, lower reproducibility in early recoil (R1) indicates that greater attention is needed in this phase. Overall, the machine offers a promising tool for evaluating pole behavior under variable configurations and could support athlete-specific pole selection in the future.

References

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