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Comparative Analysis of Concentric Variables during unloaded and loaded Depth Jumps

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Abstract: This study explores the influence of external loading on concentric performance variables during depth jumps, a widely used plyometric exercise to enhance explosive power. Ten male athletes (mean age 22 ± 1 years) performed depth jumps from a standardized 75 cm height under three conditions: unloaded, with 5% of body weight, and with 10% of body weight added via weighted vests. Performance measures included jump height, take-off force, impact force, maximum concentric power, average concentric speed, and peak speed, recorded using a tri-axial G-sensor. Results revealed significant differences across conditions, with the 5% load producing notable improvements in force production and neuromuscular activation without compromising movement efficiency. Although the 10% load further altered performance, excessive resistance tended to reduce jump height and efficiency. These findings highlight the importance of optimizing external load in plyometric training, suggesting that moderate resistance (around 5% body weight) enhances concentric output while maintaining effective technique. The study provides valuable insights for strength and conditioning professionals in refining training prescriptions to maximize explosive strength, and it underscores the need for future research on long-term adaptations to incremental loading strategies.

Keywords: Comparative Analysis, Concentric Variables, Unloaded and Loaded Depth Jumps

INTRODUCTION

Plyometric training has long been a significant focus for coaches and researchers, with the drop jump as a central element of such programs. Depth jumps are frequently incorporated into training regimens (McClenton, Brown, Coburn, & Kersey, 2008). Still, their application as a stimulus for acute improvements in vertical jump height remains limited (Hilfiker et al., 2007).In the context of drop jumps, the optimal drop height refers to the height at which average power output and reactive strength reach their maximum levels (Flanagan, E. P., Ebben, W. P., & Jensen, R. L. (2008). In 1968, Verkhoshansky pioneered the establishment of drop jump (DJ) loading height parameters, proposing a range of 0.9–2.2 meters and identifying 0.75 meters as the optimal height for maximizing training efficacy. His findings indicated that a drop height of 0.75 meters yielded the most significant enhancements in lower-limb explosive power. The use of drop jump as a standard test is widely supported in the literature due to its strong metrics, including reliability, validity, and sensitivity (Bobbert, M. F. (1990). The concept of *optimum load* refers to the ideal level of external resistance that maximizes performance while maintaining efficiency and safety. Literature supports training at or near the load that optimises power output, often referred to as the "optimal load" (Kawamori & Haff, 2004). Research suggests that the optimal load for peak power output is exercise-specific for both upper-body (Soriano et al., 2017) and lower-body movements (Soriano et al., 2015). The drop jump is a widely utilized plyometric exercise for enhancing and assessing jumping performance(Matic et al., 2015) Research has shown that depth jumps are highly effective in enhancing vertical jump performance when compared to other methods, such as VertiMax training et al. (2008). In this exercise, an athlete steps off a raised platform, lands on the ground, and transitions immediately into an explosive vertical jump. The landing phase involves controlled eccentric muscle action, which is quickly followed by a rapid transition to the concentric phase during take-off. Depth jumps are a cornerstone in athletic training, aimed at improving neuromuscular efficiency, enhancing reactive strength, and maximizing vertical jump performance. Furthermore, research highlights the potential necessity of incorporating a range of loads in training, particularly as athletes advance in strength (Stone et al., 2003). Some studies, including those by Thompsen et al. (2007) and Vetter (2007), have explored various warm-up methods—such as dynamic warm-ups, submaximal warm-ups, heavy load warm-ups, and modified depth jumps—and their effects on vertical jump performance. The results from these investigations have been inconsistent. Hence to reach on conclusion the scholar had conducted the study to fulfil the gap of knowledge.

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Aim of the study

This study seeks to evaluate the effects of incremental external loading on concentric performance variables during depth jumps executed from a fixed drop height of 75 cm. Specifically, it examines how additional weighted loads influence metrics such as jump height, take-off force, impact force, maximum concentric power, average concentric speed, and peak speed, providing a deeper understanding of the trade-offs between load tolerance and explosive performance.

MATERIAL AND METHOD

Subjects

Ten male athletes (mean ± SD; age 22 ± 1 years, height 172 ± 4 cm, body mass 72 ± 2 kg) were recruited for the study. All participants were physically active, experienced in plyometric training, and had no history of lower-limb injuries or musculoskeletal disorders in the six months preceding the study. Written informed consent was obtained from all participants before the commencement of the study.

Procedure

All participants performed a standardised 10-minute warm-up routine before testing. This included dynamic stretching, plyometric drills, and mobility exercises targeting the major joints to ensure optimal readiness and injury prevention.

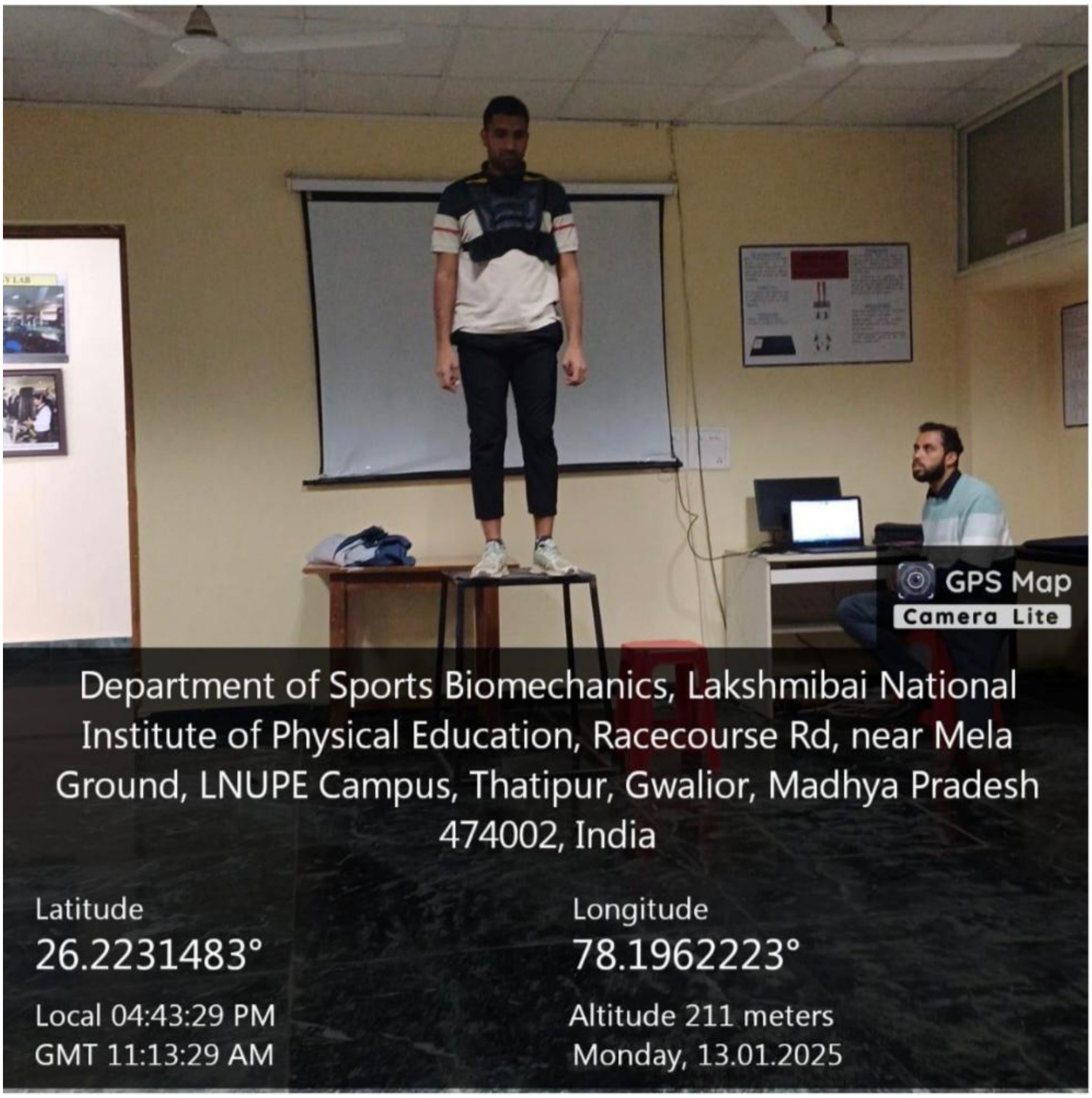
The depth jumps were conducted from a fixed drop height of 75 cm. Participants performed the jumps under three conditions:

- Body weight only (unloaded)
- With 5% of body weight added via a weighted vest
- With 10% of body weight added via a weighted vest

Athletes were instructed to step off the platform, land with minimal ground contact time, and perform an immediate, maximum-effort vertical jump. Each participant completed three trials for each loading condition, with the order of the loading conditions randomized to reduce bias. A 30-second rest interval was provided between each trial to allow adequate recovery. The performance metrics were recorded using a BTS G-Sensor (S.P.A., Italy), equipped with a tri-axial accelerometer (±1.5 g, ±6 g), a tri-axial magnetometer, and a tri-axial gyroscope (±300 gps, ±1200 gps). The G-Sensor was secured to the participant's waist, and data was captured using G-Studio software (version 3.3.22.0). Key variables measured included jump height, take-off force, impact force, maximum concentric power, average concentric speed, and peak speed. The trial yielding the highest jump height for each condition was selected for analysis. This approach assessed the most optimal performance under each loading condition.

Statistical analysis

The analysis of the gathered data was carried out using IBM SPSS (version 20.0.0). The Shapiro-Wilk test was employed to evaluate the normality of the data. For data that violated the normality assumption, the transformation of data with the help of the log_10 method is used for an impact force of 5% of body weight . Repeated measures ANOVA was employed because participants jumped three times under different conditions: unloaded, 5% of body weight, and 10% of body weight. Greenhouse-Geisser corrections were used in cases where we found violations of assumptions of sphericity using Mauchly's sphericity test. Post-hoc paired t-test with a Bonferroni adjustment (p = 0.01) was used to find any significant differences between the levels. The effect sizes were calculated using partial η2 for repeated measures ANOVA, with 0.01 defining small, 0.06 medium, and 0.14 large effect. The level of significance for all tests was set at 0.05



RESULT

The Repeated measure ANOVA was conducted to evaluate the compare of different load conditions on the dependent variables. Wilks' Lambda was utilised, yielding a statistically significant result, A = 0.006, F (6, 24) =704.991, p <0.001, n^2 =0.994 indicating that the load conditions substantially affected the dependent measures. Mauchly's Test of Sphericity assessed the assumption of sphericity for within-subject effects. The results showed a violation of sphericity (W = 0.000, x^2 = 670.537, df = 20, p < 0.001). To address this violation, the Greenhouse-Geisser correction was applied (€ = 0.174). Tests of Within-Subjects Effects After applying the Greenhouse-Geisser correction, significant differences were found between load conditions, as shown in the within-subjects effects table (F -values and adjusted degrees of freedom were used). This indicates a strong impact on the varying load on the dependent variables. This indicates a strong impact of the varying loads on the dependent variables. Post-hoc paired comparisons using the Bonferroni adjustment demonstrated significant mean differences between almost all load conditions (Load 1 vs. Load 2: M = 32.799, p < 0.001). All significant comparisons are reported with their confidence intervals and adjusted p-values, reinforcing the robustness of the observed effects.

Table 1: Multivariate Test to compare the unloaded and loaded depth jump

Effect	Value	F	Hypothesis df	Error df	Sig	Partial Eta Squared
Wilk's Lambda	.006	704.991	6.000	24.000	**.000**	.994

Table 2: Mauchly's Test of Sphericity

Within-subject effect	Mauchly'S W	Approx chi-square	df	Sig.	Greenhouse-Geisser
Load	.000	670.537	20	**.000**	.174

Table 3: Post hoc test paired comparison (Bonferroni adjustment)

Variable(I)	Variable(J)	Mean Difference (I-J)	Sig
1	2	32.799	**.000**
	3	30.446	**.000**
	4	32.294	**.000**
	5	31.279	**.000**
	6	31.402	**.000**
	7	33.160	**.000**
2	1	-32.799	**.000**
	3	-2.352	**.000**
	4	-.505	**.000**
	5	-1.519	**.000**
	6	-1.397	**.000**
	7	.361	**.433**
3	1	-30.446	**.000**
	2	2.352	**.000**
	4	1.848	**.000**
	5	.883	**.000**
	6	.955	**.000**
	7	2.713	**.000**
4	1	-32.294	**.000**
	2	.505	**.000**
	3	-1.848	**.000**
	5	-1.015	**.000**
	6	-.892	**.000**
	7	.886	**.000**
5	1	-31.279	**.000**
	2	1.519	**.000**
	3	-.833	**.000**
	4	-1.015	**.000**
	6	-.892	**.000**
	7	.866	**.000**
6	1	-31.402	**.000**
	2	1.397	**.000**
	3	-.955	**.000**
	4	.892	**.000**
	5	-.122	**.000**
	7	1.758	**.000**
7	1	-33.160	**.000**
	2	-.361	**.433**
	3	-2.713	**.000**
	4	-.866	**.000**
	5	-1.880	**.000**
	6	-1.758	**.000**

1: Height, 2: Takeoff force, 3: Maximum concentric power, 4: Average speed concentric phase, 5: peak speed, 6: Takeoff speed, 7: Impact force

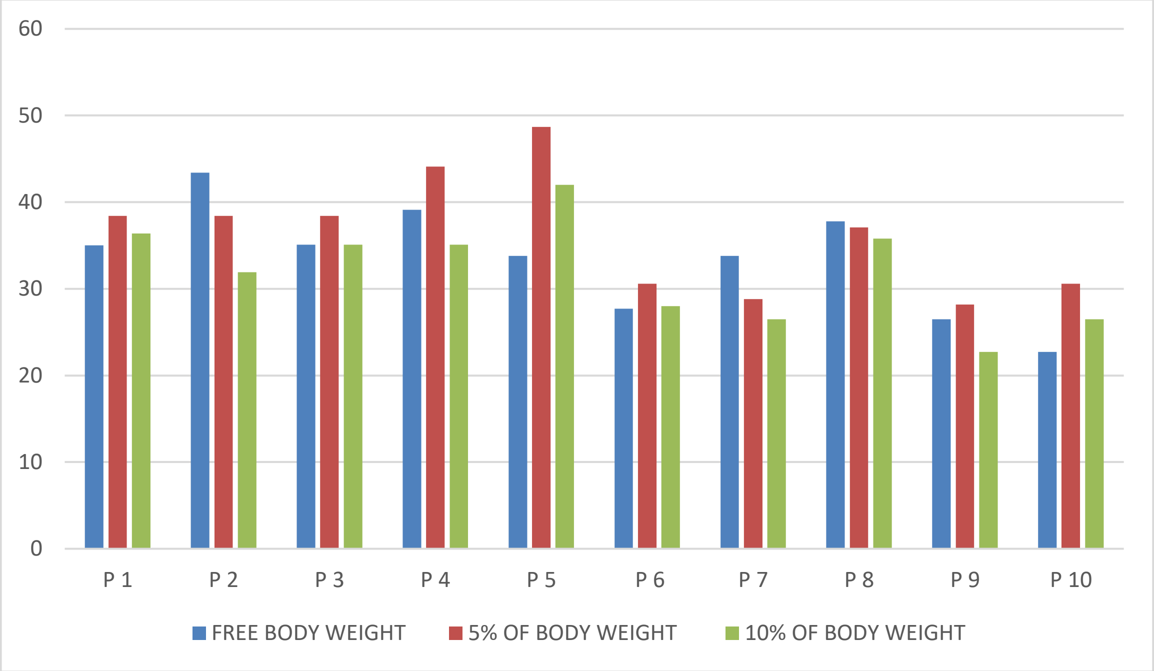


Figure 1: Comparison of flight height among athletes in different load conditions

DISCUSSION

The results of this study demonstrate that incremental external loading has a significant impact on concentric performance variables during depth jumps. The statistical analysis revealed that the addition of 5% body weight elicited significant alterations in key performance metrics compared to the unloaded condition, indicating that a moderate increase in external resistance enhances neuromuscular activation and force production. The observed significance at 5% loading may be attributed to the optimal recruitment of motor units, as the external resistance provides sufficient stimulus to enhance power output while maintaining efficient movement mechanics. This aligns with the force-velocity relationship, where a balance between external load and velocity optimizes power generation. Furthermore, the transition from 5% to 10% body weight resulted in additional performance changes, though the magnitude varied across different variables. While increased loading enhances mechanical output, excessive resistance like 10% of body weight during a depth jump may disrupt movement efficiency, thereby affecting jump height, velocity, and force application. The pairwise comparisons further indicate that some variables, such as Load 2 and Load 7, did not exhibit statistically significant differences, suggesting that beyond a certain threshold, additional load does not elicit proportional changes in all performance measures. From a practical perspective, these findings emphasize the importance of load optimization in plyometric training. Moderate external resistance, such as 5% of body weight, appears to enhance concentric performance without negatively impacting movement efficiency, making it a viable strategy for improving explosive strength. These insights have direct implications for strength and conditioning protocols, particularly in determining the appropriate external resistance for maximizing athletic performance. Future research should investigate the long-term neuromuscular adaptations to incremental loading and refine load prescriptions for various athletic populations to optimize training efficacy. Some research papers suggest that Manipulating contact time during drop jumps influences power output more than starting height, with optimal power achieved at moderate contact times (Walsh et al., 2004). Proper jump technique is crucial for maximizing performance outcomes (Walsh et al., 2004). Our research also shows significant results in impact force, Average speed concentric phase, takeoff speed,flight height increases with putting weight or external load mainly 5% of body weight. Some research also suggested that greater pennation angles in the vastus lateralis and gastrocnemius enhance initial force redirection during drop jumps, while longer gastrocnemius fascicles negatively impact early rate of force development (Earp et al., 2011). Heavy strength training may be beneficial for optimizing muscle structure for improved drop jump performance (Earp et al., 2011).

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