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Effects Of Resisted Sprint Training Devices On Velocity And Center Of Mass Distance During Maximum Velocity Sprinting: A Comparative Analysis Of Sled, Parachute, And Weight Belt

Bichu Joseph[1] & Dr. N. Premkumar[2]

[1]**Ph.D. Scholar,** Department of Physical Education, Annamalai University, Chidambaram, Tamilnadu, India.

[2]**Professor,** Department of Physical Education, Annamalai University, Chidambaram, Tamilnadu, India.

Abstract

Resisted sprint training is commonly used to enhance sprint-specific strength, yet its impact on key biomechanical variables during the maximum velocity phase requires clarification. This study examined how three resisted devices—weighted sled, parachute, and weight belt—affect sprint velocity and center of mass (COM) distance (horizontal displacement between foot contact and COM at touchdown and takeoff). Seventeen collegiate athletes (11 men, 6 women) performed 30-meter flying sprints under four conditions: unloaded, sled (16% body mass), parachute (1.2 × 1.2 m), and weight belt (9% body mass). Trials were recorded at 120 Hz using a Canon 5D Mark II camera, and kinematics were analyzed via Kinovea software. Results showed that all devices reduced velocity: sled (~12–15%), parachute (~3–6%), and weight belt (~1–3%), with the sled producing the greatest significant reductions ($p< 0.05$). In contrast, COM distance remained stable across all conditions in both sexes—ranging from 229–237 cm at touchdown and 43–54 cm at takeoff—indicating preserved foot-strike alignment and postural control. These findings suggest that resisted sprinting can impose meaningful overload without distorting fundamental sprint mechanics, provided resistance is kept within moderate limits (≤15% velocity loss). The weight belt offered the least mechanical disruption, while the sled provided the highest stimulus. For coaches in resource-limited settings, monitoring only velocity and COM distance offers a practical, evidence-based method to ensure training specificity. These results support the use of all three devices for maximum velocity training when technique is visually monitored using basic video tools.

Key Words: Resisted sprint training, maximum velocity, sled towing, parachute, weight belt, velocity, center of mass, sled towing, parachute and weight belt.

Introduction

Sprint performance at maximum velocity is a critical determinant of success in numerous field and track sports, including athletics, football, rugby, and kabaddi **(Bachero-Mena et al., 2023; Lockie et al., 2012)**. Achieving high sprint velocities relies on the athlete's ability to apply large horizontal ground reaction forces while maintaining optimal body posture and limb coordination **(Morin et al., 2020)**. Among training strategies, resisted sprinting—using devices such as sleds, parachutes, or weight belts—has gained popularity for enhancing sprint-specific strength and force production without deviating significantly from natural sprint mechanics **(Martínez-Valencia et al., 2021; Haugen et al., 2023)**.

A central consideration in resisted sprint training is velocity reduction. Research consistently shows that effective resisted loads reduce sprint velocity by 5–15%, which corresponds to a meaningful overload stimulus while preserving movement specificity **(Alcaraz et al., 2008; Cross et al., 2021)**. However, excessive resistance can compromise technique, leading to maladaptive changes in posture and stride mechanics that may hinder transfer to competitive performance.

One of the simplest yet most informative biomechanical indicators of sprinting technique under load is the horizontal distance between the center of mass (COM) and the point of foot contact—referred to here as COM distance. This metric reflects the athlete's postural control and force application direction during ground contact. A shorter COM distance (i.e., foot landing closer to the COM) often indicates reduced braking forces and more efficient propulsion, whereas excessive distance may signal overstriding or inefficient mechanics **(Bezodis et al., 2020; Clark & Weyand, 2021)**.

Recent studies emphasize that resisted sprinting should aim to minimize disruption to COM positioning while achieving a target velocity reduction (**Rabita et al., 2020; Slawinski et al., 2023**). For instance, sled towing tends to increase forward trunk lean and shift foot strike anteriorly, potentially lengthening COM distance and increasing braking impulses **(Martínez-Valencia et al., 2021)**. In contrast, vertical loading via weight belts may preserve COM alignment but offer less horizontal resistance **(Haugen et al., 2023)**. Parachutes, providing aerodynamic drag, fall between these extremes but are sensitive to environmental conditions such as wind **(Alcaraz et al., 2008)**.

Despite growing evidence, most studies have evaluated multiple kinematic variables (e.g., joint angles, stride parameters), which may obscure practical interpretation for coaches. By narrowing the focus to velocity and COM distance, this study provides a coach-friendly, functionally relevant analysis of how three common resisted sprint devices—sled, parachute, and weight belt—affect key performance and postural metrics during the maximum velocity phase.

The purpose of this research is therefore twofold: (1) To quantify the velocity reduction induced by each resisted sprint device, and (2) To assess whether these devices alter COM distance at touchdown and takeoff—two indicators critical for maintaining sprint efficiency and technique specificity.

Methodology

A quasi-experimental, within-subjects design was employed to examine the acute effects of three resisted sprint training devices—weighted sled, parachute, and weight belt—on sprint velocity and center of mass (COM) distance during the maximum velocity phase of sprinting. These two variables were selected based on their direct relevance to sprint performance and mechanical efficiency: velocity reflects the primary output of sprinting capacity, while COM distance (the horizontal displacement between the point of foot contact and the body's COM at touchdown and takeoff) serves as a practical indicator of postural control and foot-strike strategy **(Bezodis et al., 2020; Clark & Weyand, 2021)**.

Participants

Seventeen competitive athletes (11 men, 6 women; mean age = 21.3 ± 1.8 years) from CSM College, Virudhachalam—comprising sprinters and long jumpers with at least one year of resisted sprint training experience—participated in the study. All participants were free from musculoskeletal injury at the time of testing and provided informed consent. The study was approved by the Institutional Ethics Committee of Annamalai University.

Protocol

Each participant completed four 30-meter flying sprint trials on a synthetic track under the following randomized conditions:

1. Unloaded sprinting (control)
2. Sled towing (16% of body mass)
3. Parachute towing (medium-sized parachute: 1.2 × 1.2 m)
4. Weight belt (9% of body mass distributed evenly around the hips)

A 20-meter build-up zone preceded the 10-meter testing zone (centered at the 20–30 m mark) to ensure participants reached maximum velocity. Trials were separated by ~6 minutes of passive recovery to minimize fatigue. Wind speed was monitored using a handheld anemometer and kept below 2 m/s across all trials to limit environmental variability.

Data Collection

Sprint trials were recorded perpendicular to the running direction at the 25-meter mark using a Canon EOS 5D Mark II camera operating at 120 Hz. The camera was mounted on a tripod at a height of 1.2 m and calibrated using a 2-meter reference scale placed on the track surface.

Data Analysis

Video footage was analyzed using Kinovea 0.9.5 (open-source 2D motion analysis software). Two key variables were extracted from a single, clear running cycle per trial:

1. Velocity (m/s): Calculated as the horizontal displacement of the COM between two consecutive frames during mid-stance at maximum velocity.
2. COM Distance (cm): Measured as the horizontal distance between the point of initial foot contact (touchdown) and the COM position at touchdown, and similarly at takeoff. The COM was estimated as the midpoint between the greater trochanter and acromion process, consistent with simplified 2D modeling approaches validated for field-based sprint analysis **(Martínez-Valencia et al., 2021)**.

Only touchdown and takeoff instants were analyzed for COM distance, as midstance values are not applicable for this metric. All digitization was performed by a single trained operator (ICC > 0.92 for intra-operator reliability on repeated trials).

Statistical Analysis

A two-way repeated-measure ANOVA (Device × Sex) was conducted to assess differences in velocity and COM distance across the four conditions. Post-hoc pairwise comparisons with Tukey's HSD correction were used where significant main effects were observed. Statistical significance was set at $p \leq 0.05$. All analyses were performed using SPSS v22.

Results

The effects of resisted sprint training devices on sprint velocity and center of mass (COM) distance during the maximum velocity phase are summarized in Table - I. All three resisted conditions—weighted sled, parachute, and weight belt—resulted in reduced sprint velocity compared to unloaded sprinting, with the magnitude of reduction varying by device and sex. Changes in COM distance were minimal across conditions, suggesting preserved postural-stride alignment.

Table – I

Velocity (m/s) and COM Distance (cm) in Unloaded and Resisted Sprinting Conditions (Mean ± SD) (Only touchdown and takeoff presented for COM distance, as mid stance is not applicable)

Group	Condition	Velocity (Touchdown)	Velocity (Takeoff)	COM Distance (Touchdown, cm)	COM Distance (Takeoff, cm)
Men	Unloaded	9.3 ± 0.4	9.7 ± 0.5	237 ± 7	54 ± 9
	Sled	8.4 ± 0.4*	8.8 ± 0.7*	229 ± 6	53 ± 7
	Parachute	9.0 ± 0.4	9.3 ± 0.7	231 ± 9	53 ± 7
	Weight Belt	9.2 ± 0.5	9.5 ± 0.6	237 ± 10	50 ± 12
Women	Unloaded	8.1 ± 0.6	8.2 ± 0.5	234 ± 3	47 ± 5
	Sled	6.9 ± 0.4*	7.1 ± 0.4*	229 ± 6	53 ± 4
	Parachute	7.4 ± 0.4*	7.5 ± 0.4	235 ± 6	46 ± 3
	Weight Belt	7.8 ± 0.4	7.9 ± 0.5	237 ± 3	43 ± 5

Note: p < 0.05 vs. unloaded condition.

Velocity

In men, unloaded sprint velocity averaged 9.3 ± 0.4 m/s at touchdown and 9.7 ± 0.5 m/s at takeoff. The weighted sled produced the largest velocity reduction: 8.4 ± 0.4 m/s at touchdown and 8.8 ± 0.7 m/s at takeoff ($p< 0.05$), representing a **9–12% decrease**. The **parachute** reduced velocity by ~3–6% (9.0 to 9.3 m/s), which was not statistically significant at touchdown but approached significance at takeoff. The **weight belt** induced the smallest reduction (~1–2%), with values not significantly different from unloaded sprinting (9.2–9.5 m/s; *p* > 0.05).

In women, unloaded velocity was 8.1 ± 0.6 m/s (touchdown) and 8.2 ± 0.5 m/s (takeoff). The sled again caused the greatest decline: 6.9 ± 0.4 m/s and 7.1 ± 0.4 m/s ($p< 0.05$), corresponding to a 12–15% reduction. The parachute significantly reduced velocity (7.4–7.5 m/s; $p< 0.05$), while the weight belt showed non-significant reductions (7.8–7.9 m/s).

COM Distance

COM distance at touchdown (representing horizontal displacement of the foot ahead of the COM) was largely unaffected by resistance in both sexes. Men exhibited values of 237 ± 7 cm (unloaded) versus 229–237 cm in resisted conditions. Women averaged 234 ± 3 cm (unloaded) and 229–237 cm under load, with no statistically significant differences across devices ($p > 0.05$).

At takeoff, men's COM distance ranged from 50 ± 12 cm (weight belt) to 54 ± 9 cm (unloaded), with no significant device effects. In women, the weight belt produced a slight reduction to 43 ± 5 cm, compared to 47 ± 5 cm in unloaded sprinting—though this difference did not reach statistical significance ($p = 0.07$).

Across both sexes, the sled and parachute showed minimal influence on COM positioning at either touchdown or takeoff, while the weight belt yielded the most consistent COM alignment relative to unloaded sprinting.

This focused presentation of results highlights that velocity is highly sensitive to resistance type, while COM distance remains remarkably stable, supporting the idea that these devices can provide overload without distorting fundamental sprint mechanics—at least within the loading schemes used (sled: 16% BM; weight belt: 9% BM.

Discussion

This study examined how three commonly used resisted sprint training devices—weighted sled, parachute, and weight belt—affect sprint velocity and center of mass (COM) distance during the maximum velocity phase. The results demonstrate that all three devices reduced sprint velocity to varying degrees, with the sled inducing the greatest reduction (~12–15%), followed by the parachute (~3–6%), and the weight belt (~1–3%). Crucially, COM distance remained largely unchanged across conditions in both men and women, indicating that these devices impose overload without substantially disrupting fundamental postural or stride mechanics.

The observed velocity reductions align with contemporary recommendations that effective resisted sprint loads should reduce maximum velocity by 5–15% to provide a meaningful neuromuscular stimulus while preserving technique **(Alcaraz et al., 2008; Cross et al., 2021)**. The sled's greater impact on velocity likely stems from its combined horizontal and vertical resistance vector, which increases braking forces and demands greater propulsive effort **(Martínez-Valencia et al., 2021)**. In contrast, the parachute generates purely horizontal drag, resulting in moderate overload with minimal postural perturbation. The weight belt, applying vertical loading, had the mildest effect on speed—consistent with recent findings that vertical resistance minimally alters sprint-specific force application **(Haugen et al., 2023)**.

Perhaps the most practically significant finding is the stability of COM distance across all resisted conditions. COM distance—at both touchdown and takeoff—serves as a proxy for foot-strike strategy and postural alignment relative to the base of support. A consistent COM distance suggests that athletes maintained a similar strike pattern and body orientation under load, which is critical for preserving movement specificity **(Bezodis et al., 2020; Clark & Weyand, 2021)**. Even with the sled's notable forward lean (not analyzed here but noted in the original data), the horizontal foot-COM relationship remained stable, implying that athletes adjusted trunk posture without overstriding or compromising landing mechanics.

Gender differences were evident in absolute velocity—women sprinted ~12% slower than men—but COM distances were comparable when scaled to body size, reinforcing that technique was not disproportionately disrupted in either group. This supports the view that sex-based differences in sprint performance stem primarily from anthropometric and strength-to-mass disparities, not biomechanical inefficiencies **(Bachero-Mena et al., 2023)**.

From a practical standpoint, these findings support the judicious use of resisted sprinting in the maximum velocity phase. Coaches seeking greater overload (e.g., for strength-dominant athletes) may prioritize the sled, provided technique is monitored. Those emphasizing technique retention under mild resistance might opt for the weight belt or parachute. Importantly, the minimal change in COM distance across devices suggests that all three can be used without fear of ingraining maladaptive mechanics, as long as resistance is kept within the 5–15% velocity reduction range **(Rabita et al., 2020; Slawinski et al., 2023)**.

A key strength of this focused approach is its coach-friendly interpretability. By narrowing analysis to velocity and COM distance—both measurable with basic video tools like Kinovea—practitioners in resource-limited settings (e.g., Indian intercollegiate sports) can make informed decisions without advanced biomechanical infrastructure.

Limitations include the use of fixed resistance loads (16% BM for sled, 9% for belt), which may not reflect individualized optimal loads. Future studies should explore individualized velocity-loss thresholds (e.g., 10% reduction per athlete) and examine longitudinal performance outcomes.

Conclusion

This study demonstrates that resisted sprint training using a weighted sled, parachute, or weight belt effectively reduces sprint velocity during the maximum velocity phase, with the magnitude of reduction proportional to the resistance type—sled (≈12–15%), parachute (≈3–6%), and weight belt (≈1–3%). Critically, center of mass (COM) distance at both touchdown and takeoff remained largely unchanged across all conditions, indicating that these devices impose overload without disrupting fundamental sprint mechanics.

These findings support the use of all three devices for developing sprint-specific strength, provided resistance levels are selected to induce a 5–15% velocity reduction, as recommended in contemporary literature **(Alcaraz et al., 2008; Cross et al., 2021)**. The minimal impact on COM positioning suggests preserved foot-strike strategy and postural control, enhancing the movement specificity of resisted training—a key principle for transfer to performance.

For practical application in settings such as Indian intercollegiate sports—where access to advanced biomechanics labs is limited—coaches can confidently use basic video analysis tools (e.g., Kinovea) to monitor only velocity and COM distance as sufficient indicators of technique integrity under load. The weight belt is ideal for technique-focused overload, the parachute offers moderate resistance with aerodynamic realism, and the sled provides the greatest neuromuscular stimulus when technique is carefully supervised.

Future work should explore individualized loading based on athlete-specific velocity-loss thresholds and investigate longitudinal performance adaptations. Nonetheless, this two-variable approach offers a simple, valid, and coach-accessible framework for optimizing resisted sprint training during the maximum velocity phase.

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