ORİJİNAL MAKALE / ORIGINAL ARTICLE

Uluslararası Beden Eğitimi ve Spor Bilimleri Dergisi/ KMÜ UBESBD
Internatıonal Journal Of Physıcal Educatıon And Sport Scıences / KMU JIPES

VELOCITY-BASED RESISTANCE TRAINING AND SPORTS PERFORMANCE: CONCEPTUAL AND APPLIED APPROACHES

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Geliş Tarihi / Received: 09.09.2025, ***Kabul Tarihi / Accepted:*** 26.09.2025

ABSTRACT

Velocity-based resistance training (VBT) has gained recognition as a sophisticated method for prescribing individualized training loads and monitoring adaptations in strength development. In contrast, the traditionally employed percentage-based training (PBT) often falls short in accounting for daily fluctuations in athletes' neuromuscular status, which can diminish the overall effectiveness of training. The present narrative review critically examines VBT by outlining its theoretical underpinnings, methodological applications, and practical implications. A structured literature search conducted in PubMed, Scopus, Web of Science, and SPORTDiscus between 2009 and 2024 identified 30 studies, of which 10 satisfied the inclusion criteria and were subjected to qualitative synthesis. Findings demonstrate that maintaining low velocity-loss thresholds (VL ≤20%) is associated with improvements in strength and power performance, while higher thresholds (VL ≥30%) promote hypertrophic gains but concurrently increase neuromuscular fatigue. Compared to PBT, VBT exhibits greater sensitivity in detecting day-to-day variations in performance readiness. However, widespread adoption remains constrained by challenges related to equipment costs, accessibility, and measurement validity. Taken together, the evidence positions VBT as a rigorous and practically meaningful framework for optimizing resistance training. Future research directions include extending its application across broader populations, evaluating hybrid approaches that integrate VBT with PBT, and developing cost-efficient technological solutions to enhance its feasibility in applied settings.

Keywords: Velocity-based resistance training; Velocity loss; Load–velocity relationship

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1. INTRODUCTION

Strength and conditioning programs are fundamental for improving athletic performance, preventing injuries, and optimizing long-term training adaptations. Traditionally, resistance training loads have been prescribed using percentage-based training (PBT), where relative intensities are determined according to a percentage of one-repetition maximum (1RM). Although widely applied in practice, this approach presents critical limitations. Chief among these is its inability to accommodate daily fluctuations in athletes' neuromuscular readiness, which are influenced by factors such as fatigue, sleep quality, and accumulated training stress (Banyard, Nosaka, & Haff, 2017; Jovanović & Flanagan, 2014). Consequently, percentage-based prescription may lead to undertraining or overtraining, thereby reducing training efficiency and increasing the risk of maladaptation.

To overcome these limitations, velocity-based training (VBT) has emerged as an innovative approach that uses movement velocity as the primary metric for load prescription and performance monitoring. This method is grounded in the principle that barbell velocity during resistance exercises is strongly correlated with the relative intensity (%1RM), allowing coaches to estimate loading zones and monitor fatigue in real time (González-Badillo & Sánchez-Medina, 2010). Unlike fixed-load strategies, VBT enables the adjustment of training intensity on a session-by-session basis, reflecting athletes' current performance capacity (Weakley et al., 2021).

A growing body of research supports the efficacy of VBT in enhancing maximal strength, explosive power, and neuromuscular efficiency. For example, studies demonstrate that low-to-moderate velocity loss thresholds (<20%) optimize strength and power adaptations, while higher thresholds (>30%) are more conducive to hypertrophy but may increase neuromuscular fatigue (Pareja-Blanco et al., 2017; Sánchez-Medina & González-Badillo, 2011). Additionally, velocity monitoring has been shown to provide a more sensitive measure of training readiness compared to subjective markers such as rating of perceived exertion (RPE) (Mann, Ivey, & Sayers, 2015). A recent meta-analysis also confirmed that VBT significantly improves lower limb strength, endurance, jumping, and sprint performance in trained individuals (Zhang, Feng, Peng, & Li, 2022).

Despite these promising applications, VBT is not without limitations. The implementation of this method often requires access to velocity-tracking devices, which may be costly and technically demanding, limiting its widespread adoption in field settings (Weakley et al., 2020). Moreover, much of the existing evidence has been derived from trained male athletes, raising questions about the generalizability of VBT to other populations such as female athletes, youth, or clinical groups (Randell et al., 2011).

The importance of VBT lies in its ability to provide a real-time, individualized, and objective framework for resistance training prescription. By accounting for daily variations in neuromuscular readiness, VBT helps maximize performance adaptations, minimize the risk of injury, and optimize long-term athlete development. Furthermore, its application extends beyond elite athletes, offering potential benefits in educational, rehabilitative, and youth sport contexts (Zhang et al., 2022).

Given these strengths and limitations, a comprehensive synthesis of the literature is needed to provide clarity on the theoretical foundations, methodological approaches, and practical applications of VBT. Accordingly, the present review seeks to (a) examine the methodological approaches used in VBT studies, (b) evaluate the evidence regarding its effects on strength and performance outcomes, and (c) highlight the practical benefits and challenges of implementing VBT in diverse training contexts. This narrative review aims to advance the understanding of VBT as a tool for individualized and scientifically informed resistance training prescription.

This investigation was structured as a narrative review and reported in accordance with the SANRA (Scale for the Assessment of Narrative Review Articles) guidelines (Baethge, Goldbeck-Wood, & Mertens, 2019). The primary objective was to integrate and critically evaluate the conceptual foundations, methodological approaches—such as load–velocity profiling and velocity-loss thresholds—and the practical implications of velocity-based resistance training (VBT).

Although the body of literature on VBT has grown in recent years, substantial gaps remain. Much of the existing evidence is limited to resistance-trained male athletes, primarily within strength- and power-oriented sports (Randell, Cronin, Keogh, Gill, & Pedersen, 2011; Weakley et al., 2020). By contrast, research investigating the efficacy of VBT in female athletes, youth populations, and endurance-based or skill-dominant sports remains scarce (Banyard, Tufano, Delgado, Thompson, & Nosaka, 2019; Zhang, Feng, Peng, & Li, 2022). Moreover, studies differ markedly in their methodological approaches, velocity-monitoring technologies, and performance outcomes assessed, making it difficult to generalize findings or establish standardized guidelines for practice (González-Badillo & Sánchez-Medina, 2010; Pareja-Blanco, Rodríguez-Rosell, Sánchez-Medina, Gorostiaga, & González-Badillo, 2017).

Therefore, the present review was conducted to address these research gaps. Specifically, it seeks to synthesize the available evidence, clarify the practical significance of VBT across diverse athletic contexts, and highlight directions for future studies to enhance its generalizability. Given the considerable heterogeneity in study designs and outcome measures, a formal meta-analysis was deemed inappropriate.

2. METHOD

2.1. Research Design

This paper presents a narrative review prepared in accordance with the SANRA (Scale for the Assessment of Narrative Review Articles) criteria, which provide a structured framework for assessing the quality of narrative reviews in terms of justification of the article's importance, statement of concrete aims, description of the literature search, referencing, scientific reasoning, and the overall presentation (Baethge, Goldbeck-Wood, & Mertens, 2019). The intention was to deliver a conceptually coherent synthesis of velocity-based resistance training (VBT), with particular emphasis on its theoretical underpinnings, methodological approaches—such as load–velocity profiling and velocity-loss thresholds—and practice-oriented applications. In view of the considerable heterogeneity in research designs and reported outcomes, and consistent with SANRA's emphasis on methodological transparency and critical synthesis rather than statistical aggregation, the implementation of a meta-analysis was not considered appropriate.

2.2. Search Strategy

A comprehensive literature search was undertaken across PubMed/MEDLINE, Web of Science, Scopus, and SPORTDiscus to identify studies published from January 2009 through December 2024. The search strategy employed a combination of controlled vocabulary and free-text terms, including "velocity-based resistance training," "velocity loss," "load–velocity profiling," and "strength training outcomes." In addition, the reference lists of relevant reviews and eligible articles were manually screened to capture supplementary sources. Following the removal of duplicate records, 30 publications were retrieved, of which 10 satisfied the inclusion criteria and were subsequently included in the qualitative synthesis.

2.3. Inclusion and Exclusion Criteria

Studies were deemed eligible for inclusion if they met the following criteria: (i) publication in peer-reviewed journals in the English language between 2009 and 2024; (ii) a focus on velocity-based resistance training (VBT) or its core methodological components; and (iii) assessment of outcomes pertaining to strength, hypertrophy, power, or indices of fatigue monitoring. Eligible designs encompassed randomized controlled trials, quasi-experimental investigations, crossover studies, and cross-sectional profiling research that directly informed load–velocity relationships or evaluated device validity. Participant groups included healthy youth, adult, and athletic populations of both sexes and across varying levels of training experience. Exclusion criteria comprised non-English publications, conference proceedings, theses or dissertations, opinion pieces, animal studies, and rehabilitation-oriented trials that lacked sport-performance outcomes.

2.4. Study Selection Process Analysis

Study selection followed a multi-step process. After the removal of duplicate records, 30 articles were initially screened based on titles and abstracts, resulting in the exclusion of 20 studies that did not meet the predetermined eligibility criteria. The remaining 10 articles were retrieved for full-text evaluation, and all were deemed suitable for inclusion in the qualitative synthesis. Backward citation tracking did not yield any additional eligible studies.

2.5. Data Extraction

For each study meeting the inclusion criteria, information was systematically extracted regarding study design, participant characteristics, intervention protocols, velocity-loss thresholds, and reported outcomes. The collected data were synthesized using thematic content analysis, a qualitative technique that involves identifying, coding, and categorizing recurring patterns or themes within the reviewed studies (Braun & Clarke, 2008). This method enabled the organization of evidence into recurrent categories, including load–velocity profiling, strength adaptations, power and explosive performance, hypertrophy, fatigue monitoring, and practical applications. Such an analytical approach facilitated a structured comparison across studies, allowing for the identification of consistent findings, methodological divergences, and persisting gaps within the literature.

2.6. Data Analysis

The evidence was integrated through qualitative content analysis combined with thematic categorization, emphasizing shared methodological characteristics, practical implications, and points of divergence across studies (Elo & Kyngäs, 2008; Thomas & Harden, 2008). This strategy enabled the recognition of recurring patterns, the emergence of key themes, and the identification of unresolved questions within the VBT literature. Although statistical aggregation of findings was not undertaken, the narrative synthesis provided a structured and critical appraisal of the current body of knowledge.

2.7. Ethical Considerations

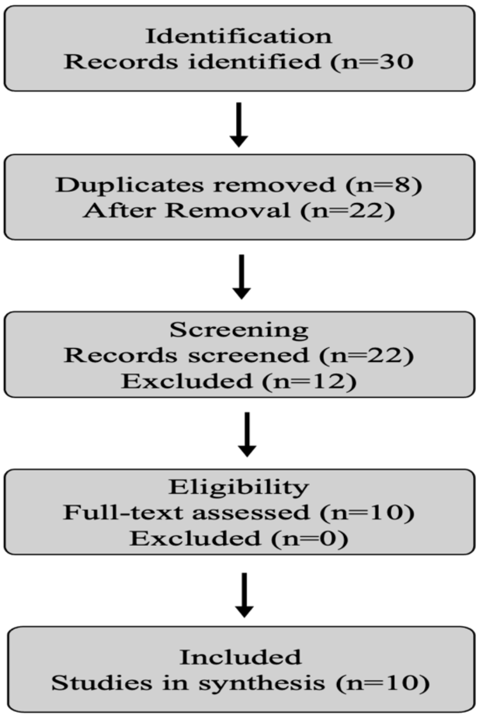
This review did not entail the collection of primary data from human or animal subjects. As the analysis relied exclusively on the synthesis of previously published research, formal approval from an institutional ethics committee was not necessary. The review was carried out in line with established best practices, ensuring transparency, proper attribution through accurate citation, and adherence to principles of academic integrity and intellectual property.

2.8. Reporting Statement

The review was developed in accordance with the SANRA guidelines for narrative reviews, which emphasize clarity of objectives, rigor in literature searching, accurate referencing, sound scientific reasoning, and appropriate data presentation (Baethge, Goldbeck-Wood, & Mertens, 2019). While this review was not conducted as a systematic review and no protocol was prospectively registered, the selection process of the included studies has been outlined to enhance transparency. To further facilitate the reader's understanding of the methodological flow, a PRISMA-style flow diagram (Page et al., 2021) has been incorporated to visually represent the identification, screening, eligibility, and inclusion phases of the literature search. This addition complements the narrative approach of SANRA by providing a clear depiction of the study selection pathway, thereby strengthening the methodological rigor of the review.

Figure 1. PRISMA 2020 flow diagram of the study selection process.

PRISMA 2020 Flow Diagram



2.9. Study Quality and Limitations

Study Quality and Limitations. As this work represents a narrative review conducted in line with SANRA recommendations, no formal risk-of-bias assessment or GRADE evaluation was undertaken. Nonetheless, several recurring methodological shortcomings were observed across the included studies (n = 10). These included relatively small sample sizes, heterogeneity in exercise selection and velocity-loss thresholds, underrepresentation of female and youth athletes, inconsistencies in device validity and inter-device reliability, limited reporting of effect sizes and confidence intervals, and potential risks of selection or measurement bias. Such limitations should be carefully considered when interpreting both the strength and the generalizability of findings on VBT.

3. RESULTS

In total, 10 studies fulfilled the eligibility criteria and were subjected to thematic analysis. The synthesized findings were organized into six overarching domains: (i) load–velocity profiling, (ii) strength-related adaptations, (iii) power and explosive performance, (iv) hypertrophic outcomes, (v) fatigue monitoring and training efficiency, and (vi) practical applications along with associated limitations. These results are summarized in the narrative synthesis and further illustrated in Table 1.

Table 1. Thematic Summary of Findings on VBT

Theme	Key Findings	Representative Studies
Load–Velocity Profiling	Linear load–velocity relationship enables individualized prescription	González-Badillo & Sánchez-Medina (2010); Banyard et al. (2017)
Strength Adaptations	VL thresholds **≤20–30%** improve strength and help manage fatigue	Pareja-Blanco et al. (2017); Dorrell et al. (2020)
Power & Explosive Performance	Low VL (**≤20%**) enhances sprint/jump performance	Pareja-Blanco et al. (2016); Loturco et al. (2019)
Hypertrophy	Higher VL (**≥30–40%**) promotes hypertrophy via metabolic stress	Sánchez-Medina & González-Badillo (2011); Weakley et al. (2021a)
Fatigue Monitoring & Efficiency	Velocity monitoring reduces unnecessary volume and optimizes efficiency	Pareja-Blanco et al. (2017); Weakley et al. (2021a)
Practical Applications	Portable devices increase accessibility; costs and validity variability remain limiting	Jovanović & Flanagan (2014); Orange et al. (2022)

Table 2. Summary of Consistencies and Contradictions in VBT Research

Theme	Consistencies	Contradictions / Limitations	Representative Studies
Load–Velocity Profiling	Strong load–velocity relationship; %1RM prediction	Variability across exercises and populations	González-Badillo & Sánchez-Medina (2010); Banyard et al. (2017)
Strength Adaptations	VL **≤20–30%** improves maximal strength	Some trials show similar gains with PBT; individual differences	Pareja-Blanco et al. (2017); Dorrell et al. (2020)
Power / Explosive Output	Low VL (≤10–20%) enhances sprint/jump	Non-elite results inconsistent	Pareja-Blanco et al. (2016); Loturco et al. (2019)
Hypertrophy	High VL (≥30–40%) induces hypertrophy	Often offset by fatigue and reduced explosiveness	Sánchez-Medina & González-Badillo (2011); Weakley et al. (2021a)

Fatigue Monitoring	VBT reduces unnecessary volume; tracks readiness	Reliable devices/access remain limitations	Pareja-Blanco et al. (2017); Weakley et al. (2021a)
Practical Applications	Hybrid (VBT+PBT) improves feasibility	Cost/learning curves; app validity concerns	Jovanović & Flanagan (2014); Orange et al. (2022)

Taken together, the evidence indicates that VBT is most effective when integrated as part of a hybrid approach, combining its precision in fatigue management with the accessibility of traditional percentage-based programming. Coaches should align velocity thresholds with training objectives (strength, power, hypertrophy) and consider contextual factors such as athlete experience, competition phase, and available resources.

Load–Velocity Profiling

The body of reviewed evidence consistently demonstrates a robust linear association between movement velocity and relative load, particularly in fundamental exercises such as the squat and bench press. This relationship enables reliable estimation of %1RM without the necessity of direct maximal strength testing, thereby facilitating the prescription of individualized training loads (González-Badillo & Sánchez-Medina, 2010; Banyard et al., 2017).

Strength Adaptations

Regulating training intensity through predefined velocity-loss thresholds (e.g., 20–30%) has been shown to promote favorable neuromuscular adaptations, yielding substantial improvements in maximal strength while simultaneously mitigating the risk of excessive fatigue and overtraining (Pareja-Blanco et al., 2017; Dorrell et al., 2020).

Power and Explosive Performance

Empirical evidence suggests that implementing low velocity-loss thresholds (10–20%) leads to notable improvements in explosive performance indicators, including vertical jump height and sprint velocity. Such outcomes highlight the relevance of VBT in sports contexts where maximal power production is a critical determinant of performance (Loturco et al., 2019; Pareja-Blanco et al., 2017).

Hypertrophy

Although hypertrophy is not the principal objective of VBT, research indicates that employing higher velocity-loss thresholds (30–40%) elevates metabolic stress, thereby promoting muscle hypertrophy. Nevertheless, these adaptations may come at the expense of explosive performance, as elevated fatigue levels can undermine neuromuscular efficiency (Sánchez-Medina & González-Badillo, 2011).

Fatigue Monitoring and Training Efficiency

Although hypertrophy is not the principal objective of VBT, research indicates that employing higher velocity-loss thresholds (30–40%) elevates metabolic stress, thereby promoting muscle hypertrophy. Nevertheless, these adaptations may come at the expense of explosive performance, as elevated fatigue levels can undermine neuromuscular efficiency (Sánchez-Medina & González-Badillo, 2011).

Practical Applications and Limitations

The wider availability of linear position transducers, accelerometers, and mobile-based applications has broadened the implementation of VBT within both elite and semi-professional training environments. Despite this progress, barriers such as high equipment costs, steep learning requirements, and inter-individual variability in velocity–load relationships continue to constrain its widespread adoption (Jovanović & Flanagan, 2014; Orange et al., 2022).

4. DISCUSSION

The synthesis of current evidence indicates that velocity-based training (VBT) provides an effective framework for enhancing strength, power, and fatigue management, though its outcomes are influenced by methodological design, athlete characteristics, and sport-specific demands. Low velocity-loss (VL) thresholds (<15–20%) consistently improve explosive performance outcomes such as countermovement jump (CMJ) height, sprint speed, and change-of-direction ability (Pareja-Blanco et al., 2017; Sekulović et al., 2024), supporting the principle that limiting intra-set fatigue promotes greater recruitment of fast-twitch fibers. In contrast, higher VL thresholds (>30%) appear to facilitate hypertrophic adaptations through greater metabolic stress, but at the expense of increased neuromuscular fatigue and potentially diminished explosive performance (Sánchez-Medina & González-Badillo, 2011). Importantly, systematic evidence suggests that VBT can achieve strength and power gains equal to or greater than conventional percentage-based training (PBT), often with reduced training volume and lower accumulated fatigue (Orange et al., 2022; Dorrell, Smith, & Gee, 2020). Nevertheless, inconsistencies exist, as demonstrated by Jiménez-Reyes et al. (2021), who reported superior outcomes with non-adjusted loads compared to velocity-adjusted protocols, highlighting the protocol-dependent variability of VBT's effectiveness. Athlete age and sex also moderate responsiveness to VBT; greater neuromuscular plasticity has been observed in younger athletes (González-Badillo, Marín, Pareja-Blanco, & Rodríguez-Rosell, 2015), while recent findings in female cohorts indicate comparable improvements to PBT but with reduced fatigue markers (Zhang et al., 2023). From a practical perspective, VBT equips practitioners with objective, real-time feedback that surpasses subjective measures such as ratings of perceived exertion (Mann, Ivey, & Sayers, 2015), yet widespread adoption remains limited by the cost, technical expertise, and validity of velocity-tracking devices (Weakley et al., 2021). Overall, VBT emerges as a valuable tool for individualized resistance training prescription, but further high-quality research is required to refine standardized guidelines across diverse populations, sporting contexts, and competitive levels.

5. CONCLUSION

This narrative review underscores the expanding body of evidence supporting velocity-based training (VBT) as a reliable and effective framework for prescribing and monitoring resistance exercise. In contrast to traditional percentage-based approaches, VBT provides greater precision for accommodating daily variations in performance capacity and for tailoring individualized load–velocity profiles (González-Badillo & Sánchez-Medina, 2010; Banyard, Nosaka, & Haff, 2017). The literature shows that low velocity-loss thresholds (≈≤20%) enhance maximal strength and explosive power (Pareja-Blanco et al., 2017; Pareja-Blanco et al., 2017—soccer), whereas moderate-to-high thresholds (≈≥30–40%) can facilitate hypertrophic adaptations but at the cost of greater neuromuscular fatigue (Pareja-Blanco et al., 2017; Sánchez-Medina & González-Badillo, 2011). From a practical perspective, adoption is influenced by the validity/reliability and cost of measurement devices as well as the technical expertise required (Weakley et al., 2021a; Balsalobre-Fernández et al., 2016). A hybrid approach that combines VBT with conventional methods is reasonable—especially given evidence that VBT and percentage-based training can produce broadly similar strength outcomes—while leveraging VBT's day-to-day autoregulation (Liao et al., 2021; Weakley et al., 2020/2021). Future research should broaden sampling to youth, women, recreational athletes, and rehabilitation contexts and continue developing more accessible, cost-effective velocity-monitoring technologies.

Future Directions

Future research should focus on several key directions to advance the application of velocity-based resistance training (VBT). First, there is a need to standardize protocols for velocity–load profiling to ensure consistency and comparability across studies. Additionally, further investigations should address underrepresented populations, including women, youth, and rehabilitation groups, to broaden the scope and inclusiveness of VBT research. Long-term adaptations should also be examined over entire competitive seasons to provide a clearer understanding of sustained performance outcomes. Finally, the development of cost-effective and accessible technologies is essential to enhance the feasibility of VBT implementation in applied field settings. By addressing these issues, the field can progress toward more precise, inclusive, and practically feasible applications of VBT, thereby bridging the gap between research and practice.

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