The Theoretical Basis and Application of Velocity-based Training

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Abstract

Currently, velocity-based training(VBT) is an effective way to improve exercise capacity, but how to recommend the ideal program based on the effects of VBT on maximum strength, power and related performance, related performance, muscle endurance, and hypertrophy is uncertain.This review attempts to summarize evidence and rationale for the application of velocity based training , and present the ideal program due to the effects of the VBT on maximum strength, power and related performance, muscular endurance and hypertrophy. Although the relevant studies showed the advantages of VBT, there is no clear evidence that VBT has advantages over PBT so far. Compared to PBT, VBT achieved similar or better effects at the same or significantly lower training volume. VBT with suitable load and LV can effectively improve maximum strength, jump ability, muscular endurance and thickness of adults and non-elite athletes. Research finding,VBT with high load should be suitable for developing 1RM, and low to moderate VL should be suitable for developing jump ability, especially for adults with resistance training experience. VBT with low VL and moderate load seemed suitable for athletes to improve power-related performance. VBT with high VL should be suitable for improving muscular hypertrophy. VBT lasting at least 8 weeks could usually achieve statistically significant results.

Keywords: Theoretical Basis; Application; Velocity-Based Training

Introduction

Strength is the ability of the body or the ability of apart of the body's muscles to overcome internal and external resistance while working. It is an important component of performance-related physical fitness. Muscle strength and other abilities and characteristics, such as power, endurance and hypertrophy, are closely related to the ability to complete vertical jumps, sprints and multi-directional movements. As such, it is also one of the key factors in improving performance. Resistance training (RT) is the most important means of improving muscle strength, power, endurance and hypertrophy. Different resistance training goals ,such as strength, power, endurance and hypertrophy, can be achieved through the specific arrangement of training type, sequence, load, number of repetitions and other variables (Crewther et al.,2005; Gonázlez- Badillo et al.,2011; Sánchez-Medina & Gonázlez-Badillo, 2011). Among them, the load is the most important variable that influences the strength and the achievement of other training goals (Flanagan & Jovanovi, 2014). In practice, the load is usually determined by the percentage of maximum load (%1RM) that the trainer can handle. The traditional process of RT is to first assess the trainer's maximum strength (1RM) and then design the intensity and amount of load required based on the trainer's goals before training, such as developing maximal strength with 85% 1RM and 6 repetitions. For this reason, it is also known as percentage-based resistance training (PBT).

* Received: April 3 2024; Revised: April 22 2024; Accepted: April 24 2024

However, PBT also has some limitations, including time-consuming (González-Badillo et al.,2011), frequent (Flanagan & Jovanovi, 2014) and unsafe during the 1RM test (Weakley et al.,2019), and the load cannot adapt to the state fluctuation of the day and lead to excessive fatigue during training (Kraemer W J & J, 2007; Zourdos et al.,2016). PBT relies more on the subjective feelings of the athletes and the experience of the coaches. VBT is a novel RT method that uses velocity as a means to control the load of training, and uses measurement equipment to provide timely feedback on movement velocity. For different training targets, VBT uses load-velocity curve (LVP),target velocity (target speed or intended velocity) and VL as the main variables to control the intensity and quantity of load, and arranges the corresponding number of repetitions, sets and intervals (González-Badillo et al.,2011; Sánchez-Medina & González-Badillo, 2011). In recent years, it has become a new hot spot in the field of strength training with its unique advantages, overcoming the disadvantages of PBT and showing better training effects. Many researchers who believe that VBT is a more effective method than PBT to improve muscle strength, power or straight-line sprinting ability.

Although the relevant studies showed the advantages of VBT, there is no clear evidence that VBT has advantages over PBT so far.This study provides a narrative review of the existing literature on the effects of VBT on maximum strength, strength and related performance, muscle endurance, and hypertrophy with the aim of providing recommendations for the use of VBT.

Rationale for the review

However, recent studies using meta-analysis have shown that VBT is superior to PBT is controversial (Baena-MarÌn et al.,2022; Banyard et al.,2021; Liao et al.,2021; Orange et al.,2022; Zhang et al.,2023), understanding the effects of VBT on 1RM, power, endurance and hypertrophy is still required. Meanwhile, no scholars have attempted to figure out how to select key variables, such as the intensity of load, the volume of load(including VL and the number of sets), interval time, and periodic arrangement, when designing training plans for different populations.

Intended audience and organization

Understanding the effect of VBT on 1RM, power, endurance and hypertrophy may allow coaches, medical departments, and researchers to improve training plans and progress.We provide this review for students, researchers, coaches, and training related practitioners who study or engage in sports physiology, strength, and conditioning training.

This review synthesized and critically analyzed relevant experimental studies involved the effects of VBT on 1RM, power and relative performance, muscular endurance and hypertrophy for providing a basis for the application of VBT. In addition, this review summarized the key variables researched in VBT and outlined practical recommendations for improving strength, power, endurance and hypertrophy for different populations.

Survey Methodology

Electronic searches of computerized databases were performed according to the search strategy jointly determined by all authors. Three databases-EBSCO SPORTDiscus, Scopus and Web of Science-were searched. A literature search for papers was carried out using keyword combinations: (1) velocity-based training Or velocity-based resistance training Or velocity-based strength training, (2) velocity loss Or velocity loss threshold (VL), (3) effects Or impact Or consequences Or influence Or outcomes.

A secondary search was performed by selecting the reference list and relevant review articles included in the study. The screening process was conducted using the following method: (1) all studies obtained were selected by title, and duplicates were deleted, and (2) an integral reading of the remaining studies was conducted, and those deemed outside the scope of the current review were excluded. The criteria for inclusion were as follows: (1) studies published in English, (2) full texts available, (3) studies involving athletes and adults, (4) including the indicators of strength, power, muscular endurance, hypertrophy and fatigue, (5) included any study that used resistance training with different percentages of 1RM and in which velocity was monitored during training.

The effects of VBT compared with itself and PBT for the main training purpose

1RM. A study by Loturco et al.,(2015) showed that VBT with two deep squat exercises per week during the first 6 weeks of the season was effective in improving the 1RM squat in elite soccer players. 7 studies compared the effects of VBT and PBT on 1RM, and three of them demonstrated that VBT was statistically more effective than PBT in improving 1RM (Andersen et al.,2021; Banyard et al.,2021; Dorrell et al.,2020; Held et al.,2021; Kilgallon et al.,2021; Muñoz-López et al.,2022; Ortega J A F et al. 2020). For example, Dorrell et al.,(2020) compared the effects of VBT and PBT on 1RM in adults with RT experience. Held et al.,(2021) explored the effects of VBT and PBT on 1RM in rowers. They both found that VBT was more effective in improving 1RM during routine exercises such as back squat, bench press and dead lift. In contrast, Banyard et al.,(2021) found that both PBT and VBT were effective in improving the 1RM back squat in adults with RT experience, and that PBT improved the 1RM back squat more than VBT (12.5% vs. 11.3%), but the difference between PBT and VBT in improving the 1RM back squat was not statistically significant. More recently, Kilgallon et al.,(2021) found thatPBT significantly improved the 1RM floor press in professional American football athletes, while VBT had no significant effect, suggesting that VBT may not be the best option for elite athletes to develop maximal upper body strength in the short term. Most of the existing controlled trial studies have shown that VBT improves 1RM training better than or equal to PBT. Inconsistencies in previous studies may be due to differences in subjects' training levels and intervention duration. For example, studies demonstrating the superiority of PBT over VBT lasted less than 6 weeks, whereas studies demonstrating the superiority of VBT over PBT typically lasted longer than 8 weeks. Therefore, more research is needed in terms of subjects' training levels and duration of training.

Many scholars have explored the optimal VL for developing 1RM in VBT (Andersen et al.,2021; Galiano et al,2023; González-Badillo et al.,2015; Pareja-Blanco et al.,2020b; Pareja-Blanco et al.,2017a; Pérez-Castilla et al.,2018; Rissanen et al.,2023; Rodiles-Guerrero et al.,2022; Rodiles-Guerrero et al.,2020; Rodríguez-Rosell et al.,2020; Rodríguez-Rosell et

al.,2021; Sánchez-Moreno et al.,2020). Most previous studies have shown that lower VL (0%-25%) is more effective in training male subjects to develop 1RM, although there is no statistically significant difference between moderate VL to higher VL (30%-50%). For example, Rodiles-Guerrero et al.,(2020) and Sanchsanz-Moreno et al.,(2020) explored the effect of VBT to improve upper body strength training and showed that compared to moderate VL and higher VL (VL30, VL25, VL20 for bench press and VL50 for pull-ups), lower VL (VL15, VL10 for bench press andVL25 for pull-up) significantly improved the 1RM pull-up and 1RM bench press in adults with RT experience (Pareja-Blanco et al.,2020a; Rodiles-Guerrero et al.,2020). However, one study showed that female subjects developed 1RM better using higher VL (40%) than lower VL (20%) (Rissanen et al.,2023). VL10, VL15, VL20 and VL25 all have the potential to improve 1RM, and future studies are needed depending on specific conditions, such as gender and training experience.

The Power and Related Performance. Six studies compared the effects of VBT and PBT on jumping ability and found that VBT was effective in developing the power of the lower limb, particularly on the CMJ (Banyard et al.,2021; Dorrell et al.,2020; Held et al.,2021; Orange et al.,2019; Ortega J A F et al.,2020; Randell et al.,2011). For example, Ortega et al.,(2020) found that VBT for 12 weeks, three times per week, significantly improved performance on the CMJ, power in the deep squat, and maximal power in the Wingate anaerobic test, and demonstrated that VBT improved training in female child soccer players better than PBT. This may be due to the fact that the velocity of the exercise movements in VBT more closely resembles the CMJ, thus causing neuromuscular adaptive changes. However, when adult athletes were selected as the study subjects to compare the effects of VBT and PBT, there was no statistically significant improvement in either group after the training intervention.

Sprinting ability and the ability to change direction is closely related to the explosive power of the athlete's lower limbs. However, studies have been conducted to show that VBT does not have an outstanding potential to develop sprinting ability and the ability to change direction compared to PBT. For example, a study by Orange et al.,(2019) found that both VBT and PBT performed twice weekly for 7 weeks were effective in improving lower body strength and power in college rugby players, but negatively affected performance in the 5, 10, 20, and 30m sprints. A study by Banyard et al.,(2021) showed that VBT performed twice weekly for 6 weeks significantly improved weighted jumping, sprinting and change of direction in adults with RT experience, with better results than the PBT group.

Seven studies compared the effects of different VL on jumping ability and sprinting ability and demonstrated that VBT with lower VL was more effective in improving jumping ability and sprinting ability in subjects than VBT with moderate or higher VL, especially in adult males with RT experience(Galiano et al.,2023; González-Badillo et al.,2015; Grazioli et al.,2020; Pareja-Blanco et al.,2017a; Pérez-Castilla et al.,2018; Rodríguez-Rosell et al.,2020; Rodríguez-Rosell et al.,2021). For example, González-Badillo et al.,(2015) studied the effect of VBT with different VL (15% vs. 30%) on the performance of professional soccer players and found that after three weekly interventions for 6 weeks, the VL15 group was effective in improving CMJ performance, while the VL30 group negatively affected CMJ.Galiano et al.,(2023) found that after a 7-week VBT intervention twice a week, different VL (5% vs. 20%) were effective in improving CMJ and 20 m sprint performance in young men with RT experience, and the VL5 group obtained similar training effects to the VL20 group at a

significantly lower training volume. Pérez-Castilla et al.,(2018), Pareja-Blanco et al.,(2020) and Rodríguez-Rosell et al.,(2021) investigated the effects of deep squats and deep squat jumps using different VL on neuromuscular performance and found that the lower VL group (10%) improved CMJ and 10m and 20m sprint performance better than those with moderate to higher VL (20%, 30%, 40%, and 45%). Grazioli et al.,(2020) studied the training effects of sled training using different VL (10% vs. 20%) on professional soccer players and showed that the application of the low VL10 group was effective in improving the participants' 10m and 20 m sprint performance. Orange et al.,(2019) argued that the improvement in jumping ability obtained through deep squat and squat jump training needs to be translated into sprint running ability through some translating training. Training at a specific velocity can produce corresponding neuromuscular adaptations, and high-speed repetitions can adapt the neuromuscular system and improve the ability to perform fast movements, but exceeding a certain limit of VL (more than 30%) may lead to a decrease in movement quality, slow movements, and fatigue accumulation, allowing the neuromuscular system to adapt toward slow speed and endurance, ultimately leading to a decrease in CMJ and sprinting performance (Behm & Sale, 1993).

Muscular Endurance. The effect of VBT on muscular endurance is usually assessed by a fatigue test that requires subjects to perform as many repetitions as possible at a 70% 1RM load. Currently, there are no studies comparing the effects of VBT and PBT in improving muscular endurance. VBT over 8 weeks significantly improved muscular endurance in adult males with RT experience under both moderate and moderate to high load conditions, and better neuromuscular adaptations could be achieved at lower training volumes by using lower VL. Five studies have examined the effects of VBT at different VL and loading conditions on muscular endurance in adult males with RT experience (Pareja-Blanco et al.,2020a; Pareja-Blanco et al.,2020b; Rodiles-Guerrero et al.,2022; Rodríguez-Rosell et al.,2021; Sánchez-Moreno et al.,2020). For example, Pareja-Blanco et al.,(2020) examined the effect of VBT at moderate to higher loads (70%-85%1RM) for 8 weeks on muscular endurance of the lower body and found that the low VL group (0%), the moderate to low VL group (10%, 20% and 30%) and the high VL group (40%, 45%) all showed statistically significant improvements in fatigue test scores, but there were no statistically significant differences in the effects between groups, although the high VL group had significantly higher training volume. Rodríguez-Rosell et al.,(2021) examined the effect of moderate loading (55%-70% 1RM) at an 8-week VBT on endurance of lower limb muscles and found that different VL groups (10%, 30% and 45%) significantly improved muscular endurance. Pareja-Blanco et al.,(2020) found that VBT at moderate to higher loads (70%-85% 1RM) with different VL (0%, 15%, 25% and 50%) were able to significantly improve the endurance of upper limb muscles.

Hypertrophy. Muscle mass is the structural basis for maximum muscle strength, power and endurance. Previous studies assessed the effect of VBT on muscle hypertrophy mainly by muscle cross-sectional area (CSA), myosin heavy chain (MHC) and muscle volume (MVL) and found that moderate to high VL significantly promoted muscle hypertrophy, but high VL (>40%) resulted in the loss of fast muscle fibers (Andersen et al.,2021; Pareja-Blanco et al.,2020a; Pareja-Blanco et al.,2020b; Pareja-Blanco et al.,2017a; Rissanen et al.,2023; Rodiles-Guerrero et al.,2022) . Pareja-Blanco et al.,(2017) studied investigated the effect of VBT at different VL conditions (40%, 20%) on the quadriceps structure of male college students in physical education and found that the muscle cross-sectional area increased more significantly in the VL40 group, and the area and muscle mass of type I muscle fibers and type

II (including IIC, IIA, IIAX, and IIX) muscle fibers increased significantly in the VL40 group, but the muscle length and the Type II muscle fibers did not change significantly, and the proportion of Type IIX muscle fibers in Type II muscle fibers decreased significantly, while Type IIX muscle fibers in the VL20 group remained largely unchanged. Pareja-Blanco et al.,(2020) studied the effects of VBT under different VL conditions on muscles in the upper and lower extremities of male college students majoring in physical education circumference and found that muscle cross-sectional area increased significantly in all groups after the intervention, with no statistically significant difference in effect between the high VL group (50%, 40%) and the medium VL group (25%, 20%), but a significant decrease in force development rate in the high VL group. Andersen et al.,(20201) found that unilateral lower extremity with different VL (30%, 15%) and the same total training volume training could slightly promote quadriceps hypertrophy. Previous studies have demonstrated that muscle hypertrophy, as an adaptive change in muscle structure, requires relatively high levels of fatigue (exhaustion) and total training volume (González-Badillo et al. 2005; Sánchez-Medina & González-Badillo 2011; Schoenfeld 2010). Although no studies have compared the role of VBT and PBT in promoting muscle hypertrophy, VBT at moderate VL (20-25%) can effectively promote muscle hypertrophy while improving neuromuscular adaptations at relatively low training volumes and moderate fatigue (non-exhaustion).

Key variables should be considered in the application of VBT

Intensity of Load. For the specific training purpose, various loads should be chosen by different subjects. The velocity range corresponding to moderate to high intensity (60% -

95%1RM) seemed the appropriate magnitude of intensity for non-athletes to develop maximum strength and power of the lower body, while athletes usually used a relatively higher load (70%-85% 1RM) to improve maximum strength (Pareja-Blanco et al.,2020a; Pareja-Blanco et al.,2020b; Pareja-Blanco et al.,2017a; Rodiles-Guerrero et al.,2020; Rodríguez-Rosell et al.,2020), and a faster target velocity (1.0 -1.2 m·s-1) to develop power specifically (Galiano et al.,2023; González-Badillo et al.,2015; Pérez-Castilla et al.,2018). It is recommended to use V1LOAD as the optimum intensity for athletes to develop power by squats (González-Badillo et al.,2015). Developing endurance and thickness of muscle need moderate to relatively high intensity (55% -85%1RM) (Pareja-Blanco et al.,2020a; Pareja-Blanco et al.,2020b; Rodiles-Guerrero et al.,2022).

Volume of Load(include VL and number of sets) and Interval Time. Training context involved 3-4 sets of exercise and 3-4 minutes' rest are commonly used by VBT. The training effect of different VL (0% -50%) has been explored in the existing literature about VBT. VL10 or VL20 with three to four sets and 3- to 4-min intervals is recommended for exercises for lower limbs as the ideal load and interval for developing maximum strength, CMJ and muscular endurance (Galiano et al.,2023; Ortega J A F et al.,2020; Pareja-Blanco et al.,2020b; Pérez-Castilla et al.,2018; Rodríguez-Rosell et al.,2021). VL5 or VL10 with three to four sets and 3- to 4-min intervals is recommended as an ideal load and interval for developing short-distance sprint ability (Galiano et al.,2023; Grazioli et al.,2020; Pérez-Castilla et al.,2018; Rodríguez-Rosell et al.,2020; Rodríguez-Rosell et al.,2021). VL40 with three to four sets and 3- to 4-min intervals is recommended as an ideal load and interval for developing maximum strength, endurance and thickness of muscle (Pareja-Blanco et al.,2020b; Pareja-Blanco et al.,2017a). VL25 with three to four sets and 3- to 4-min intervals is

recommended as an ideal load and the interval for exercises to improve maximum strength and endurance of the upper body (Pareja-Blanco et al.,2020a; Rodiles-Guerrero et al.,2022; Sánchez-Moreno et al.,2020).

Periodic Arrangement. A recent review of studies concluded that a set of 6-12 repetitions until exhaustion at a load of 70%-85% 1RM, two to three times a week for 8-12 weeks of training might be the minimum training dose required to increase strength (Androulakis-Korakakis et al.,2020). Previous studies about VBT showed that significantly improved Maximum strength, jump height, muscle endurance, and muscle thickness by VBT need more than 8 weeks and twice sessions a week. Previous studies adopted five periodic training arrangements on VBT, such as the fixed optimal velocity of power development (undulating increasing load), steadily increasing load (decreasing velocity), undulating increasing load (unfixed velocity), decreasing load (increasing velocity), and undulating decreasing load, and compared their effects. The results showed that the aforementioned periodic arrangement significantly improved the maximum strength, vertical jump height, and 20-m sprint performance of non-athletes. However, the periodic arrangement with fixed optimal velocity of power development had a relatively better effect on improving power, while the nonlinear periodic arrangement (undulating increasing or decreasing) had the worst effect on improving the 3 maximum strength and endurance of muscle. Therefore, it was not recommended to use the nonlinear periodic arrangement to develop the power (Loturco et al.,2013; Martínez-Cava et al.,2021; Muñoz-López et al.,2022; Randell et al.,2011; Rauch et al.,2018; Riscart-López et al.,2021; Rissanen et al.,2023; Rodríguez-Rosell et al.,2017; Sánchez-Moreno et al.,2021).

Others. In addition to the intensity of load, the amount of load, the rest time between groups, and the periodic arrangement of training, there is also the tempo of movement and training combination that affect the effect of VBT (Martínez-Cava et al.,2021; Rodríguez-Rosell et al.,2017; Sánchez-Moreno et al.,2021). A study suggested using the movement without pause to improve CMJ performance, and using the movement with a pause to improve the starting velocity and anaerobic power (Martínez-Cava et al.,2021). A study advised using the combination training method of VBT plus plyometrics to improve the lower limb power of elite athletes (Rodríguez-Rosell et al.,2017). A study recommended using VBT in the concurrent training training of strength and endurance to avoid the negative impact of PBT on neuromuscular performance and further improve the effect of training on endurance (Sánchez-Moreno et al.,2021).

Table 1: Study of VBT tempo of movement and training combination

Author	Subject	Drills	Program	Duration	Effects
Martínez-Cava et al (Martínez-Cava et al.,2021),2021	26 well-trained men: PAUSE (n = 13) and REBOUND (n = 13)	Free weight	PAUSE: minimize the contribution of the stretch-shortening cycle REBOUND: taking advantage of the stretch-shortening cycle	10weeks; twice a week	PAUSE: ES = 0.76–1.12 REBOUND: ES = 0.45–0.92
Rodríguez-Rosell et al(Rodríguez-Rosell et al.,2017),2017	30 adult soccer players : FSG(n = 10), COM(n = 10) and control group CG(n = 10)	Free weight	FSG: assigned to perform only FS COM: performed FS combined with jump and sprint exercises CG: merely conducted typical soccer	6weeks; twice a week	FSG: ES=0.52 COM: ES=0.69 CG: ES=－0.17

			training VL15%： concurrent strength and endurance training VL45%： concurrent strength and endurance training EG： endurance training		
Sánchez-Moreno et al(Sánchez-Moreno et al.,2021),2021	33 resistance- and endurance-trained men: VL15%(n=11),VL45%(n=11), and endurance group EG(n=11)	Free weight		8weeks; twice a week	VL15%：ES=0.24 VL45%：ES=0.22 EG：ES=－0.18

Source of the data: collected from the research.

Conclusion

No clear evidence exists to date on the superiority of VBT over PBT, especially in elite athletes. By setting suitable VL, VBT can achieve the same or better training results as PBT while significantly reducing the amount of training, and can significantly improve strength and power-related performance. There's a mountain of evidence suggests that moderate to high load (i.e.,60%-85%1RM) is suitable for developing 1RM, and low to moderate VL (i.e., 10%-20%) is suitable for developing jump ability, especially for adults with RT experience. Low VL and moderate load (V1LOAD) seemed more suitable for athletes to improve power-related performance from aspects of avoiding excessive fatigue and reducing the negative impact on the latter session. Moreover, a solid body of evidence suggests that high VL (i.e., 40%-50%) is suitable for improving muscular hypertrophy. The program of VBT included 3-4 sets of exercise and 3-4 minutes rest, arranged 2 times a week, and last 8 weeks at least, can usually achieve statistically significant effects.When developing sprint ability, Coaches need to consider adding transformation training to translate the explosive force in a vertical direction obtained by VBT into explosive force in a horizontal direction. In addition to the intensity of load, the amount of load, the rest time between groups, and the periodic arrangement of training, there are also the issues with tempo of movement, the complex training and the concurrent training considered by researchers. Therefore, further research is needed on how to apply the tempo of movement and various training combinations to achieve specific training goals.

New Body of Knowledge

About VBT:

1.That moderate to high load (i.e.,60%-85%1RM) is suitable for developing 1RM, and low to moderate VL (i.e., 10%-20%) is suitable for developing jump ability, especially for adults with RT experience.

2.Low VL and moderate load (V1LOAD) seemed more suitable for athletes to improve power-related performance from aspects of avoiding excessive fatigue and reducing the negative impact on the latter session.

3.When developing sprint ability, Coaches need to consider adding transformation training to translate the explosive force in a vertical direction obtained by VBT into explosive force in a horizontal direction.

4. In the VBT study, in addition to the intensity of load, the amount of load, the rest time between sets, and the periodic arrangement of training, researchers also consider issues with tempo of movement, complex training and concurrent training.

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