Effects of Assisted Jumping on Vertical Jump Parameters

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Abstract

Vertical jumping ability is a critical skill for success in many sports. Previous studies have reported conflicting results on the effects of heavy-load, light-load, contrast, or plyometric training to improve vertical jump height. A novel jump training method, using assistance via elastic cords or an absolute weight, has received little attention. These studies, using an overspeed paradigm, support assistance as an effective training method compared with free or overload jump training. However, there is a lack of investigation and standardization related to the critical assisted jump training variables of frequency, intensity (assistance level), volume, and rest. Therefore, the purpose of this review was to provide an overview of assisted jump training, associated variables, and potential benefits to enhance vertical jump height.

Introduction

Improving vertical jump continues to be of great interest for sport scientists and practitioners as they continuously strive to find effective training methods to increase vertical jump with minimal risk of injury. Traditionally, training methods have utilized an overload system of low-velocity heavy-load training. In addition, contrast, plyometrics, or combinations of these in a training program also have been shown to positively influence vertical jump performance (1). Plyometric jump training has been a popular practice that primarily utilizes body weight as resistance and employs the stretch-shortening cycle to increase vertical jump performance. However, an overspeed system utilizing an assisted high-velocity light-load method recently has received renewed interest (1,15–17,20,22,24). This emerging method recently has reported improvements in vertical jump height (JH) (1,16,20,22,24) by reducing body weight and assisting the jumper into the air. This form of training, termed "overspeed," may increase the athlete's takeoff velocity (TOV), thus leading to greater JH.

The overspeed concept has been examined extensively in sprinting (2,7–9, 18,19,21); however, it has not been researched broadly in the vertical jump. Overspeed is a means of assisting an athlete to sprint faster or jump faster than he or she can achieve under a body weight condition. The underlying theory is that an athlete can reduce his or her body weight via an assisted device that increases lower limb speed, resulting in greater sprint speed or JH. This increased velocity may occur in the absence of increased force production (4) leading to greater lower limb power. The ability to generate power is of great importance in athletic performance (6,13) and often determines the outcome of a competition. Depending on the demands of the sport, training should replicate specific movement speeds to allow the body to adapt in a sport-specific manner. Therefore, this type of assisted training, which increases velocity, is contrasted with traditional overload training that requires subjects to lift or jump against a heavy load, thereby decreasing velocity (11).

Assisted sprint methods such as downhill sprinting (8,9), treadmill sprinting (19), and towing via elastic cords (3,7) or a vehicle (21) have been used in an effort to increase sprint speed via stride rate and stride length. Previous studies have demonstrated that supramaximal sprinting (>100%) via assisted devices improves sprint time (2,8,9,18,19,21). Similar to assisted sprinting, the overspeed concept also may be incorporated into a vertical jump training environment. Borrowed from the concept of "tow training" for sprinters, early pioneers such as Cavagna *et al.* (5) and Imachi *et al.* (12) applied this innovative training method by utilizing a pulley system to assist athletes to jump faster via elastic cords suspended overhead. Recent studies also have utilized elastic cords as a means of overspeed method in a vertical direction and have demonstrated increases in vertical JH (1,16,20,22,24). With limited research on assisted vertical jumping, practitioners may question what levels of assistance are optimal to develop greater lower limb velocity

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without altering jump mechanics. Similar to overspeed sprinting, minimal assistance may result in none or limited adaptation, whereas excessive assistance may alter vertical jump mechanics.

It is important to note that previous studies have not standardized absolute or relative assistance levels or the mechanical properties of the elastic cords. Therefore, it remains unclear what are the optimal assistance levels and how the modulus of elasticity of the different cords affect vertical jump. To better understand how elastic cord assistance affects jumping, further study is needed to investigate standardization of the critical variables associated with this type of method. The following overview seeks to provide insight into this emerging method as well as stimulate future research.

Concept of the Overspeed Method

Limb speed is an important sport component regardless of the level of competition. Overspeed enables an athlete to increase his or her limb velocity beyond his or her maximal level (supramaximal), thus increasing power output. Previous overspeed sprinting studies (2,8,9,18) have demonstrated various methods to optimize sprint performance and have shown that the assisted sprint method maximizes sprint speed via stride length or stride rate. Some have investigated overspeed method via downhill slopes to enhance sprint speed (8,9,18). Ebben (8) measured downhill sprinting velocity and acceleration in 44 male athletes as they ran down five slopes ranging from 3.4° to 6.9°. They concluded that 5.8° was the optimal slope as determined by decreased sprint time in 10- and 40-yd splits. In another study, Ebben *et al.* (9) used 13 male athletes and found similar results. A downhill slope of 5.8° also was determined to be optimal for decreasing sprint time when compared with the slower times at slopes of 2.16°, 3.3°, 4.7°, and 6.9°. The increase in sprint time at a slope of 6.9° may be due to the foot landing farther from the center of mass, therefore creating a braking mechanism in an attempt to prevent falling (9).

In a similar study, Paradisis and Cooke (18) investigated sprint training on a customized 3° uphill-downhill platform. After 6 wk of training, the downhill group demonstrated increased sprint speed and stride rate. The combined uphill-downhill group also significantly decreased their sprint time and increased their stride rate. They suggested that stride rate and stride length should be considered when attempting to maximize sprint speed. This is in agreement with Corn and Knudson (7), who stated that sprint speed is a function of stride rate and stride length; therefore, increasing sprint speed may be accomplished via increases in either or both. Use of the overspeed concept via downhill running may have the greatest impact on stride rate.

Bartolini *et al.* (2) investigated sprint performance in collegiate women soccer players via elastic cord assistance to determine an optimal assistance level. Their study utilized 10% to 40% body weight assistance and concluded that 30% elastic cord assistance was the optimal assistance level for maximizing sprint time in distances up to 15 yd. They also showed that in increments of 5 yd out to 20 yd, split times decreased as body weight assistance increased to 30%. Although their study did not investigate stride rate or stride length, they demonstrated that elastic cord assistance can decrease sprint time. Collectively, these findings support the overspeed concept as a means to enhance sprint speed. Therefore, this horizontal overspeed concept also may be utilized as an assisted methodology in a vertical environment to increase TOV and JH.

Absolute Assistance for Overspeed

Absolute assistance utilizes a constant force across individuals to reduce their body weight during vertical jumping; however, an absolute assistance level does not account for individual subject differences. Therefore, it is necessary to standardize assistance level as a critical variable in order to establish individualized body weight reduction (BWR). For example, in the traditional resistance training overload model, the critical variables of frequency, intensity, volume, and rest have been studied extensively as they relate to hypertrophy, strength, power, and muscular endurance. Prescribing relative load percentages (intensity) of an individual's one-repetition maximum (1RM) when performing resistance training is imperative to provide progressive overload continuously, prevent overtraining, and increase maximal strength and power. Differences between individuals such as age, sex, or training status also affect training and overload prescription. Therefore, prescribing an absolute load for an entire group of people may not be optimal for each individual. Similar to the resistance training overload model (%1RM), standardizing assistance levels for overspeed training based on a criterion method is critical as it relates to intensity.

Historically, vertical jump studies have used resisted (overload), assisted (BWR), or body weight (free) alone as a measure of intensity to determine the transfer of training to free jumping. Previous absolute assistance BWR studies have demonstrated increases in velocity and JH (1,20). Sheppard *et al.* (20) reported that assisted jump training using an absolute assistance of 10 kg increased peak vertical acceleration and velocity of free jumping for volleyball players over a 5-wk period. They demonstrated that assistance training resulted in approximately a 2.7- and 4.6-cm improvement in the countermovement free vertical jump and spike jump, respectively. In another study, Argus *et al.* (1) investigated contrast training in addition to assisted, free, and resisted jump training over a 4-wk period using an absolute assistance force of 27% ± 3% BWR. They reported that assisted vertical jump training increased free JH by 6.7% (±9.6%) compared with 1.3% (±9.2%) for free training. The studies of Sheppard *et al.* (20) and Argus *et al.* (1) are in agreement that assisted jump training with an absolute assistance force seems to positively influence free JH in highly trained athletes. However, although free JH increased, other critical variables such as force, velocity, or power were not reported by Argus *et al.* Therefore, it remains unclear which free vertical jump parameters may be impacted via an absolute assistance force.

Relative Assistance for Overspeed

Assisted jumping via elastic cords is a novel method used for jump training, which reduces body weight using a customized overhead pulley system (5,12,15,16,20,22) or cords attached at both hips (1). With this method, individuals wear a full-body harness that is secured around the shoulders and pelvic area or wear a belt around their waist. With the pulley system, one end of the elastic cord is attached to the harness while the other end is attached overhead (Fig.). With the waist belt system, cords are attached and pulled upward and attached on both sides to a power rack (1). Relative assistance is measured by having the individual stand completely still on a force plate to determine body weight. Once body weight is obtained, the individual is assisted by reducing his or her body weight by a percentage (*i.e.*, BWR). For example, if the level of assistance is 30% and an individual weighs 150 lb, then he or she would be reduced by 45 lb till his or her weight was measured on the force plate as 105 lb.

Reducing body weight via elastic cords assists the individual by increasing TOV (22). It also allows for the intensity of training (BWR) to be prescribed carefully in a relative and individualized manner. This method seems to be an effective method of jump training compared with free training alone to increase JH. However, as in all forms of training, the outcome is largely dependent on the intensity of the activity as manipulated by BWR level, elastic cord tension, and the system used for assistance. Cavagna *et al.* (5) were one of the first to apply the assisted jump concept using an overhead pulley system. This innovative method involved BWR to different gravity (*g*) values. They estimated that as body weight was reduced from 1*g* to 1/6*g*, TOV increased from 2.6 to 3.7 $m{\cdot}s^{-1}$. This increased TOV of 3.7 $m{\cdot}s^{-1}$ corresponded to an estimated vertical JH of approximately 157 inches. Although their study utilized only two participants, they provided a unique foundation for future studies.

Imachi *et al.* (12), another pioneer in this type of training, demonstrated significant improvements in TOV with assisted jump training compared with free jumping. They conducted a study on the effects of "suspension" training on vertical jumping ability over a period of 10 wk. Male high school volleyball players were assigned to one of three groups: free jump, 10% BWR, or 20% BWR. They demonstrated that 10% and 20% BWR training was a superior method for increasing free JH when compared with free training. However, there was no significant difference between 10% and 20% BWR. They then followed up using 10% BWR in female athletes and also found increased free vertical JH. Imachi *et al.* also reported that assisted jump training seemed to be ineffective for nonathletes. Regardless of gender, assisted jump training demonstrated an improvement in free vertical JH for athletes compared with nonathletes. In addition, they also concluded that assisted jump training seems to be ineffective when jumping is performed with the arms restricted, as would be done with hands on hips. It has been suggested that arm swing contributes to greater JH through increased TOV because of the ability of the arms storing elastic energy during the swing phase (14).

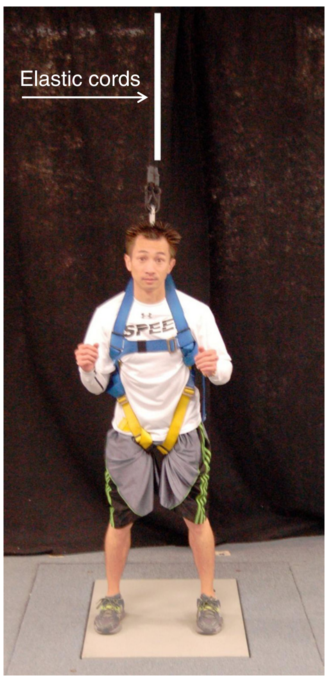

Figure: Subject in an assisted jump apparatus.

Three more recent studies performed by Markovic and Jaric (15), Markovic *et al.* (16), and Vuk *et al.* (24) compared free jumping to either assisted or resisted jumping at 30% BWR or 30% overload. They demonstrated that overload jumping resulted in greater peak ground reaction force, yet peak velocity and peak power were reduced (15). Furthermore, power was greatest in the free condition, so they concluded that 1*g* seems to maximize jumping power performance. They followed up with a 7-wk training study (16) that examined jumping with either 30% overload (using dumbbells) or 30% BWR. Their results demonstrated that 30% BWR training resulted in greater free JH and peak velocity when compared with 30% overload training. These findings are consistent with Vuk *et al.* (24), who had both trained and untrained subjects perform vertical jumps across a spectrum of assisted and resisted loads varying between 30% BWR and 30% overload. They reported that assisted jumping significantly increased JH and peak velocity compared with free jumping. Also, similar to Imachi *et al.* (12), they found that the changes in trained athletes were significantly greater than those in untrained subjects. Some of the seemingly conflicting results of these studies related to free versus BWR may be due to differences in the properties of the elastic cords used or the apparatus used for overload training.

Argus *et al.* (1) also investigated 20% BWR, 20% overload, or free jumping. Their results demonstrated that BWR jumping increased peak velocity ~37% and ~6% greater than resisted and free jumping, respectively. In a comparable study by Nuzzo *et al.* (17), they demonstrated that free jumping was optimal to achieve peak and mean power output during a countermovement free jump in trained and untrained male subjects. A similar finding by Markovic and Jaric (15) found that mean power was achieved at body weight. However, there was a discrepancy in peak power output between Markovic and Jaric (15) and Nuzzo *et al.* (17). Peak velocity and power increased as BWR increased in the study of Markovic and Jaric (15), whereas Nuzzo *et al.* (17) reported decreases in peak power as BWR increased. Nuzzo *et al.* stated the differences might be due to either the elastic cords used in the study of Markovic and Jaric or the pulley system used. Instead of using elastic cords, Nuzzo *et al.* used a counter mass to keep a constant pull during the jumps. These results demonstrate the

Table
Summary of assisted jump studies.

Study	Training Status	Weeks of Training	Assistance Level (BWR)	Elastic Modulus Reported	GRF (N)	TOV ($m \cdot s^{-2}$)	Power (W)	JH (cm)
Argus *et al.* (1)	[1] 8 Rec trained males	[1] N/A	[1] 20%	No	[1] ↓	[1] ↑	[1] ←→ (rPP)	[1] N/A
	[2] 9 pro rugby males	[2] 4 wk, 2 $d \cdot wk^{-1}$	[2] 22% to 34% absolute load		[2] N/A	[2] N/A	[2] N/A	[2] ↑
Cavagna *et al.* (5)	2 untrained males	N/A	0.15*g*, 0.22*g*, 0.39*g*, and 0.46*g*	No	N/A	↑ all levels	↑ 0.22*g*, ↓ 0.15*g*, 0.39*g*, and 0.46*g*	↑ all levels
Imachi *et al.* (12)	[1] 12 trained males	[1] 10 wk, 3 $d \cdot wk^{-1}$	[1] 10% and 20%	No	N/A	[1] N/A	[1] N/A	[1] ↑
	[2] 10 trained females	[2] 8 wk, 3 $d \cdot wk^{-1}$	[2] 10%			[2] N/A	[2] N/A	[2] ↑
	[3] 21 untrained males	[3] 8 wk, 3 $d \cdot wk^{-1}$	[3] 10%			[3] N/A	[3] N/A	[3] ←→
	[4] 10 untrained males	[4] 8 wk, 3 $d \cdot wk^{-1}$	[4] 10% and 20%			[4] N/A	[4] N/A	[4] ←→
	[5] 10 trained females	[5] 8 wk	[5] 10%			[5] ↑	[5] ←→	[5] N/A
Markovic and Jaric (15)	15 untrained	N/A	15% and 30%	No	↓ 15%	↑ 15% and 30%	←→ 15% and 30%	N/A
Markovic *et al.* (16)	10 untrained	7 wk, 3 $d \cdot wk^{-1}$	15% and 30%	Yes	←→ 15% and 30%	↑ 15% and 30%	←→ 15%, ↑ 30%	↑ 15% and 30%
Nuzzo *et al.* (17)	[1] 14 trained males	N/A	[1] 10%, 20%, and 30% MDS	N/A	N/A	N/A	[1] ↓ 10% to 30% MDS	N/A
	[2] 6 untrained males		[2] 10%, 20%, 30%, and 40% MDS				[2] ↓ 10% to 30% MDS	
Sheppard *et al.* (20)	7 trained males	5 wk, 3 $d \cdot wk^{-1}$	10-kg absolute load	N/A	↓ CMJ	↑ CMJ	N/A	↑ CMJ
					↓ SPJ	↑ SPJ		↑ SPJ
Tran *et al.* (22)	[1] 15 untrained males	N/A	10%, 20%, 30%, and 40%	Yes	[1] ←→ 10%, ↑ 20% to 40% (rGRF)	[1] ←→ 10% and 20%, ↑ 30% and 40% (rGRF)	[1] N/A	[1] ↑ all levels
	[2] 15 untrained females				[2] ←→ 10%, ↑ 20% to 40% (rGRF)	[2] ←→ 10% and 20%, ↑ 30% and 40% (rGRF)	[2] N/A	[2] ↑ all levels
Vuk *et al.* (24)	[1] 9 trained males	NA	15% and 30%	No	[1] ←→ 15%, ↓ 30%	[1] ↑ 15% and 30%	[1] ↑ 15% and 30%	[1] ↑ 15% and 30%
	[2] Speed-trained males				[2] ←→ 15%, ↓ 30%	[2] ↑ 15% and 30%	[2] ↑ 15% and 30%	[2] ↑ 15% and 30%
	[3] 10 untrained males				[3] ←→ 15%, ↓ 30%	[3] ↑ 15% and 30%	[3] ↑ 15% and 30%	[3] ↑ 15% and 30%

Results are compared with free body weight jumps.

CMJ, countermovement jump; GRF, ground reaction force; MDS, maximal dynamic strength (1RM + [body mass − shank mass]); Pro, professional; Rec, recreational; rGRF, relative ground reaction force ($N \cdot kg^{-1}$); rPP, relative peak power ($W \cdot kg^{-1}$); SPJ, spike jump.

importance of standardizing the assistance levels, as it affects vertical jump parameters.

In a descriptive study by Tran *et al.* (22) using 10% to 40% BWR, JH demonstrated a linear increase as BWR increased. An interesting finding was that TOV increased up to 30%; however, there were no significant differences between 30% and 40% BWR. It was unclear from this study why vertical JH significantly increased up to 40% BWR but TOV was not significantly different until 30% BWR. Another interesting finding was that relative peak ground reaction force increased linearly as BWR increased. Therefore, the reduction in body weight and absolute peak ground reaction force was not linear. According to Hanson *et al.* (10), enhancing vertical JH can be achieved from an increase in net impulse (force × time), which will lead to greater TOV. In support of greater vertical JH due to greater TOV, Bobbert *et al.* (3) reported that vertical JH increased more than 2.5 cm as a result of greater TOV. Accordingly, it may be suggested that utilizing high-velocity movements rather than near-maximal or maximal overload may be more beneficial for improving high-velocity performance.

One critical factor associated with elastic-band-assisted jumping is how the bands might affect different jump parameters. There have been only two studies (16,22) that have reported the elastic modulus of the cords used. Tran *et al.* (22) reported the elastic modulus of their cords to be 100.72 $N{\cdot}m^2$ (calculated by dividing delta force by delta length during band stretch). Markovic *et al.* (16) reported their cords' elastic modulus to be 2.5 MPa but did not report their calculation method. Since many previous studies have not reported their cords' elastic modulus, the results of jump parameters are difficult to compare across studies. With the exception of the two studies by Imachi *et al.* (12) that used nonathletes, the assisted jump method has demonstrated (Table) increased free JH and TOV (1,5,12,16,17,20,22,24), decreased or no changes in peak force (1,15,16,20,24), increased relative ground reaction force (22), and either decreased or no changes in power (1,12,15). These results demonstrate that different levels of assisted jump will have different effects on jump parameters. Overall, if increasing vertical JH and velocity is the desired goal, then assisted jump training may be a more effective method than free jump training.

Conclusions

Improving vertical jumping ability is one of the most desired goals for athletes, personal trainers, and strength and conditioning coaches. An innovative training concept using assistance through either elastic cords or an absolute load to reduce body weight and achieve overspeed may be an additional training tool for athletes. This method, using an assistance level between 10% and 40% BWR, can increase TOV, relative ground reaction force, and power, thus leading to greater JH either acutely or chronically. However, much of the research supports these changes primarily in trained subjects only. Previous assisted jump studies have not standardized the BWR on either an absolute or a relative basis, the elastic modulus of the cords used, or the calculation method of the elastic modulus. Therefore, future studies should investigate and determine standardization of these parameters in order to maximize assisted vertical jump training.

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