Kinetic and Training Comparisons Between Assisted, Resisted, and Free Countermovement Jumps

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Abstract

Argus, CK, Gill, ND, Keogh, JWL, Blazevich, AJ, and Hopkins, WJ. Kinetic and training comparisons between assisted, resisted, and free countermovement jumps. *J Strength Cond Res* 25(8): 2219–2227, 2011—Elastic band assisted and resisted jump training may be a novel way to develop lower-body power. The purpose of this investigation was to (a) determine the kinetic differences between assisted, free, and resisted countermovement jumps and (b), investigate the effects of contrast training using either assisted, free, or resisted countermovement jump training on vertical jump performance in well-trained athletes. In part 1, 8 recreationally trained men were assessed for force output, relative peak power (PP·kg^{-1}) and peak velocity during the 3 types of jump. The highest peak force was achieved in the resisted jump method, while PP·kg^{-1} and peak velocity were greatest in the assisted jump. Each type of jump produced a different pattern of maximal values of the variables measured, which may have implications for developing separate components of muscular power. In part 2, 28 professional rugby players were assessed for vertical jump height before and after 4 weeks of either assisted ($n = 9$), resisted ($n = 11$), or free ($n = 8$) countermovement jump training. Relative to changes in the control group (1.3 ± 9.2%, mean ± *SD*), there were clear small improvements in jump height in the assisted (6.7 ± 9.6%) and the resisted jump training group (4.0 ± 8.8%). Elastic band assisted and resisted jump training are both effective methods for improving jump height and can be easily implemented into current training programs via contrast training methods or as a part of plyometric training sessions. Assisted and resisted jump training is recommended for athletes in whom explosive lower-body movements such as jumping and sprinting are performed as part of competition.

Key Words elite athletes, in season, vertical jump, rugby union

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Introduction

The ability to develop high levels of muscular power is critical for a successful performance in many sports (18). However, as the training age of an athlete increases, there is a tendency toward a diminishing rate of improvement in muscular power (5). Furthermore, Argus et al. (2) recently reported that reductions in power may occur over a competitive season of professional rugby union. These points highlight the need to develop training methods that promote positive adaptation in power output in well-trained athletes, especially during the competitive phase of a season.

Because power is the product of force and velocity, manipulation of these 2 variables in a periodized resistance training program via alterations of the training loads may be essential for positive power adaptation (30). The better developed a single component, the less potential there is for power adaptation to occur; therefore, training schemes need to focus on the components of power, which are less developed. For example, for athletes who have already acquired high levels of strength (force), the use of traditional strength training methods may be insufficient for enhancing explosive power. For these athletes, more specific training interventions focusing on the velocity of the movement may be required to improve power output (23,30). The use of assisted and resisted countermovement jump training with the aid of elastic bands may be a useful approach to manipulate the force velocity relationship and develop lower-body power. Cronin et al. (12) reported improvements in peak movement velocity (5.4%), peak power (PP, 14.3%), and single leg jump height (2.5%) after 10 weeks of ballistic training when resistance was added to a countermovement jump exercise by elastic bands. Alternately, several authors have reported that greater power output and velocities can be produced during unloaded or assisted countermovement jumping (10,22,28), commonly with the aid of elastic bands (22,28). Using elastic bands to perform assisted jump training therefore appears somewhat similar to overspeed sprint training.

It is commonly accepted that overspeed or downhill running can improve sprint performance. Corn and Knudson (11) reported a 7.1% increase in velocity in the acceleration phase of a 20-m sprint using elastic cord to provide horizontal assistance. Additionally, Majdell and Alexander (26) reported increases in 40-yd sprint time after 6 weeks of overspeed sprint training. Thus, the possibility exists that assisted jump training might provide similar adaptations to those observed with overspeed or downhill running.

To date, research examining the kinetic differences between assisted, free (i.e., bodyweight) and resisted countermovement jumps is scarce. Understanding the kinetic characteristics of these jumps may help us to more accurately predict potential changes in performance after long-term use. In turn, this understanding may allow for enhanced individualized prescription of training through more specific programing of separate components of muscular power (30).

One way in which plyometric jumps are often incorporated into a resistance training program is with a contrast-loading scheme. Contrast training is a method that combines low- and high-velocity resisted movements by alternating an exercise set of moderate to heavy load with a similar exercise performed with a lighter load (4,16). The moderate to heavy load is generally a strength-oriented exercise, whereas the lighter load is a velocity-oriented exercise, where acceleration occurs over the full range of the movement (4). Contrast training methods have been shown to acutely enhance power output in both upper and lower extremities by approximately 5% (3,4,35), although it has been suggested that this method may be more advantageous in athletes with relatively high levels of strength (4,16).

Therefore, the purpose of this investigation was to (a), determine the kinetic differences between assisted, free, and resisted countermovement jumps and (b) investigate the effects of contrast training using either assisted, free, or resisted countermovement jump training on vertical jump performance in well-trained athletes. We hypothesized that (a) jumping with assistance would result in the greatest maximal velocity and (b) because of the lack of previous overspeed training assisted jump training would produce the greatest improvements in jump height.

Methods

Part 1

Experimental Approach to the Problem. To determine the kinetic differences between assisted, free, and resisted countermovement jumps subjects performed 3 trials of each jump on a Kistler force plate (Kistler Instruments Inc, Winterthur, Switzerland) in a randomized order within a single session. Peak power relative to the adjusted bodyweight once assistance or resistance had been provided ($PP{\cdot}kg^{-1}$) and peak velocity were determined for all jumps using the vertical ground reaction force data (15). Power was calculated using methods described in Dugan et al. (15) where (i) = time point based on sampling frequency, F = force, $t = 1/$sampling frequency, m = total mass, v = velocity, P = power:

$$v(0) = 0,$$

$$F_{(i)}t = m\left(v_{(i+1)} - v_{(i)}\right),$$
$$\Delta v = \left(F_{(i)}t\right)/m,$$
$$P_{(i)} = F_{(i)} \times v_{(i)}.$$

The absolute force trace (which included the unloaded or increased bodyweight once assistance or resistance had been provided) for each jump was analyzed in 4 separate phases (Figure 4). For each phase, the peak force and the rate of force development or unloading were calculated as the slope of the force–time curve from minimum force to peak force, or peak force to minimum force, respectively (8). These dependent measures were selected because they are considered important factors that contribute to explosive muscular power (30). Each subject performed 2 familiarization trials within the 10 days before, but not within 36 hours of the testing day. Each familiarization trial consisted of each subject performing 3 sets of 5 repetitions for each of the 3 jump conditions.

Subjects. Eight recreationally trained men volunteered to participate in this part of the investigation (mean ± *SD*; age, 27.5 ± 5.5 years; height, 179.9 ± 4.9 cm; mass, 84.2 ± 14.3 kg). All subjects had been performing resistance training, which included plyometrics twice a week for at least 6 months before the beginning of the investigation. None of the subjects were competing in any competitive sport at the time of assessment. Subjects were informed of the experimental risks and signed an informed consent document before the investigation. The investigation was approved by an Institutional Review Board for the use of human subjects.

Procedures. ***Warm-up.*** Subjects performed a standardized warm-up of 2 sets of 10 bodyweight squats at a self-selected velocity followed by 2 sets of 5 free countermovement jumps performed with maximal effort. Each warm-up set was separated by a 1-minute rest period. Subjects then performed each of the 3 jump conditions in a randomized order. There were 6 randomized sequences of treatment (A–B–C, A–C–B, B–C–A, B–A–C, C–A–B, and C–B–A), which meant 2 sequences were performed twice.

Assisted jumps. Subjects performed assisted jumps inside a squat cage while wearing a climber's harness. An elastic band was attached to either side of the harness at the hip level, with the other end attached to the squat cage above the subject (Figure 1). The harness straps were adjusted (tightened or loosened) so the elastic bands provided upward vertical tension which reduced the bodyweight of each subject by 20% when in a standing position on the force platform with hip and knee fully extended. The jump execution consisted of subjects

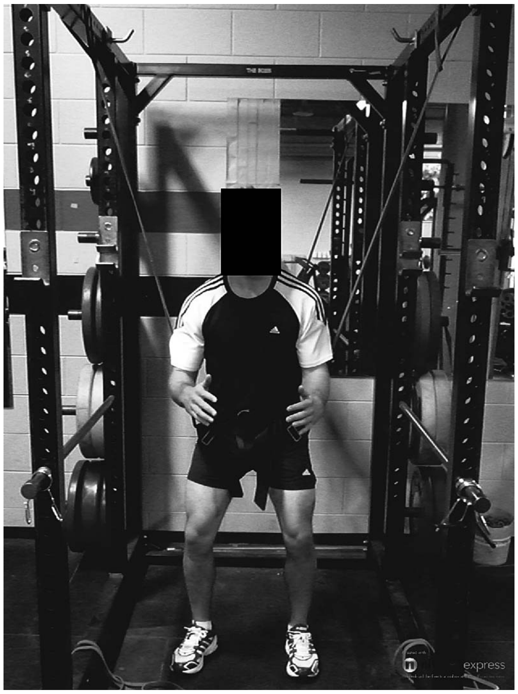

Figure 1. Example of the assisted jump setup. A harness and elastic bands were attached to the participant and to the squat cage above.

lowering themselves to a self-selected depth and then jumping for maximal height. The assistance provided by the bands decreased as the subject left the ground after the concentric phase of the movement and was greatest as subjects lowered themselves to a self-selected depth. An arm swing was permitted during each jump but was abbreviated because of the placement of the elastic bands.

Resisted jumps. Subjects performed resisted jumps inside a squat cage while wearing a climber's harness with an elastic band attached; the bands were attached to the squat cage below the subject (Figure 2). The harness straps were adjusted (tightened or loosened) so that the elastic bands provided downward vertical tension, which increased the bodyweight of each subject by 20% when in a standing position on the force platform with hip and knees fully extended. The resistance provided by the bands increased as the subject left the ground after the concentric phase of the movement and was at its least as subjects lowered themselves to a self-selected depth. The jump execution was consistent with that described above for the assisted jumps.

Free jumps. Subjects performed free countermovement jumps with no assistance or resistance (i.e., bodyweight only). The jump execution was consistent with that described above for the assisted and resisted jumps (17).

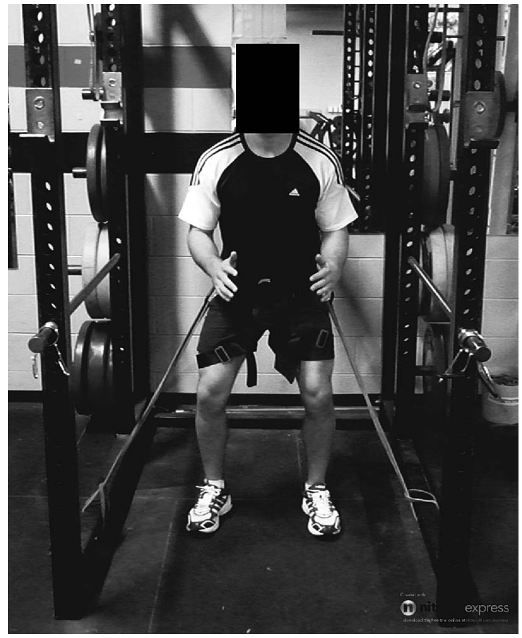

Figure 2. Example of the resisted jump setup. A harness and elastic bands were attached to the participant and to the squat cage below.

Statistical Analyses. The greatest peak force during the loading phase was used to determine the best trial for each condition and was subsequently used for the analysis. All kinetic data were log-transformed to reduce nonuniformity of error, and the effects were derived by back transformation as percent changes (21). Standardized changes in the mean of each measure were used to assess magnitudes of effects by dividing the changes by the appropriate between-subject *SD*. Standardized changes of <0.2, <0.6, <1.2, <2.0, and >2.0 were interpreted as trivial, small, moderate, large, and very large effects (20). An effect size (ES) of 0.2 was considered the smallest worthwhile positive effect. To make inferences about true (large-sample) value of an effect, the uncertainty in the effect was expressed as 90% confidence limits (CLs). The

Table 1. Intraclass correlations (*r*) of peak force, peak velocity, and peak power in 3 different countermovement jumps (assisted, free, resisted) performed by 8 recreationally trained men.

	Assisted	Free	Resisted
Force	0.964	0.987	0.996
Velocity	0.860	0.985	0.849
Power	0.908	0.990	0.989

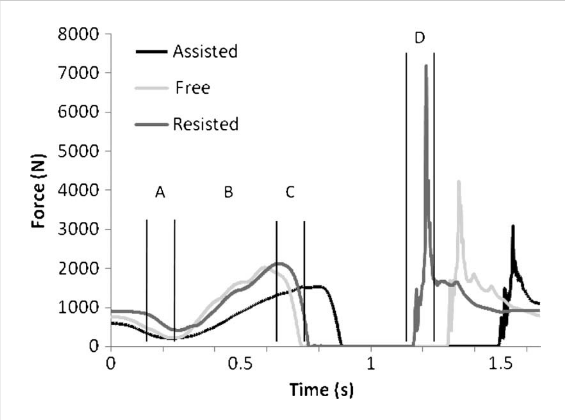

Figure 4. Example from 1 participant of forces produced in the 3 different jump conditions. The different phases of the movement have also been labeled (resisted jump only). A) early unloading phase; B) loading phase; C) unloading phase before flight; D) impact.

intraclass correlations for the each jump condition are presented in Table 1.

Part 2

Experimental Approach to the Problem. This part of the study sought to investigate the effect of contrast training using assisted, free, or resisted countermovement jumping on the vertical jump performance of rugby players. Subjects were assessed for maximal jump height and performed 4 weeks of contrast training consisting of a power clean exercise alternated with an assisted, free, or resisted jumping exercise twice a week (Tuesday and Thursday morning; Figure 3). Subjects were then reassessed for maximal jump height at the end of the 4-week training phase. All training was performed in conjunction with, and during, the subject's regular training program. Jump height was chosen as the primary outcome measure because it is a reliable and valid measure for the assessment of lower-body power and has been shown to correlate with sprint performance (34). Fifteen subjects were assessed 1 week apart to assess reliability of the measure. All assessments for vertical jump height were performed in the morning between 8.30 AM and 9.45 AM. All subjects were also requested to use similar nutrition and hydration strategies in the 24 hours proceeding each testing session.

Subjects. Twenty-eight professional rugby union players from a New Zealand Super 14 rugby team volunteered to take part in this study during their competitive season (Table 2). Each subject had been performing intensive and regular resistance and plyometric training for a minimum of 2 years. The subjects were matched for jump height and playing positions and were placed into 1 of 3 separate training groups: assisted jumps ($n = 9$), free jumps ($n = 8$), or resisted jumps ($n = 11$). Subjects were informed of the experimental risks and signed an informed consent document before the investigation. The investigation was approved by an Institutional Review Board for the use of human subjects.

Table 2. Subject characteristics of 3 separate countermovement jump training groups.

	Assisted ($n = 9$)	Free ($n = 8$)	Resisted ($n = 11$)
Age (y)	25 ± 2	24 ± 2	23 ± 2
Height (cm)	184 ± 8	186 ± 6	183 ± 4
Mass (kg)	101 ± 10	101 ± 10	100 ± 4

All data are mean ± *SD.*

Procedures. ***Performance assessment.*** Jump height was assessed using a countermovement jump. Subjects completed a standardized warm-up of 2 sets of 10 bodyweight squats at a self-selected velocity followed by 2 sets of 5 free countermovement jumps performed with maximal effort. Subjects then performed 2 sets of 4 maximal countermovement jumps with the highest jump used for analysis (31). Three minutes of rest was allowed between each set. Jump height was assessed and recorded using a Gymaware™ optical encoder (50-Hz sample frequency with no data smoothing or filtering; Kinetic Performance Technology, Canberra, Australia) using the methods described elsewhere (14). Briefly, Gymaware® consists of a spring-powered retractable cord that passes around a pulley mechanically coupled to an optical encoder. The retractable cord is then attached to the broomstick and displacement is calculated from the spinning movement of the pulley upon movement of the barbell. The encoder gave one pulse approximately every 3 mm of load displacement, with each displacement value time stamped with a 1-millisecond resolution (14).

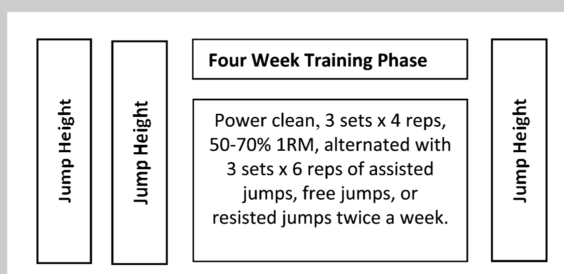

Figure 3. Outline of assessment and training in elite rugby union athletes. Seven days separated jump height assessments and training phases. Reps = repetitions; RM = repetition maximum. Assisted jumps, $n = 9$; free, $n = 8$; resisted jumps, $n = 11$.

Table 3. Relative peak power and peak velocity produced in 3 different countermovement jump conditions (assisted, free, and resisted). ($n = 8$).*

	Assisted	Free	Resisted
Peak power (W·kg^{-1})	50.4 ± 8.0†	49.4 ± 6.0†	33.3 ± 8.3
Peak velocity (m·s^{-1})	2.8 ± 0.3†‡	2.7 ± 0.2†	1.8 ± 0.3

*All data are mean ± *SD*.
†Very large effect size vs. resisted jumps.
‡Moderate effect size vs. free jumps.

Training. All subjects performed 4 repetitions of a power clean exercise 60 seconds before 6 repetitions of assisted jumps, resisted jumps, or free jumps. Each subject performed this for 3 sets, with 3 minutes rest between each set. The load lifted for the power clean exercises was between 50 and 70% of 1 repetition maximum and was dependent on the training microcycle for each individual. Variation in the load lifted was because of a greater volume of rugby union game time completed by some subjects.

Assisted jumps. Assisted jumps were performed in the same manner as described for part 1, but without rest between each repetition. The elastic bands provided upward vertical tension which reduced the bodyweight of each subject by 28 ± 3% when the subject was in a standing position with the hip and knee fully extended. Each participant was weighed on 2 separate occasions to assess the assistance provided. The assistance varied from part 1 as no adjustments (tightening or loosening) were made to the harness; time constraints of the training session made it impossible to weigh and adjust the weight of each athlete before each set of jumping.

Resisted jumps. Resisted jumps were performed as described in part 1, but without rest between each repetition. The elastic bands provided a downward vertical tension, which increased the load by 27 ± 5% above bodyweight when subjects were in a standing position with their hips and knees fully extended.

Free jumps. Free jumps were performed as described for part 1.

Additional training. All jump training was performed in conjunction with, and as part of, the subject's regular resistance training sessions. Each week the subjects typically performed 2 resistance training sessions (30–50 minutes, 4–6 exercises, 1–6 repetitions [strength and power], 2–3-minute rest), 1 speed development session (20–30 minutes, including fast foot ladders, mini hurdles, weighted sled towing, maximal sprinting), 4 team training sessions (30–75 minutes, including specific rugby skill, tactical, tackling, etc.), 1 competitive match, and 1 recovery session (20–40 minutes, including light exercise, stretching, hot and cold baths).

Statistical Analyses. All data were analyzed in the same manner as in part 1. Changes in jump height were presented as mean ± *SD*, whereas comparisons between training conditions were presented as mean ± 90% CLs. An ES of 0.2 was considered the smallest worthwhile positive effect. Validity of the Gymaware™ optical encoder has been previously reported elsewhere (14). The coefficient of variation and intraclass correlation (r) for the vertical jump height performance by the subjects were 4.3% and 0.83, respectively.

Results

Part 1

The peak vertical velocity attained in the loading phase (phase B, Figure 4; Table 3) of the assisted jump was 37.4% (±5.3%; 90% CLs) and 6.3% (±3.7%) greater than attained in the resisted and free jump (ES, very large and moderate, respectively). A very large difference (33.5 ± 6.8%) in velocity between the free and resisted jump was also observed (Table 3).

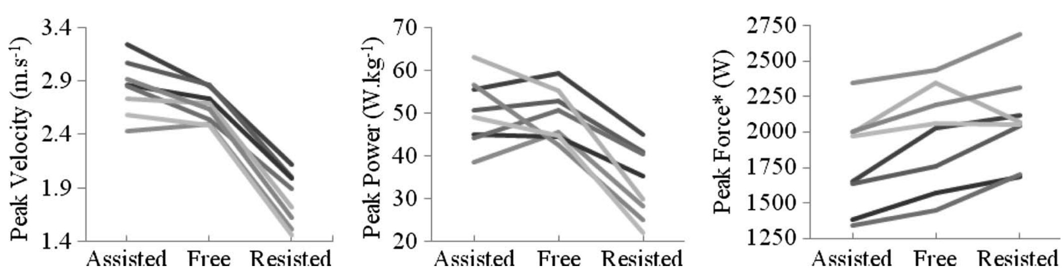

Figure 5. Subject variation ($n = 8$) in peak velocity, peak power, and peak force, in 3 separate countermovement jumps, assisted, free, resisted. *Peak ground reaction force during the concentric phase of the jump before flight. W = watts.

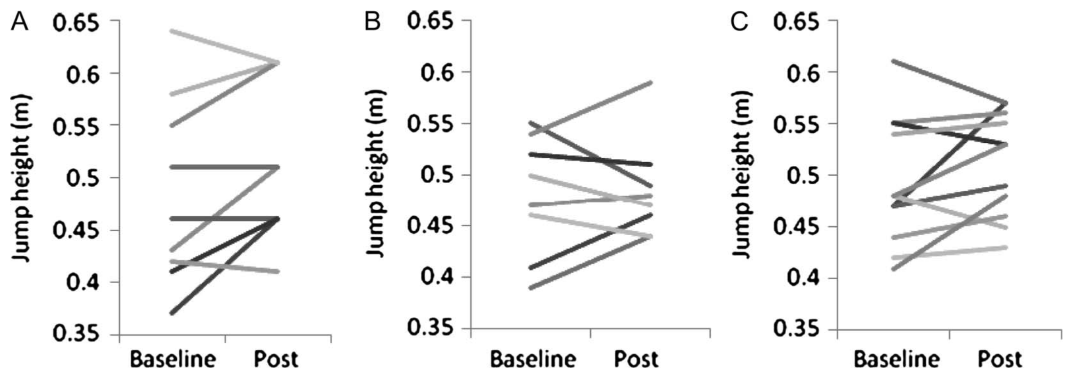

Figure 6. Subject variation in vertical jump height change after a 4-week training phase of assisted (A, $n = 9$), free (B, $n = 8$), or resisted (C, $n = 11$) countermovement jumps.

Relative PP was greatest in the assisted jump and was 35.0% (±22.7%) greater than the resisted jump (very large ES). Additionally PP ($W \cdot kg^{-1}$) was 34.0% (±13.7%) greater in the free than in the resisted jump (very large ES). There was no difference in relative PP between the free and assisted jump conditions (Table 3). Figure 5 illustrates the variation in velocity, PP, and peak force, in the separate countermovement jumps between subjects.

The amplitude of force unloading during the early unloading phase (phase A) of the jump was 16.9% (±17.1%) greater in the resisted jump than in the assisted jump (moderate ES) (Table 4). There was no difference in the rate of force unloading during the early unloading phase.

The peak force produced during the loading phase (phase B) was 5.8% (±6.4%) and 17.2% (±5.8%) greater in the resisted jump than in the free and assisted jumps (small and moderate ES, respectively). Additionally peak force was 10.7% (±4.0%) greater in the free jump compared to in the assisted jump (small ES). A small difference was observed in the change in force during the loading phase and was 7.9% (±11.5%) greater in the resisted jump when compared to in the assisted jump method.

The rate of force development, measured as the slope of the force–time curve in the loading phase (phase B), was greatest in the resisted jump (4,268 ± 2,125 $N \cdot ms^{-1}$). A moderate difference of 21.6% (±26.5%; 90% CL) was observed in the rate of force development during the loading phase between the resisted jump and free jumps.

The rate of force decline, calculated as the (negative) slope of the force–time curve from peak force to zero force (phase C) was greatest in the resisted jump when compared to in free (19.5 ± 22.5%; 90% CL) and assisted jumps (78.2 ± 75.7%; 90% CL) and represented a small and moderate ES, respectively.

The greatest impact force was generated in the resisted jump (phase D) and was 66.5% (±41.3%; 90% CL) and 22.0% (±25.0%; 90% CL) greater than in the assisted jump and resisted

Table 4. Comparison of jump force data between assisted, free, and resisted countermovement jumps in 8 recreational level subjects.*

	Assisted	Free	Resisted
Phase A: early unloading phase			
Max (N)	680 ± 110	840 ± 140	1,030 ± 180
Min (N)	230 ± 130	360 ± 150	500 ± 240
Amplitude (N)	440 ± 100	490 ± 220	540 ± 230
Rate ($N \cdot ms^{-1}$)	−2.1 ± 1.2	−2.1 ± 1.1	−2.6 ± 1.7
Phase B: loading phase			
Max (N)	1,790 ± 350	1,980 ± 360	2,080 ± 320
Min (N)	230 ± 130	360 ± 150	500 ± 240
Amplitude (N)	1,550 ± 270	1,620 ± 430	1,580 ± 240
Rate ($N \cdot ms^{-1}$)	3.4 ± 1.3	3.5 ± 1.7	4.3 ± 2.1
Phase C: unloading phase before flight			
Max (N)	1,790 ± 350	1,980 ± 360	2,080 ± 320
Rate ($N \cdot ms^{-1}$)	−11.3 ± 6.5	−15.1 ± 6.5	−17.3 ± 5.5
Phase D: impact			
Max (N)	3,180 ± 1260	4,130 ± 840	5,330 ± 1970
Rate ($N \cdot ms^{-1}$)	46.1 ± 21.4	62.7 ± 12.9	94.0 ± 43.4

*All data are mean ± *SD*.

jump, respectively (ES, moderate). Additionally, the free jump produced 36.4% (±35.3%; 90% CL) greater force on impact when compared to the assisted jump (ES, moderate). Similarly, the greatest rate of force development on impact was generated in the resisted jump, being 98.7% (±45.8%; 90% CL) and 35.7% (±33.4%; 90% CL) greater than the assisted jump and free jump (ES, moderate and small, respectively). Additionally, the rate of force development on impact was 46.4% (±39.8%; 90% CL) greater in the free jump when compared to the assisted jump (ES, moderate).

Part 2

The analysis revealed that both assisted and resisted jump training groups had a small increase in jump height of 6.7% (±9.6%) and 4.0% (± 8.8%), respectively, whereas the free jump group produced a trivial increase in jump height of 1.3% (± 9.2%). A small effect was observed for the between-group difference in the change in jump height between assisted and free jump training (5.6, 90% CL ±6.8%), and resisted and free jump training (3.7 ± 6.1%). Trivial but unclear between-group differences were observed in the change in jump height between the assisted and resisted jump training protocols. Figure 6 illustrates the variation in vertical jump height change of each subject in the 3 separate conditions.

Discussion

The purpose of part 1 was to examine the differences in the kinetics of assisted, resisted, and free countermovement jumps. The findings were then used to help plan and implement the training protocols in part 2, which examined the differences in training effect of these training methods.

As expected from the concentric force–velocity relationship, the greatest peak velocity was achieved during the assisted jump because the vertical assistance provided by the elastic bands reduced the effective bodyweight of the subject by providing an upward propulsive force. The assisted jump therefore allowed subjects to jump more quickly than is possible without assistance. Previous literature has shown increased neural activation (via integrated electromyography) when performing at supramaximal velocities (29) that may have positive training implications. The greatest PP relative to bodyweight was also achieved in the assisted jump condition, with this effect likely because of the increased velocity of the movement. Assisted training may be particularly beneficial for athletes who have already obtained high levels of strength, but lack the ability to produce higher power outputs or movement velocity, especially at low loads.

There was a reduced amplitude of force unloading in the early unloading phase of the assisted jump in comparison to resisted and free jumps, and may have reflected in some ways a decreased stretch-shortening cycle force contribution. Reductions in force unloading and rate of unloading may have resulted in less stretch on the muscle–tendon complex, and therefore, the tendon would have recoiled with reduced force (24). As such, the total force produced during the assisted jump would have had a greater reliance on concentric-only muscle force production, which may help to explain the smaller change in force compared to the resisted jump during the loading phase (24).

The assisted jump was associated with substantially smaller impact forces than both resisted and free jumps. In a training environment, the reduced impact forces observed during assisted jumps may be a safer way to graduate the intensity of plyometric loading, especially after recovery from lower-body injury or in large athletes who may not tolerate high landing ground reaction force.

Maximum force, rate of force development, and impact force were greatest in the resisted jump condition. The observation that the resisted jump condition allowed the greatest peak force is likely because of the increased resistance reducing movement velocity. Indeed, according to the force–velocity relationship, force is greater at slower concentric contraction speeds and reduces as the velocity of the concentric action increases (19). In contrast to assisted jumping, the greater force and rate of force development produced in the resisted jumps may have been because of the larger force unloading in the early unloading phase of the jump. Greater unloading forces and rate of force unloading during this phase may have increased tendon recoil thus enhancing stretch-shortening cycle function. Indeed Kubo et al. reported that a faster prestretch of human muscle led to greater muscle–tendon complex lengthening with 22.3% greater work completed in the following concentric action than at a slower prestretch rate (24).

It is well known that power production during complex movement is influenced by many different factors (e.g., force, velocity, rate of force development, stretch-shortening cycle efficiency) (30). Part 1 of this investigation determined that both assisted and resisted jump methods produced distinct maximal outputs, which may be expected to develop different components of muscular power (high speed and low force, low speed and high force, respectively). The free jump did not result in a greater output than the assisted or resisted jumps in any of the measured variables.

There are some limitations that should be considered before attempting to interpret the results from part 2 of this investigation. Firstly, the assistance and resistance provided varied between participants and was not assessed on every set of every training session; and secondly, the competition game performed by the subjects could not be completely controlled in terms of the specific role each athlete played within the match, tasks completed or time on the field.

Results of part 2 indicated that assisted and resisted jump training led to small improvements (4.0–6.7%) in vertical jump height in well-trained rugby players during the competitive phase of their season. In contrast, trivial improvements (1.3 ± 9.2%) in jump height were observed after free countermovement jump training. These findings are important considering prior research from this group indicating a 3.3% decrease in lower-body power in similar well-trained rugby players over a competitive season (2). It is also important to note that in similar well-trained athletes Baker and Newton (5) reported 5% improvements in power over a 4-year training period, as such, trivial performance improvements may still be important. If 4.0–6.7% improvements in jump height can be achieved with assisted or resisted jump training over a 4-week training period with minimal disturbance to training, without the risk of injury and at minimal cost, then coaches should confidently employ such training methods. Furthermore it should be restated that these results were obtained where resistance training, speed development, team skills, and training sessions, along with competitive matches were being performed within the same training phase. As such, these findings are likely more transferable to real-world applications compared to what is observed in single training mode or laboratory-based investigations.

Assisted jump training resulted in the greatest increase in vertical jump height and was associated with the greatest acute peak velocity and power outputs. Findings from part 1 revealed that performing assisted jump training allowed participants to jump with a movement velocity greater than in the free and resisted jump conditions. Training at a higher movement speed may have resulted in decreased antagonist coactivation or an increase in Myosin heavy chain-II fiber activation (1). Indeed, there is a close relationship between muscle shortening speeds and the expression of the different (MHC) isoforms (9,25). Additionally, muscle fibers that contain MHC-I have slower maximal shortening velocities and lower power outputs than muscle fibers containing MHC-II isoforms (9,25). Although it was not assessed in this investigation, our results may suggest that the higher velocity training resulted in very specific morphological adaptations. Neuromuscular adaptations should not be discounted as possible mechanisms for the improvements observed in jump height. Indeed, Newton et al. (32) reported that greater velocity and force production (as observed in assisted and resisted jumps, respectively) provides superior loading conditions for the neuromuscular system. As such, the greater stimulus may have promoted positive adaptation (6).

Resisted jump training improved vertical jump height by 4.0% and was associated with the greatest peak force and rate of force development. It is likely that the increased force requirements of resisted jumping led to positive adaptation. Attempting to move at high speeds against a larger external load may induce numerous adaptations including an increase in contractile force, perhaps through increased neural activation, reduced coactivation, and muscle architectural and fiber size adaptations, although the mechanisms are yet to be completely defined (7,12,27,31).

In support of the current findings, Cronin et al. (12) reported that resisted bungy countermovement jump training (performed on a isoinertial supine squat machine) improved a variety of lower-body strength and power measures after a 10-week training phase. Cronin et al. (12) also reported that resisted bungy countermovement jump training produced greater electromyographic activity (70–100%) during the later stages of the eccentric phase of the jump, when compared to the free jump method. Accentuated eccentric loading increases the force that can be produced in the concentric phase of the movement and may be because of increased elastic energy storage as a result of the greater eccentric load increasing tendon elongation (13). Sheppard et al. (33) reported that 5 weeks of accentuated eccentric loading countermovement jump training increased vertical jump height by 11% in high performance volleyball players. The increase was significantly larger than the control group who performed regular countermovement jumps. Therefore, improvements in vertical jump after resisted jump training might also be related to an increased eccentric loading after the flight phase of the jump and similar to those observed after drop jump training.

The free jump group produced a trivial increase in vertical jump. The lack of improvement may be because of the subject's regular use of the free jumps as part of their training program before the beginning of the study. As such, the kinetic components of power that are optimized by free jump training may have been previously developed; thus, there was less potential for adaptation to occur (33).

Practical Applications

Inclusion of assisted or resisted jumping (3 sets of 6) twice a week to a conditioning program can improve vertical jump height over a 4 week training phase to levels comparable to that found over a 4-year period in similarly trained rugby league athletes (5). Conditioning coaches and athletes can simply integrate these methods of jump training into their current resistance training via contrast training methods or as a part of their plyometric training sessions. The improvements in jump height in the current investigation were made in well-trained rugby athletes; however, we believe that the improvements are not limited to this form of athlete and should be performed by any athlete where jumping, sprinting, or any explosive lower-body movements are performed in competition. Finally, assisted jumping may also provide a lower impact method of plyometrics, which may be useful for progressing the intensity of plyometric loading after lower-body injury or for heavy athletes who do not tolerate the high impact ground reaction forces on landing. Future research in this area should look at investigating the effects of individualized prescription of assisted compared to resisted jump methods for athletes with limitations in their velocity and force components of power, respectively. When combined with appropriate testing methodologies, such an approach may maximize the potential for power gain in these athletes.

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