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Research Article

Acute Effects of Assisted Jumping on Muscle Activation and Performance

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Abstract

Introduction: Research has shown that assisted jumping results in an acute performance enhancement, however the underlying mechanisms of this are unclear.

Purpose: To investigate lower body muscle activation and jump performance following assisted jumping.

Methods: Eight collegiate female volleyball players (19.11 ± 1.05 yrs.; 175.99 ± 7.52 cm; 75.47 ± 10.88 kg) completed 2 experimental conditions (0% bodyweight or 40% bodyweight reduction (BWR)). For assisted jumping, participants wore a harness with elastic cords stretched to the ceiling by a rope and attached to their hips. In each trial, participants performed 5 plyometric countermovement jumps (CMJ), rested for 1 minute, then performed 3 individual bodyweight CMJ separated by 15 seconds rest. Electromyography was used to measure concentric and eccentric root mean square (RMS) amplitude of the gluteus maximus, vastus lateralis, and gastrocnemius lateralis prior to take-off. Vertical jump performance variables of impulse, jump height, takeoff velocity, relative ground reaction force, and relative peak power were collected on a force plate.

Results: ANOVA for EMG RMS showed no 3 way interaction but there was a 2 way interaction of muscle x action for each muscle. Concentric actions of all muscles were greater than eccentric: gluteus maximus concentric 0.11 ± 0.03mV vs. eccentric 0.02 ± 0.01mV; vastus lateralis concentric 0.43 ± 0.09mV vs. eccentric 0.10 ± 0.03mV and gastrocnemius lateralis concentric 0.29 ± 0.08mV vs. eccentric 0.06 ± 0.04mV. There was no main effect for any performance variable.

Conclusions: Based on the findings of the current study, there does not appear to be an acute PAP effect of assisted jumping on subsequent bodyweight countermovement vertical jumping in highly trained female volleyball players.

Keywords: Overspeed; Assisted Jumping; Vertical Jump; Electromyography

Abbreviations

ANOVA: Analysis of Variance;

BWR: Body Weight Reduction;

CMJ: Countermovement Vertical Jump;

EMG: Electromyography;

GC: Gastrocnemius Lateralis;

GL: Gluteus Maximus;

JH: Jump Height;

NCAA: National Collegiate Athletic Association;

PAP: Postactivation Potentiation;

rGRF: Relative Ground Reaction Force;

RMS: Root Mean Square;

rPP: Relative Peak Power;

SD: Standard Deviation;

TOV: Take-Off Velocity;

VL: Vastus Lateralis

Introduction

The ability to produce elevated levels of muscular power is critical in jumping sports. Increased power has been shown to improve vertical jumping [1-4] which can enhance performance for athletes involved in competition. This increase in power could be the difference between success and failure in a specific sport. Traditionally, athletes train for power by overloading a muscle through resistance, therefore increasing strength, but enhanced velocity development is also a contributor to muscle power [1].

Overspeed training is a training concept that utilizes assistance rather than overload resistance, and has been introduced as a unique training tool designed to enhance a variety of athletic tasks, including vertical jumping [1,2,4-17]. Implementing overspeed training involves providing assistance via elastic cords in the direction of movement, and focuses on increasing performance by enhancing lower limb velocity development [2,4,5]. In studies that have utilized assisted training, power is significantly greater with assistance than without [1,2,4,6,11,15-17] leading to acute performance enhancements [2,15]. These acute enhancements may be due to postactivation potentiation (PAP) since they cannot be attributed to hypertrophy[2]. However, previous investigations have not examined a highly trained jumping population [2] within an acute PAP environment [4].

Direct measurement of muscle activation has not been investigated in conjunction with an assisted jump protocol. Therefore, to better understand the mechanisms underlying previously reported performance increases, the purpose of this study was to investigate the acute effects of assisted jumping on subsequent muscle activation and bodyweight vertical jump performance.

Methods

Participants

Eight females volunteered to participate (19.11 ± 1.05 yrs.; 175.99 ± 7.52 cm; 75.47 ± 10.88 kg). They were members of an NCAA Division I women's volleyball team, and were tested in the offseason. Subjects were excluded if they had an existing orthopedic or musculoskeletal injury that would prevent them from performing a CMJ. Prior to involvement, all participants read and signed a University institutional review board approved informed consent.

Procedures

Participants attended 3 days of testing separated by a minimum of 24 hours. They were required to maintain their normal training status and their normal nutrition, hydration, and sleep habits throughout the study. On day 1, they read and signed an informed consent document, and were measured for height and mass. Placement of electromyographic (EMG) sensors on the gluteus maximus (GL), vastus lateralis (VL), and gastrocnemius lateralis (GC) were recorded and applied. They were also fitted with a harness (Black Diamond Momentum AL Harness, model number: 651053, Salt Lake City, UT, USA) with elastic cords attached to the lateral portion of the leg straps. The design of the harness allowed participants to perform a CMJ without movement restriction, and allow a natural jumping motion as they were pulled vertically upward. Participants wore the harness throughout each trial, and began with a dynamic warm-up that included Frankenstein walks, knee hugs, and gate swings. Each warm-up exercise was performed twice by walking 10m in each direction. EMG sensors were connected and participants executed 3 control maximal bodyweight CMJ with arm swing on an AMTI force plate (Advanced Mechanical Technology, Inc., Watertown, MA, USA) sampling at 1000 Hz. Fifteen seconds of rest was provided between each CMJ. Each jump required participants to reach up with both hands at the peak of their jump to simulate a block as performed in a volleyball match. The control condition was performed to collect variables without any prior jumping. After control jumps were recorded, participants were familiarized with the assisted pulley system.

On days 2 and 3, participants were outfitted with the same EMG sensors and harness and performed the identical dynamic warm-up as day 1. After the warm-up, they performed one of 2 counterbalanced conditions (bodyweight CMJ or assisted CMJ). In plyometric fashion, participants performed 5 consecutive CMJ on the force plate at bodyweight or at 40% bodyweight reduction (BWR). After each condition, they rested for 1 minute then performed 3 individual bodyweight CMJ separated by 15 seconds rest. Data were synced and recorded by the force plate and EMG system then analyzed via custom LabVIEW software (version 2013, National Instruments, Austin, Texas).

Assisted Pulley System

Participants stood on the force plate and body weight was measured while they were wearing the harness. The harness was attached to four, 0.91-m elastic cords, (Ver Sales, Burbank, CA, USA). The elastic modulus of the cords was determined by dividing delta force by delta length, and was calculated at 188.337 ± 32.65 Nm^2 when stretched between 0.3 and 0.6 m. The elastic cords were attached to a canyoneering 9-mm static rope that was looped through a double cargo block then through a 40-mm triple cargo block (Harken, Pewaukee, WI, USA), which was bolted to the ceiling. From the ceiling, the rope led to a 57-mm cargo block with a lock cam (Harken) that was attached to the wall. As the participants stood on the force plate, their bodyweight could be reduced (i.e. BWR assistance) by pulling on the rope.

Assessment of EMG

EMG data of three muscles were recorded at baseline and for all post-condition bodyweight CMJ. Electrodes (EL500 silver-silver chloride; BIOPAC Systems, Inc., Goleta, CA, USA) were applied to the gluteus maximus (GL), vastus lateralis (VL), and gastrocnemius lateralis (GC) [18]. Sensors were applied per setup recommendations of SENIAM [19]. Bipolar electrodes were applied after hair removal, cleaning the skin with an alcohol wipe, and abrasion of the area [19]. EMG signals were filtered (fourth order Butterworth, 10-500 Hz) and preamplified using a differential amplifier (Myopac MPRD-101; Run Technologies, Mission Viejo, CA; bandwidth = 1-500 Hz) with a sampling frequency of 1,000 Hz. Root mean square (RMS) amplitude was used for analysis.

Assessment of Vertical Jump Performance

Participants performed all CMJ on the force plate. Impulse was calculated as the net sum of negative (eccentric) and positive (concentric) force and time (N x sec). CMJ height was estimated using the time in air equation (see equation 1). Take-off velocity (TOV) was recorded at feet off. Relative ground reaction force (rGRF) was determined by dividing peak delta ground reaction force by body mass, and relative peak power (rPP) was calculated as the product of force and velocity divided by body mass. This procedure has previously been shown to have high reliability (ICC between 0.80 and 0.90) [15]. Force-time and velocity-time curves were collected for analysis.

Equation 1: Jump height = $(1/2\ gt^2)/2$, where g is gravity at 9.81 m/s^2 and t is flight time.

Statistical Analyses

The best of the three repetitions was used for variable data analysis. One 3x2x3 (condition x action x muscle) repeated measures analysis of variance (ANOVA) was used to determine differences in RMS amplitude of GL, VL, and GC. Five 1x3 (between conditions) ANOVAs were used to determine differences in IP, JH, TOV, rGRF, and rPP. Interactions were analyzed first followed my main effects. An a-priori alpha of 0.05 was used to determine statistical significance. The Statistical Package for the Social Sciences (SPSS 21 for Windows, SPSS, Inc., Chicago, IL, USA) was used for all analyses.

Results

For EMG RMS, there was no three way interaction ($p = 0.91$), but there was a two way interaction of muscle x action ($p = 0.00$). This was followed up with three paired t-tests, one for each muscle between actions. For all muscles, concentric was significantly greater than eccentric with GL demonstrating the smallest difference (Table 1).

There was no main effect for any performance variable (Table 2).

Table 1. RMS Amplitude (mean ± SD in mV) for each condition and collapsed across all conditions.

	Baseline		Bodyweight		Assisted		All Conditions	
	Eccentric	Concentric	Eccentric	Concentric	Eccentric	Concentric	Eccentric	Concentric
GL	0.01 ± 0.01	0.10 ± 0.03*	0.02 ± 0.01	0.11 ± 0.03*	0.02 ± 0.01	0.12 ± 0.05*	0.02 ± 0.01	0.11 ± 0.03*
VL	0.09 ± 0.03	0.40 ± 0.10*	0.12 ± 0.04	0.43 ± 0.15*	0.10 ± 0.03	0.45 ± 0.14*	0.10 ± 0.03	0.43 ± 0.09*
GC	0.05 ± 0.04	0.28 ± 0.07*	0.07 ± 0.07	0.30 ± 0.10*	0.06 ± 0.04	0.30 ± 0.09*	0.06 ± 0.04	0.29 ± 0.08*

Gluteus maximus (GL), vastus lateralis (VL), gastrocnemius lateralis. *significantly ($P<0.05$) greater than eccentric.

Table 2. Performance variables (mean ± SD) for each condition.

	Control	Bodyweight	Assisted	p-value
IP (Ns)	194.53 ± 37.57	203.37 ± 28.18	196.24 ± 36.00	0.23

JH (cm)	33.85 ± 4.56	33.74 ± 5.40	34.10 ± 4.99	0.57
TOV (m/s)	2.51 ± .20	2.53 ± .23	2.52 ± .21	0.38
rGRF (N/kg)	14.40 ± 3.95	14.77 ± 3.32	14.13 ± 2.79	0.48
rPP (W/kg)	52.39 ± 7.93	52.54 ± 7.49	51.53 ± 7.19	0.14

Impulse (IP), jump height (JH), take-off velocity (TOV), relative ground reaction force (rGRF), and relative peak power (rPP).

Discussion

The purpose of this study was to investigate the acute effects of assisted jumping on muscle activation and vertical jump performance. Our results indicated there were no acute enhancements in post-assisted CMJ performance or differences in muscle activation between conditions; however EMG RMS was greater concentrically than eccentrically. These findings differ from previous research, which may be explained by the stimulus amplitude, rest intervals, or the population tested.

Several assisted jump training studies utilizing 10-34% body weight assistance, have shown long term improvement in vertical jump performance [1,4,11,20]. Previous research has demonstrated that jump height continues to increase up to 40% BWR [15] which was adopted in the current study, but is different than previous studies utilizing either an absolute constant assistance load of 10kg [4], or a relative load to each participant's bodyweight [1]. Additionally, these were longitudinal training studies not acute, as was the current study. While their results demonstrated significant enhancements in vertical jump height, the mechanisms of these performance increases are still unknown. Lastly, the optimal volume, intensity, and rest for assisted jump training have yet to be determined, as it has largely been unexplored.

The present study is the first known to examine acute muscle activation changes following assisted jumping. Our results demonstrated neither an increase in performance or muscle activation. This lack of an acute effect may have been consequent to the volume used. In assisted jump training studies that reported performance enhancements, the stimulus ranged from one set of 10 assisted jumps, 3 times per week, to 12 sets of 6 assisted jumps, 3 times per week. Thus, the weekly total volume ranged between 30 and 216 jumps. In contrast, much less volume (1 set of 5 jumps) has demonstrated an acute positive effect on jump height, but with untrained subjects [2]. This volume discrepancy might explain the absence of an acute performance enhancement in the present study. Even though our participants were in the off-season, they still maintained a rigorous exercise regimen that included a high volume of jumping activities in sport practice as well as traditional overload resistance training. Implementing five assisted jumps may not have been an adequate stimulus to elicit a positive adaptation in this habitual jumping population.

Identifying an ideal formula for individualized manipulation of training variables is a complex challenge. It has been suggested that performance enhancement following assisted exercise may be caused by the same mechanisms found to occur with PAP [2]. PAP is an acute enhancement of muscular power following a heavy overload strength exercise and occurs when fatigue from the overload subsides and potentiation exists. The two main physiological mechanisms of PAP are increased regulatory light chain phosphorylation and greater recruitment of higher order motor units [21-24]. Increased muscle activation during performance tasks following an overload stimulus has been demonstrated in previous literature [22,23]. To induce these physiological mechanisms, optimal overload and rest for each individual must be identified. Optimal rest for overload PAP may be between 7-10 minutes [25], however this is highly individualized [26,27]. Since fatigue is minimal in assisted jumping, the time course between fatigue and potentiation is expected to be much shorter. In a study by Cazas [2], relative peak power and take-off velocity post assisted jumping were greatest at 1 minute following the assisted stimulus in an untrained population. Similarly, the present study implemented a 1 minute rest period post assisted jumping; however our results conflict. The mechanisms of PAP resulting from a heavy overload stimulus may be similar in overspeed stimuli, yet the current study was unable to support this, as there was neither increased performance nor muscle activation. Use of an athletic population probably contributed to our results conflicting with Cazas as the PAP differences between athletic and untrained populations have been previously described [25,26], albeit not in an assisted paradigm.

As reported by Rhea [28], an athletic population requires a greater stimulus than untrained individuals to generate strength gains. This may be similar in assisted training. Previous studies attempting to identify optimal BWR [15], and rest intervals [2] for assisted jumping have used recreationally trained men. Participants in the present study were highly trained collegiate female volleyball players. These athletes were well trained and close to their peak performance ceiling, which makes further significant changes difficult to attain. Large performance gains are more easily attained in an untrained population as athletes may already be close to their peak performance ceiling [28]. This ceiling effect would suggest that a change in performance may be so small that enhancement may take a long period of time. A greater jump volume or BWR stimulus may have altered our results with this athletic population.

Along with no change in bodyweight jump performance following assisted jumping, we also found no difference in muscle activation. In supramaximal sprint research, neural activation has been shown to positively influence stride rate which was correlated with running velocity [29]. It has been hypothesized [2] that neural activation might have a similar effect on vertical take-off velocity in jumping, but cannot be concluded from our current study. Measurements of EMG RMS amplitude were consistent with previous research demonstrating each muscle to have greater activation concentrically than eccentrically [30]. However, with no change in jump performance, muscle activation was not expected to be altered. Future assisted jump research would be enriched by collecting muscle activation across a longitudinal training program.

Conclusion

Based on the findings of the current study, there does not appear to be an acute PAP effect of assisted jumping on subsequent bodyweight countermovement vertical jumping in highly trained collegiate female volleyball players. Future assisted jump research should investigate optimal volume, BWR and rest intervals for athletic populations. Kinematic research should also be analyzed to identify any alterations in jump mechanics resulting from assisted jumping.

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