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A comparison of power variables for two loading methods in weighted vertical jumps 2020

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A Comparison of Power Variables for Two Loading Methods in Weighted Vertical Jumps

by

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Abstract

Training exercises to develop muscular strength and power, such as the weighted jump squat, commonly utilize barbells and dumbbells to increase resistance. Strength coaches often measure improvements in peak force, peak power, and rate of force development to determine effectiveness of a training program. The purpose of this study was to determine if equipment selection (barbells vs. dumbbells) affects peak force, peak power, and/or rate of force development in weighted jump squats. Thirteen physically active, college-aged males (age: 21.6 ± 2.0 years, height: 182.8 ± 9.7 cm, body mass: 87.2 ± 9.0 kg, lean mass: 72.3 ± 8.1 kg) performed weighted jump squats on a force platform while holding 30% of their body weight with dumbbells or a barbell on two separate days. Peak force, peak power, and rate of force development during the concentric phase of each jump were measured. The measures for the squat jumps with the dumbbells were compared to those for the squat jumps with the barbell. Significantly greater ($p < .001$) peak force and peak power were produced when using dumbbells (25.07 ± 2.20 Bodyweights and 81.083 ± 10.796 $W \cdot kg^{-1}$) compared to barbells (24.09 ± 2.17 Bodyweights and 73.66 ± 9.53 $W \cdot kg^{-1}$). The results suggest the use of dumbbells over a barbell of the same weight when performing weighted squat jumps, as an athlete may be able to produce more physiological stress with the same weight. Athletes and strength coaches can use this information to optimize programs for improving lower extremity strength and power.

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CHAPTER 1

INTRODUCTION

The vertical jump test is used by many sports leagues to determine a baseline of athletic ability (National Football League, 2019; NBA Media Ventures, 2019), and often the results of these tests can determine playing time within a team (Hoffman, Tenebaum, Maresh, & Kraemer, 1996). Additionally, Strength and Conditioning Coaches from various professional sports utilize some variation of a vertical jump test to determine baseline lower body power for their individual athletes (Ebben & Blackard, 2001; Ebben, Simenz, & Carroll, 2004; Sutherland & Wiley, 1997). In order to create programs that can improve lower body power, these strength and conditioning coaches – as well as the athletes they coach – look to the literature to inform their programs. Some of the basic methods utilized to improve power include Olympic lifts, loaded vertical jumps, and plyometrics (Ebben & Blackard, 2001; Ebben et al., 2004; Simenz, Dugan, & Ebben, 2005).

A variety of external load configurations are available to athletes, including various types of barbells, dumbbells, pulleys, among others. Despite the interest in improving lower body power, there has been a lack of comparative analysis to determine the optimal equipment to use when training the vertical jump. To date, the author has found only one previous article comparing two methods of loading – a barbell across the shoulders and a hexagonal barbell for this purpose (Swinton, Stewart, Lloyd, Agouris, & Keogh, 2012). However, past literature has focused on comparisons between the deadlift and back squat (Barnes, Miller, Reeve, & Stewart, 2017; Hales, Johnson, & Johnson, 2009; Rossow et al., 2018), the impact of external load on kinematic and kinetic measures during the vertical jump (Feeney, Stanhope, Kaminski, Machi, & Jaric, 2016; Harry, Barker, & Paquette, 2018), and the use of weighted vertical jumps as a training method (Hales et al., 2009; Khlifa et al., 2010). Findings from these investigations are inconclusive and further research is warranted to elucidate optimal training stimuli for maximizing vertical jump power.

Statement of the Problem

Previous research has established biomechanical differences between the squat and deadlift exercises (Hales et al., 2009; Hamlyn, Behm, & Young, 2007; Helms et al., 2017; Robbins, 2011; Rossow et al., 2018); however, a comparative analysis between the dumbbell and barbell jump squat has never been reported. The dumbbell and barbell have historically been used to load athletes while performing the jump squat, and it would be useful to determine if there are differences in relevant kinetic variables between the two loading methods. This information could aid development of training programs intended to improve jumping performance.

Purpose

The purpose of this study was to determine if there are differences in peak power, peak force, and rate of force development between dumbbell- and barbell-loaded jump squats performed using the same load magnitude.

Hypotheses

H_0: There are no differences in peak power, peak force, and rate of force development between dumbbell- and barbell-loaded countermovement jumps performed with the same load.

H_a: There are differences in peak power, peak force, and rate of force development between the two loading methods.

Delimitations

The delimitations of this study include:

1. Participants were recreationally active and had been for at least a year prior to participating in the study (≥ 3 days a week of 30-60 minutes of activity or at least 90 minutes of activity per week).
2. Participants had at least one year of experience with weightlifting prior to participation in the study.
3. Participants had at least six months of experience with jumping by participating in an organized activity in which jumping is prevalent. Some examples of these activities include basketball, football, soccer, volleyball, and Crossfit.

Limitations

The limitations of this study include:

1. Use of a convenience sample may not reflect population characteristics.
2. Testing a single load prevents the ability to determine if there is a load-specific effect.

3. COVID-19 forced facility closures and travel restrictions, causing an inevitable decrease in the number of participants recruited for this study.
4. Testing only males prevents the ability to determine if there is a gender-specific effect.

Assumptions

The following assumptions were made about this study:

1. All participants gave maximal volitional effort on all countermovement jump attempts.
2. The participants jumped perfectly vertically with no movement in the horizontal plane.

Definition of Terms

Peak Power Output – the highest power produced during the concentric phase of the jump movement.

Rate of Force Development – slope of the force-time curve from the start of the concentric phase of the movement until the peak force before toe-off.

One Repetition Maximum – the weight at which an athlete can only complete one repetition of a given movement.

Countermovement Jump – a two phase movement in which the athlete begins erect, initiates a downward movement of the center of mass by flexing at the knees and hips and then, after reaching the lowest point, immediately extending the ankles, knees, and hips to jump vertically off the ground.

Squat Jump – a one phase movement in which the athlete begins in the bottom of a squat and extends their ankles, knees, and hips to jump vertically off the ground.

Back Squat – a two phase movement beginning from an upright position in which the athlete pushes their hips backwards and flexing at the knees; the athlete drives the bar upwards after the top of their thighs are parallel with the ground.

Deadlift – a single phase movement in which the athlete begins with the barbell resting on the floor and ends with the athlete standing erect while holding the barbell.

Significance of the Study

The results of this study may produce information that will be valuable to strength and conditioning coaches and athletes in the design and implementation of training programs to improve vertical jumping ability.

CHAPTER 2

LITERATURE REVIEW

Previous literature regarding jump squats has not produced a direct comparison of kinetic variables between dumbbell- and barbell-loaded training stimuli. As such, this review of literature will focus first on the differences between the squat and deadlift, as those two lifts are very similar to the barbell- and dumbbell-loaded jumps, respectively. The review will also include an examination of the effectiveness of training with weighted vertical jumps on improving performance.

Comparative Analysis of Back Squat and Deadlift Movements

The National Strength and Conditioning Association (NSCA) describes the back squat as a two-phase movement. These phases are descent and ascent. The first phase begins from the upright position with the barbell resting on the shoulders of the athlete. The athlete then pushes their hips backwards while maintaining a neutral back and flexing at the knees. This downward motion is continued until the top of their thighs are parallel with the floor. Then, the athlete transitions into the second phase, where the athlete drives the bar upwards by pushing through the whole foot while extending their hips and knees to return to the starting position (Baechle & Earle, 2008). While the descent phase is considered an eccentric effort the ascent phase is concentric.

In contrast, the deadlift is a single-phase movement (ascent only) and begins with the barbell on the floor, which is gripped by the athlete with their arms just beyond shoulder width, and the feet shoulder width apart. The athlete extends their hips and knees and, keeping elbows fully extended, lifts the barbell off the floor. Once the barbell clears the knees, the athlete extends the trunk to move to an upright position (Baechle & Earle, 2008). The ascent phase of the squat and deadlift are similar motions, and both exercises utilize hip and knee extensor muscle groups (Baechle & Earle, 2008); however, there are differences in kinetics and muscular activation between the two. Based on these descriptions, it is clear that the squat utilizes both eccentric and concentric loading, while the deadlift requires concentric muscle activity only.

In 2009, Hales, Johnson, and Johnson performed a kinematic comparison of the squat and deadlift, and were hoping to determine a cross-over effect. That is, if increased performance on one task would translate to increased performance on the other. Twenty-five competitors in a national qualifying powerlifting competition had their motion analyzed while they performed both the back squat and deadlift exercises at maximal effort. The analyses revealed significant differences in vertical bar velocity, with the deadlift having greater velocity than the squat at the beginning of the ascent phase. The researchers ultimately concluded that no cross-over effect exists because the kinematic analyses showed the two lifts are “markedly different” (Hales et al., 2009). That is, the motor pattern necessary to complete one lift is unique from the other and thus adaptations made for one lift would likely translate to optimal ability in the other. In order to further examine differences in kinetics between the squat and deadlift, Rossow et al. (2018) examined the average concentric velocity and average power of the squat and deadlift in both submaximal and maximal effort lifts. The researchers tested 51 subjects and determined that “deadlift velocity ranges should be lower than squat velocity ranges for the same relative loading.” The data also revealed that average power was greater in the deadlift for loads ≥55% one repetition maximum (1RM) (Rossow et al., 2018). In another study comparing rating of perceived exertion (RPE) and average concentric velocity in the squat, bench press, and deadlift, Helms et al. (2017) again found that average concentric velocity is higher in the squat than the deadlift for loads ≥80% 1RM. The researchers tested fifteen female powerlifters for their 1RM "according to the rules of the International Powerlifting Federation," recording RPE after every set, and average concentric velocity for all sets ≥80% estimated 1RM (Helms et al., 2017). Thus, despite similar instructions for the ascent phase of these exercises, there are quantitative differences detectable between their actual performances. Specifically, movement velocity differs between these two tasks, which would influence the mechanical power (product of force and velocity) produced during the movements.

Researchers have also found differences in muscle activation between the squat and deadlift. Robbins (2011) examined muscular activation during the squat and deadlift in the erector spinae, gluteus maximus, biceps femoris, vastus medialis, and gastrocnemius; he then compared these to the activation patterns in the countermovement jump (CMJ). The results of testing ten college aged males who were all experienced with weightlifting revealed that the deadlift required a similar neuromuscular pattern to the CMJ whereas the back squat differed. Specifically, the gastrocnemius activation was significantly higher in the CMJ than the back squat; unfortunately, the author did not include information regarding any temporal differences in these muscles' activation which would have provided better insight into the neuromuscular coordination of the tasks (Robbins, 2011). Similarly, Hamlyn, Behm, and Young (2007) examined the activity of the lower abdominals, external obliques, upper lumbar erector spinae, and lumbar-sacral erector spinae during various weight training and isometric instability exercises. The researchers found that there was significantly more upper lumbar erector spinae activation in the deadlift than in the squat, and the opposite was true for the lumbar-sacral erector spinae (Hamlyn et al., 2007). Despite the similar ascent phase between the two lifts, there are significant differences between the deadlift and back squat both kinetically and in terms of muscular activation patterns. The differences in muscular activation are of interest for this study as the barbell loading method reflects a back squat, while the dumbbell loading method resembles a deadlift.

Weighted Jumps as a Training Stimulus

According to the NSCA, “an exercise intensity that is too low does not overload the body’s systems and induce desired physiological adaptations” (Baechle & Earle, 2008). This principle of overload has long been applied to traditional resistance exercises in order to increase an athlete’s ability to produce high force; more recently, researchers have investigated whether the same effect is true for explosive exercises such as vertical jumps where power (product of force and velocity) is the critical factor. This section of the review of literature will first focus on the acute effects of utilizing additional external load and conclude with a review of longitudinal studies.

Burkett, Phillips, and Ziuraitis (2005) investigated four distinct warm-up methods to determine the ideal method to prepare athletes for a maximal vertical jump. The four protocols were (a) submaximal jumps roughly equivalent to 75% of the participant’s maximum jump height, (b) submaximal jumps loaded with ~10% of the participants body weight, (c) a static stretching protocol, and (d) no warm-up. After analysis, the researchers found that the warm-up utilizing additional load was the most beneficial, as their participants performed 1.67cm on average better following the overload warm-up compared to all other warm-up protocols (Burkett, Phillips, & Ziuraitis, 2005). Alternative methods to provide external loading during jump training have also been explored. For example, Barr et al. (2015) investigated the effects of eight days of hypergravity on rugby players during preseason rugby training. Half of the participants wore a vest that corresponded with 12% of their body weight during all practices and team activities, while the other half was a control group that wore no weight vest. Data collection revealed no group differences for sprint speed over 40m; however, the experimental group displayed a decrease in ground contact time during the acceleration phase of the 40m sprint, and increase in 15kg CMJ peak velocity. The results from both of these studies suggest that utilizing weight vests – even acutely – can improve CMJ performance.

There have been numerous studies that have investigated the use of weighted vertical jumps as training over time to produce improved unweighted jump performance. In 2010, Khlifa et al. investigated how 10 weeks of plyometric training with no strength training impacted both squat jump and CMJ performance. The participants were split into three groups: a control group and two experimental groups who participated in the plyometric training, with one group performing the training while wearing a weighted vest with 10-11% of their body weight. Following training, both of the training groups improved vertical jump performance; however, gains in squat jump, CMJ, and horizontal jump were greater in the group who performed the weighted plyometric training (Khlifa et al., 2010). In order to further investigate the effect of heavy- versus light-loaded vertical jumps, McBride et al. (2002) split participants into three groups: control; a group that trained with an additional 30% 1RM; and a group that trained with an additional 80% 1RM. Following eight weeks of training twice per week, the light training group increased peak power and velocity in the tested weighted jumps with 30%, 55%, and 80% 1RM. This group also increased their 1RM and exhibited a trend towards improving their 20m sprint time and increased EMG activity in the vastus lateralis during the weighted jump with 30% 1RM compared to control group. The heavy training group also increased peak power and peak force in the tested weighted jumps with 55% and 80% 1RM, increased their 1RM, but also their performance in the 20m sprint was slower; this group also increased EMG activity in the 80% 1RM weighted jump. These results indicate that training with lighter loads may be more beneficial than training with heavier weight when training to improve power (e.g., sprinting) vs. absolute force (e.g., higher percentages of 1RM). These results also suggest that a load specific training effect may exist, as the heavy group showed increased EMG activity in the heaviest of tested jumps (McBride, Triplett-McBride, Davie, & Newton, 2002). Markovic, Mirkov, Knezevic, and Jaric (2013) went in the opposite direction by investigating how training utilizing a negative load would impact CMJ performance. The researchers split their participants into four groups: a control, no added load, negative load of 30% BW achieved using bands and pulleys, a positive load of 30% BW using bands and pulleys, and a positive load of 30% BW using a weighted vest. All participants – except the control group – participated in the same training protocol three days a week for eight weeks which consisted of nine to twelve sets of six repetitions of maximal vertical jumps while under their assigned load. Following training, all groups improved jump height, average and maximum power, and maximum force during the squat jump. Additionally, all groups improved jump height in the CMJ; however, the no load and negative loading groups had the smallest and possibly negative gains in power. A novel finding from this study was that the negative loading group significantly increased the depth of the countermovement during the CMJ, “which inevitably decreases the ground reaction force due to a lower leverage of the leg extensor muscles” (S. Markovic, Mirkov, Knezevic, & Jaric, 2013). The results of this study confirm the findings of McBride et al. (2002) that training with a load of 30% 1RM can increase CMJ performance. Collectively, the principles of Overload and Specificity are apparent in these training protocols. Athletes should adopt a training program that will provide the appropriate training stimulus to achieve stated goals of their athletic competition. To date, magnitude of loading and form (e.g., back squat vs. dead lift) demonstrate that the training program dictates results. However, the type of load used (e.g., barbell vs. dumbbell) may also influence form in a given lift and thus contribute to altered outcomes for the same general movement protocol.

Summary

In review, it is clear that weighted jump or plyometric training with an added load of up to 30% 1RM in the vertical jump will lead to improved performance in the CMJ and squat jump. However, previous literature has yet to explore differences in how the load is applied. Therefore, it stands to reason that utilizing dumbbells and barbells may also elicit differing kinetic parameters. Exploring this topic will better elucidate particular training benefits from using these methods which will allow Strength and Conditioning Coaches and athletes to make more informed decisions regarding training loads to pursue their desired performance outcomes.

CHAPTER 3

METHODS

Participants

Thirteen college-aged males (age: 21.6 ± 2.0 years, height: 182.8 ± 9.7 cm, body mass: 87.2 ± 9.0 kg, lean mass: 72.3 ± 8.1 kg) who were recreationally active (≥ 3 days/week of 30-60 minutes of moderate activity) were recruited for this study. These characteristics are in line with recommendations from previous literature (Kane, 2018; Swinton et al., 2012). Participants were required to have participated in a weightlifting program for at least a year prior and an activity that incorporates explosive jumping movements for at least a year prior to participation in this study, ten of the participants had competed in rugby fifteens in the past year, the remaining three were experienced jumpers through their weightlifting regimen. Exclusion criteria included injuries to the lower limb or lower back six months prior or neurological trauma a year prior to participation in this study. Potential participants were also excluded if they were unable to hold and jump with dumbbells (DB) approximating 30% of their body weight.

Instruments

This study utilized a Bertec force platform (Columbus, Ohio) to collect ground reaction force (GRF) data at a frequency of 1000 Hz. Vertical forces were exported as a text file for processing in Microsoft Excel (Redmond, WS). External loads were added using DB and barbells (BB) (York Barbell, York, PA). Given DB vary in weight by 5 lb increments, a magnetic 1.25 lb weight was attached to each DB as necessary to obtain better resolution of loads. This meant that the maximum difference from expected and applied weights was <2.5 lb rather than <5 lb. Researchers collected height and weight using a stadiometer and scale (Detecto-Medic, Detecto Scales, Brooklyn, NY). A two contact point Tanita (Tokyo, Japan) body composition analyzer was used to determine lean body mass. A camera (iPhone 8, Apple, Cupertino, CA) was utilized during the DB loading method to examine arm swing during the trials. A treadmill (Trackmaster, Newton, KS) was utilized during the warm-up protocol, where each subject's self-selected pace was recorded and kept constant throughout the study.

Design and Procedures

Participants visited the laboratory on two occasions. The first included signing informed consent and providing physical activity history. Then, participants performed a standardized warm-up routine and familiarized themselves with jumping on the Bertec force platform for maximum height with minimal lateral motion.

The warm-up protocol included a general warm-up period and dynamic stretching. The former consisted of a 5 minute treadmill jog at a self-selected pace, which was recorded at the first session and maintained constant throughout the study (Perrier, Pavol, & Hoffman, 2011).The latter procedure (Table 1) was adapted from prior work (Perrier et al., 2011) and included movements predominantly in a single plane of motion (e.g., skipping) and multiplane movements (e.g., diagonal lunges).

Table 1. Dynamic Stretching Protocol*

Easy skip with arm swings
Skip for height
Lateral low shuffle (each direction, no walk to start)
Walking diagonal lunges
Carioca (each direction, no walk to start)
Gradual accelerations (1 x 50%, 2 x 75%)

*Each exercise was performed twice for 20 yards. Participants walked back to the starting line between repetitions.

Following the warm-up, participants were allowed to familiarize themselves with jumping and landing on the force platform. They performed this task with and without the 30% BW load using BB and DB. Each participant completed sets of two repetitions with each loading method with at least one minute separating each set and fifteen seconds between each rep within sets. This procedure is similar to methods described in previous work (S. Markovic et al., 2013). Number of sets and repetitions varied by person and this was decided based on how quickly the participant demonstrated high reliability in their performance. Reliability was determined by intraclass correlation (ICC) using an absolute agreement, two-way mixed effects model (Cohen, 1969). The participant was considered familiarized when the ICC for peak force was at least 0.8 over the most recent three sets – indicating they produced consistent data. Stance width for all trials of the same loading method were standardized to the individual's preferred stance width. Prior to the first trial of each method, tape was placed on the force platform along the participant's instep. The distance between the two pieces of tape was recorded and maintained constant for the testing session; as, "a person's weight as registered by a force platform varies slightly depending on where the feet are placed [on the platform]" (D. G. E. Robertson, Caldwell, Hamill, Kamen, & Whittlesey, 2014, p 88). After this familiarization, the participants scheduled their next visit with the researcher and then left for the day. Participants were also asked to refrain from participating in strenuous lower body activity for 24 hours prior to arrival for the testing session.

Upon arrival to the laboratory for the testing session, participants first provided anthropometric (height, weight) and demographic (age, sex) information. Then, participants performed the standardized warm-up, as described above, and then performed loaded countermovement jumps under two external loading conditions – BB and DB – with the order determined by a coin flip. Participants completed two repetitions with ~30% BW in the selected load configuration with fifteen seconds of rest between repetitions (Loturco et al., 2015). Participants were then given a five minute period of passive rest before performing the remaining loading condition (Barr, Gabbett, Newton, & Sheppard, 2014).

Trials would have been repeated if the participant dropped a DB or BB; the BB left the participant's shoulders; the participant failed to land on the force platform; there was excessive movement in the horizontal plane; there was excessive swinging of the DB; or the trial "[appeared] to be of sub-maximal effort" (Cormie, McBride, & McCaulley, 2009; Cormie, McCaulley, & McBride, 2007; Cormie, McCaulley, Triplett, & McBride, 2007; Driss, Vandewalle, Quièvre, Miller, & Monod, 2001; Harry et al., 2018). Force platform data collection was initiated at least one second before the participant began their set, in order to obtain an accurate weight measure and decrease error in data processing (Robertson et al., 2014).

Data Processing

GRF-time data were filtered by the collection software at 250 Hz (Bertec Acquire 4.0, Colombus, OH) and these filtered data were used to calculate peak power (PP), peak force (PF), and rate of force development (RFD) of the system through forward dynamics as described by Hori et al. (2007) and Robertson et al. (2014). Through forward dynamics, power output is the product of the force measured by the force platform and the calculated instantaneous velocity of the system.

First, GRF data were converted to acceleration by dividing the GRF by the mass of the system at each time point after subtracting the person's bodyweight (Equation 1):

$$a_y = \frac{(F_y - W)}{m} \qquad (1)$$

Where, a_y is the vertical acceleration in $m \cdot s^{-2}$, F_y is the vertical GRF in N, W is weight of the system (participant + load) in N, and m is mass of the system in kg.

The acceleration of the system was then integrated to obtain instantaneous velocity (Equation 2):

$$v_i = v_{i-1} + a_i(\Delta t) \qquad (2)$$

Where, v_i is the instantaneous velocity at time i in $m \cdot s^{-1}$, v_{i-1} is the instantaneous velocity at the sample prior to i in $m \cdot s^{-1}$, a_i is the instantaneous acceleration at time i in $m \cdot s^{-2}$, and Δt is the difference in time between successive samples in s. Participants were instructed to stand still when data collection was initiated; as such, $v = 0$ at the start of data collection. These velocities were used in determining descent (negative velocity) and concentric (positive velocity) phases. The point at which the velocity transitions from negative to positive indicates the lowest point of the squat motion (Mundy, Smith, Lauder, & Lake, 2017).

RFD was calculated from the beginning of the concentric phase of the jump until peak concentric force is reached. RFD represents the average slope of the force-time curve and was calculated as described in Hansen, Cronin, and Newton (2011) (Equation 3):

$$RFD = \frac{F_{Peak} - F_{con}}{time_{Peak} - time_{con}} \quad (3)$$

Where, RFD is the average slope of the force-time curve in $N \cdot s^{-1}$, F_{Peak} is the peak force observed in the concentric phase, $time_{Peak}$ is the time index of the peak force, F_{con} is the force at the initiation of the upward motion (where concentric muscle actions occur), and $time_{con}$ is the time index of the point where upward motion begins.

Instantaneous power was calculated as the dot product of the vertical velocity and vertical force profiles for the entire jump trial in Watts. Initiation of the descent phase was identified via the method above (i.e., a negative velocity) and takeoff (termination of the jump effort) was identified at the point where force reached zero N. The peak positive power value was obtained and used in further analysis. Force measures were then normalized by bodyweight and power by mass. This yielded peak force in Bodyweights, rate of force development in $\text{Bodyweights}\cdot\text{sec}^{-1}$, and power in $\text{Watts}\cdot\text{kg}^{-1}$ for comparisons between conditions. The two repetitions of each loading method were processed separately, with the dependent variables obtained from each then averaged and utilized for statistical analyses.

Statistical Analysis

Means and standard deviations are reported for all dependent variables. A repeated measures T-test was used to determine if differences exist between the dependent variables obtained from the two loading conditions. Cohen's *d* effects size was also calculated to determine the magnitude of difference between the two loading methods. The effect size will be characterized as: trivial: $d < 0.2$; small: $0.2 < d < 0.49$; medium: $0.5 < d < 0.79$; and large: $d > 0.8$ (Cohen, 1969). Significance was set at $p < .05$, and all statistical analyses were conducted using JASP version 0.11.1 (University of Amsterdam, 2019).

CHAPTER 4

RESULTS

Skilled jumpers were sought for this study and the familiarization data support their self-reported status. In familiarization, strong reliability was reached for both the DB and BB conditions, 0.97 ± 0.03 and 0.93 ± 0.05, respectively. On average, participants reached this reliability in 3.3 ± .06 and 3.4 ± 0.77 sets for DB and BB, respectively. Thus, no participants were excluded from the study and the descriptive statistics for the thirteen participants can be found in Table 2.

Table 2. Descriptive Statistics of Participants

Parameter	Mean (SD)	Range
Age (years)	22 (2)	
Height (cm)	182.83 (9.74)	
Mass (kg)	87.08 (9.10)	
Lean Mass (kg)	72.31 (8.06)	
ICC DB	.97 (.03)	
Number of Sets DB	3.3 (0.60)	3 - 5
ICC BB	.93 (.05)	
Number of Sets BB	3.4 (0.77)	3 - 5

Note: ICC = intraclass correlation coefficient; DB = dumbbell; BB = barbell

There was a large difference (d = 1.391) in PF ($p < 0.001$) when using DB (25.07 ± 2.20 Bodyweights) compared to BB (24.09 ± 2.17 Bodyweights), as well as PP ($p < 0.001$; d = 1.669) when using DB (81.083 ± 10.796 W/kg) compared to BB (73.66 ± 9.53 W/kg) (Table 3). There was also a medium difference (d = 0.603) in RFD when using DB

(43.55 ± 17.02 Bodyweights/sec) compared to BB (38.81 ± 15.54 Bodyweights/sec) but this was not significant (*p* = .05).

Table 3. Descriptive Statistics of Dependent Variables

Parameter	DB	BB	*t*	*p*	*d*
PF (Bodyweights)	25.07 (2.20)	24.09 (2.17)	5.014	<.001	1.391
PP (W/kg)	81.08 (10.80)	73.66 (9.53)	6.019	<.001	1.669
RFD (Bodyweights/sec)	43.55 (17.02)	38.81 (15.54)	2.176	.05	.603

Note: PF = peak force; PP = peak power; and RFD = rate of force development

CHAPTER 5

DISCUSSION

The purpose of this study was to determine if there were any significant differences in kinetic measures during the concentric phase of jump squats when loaded with dumbbells versus barbells approximating 30% body weight. The results of this study suggest that jumping with DB produces higher PF and PP, while also exhibiting a trend towards the same results with RFD. Athletes seeking to promote power development should opt for the dumbbell approach based on this set of outcomes.

Discussion

This study is the first to produce a direct comparison of kinetic variables between DB- and BB-loaded training stimuli. The data suggest that PF and PP are significantly greater when using DB compared to BB of the same load, and although not statistically significant, rate of force development displayed a moderate effect when using DB. These results are consistent with those of Swinton et al. (2012), who found significantly higher jump height, peak force, peak power, and peak rate of force development when using a hexagonal barbell compared to a barbell across the back of the shoulders. While discussing those results the authors hypothesized that moving the load closer to the athlete's center of mass enabled their subjects to "more closely replicate their unloaded vertical jump technique" (Swinton et al., 2012). Here, the dumbbells may have produced the same effect. Whereas the dumbbells could hang approximately in line with the body's center of mass location, the barbell requires the athlete to lean forwards slightly. This change in trunk position likely impacted the angles of pull for the lower extremity muscles and consequently lowered vertical force generation in the that condition. Future work should include three-dimensional motion analysis to determine if there are significant differences in joint kinematics and/or kinetics – specifically at the hip – between the two loading conditions (dumbbells and barbell). A joint level kinetic investigation would elucidate the specific loading pattern in the lower extremity to inform athletes and Strength Coaches as to the specific stimulus provided by each. For example, if athletes seem to rely on the hip for power generation in one of these conditions and that is the primary target for the athlete, they could adopt the program that stresses that joint to the greater degree. As of now, data presented here only allow for the conclusion that the total power produced by the entire system is greater with dumbbells than barbells.

Another possible explanation for the differences between variables could be the dynamics present at the ankle throughout the movement. As stated above, Robbins (2011) found greater activation in the gastrocnemius during the deadlift movement when compared to the back squat; similarly, Escamilla et al. (2002) found a plantarflexion moment was present throughout the conventional deadlift. Therefore, there may be increased plantar flexor activity about the ankle joint during the dumbbell condition of the current study. As mentioned above, future research should focus on a three-dimensional motion analysis to determine the specific loading pattern to inform on the specific stimulus provided by each loading method.

A limitation of the current study is the testing of a single load, as the authors were unable to determine if there is a load-specific effect on these kinetic variables across load configurations. For example, Swinton et al. (2012) found that peak power was significantly greater when loaded with 20% 1RM with the hexagonal barbell compared to all other weight conditions studied and Rossow et al. (2018) found similar results when comparing the deadlift and back squat. In their investigation, average power values were higher in the deadlift compared to back squat at loads ≤55% 1RM. These results suggest the existence of a load-specific effect where a particular load configuration (e.g., barbell vs. dumbbell) may be optimal for a given weight but not another. However, moderate loads such as that imposed here (30% bodyweight) are optimal for power production (McBride et al., 2002), rather than extremely light or heavy loads, and identifying the load configuration optimal for producing peak power was the goal of the present investigation.

Another limitation of the current study is the use of a convenience sample that may not reflect the population characteristics. Additionally, all participants were male. Female athletes, whose anthropometrics differ (e.g., have lower center of mass locations) may produce different results. Finally, COVID-19 forced facility closures and travel restrictions, which ultimately led to a limit on recruitment of participants and lower statistical power than desired.

The current study examined acute use of two different loading methods of equal weight and concludes that dumbbells are preferred over barbells for peak force and power production in squat jumps. Future research should focus on how training, or chronic use of the two loading methods impacts both kinetic and performance outcomes. Future research could also focus on other common load configurations, such as a weighted vest or pulleys, to further elucidate the impact of loading method on power production in power athletes. Indeed, it is well established that loading an athlete utilizing weighted vests and bands and pulleys during plyometric training results in improvements in kinetic variables and athletic tests (Khlifa et al., 2010; G. Markovic & Jaric, 2007; McBride et al., 2002). However, there has not been direct comparison of chronic training adaptations using the two loading methods examined in the current study.

Conclusion

The results of the current study suggest that dumbbells may provide a more effective training stimulus during a weighted jump program than barbells. Athletes and Strength and Conditioning Coaches may use this information to promote development of peak force and power production in the weight jump exercise. However, given peak force and power differed by load configuration here, Coaches should be mindful that the absolute prescribed load (e.g., 30% bodyweight) may represent different challenges to the athlete than the weights would indicate (e.g., force production). Dumbbells may place more physiological stress on the athlete than a barbell for the same load; therefore, Coaches may have to edit the set and rep schemes for individual athletes to meet the expected training stimulus.

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Appendix A – Informed Consent

ADULT CONSENT
State University of New York College at Cortland

The research in which you have been asked to participate is being conducted by Jonathan Tanguay of the Kinesiology Department at SUNY Cortland. We request your informed consent to be a participant in the project described below. *Please feel free to ask about the project, its procedures, or objectives.*

Information and Procedures of This Research Study:
The purpose of this study is to compare the force, power, and rate of force production during maximal vertical jumps while holding dumbbells versus barbells. Eligible participants are physically active adults who currently include jumping in their weightlifting routine and are free form musculoskeletal and neurological injury for at least 6 months leading up to the study. Participation includes two individual days of activity (approximately 1.5 hours total). Participants will perform maximal vertical jump efforts while holding a weight (dumbbell or barbell) approximately 30% of their body weight. Researchers will record the amount of force produced during these tasks via a force platform embedded in the floor of the Biomechanics Laboratory (Professional Studies 1163). Researchers will also record video of the trials utilizing dumbbells in order to determine a successful trial.

Before agreeing to participate you should know that:

A. Freedom to Withdraw
You are free to withdraw your consent at any time without penalty. Even if you arrive for and/or have begun a testing session and realize for any reason that you do not want to continue, you are free to withdraw from the study. Additionally, you may ask the researcher to destroy any responses you may have given or data you may have provided.

B. Protection of Participants' Responses
Your responses and data are strictly confidential. Only the presiding faculty member and research assistants will have access to your responses. The researchers will assign you an identification number that will be used in all digital and/or physical records of the data you provide. All informed consents and copies of the data will be locked in the principal investigator's office.

C. Length of Participation and Remuneration
The study should take approximately one and a half hours, split into two visits to the laboratory, separated by seven to ten days.

D. Risks Expected
Risks associated with participation in this activity will not exceed those of your normal physical activity routine. However, typical injuries such as strains or sprains, trips, and/or falls associated with any physical activity may occur in performing the tasks involved in this study. Some mild muscle soreness may also occur as a consequence of the activities performed in this study. These risks will not exceed the normal level of exercise performed in daily living by the eligible participants in this study.

E. Benefits Expected
Participation in this study may enhance your knowledge of vertical jump training and potential methods for increasing your performance of the same.

F. Contact Information
If you have any questions concerning the purpose or results of this study, you may contact Jonathan Tanguay, ph: (717) 503-9032, email: jonathan.tanguay@cortland.edu. **For questions about research or research participants' rights, contact Research and Sponsored Programs Office, SUNY Cortland, at (607) 753-2511.**

I ____________________________ have read the description of the project for which this consent is requested, understand my rights, and I hereby consent to participate in this study.

____________________________ Signature **____________ Date**

Optional

I ____________________________ consent for researchers to use photographs and/or video of my performance for academic purposes.

____________________________ Participant Signature **____________ Date**

Appendix B – Data Collection Sheet

ID #: ___________________

Demographics

Age: ________ Sex: _________

Are you able to hold and jump with dumbbells equivalent to approximately 30% of your bodyweight?

Yes No

Have you had a lower extremity or lower back injury that would impair jumping performance in the last 6 months?

Yes No

Have you participated in 30-60 minutes of physical activity three days a week for at least the past year?

Yes No

Do you currently participate in a sport or activity where jumping is prevalent?

Yes No

If yes, what sport(s)?

____

And for how long have you been participating?

____

Anthropometrics

Height: _________ cm Weight: __________ lb 30% Bodyweight: ___________ lb

Lean body mass: __________ lb

Preferred stance width: _____________ cm

Barbell load: _________ lb; traditional or body pump bar; ____________ lb plates

Dumbbell load: 2 x _______ lb dumbbells

Warm-up:

Check off when each exercise completed

Exercise	Familiarization	Data Collection
Skip w/arm swings		
Skip for height		
Shuffle		
Diagonal lunges		
Carioca		
Accel to 50%		
Accel to 75% x 2		

Familiarization:

Equipment:

- Barbell
- Plates
- Dumbbells
- Tape
- Tape measure (for stance width)

Record peak force for each jump, ICC overall at that point, and whether it would have counted as a trial.

	Dumbbells				Barbell			
Trial	**Jump1**	**Jump2**	**ICC**	**Good?**	**Jump1**	**Jump2**	**ICC**	**Good?**
Trial 1								
Trial 2								
Trial 3								
Trial 4								
Trial 5								
Trial 6								
Trial 7								

Data Collection:

Equipment:

- Barbell
- Plates
- Dumbbells
- Tape
- Tape Measure

	Dumbbells		Barbell	
Trial	**Good Trial?**	**File name**	**Good Trial?**	**File name**
Trial 1				
Trial 2				
Trial 3				