Squat Jump Training at Maximal Power Loads Vs. Heavy Loads: Effect on Sprint Ability

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Abstract

Harris, NK, Cronin, JB, Hopkins, WG, and Hansen, KT. Squat jump training at maximal power loads vs. heavy loads: effect on sprint ability. *J Strength Cond Res* 22(6): 1742–1749, 2008—Training at a load maximizing power output (P_{max}) is an intuitively appealing strategy for enhancement of performance that has received little research attention. In this study we identified each subject's P_{max} for an isoinertial resistance training exercise used for testing and training, and then we related the changes in strength to changes in sprint performance. The subjects were 18 well-trained rugby league players randomized to two equal-volume training groups for a 7-week period of squat jump training with heavy loads (80% 1RM) or with individually determined P_{max} loads (20.0–43.5% 1RM). Performance measures were 1RM strength, maximal power at 55% of pretraining 1RM, and sprint times for 10 and 30 m. Percent changes were standardized to make magnitude-based inferences. Relationships between changes in these variables were expressed as correlations. Sprint times for 10 m showed improvements in the 80% 1RM group (−2.9 ± 3.2%) and P_{max} group (−1.3 ± 2.2%), and there were similar improvements in 30-m sprint time (−1.9 ± 2.8 and −1.2 ± 2.0%, respectively). Differences in the improvements in sprint time between groups were unclear, but improvement in 1RM strength in the 80% 1RM group (15 ± 9%) was possibly substantially greater than in the P_{max} group (11 ± 8%). Small-moderate negative correlations between change in 1RM and change in sprint time ($r \approx -0.30$) in the combined groups provided the only evidence of adaptive associations between strength and power outputs, and sprint performance. In conclusion, it seems that training at the load that maximizes individual peak power output for this exercise with a sample of professional team sport athletes was no more effective for improving sprint ability than training at heavy loads, and the changes in power output were not usefully related to changes in sprint ability.

Key Words impulse, strength, velocity, kinetics, kinematics

Introduction

The optimal combination of training variables for the improvement of functional performance such as sprinting, jumping, and throwing remains an area of great contention among sports science researchers and strength and conditioning practitioners. A key area of conjecture is which training load, usually expressed as a percent of one-repetition maximum (%1RM), and associated training velocity, should be used. Some researchers proclaim the superiority of heavy (80% 1RM and above) loading schemes (32,35,37), some lighter (50–60% 1RM and below) (26,28,36), and some a combination of loads (1,17). Other studies have reported no statistical difference in training effects between groups using different loads (8,14).

A number of researchers and practitioners have postulated that training at loads where mechanical power output is maximized (P_{max}) is optimal for improvements in functional performance (4,24,29,33,34,36,39). Progressing this contention, some studies have sought to determine the relative effectiveness of training with so-called P_{max} loads vs. other training loads (9,17). Blazevich and Jenkins (9) hypothesized that training with loads corresponding to optimum power output should result in superior improvements in 20-m sprint times over the course of a 7-week training period in nationally ranked sprinters. One group trained with 30–50% 1RM, and the other 70–90% 1RM. Both groups significantly decreased sprint times (−4.3 and −2.9% for the 70–90 and 30–50% 1RM groups, respectively), but there were no significant differences between groups. Harris et al. (17) also examined the effects of training at either high force (80% 1RM), high power (30–45% 1RM), or a combination of loads using various lower-body exercises on strength, power, and 30-m sprint time during a 9-week training period. Only the combination training group significantly improved sprint times (−1.6%). Results from these two studies are difficult to interpret, however, because total training volume (e.g., sets × reps × load) was not equated between groups, and so the

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reported differences between the training protocols could be a result of differences in training volume rather than specific kinematic and kinetic characteristics of the different loading intensities (20). Additionally, both studies chose the so-called high-power loads based on previous research that reported that power was maximized at approximately 30% of maximum isometric strength (24,36). Neither study identified P_{max} for each individual or for the respective resistance training exercise used for testing and training.

A common assumption of many authors is that power is maximized at loads of 30–45% 1RM (3,7,24,27,36). However, there are large interindividual and exercise-specific differences in the load where P_{max} occurs (19,33). Hence, it would seem important to specifically identify the load where P_{max} occurs for each individual subject on specific exercises to adequately investigate the effects of P_{max} training on force, power, and functional performance. Only two studies to date have attempted this (30,36), but each is characterized by its own methodological limitations. Newton et al. (30) have reported that 4 weeks of Smith machine jump squat training at the load where mechanical power was maximized for each individual attenuated declining jump performance in women volleyball athletes during a competitive season. Average power (12.0%) and force (12.4%) during a loaded Smith machine jump squat were also significantly improved post-training, in addition to significant increases for peak force (5.7%) and peak velocity (8.8%) during an unloaded jump squat. No control group or alternative training groups were investigated, because of the ethical issue of using elite competitive athletes in-season as subjects, so no comparison could be made with other training modalities, thus limiting the validity of determining the superiority of such training. Additionally, although it was specifically noted that training loads were continually adjusted to the point where maximal mechanical power was maximized for each individual, the methods used for determining peak power are not clear, and the loads used during training were not reported as percent 1RM; thus, applying the recommendations to a practical setting is problematic.

Wilson et al. (36) also have investigated the effect of training with individual P_{max} loads during a 10-week period. One group trained with maximal power loads, but, in contrast to the study by Newton et al. (30), P_{max} was identified as the load that maximized mean mechanical power output rather than peak mechanical power output. It was stated that loads were around 30% of maximum isometric force. Two other groups trained with either heavy loads (6-10 RM $\approx$ 75–84% 1RM) or with body-weight jumps. Pre- and posttesting included 30-m sprint times and jump height. The P_{max} training resulted in an improvement in sprint times (-1.5%) described as "approaching statistically significant," whereas sprint times for the other two training groups were virtually unchanged (-0.2%). The P_{max} group also experienced significantly greater gains in jump height (17.6%) than the other groups (5.1 and 10.3% for the heavy load and body weight groups, respectively) pre- to posttraining. The authors conclude that their results strongly suggest the superiority of training at P_{max} loads for the improvement of athletic performance, and they state that loads of 30% of maximum should be used. However, the study suffers from a similar methodological problem to that of Newton et al. (30) in that the methods for determining P_{max} are not clearly described. Also, volume was not equated between training groups.

No study to date has specifically identified peak power outputs for each individual on the specific isoinertial resistance training exercise used in both testing and training. Furthermore, no study has tracked strength, force, and power outputs on that exercise and related these factors to changes in sprint ability over a training period. Thus, this study aimed to quantify the effect of training at individual peak P_{max} load vs. training at heavy loads (80% 1RM) on changes in concentric strength and power outputs, and sprint ability in well-trained athletes after 7 weeks of equal-volume training on a machine squat jump.

Methods

Experimental Approach to the Problem

To determine the effectiveness of training at P_{max} on changes in sprint times in well-trained athletes, two groups trained for 7 weeks with a machine squat jump at either 80% 1RM or at the load where peak power was maximized for the individual. Training volume was equated between groups, and a 4-week familiarization period was first prescribed for both groups to negate any learning effects and to increase the reliability of baseline measures. Training took place during the specific preparation preseason period of an elite rugby league squad. Within-subject modeling was used to estimate the changes in force and power outputs at 55% of pretraining 1RM. The relationship between these variables was determined with correlational analysis. Percent changes were standardized to make magnitude-based inferences on the differences between groups.

Subjects

Eighteen elite-level rugby league players from one premier squad volunteered and provided written consent for testing as part of their contractual arrangements with their squad. Their age, mass, and height were 21.8 $\pm$ 4.0 years, 96.2 $\pm$ 9.9 kg, and 180.7 $\pm$ 4.6 cm (mean $\pm$ *SD*). All had experience of resistance training (3.6 $\pm$ 2.2 years). The institutional ethics committee approved all procedures.

Equipment

Subjects performed their assessments on a customized standing hack-squat machine (Fitness Works, Auckland, New Zealand) described previously (18). A linear position transducer (P-80A, Unimeasure, Corvallis, Ore–mean sensitivity 0.499 $mV \cdot V^{-1} \cdot mm^{-1}$, linearity 0.05% full scale) was attached to the sled and measured vertical displacement of the sled with an accuracy of 0.01 cm. Data were sampled at 500 Hz and collected via a computer-based data-acquisition and analysis program (Labview 6.1. National Instruments, Austin, Tex). The measurement of force as described in this experiment has been verified by comparison of the linear transducer data with data gathered simultaneously from an accelerometer and a force platform across movement types (concentric only and rebound bench press-squat, counter-movement, and drop jump), loads (40–80% 1RM), and sampling frequencies (200–1000 Hz). The data from the linear transducer were shown to be reliable (coefficient of variation = 2.1–8.4%, and intraclass correlation coefficient = 0.92–0.98 for measures of mean and peak force) and valid across these conditions (13). The validity of exclusively using a linear position transducer to determine power outputs in squat jumps has also been reported previously (23).

Sprint times for 10 and 30 m were measured using the Kinematic Measurement System (KMS, Optimal Kinetics, Ind). The within-trial variability (coefficient of variation ≤ 1.2%) of this procedure has been reported previously (12).

Procedure

The maximal strength (1RM) and concentric power load spectrum (20–80% 1RM) were assessed for each subject on three occasions. The first occasion was before a 4-week familiarization period. The second occasion was immediately before a 7-week training period, and the final occasion was immediately post the 7-week training period. Instructions were issued to subjects to standardize pretest preparation (exercise levels, nutrition, etc.) as much as possible in the 24-hour period preceding the testing session. At each session, the subjects first performed a standardized warm-up procedure consisting of running, dynamic stretching, and ball drills.

At the first testing occasion, subjects were familiarized with the machine hack-squat by performing two warm-up sets at a light weight (40–60 kg). In an effort to be somewhat specific to the knee angles encountered in sprinting (38), start position was standardized to 110° at the knee, using a goniometer (centered at the lateral epicondyle of the knee and aligned to the lateral malleolus and greater trochanter). Adjustable mechanical brakes were used to fix the stop-start position for the machine at the 110° knee angle. Foot position was self-selected by subjects but standardized to within 5 cm between all subjects. Two to three trials were then performed to establish 1RM. After a standardized rest period, a load of 20% of the individual's 1RM was placed on the squat machine, and the subjects completed one lift with maximal effort. A 1-minute rest period was then allowed before the load was increased to 30% of the individual's 1RM. This process was repeated for loads 40, 50, 60, 70, and 80% of the individual's 1RM. Subjects were given instructions to move every load with maximal effort and to jump if the load permitted. All lifts were commenced from the standardized starting position, and thus the movement was concentric only.

During the second session, all subjects' sprint times were first assessed for 10 and 30 m. The starting position was standardized as a two-point crouched position with the left toe 30 cm back from the starting line and the right toe approximately in line with the heel of the left foot. All assessments were performed on an indoor court surface, and subjects wore rubber-soled track shoes. The average of the two best trials was used for subsequent analysis. After a rest period of 10 minutes, strength was measured as per the protocol outlined for testing occasion one; thus, 1RM and the associated training loads were reassessed immediately before the start of the training period. Sprint times, strength, and kinetic/kinematic outputs across 20–80% 1RM were assessed again at the third testing occasion.

Training

Before the training period, a 4-week familiarization period was first prescribed for both groups to negate any learning effects and to increase the reliability of baseline measures. Training for this period consisted of three sets of eight repetitions at 30% 1RM and three sets of five repetitions at 80% 1RM on the machine hack-squat for all subjects, in addition to regular strength training and squad sessions. Training took place during the preseason specific preparation phase of the annual periodized plan for the elite training squad, and thus all subjects were considered to be approaching peak condition. All sessions were monitored by strength and conditioning trainers.

Immediately post the second assessment occasion, subjects were divided into two separate training groups (nine subjects per group) based on approximate matching of sprint times, 1RM, and body mass. Pretraining strength, speed, and body mass values can be observed in Table 1. No clear differences were observed between groups on any of the variables of interest. Training was performed in two microcycles of 3 weeks separated by a 1-week unload cycle. Each group completed six training sessions in the first 3 weeks, one training session in week four (unload week), and six further sessions in weeks five to seven inclusive. Rather than changing the program variables in the second 3-week microcycle, subjects were encouraged to attempt to increase the explosiveness of their movement. One group performed machine squat jumps at 80% 1RM (Gr80), and one at the load where individual peak power output was maximized (GrP_{max}), as identified by the testing outlined above. Peak power occurred at 23.3 ± 5.2 and 26.3 ± 7.4% 1RM for Gr80 and GrP_{max}, respectively. Total training volume was equated between groups by multiplying sets × reps × load. The Gr80 group performed five sets of five repetitions with a 2-minute rest between sets, and the GrP_{max} group performed six sets of 10–12 repetitions with a 2-minute rest between sets. Subjects were instructed and encouraged to perform all training regardless of load as explosively as possible, and to jump if the load permitted. Owing to injuries unrelated to the study, three subjects did not complete the training and testing required to qualify for inclusion in final data analysis, and thus the final subject numbers were seven and eight for Gr80 and GrP_{max}, respectively.

TABLE 1. Pre and post 7-week training values for strength and speed for each group.

	80% 1RM group		P_{max} group	
	Pretraining Mean ± *SD*	Posttraining Mean ± *SD*	Pretraining Mean ± *SD*	Posttraining Mean ± *SD*
10-m sprint time (s)	1.83 ± 0.05	1.78 ± 0.05	1.86 ± 0.07	1.83 ± 0.06
30-m sprint time (s)	4.18 ± 0.12	4.11 ± 0.12	4.22 ± 0.18	4.17 ± 0.14
1RM (kg)	302 ± 45	352 ± 43	326 ± 52	356 ± 54
1RM (kg) per kilogram of body mass	3.21 ± 0.37	3.74 ± 0.39	3.36 ± 0.58	3.64 ± 0.59
Body mass (kg)	94 ± 10	94 ± 10	98 ± 9	99 ± 8

1RM = one-repetition maximum; P_{max} = load at which mechanical power output is maximized.

In addition to the machine squat jump training, both groups performed sprint drills, other lower-body exercises at various loads, and upper-body training twice per week. Training on the machine hack-squat therefore constituted approximately 20% of total lower-body training for either group. All training other than the machine squat jump training was identical between groups.

Data Analysis

The hack-squat displacement data were filtered using a low-pass, fourth-order, Butterworth filter with a cut-off frequency of 5 Hz. These filtered displacement time data were then differentiated to determine velocity and acceleration. From these data, the following kinetic and kinematic variables were calculated from the start of the upward movement to the peak concentric displacement: peak velocity, peak force, peak power, and total impulse. System mass (mass of the sled weight plus body mass of the subject) was used for all force calculations. All force and power variables were expressed as absolute values and relative to body mass.

Statistical Analyses

Mean values and standard deviations are used throughout as measures of centrality and spread of data. Within-subject modeling was used to estimate the changes in kinetic and kinematic outputs from pre- to posttraining. To determine individual P_{max}, a quadratic was fitted to each subject's kinetic/kinematic output and load (in percent 1RM)–a technique previously detailed (18). The load chosen for final analysis was 55% of pretraining 1RM. A load of 55% 1RM was considered an appropriate compromise between the loads used for each group's respective training program. Thus, contraction force specificity and familiarization were accounted for. Additionally, analysis based on the pretraining load of 55% 1RM negated any effect of increased 1RM load on kinetic and kinematic outputs.

Pearson correlation coefficients were used to determine the relationship between percent change in kinetic/kinematic variables and percent change in sprint times, the magnitude of which were interpreted using Cohen's (10) scale: < 0.10, trivial; 0.10–0.29, small; 0.30–0.49, moderate; ≥ 0.50, large. Correlations were applied to each group separately and were averaged to provide an overall analysis. Changes in strength and speed are expressed as percent change and effect size (ES; pretest minus posttest divided by the standard deviation of the pretest). The difference between groups (± 90% confidence limits [CLs]) is expressed with a qualitative inference of the magnitude of the difference (10). Inferences about the true (large sample) value of the correlations and percent differences were based on uncertainty in their magnitude (5); if the 90% confidence interval (derived for correlations via the Fisher *z* transformation) (16) overlapped small positive and negative values, the magnitude was deemed unclear; otherwise, the magnitude was deemed to be the observed magnitude. For trivial-small correlations, the CLs were approximately ± 0.55. Thus, the power of this study was such that only correlations greater than 0.45 or less than −0.45 were considered clear.

RESULTS

The pre- and posttraining values for sprint times, strength, and body mass of both groups can be observed in Table 1. Percent change in strength and sprint times pre- to post-training for both groups with percent difference (± CL) and a qualitative inference of the magnitude of the difference are detailed in Table 2. The CLs for the change scores within each group are not detailed in the table, but, from first principles, CLs are approximately ± 0.7 of the standard deviation of the change scores. Both groups decreased sprint times in the 10- and 30-m distances, and both groups increased 1RM and 1RM per kilogram of body mass. Only the percent change in 1RM per kilogram of body mass, and percent change in body mass pre- to posttraining, were considered clearly different between groups. The 1RM strength of Gr80 increased to greater effect, whereas the P_{max} training resulted in a relatively greater increase in body mass.

TABLE 2. Percent change in strength and sprint times for the 80% 1RM and P_{max} groups with percent difference (± confidence limits [CL]), effect sizes (pretest minus posttest divided by the standard deviation of the pretest), and qualitative inference of the magnitude of the difference.

	80% 1RM group		P_{max}group		Difference (P_{max}group - 80% 1RM group)	
	Mean ± *SD*	Effect size	Mean ± *SD*	Effect size	Mean ± 90% CL	Qualitative inference
10-m sprint time	−2.9 ± −3.2	0.88	−1.3 ± −2.2	0.68	1.7 ± 3.0	Unclear
30-m sprint time	−1.9 ± −2.8	0.74	−1.2 ± −2.0	0.63	0.7 ± 2.4	Unclear
1RM	15.0 ± 9.0	0.56	10.5 ± 7.9	0.45	−3.9 ± 8.7	Unclear
1RM per kilogram of kg body mass	15.3 ± 9.1	0.63	9.0 ± 7.9	0.47	−5.5 ± 8.4	Trivial to moderate
Body mass	0.2 ± 1.1	0.11	1.1 ± 1.2	0.13	0.8 ± 1.1	Trivial

1RM = one-repetition maximum; P_{max} = load at which mechanical power output is maximized.

Pretraining, peak power was maximized at 23.3 ± 5.2 and 26.3 ± 7.4% 1RM for Gr80 and P_{max}, respectively. The range of loads where P_{max} occurred for all subjects was 20.0–43.5% 1RM. Posttraining, there was no clear change in these values for either group.

The percent change pre- to posttraining for the kinetic/kinematic outputs of each group at 55% pretraining 1RM, difference between groups, and qualitative inference of the magnitude of the difference are shown in Table 3. All of the kinetic/kinematic variables assessed decreased from pre- to posttraining. Generally, the GrP_{max} outputs decreased to a less extent than Gr80 (except for impulse), but only the percent change in peak power, peak power per kilogram of body mass, and peak velocity were considered to be clearly different between groups. That is, the decrease in these variables was clearly less in GrP_{max} as compared with Gr80.

Values for the correlation coefficients between percent change in kinetic/kinematic outputs and percent change in sprint times were all positive and of trivial to moderate magnitude ($r = 0.11–0.43$ and 0.16–0.50 for 10- and 30-m sprint times, respectively). Correlational values between percent change in 1RM and percent change in sprint times were of negative moderate magnitude ($r = -0.28$ and -0.34 for 10- and 30-m sprint times, respectively). Similar values were observed for the correlation between percent change in 1RM per kilogram of body mass and sprint times ($r = -0.29$ and -0.33 for 10- and 30-m sprint times, respectively).

TABLE 3. Percent change in kinetic/kinematic outputs at 55% pretraining 1RM and percent differences (± confidence limits [CL]) between groups from pre to post 7-week training period with a qualitative inference of the magnitude of the difference.

	80% 1RM group	P_{max} group	Difference (P_{max} group - 80% 1RM group)	
	Mean ± *SD*	Mean ± *SD*	Mean ± 90% CL	Qualitative inference
Peak velocity	−7.5 ± 6.4	−2.4 ± 9.7	9.7 ± 7.6	Trivial to moderate beneficial
Peak force	−8.8 ± 9.9	−2.2 ± 10.1	10.1 ± 11.7	Unclear
Peak force per kilogram of body mass	−9.9 ± 8.8	−4.5 ± 10.1	6.0 ± 9.7	Unclear
Peak power	−17.1 ± 9.1	−6.0 ± 18.3	18.3 ± 15.3	Trivial to large beneficial
Peak power per kilogram of body mass	−17.1 ± 9.0	−6.5 ± 16.6	16.6 ± 13.5	Trivial to very large beneficial
Impulse	−7.3 ± 14.2	−11.2 ± 15.5	15.5 ± 14.0	Unclear
Impulse per kilogram of body mass	−7.9 ± 14.5	−11.7 ± 16.2	16.2 ± 14.3	Unclear

1RM = one-repetition maximum; P_{max} = load at which mechanical power output is maximized.

Discussion

Clearly, the subjects in the present study were a well-trained sample and were as fast and as strong as other similar athletes (2, 12). Of interest, therefore, was establishing whether training at individually determined P_{max} loads provided for superior functional performance improvements compared with heavy load training.

A key finding was that although the greatest decreases in sprint times were observed in Gr80 (−2.9 ± 3.2 and −1.9 ± 2.8% for 10- and 30-m sprint times, respectively), there were no clear differences between groups. Additionally, changes in neither group were considered "clear" based on 90% CLs. It should be noted, however, that improvements as little as 1% in sprint times for well-trained athletes may have physiological, but not statistical, significance, and such improvements may be the difference in terms of performance (22). The improvements we observed in sprint times (−1.8 ± 2.5%, ES 0.49, average of both distances and both groups) are similar to those seen in the few other studies that have tracked changes in sprint times in well-trained athletes throughout a training period (9,17,28), although there are some contrasts in terms of the relative efficacy of heavy or so-called lighter load training. For example, McBride et al. (28) investigated the effect of 8 weeks of equal-volume training using either heavy (80% 1RM) or light load (30% 1RM) jump squats on the development of sprint ability, strength, and power outputs. In contrast to our results, significantly greater improvements in 10-m sprint times (−1.6%) were reported posttraining for the 30% 1RM training group compared with the 80% 1RM training group. Jump squat peak velocity (at 30% 1RM) was also significantly improved (8.1%), but no differences were observed between groups for changes in sprint times for 5 and 20 m or for the other strength and power outputs assessed. McBride et al. (28) conclude that the lighter load training resulted in increased movement velocity capabilities compared with the heavier load training. Given the conflicting results between our study and that of Mc Bride et al. (28), it may be that the key strength stimulus for the development of sprint ability is the maximum voluntary effort or intent to develop force as fast as possible, and not the size of the load and concomitant limb velocity (6). If the rate of muscular tension development and motor unit activation in a maximum effort is relatively constant for an individual independent of the external movement velocity and external load (31), the absence of a load-specific effect would seem hypothetically logical.

Tracking percent change in peak power and impulse were of specific interest because they are perceived as theoretically important determinants of sprinting ability (21). However, neither percent change in power nor impulse was clearly, or negatively, correlated to percent change in sprint times (r = 0.25–0.44). The only negative correlations observed between percent change in any strength or kinetic/kinematic output and percent change in sprint times were for maximal strength, as assessed by 1RM and 1RM per kilogram of body mass. It might be expected that kinetic/kinematic outputs expressed relative to body mass would be more clearly related to sprint ability (4), but this was not the case; correlations were also positive and generally of unclear magnitude. Given these findings, the value of instrumenting a machine hack-squat for kinetic/kinematic outputs seems limited, and perhaps simply increasing maximal strength is of greater influence on sprinting ability.

The Gr80 group experienced greater increases in strength (1RM and 1RM per kilogram of body mass) than the GrP_{max} group, although only the difference between groups for percent change in 1RM per kilogram of body mass was considered to be clear (−6.0 ± 8.2%). It is not unexpected that the group training with heavier loads should experience greater improvements in strength relative to body mass (25). Additionally, GrP_{max} increased body mass more than Gr80, although changes were very small (ES 0.03–0.11) for both groups. Despite equating for overall volume between groups, it is possible that the greater mechanical overload experienced by GrP_{max} (i.e., greater total work, force, time under tension) would explain this difference (15). The GrP_{max} group also experienced an increase in 1RM strength (15.0 ± 9.0% ES = 0.50), results that are similar to other studies that have observed strength increases in training groups using training loads from opposing ends of the load spectrum. For example, McBride et al. (28) observed significant increases in 1RM squat strength for both heavy and light training groups (8.3 and 10.5%, respectively), with no significant differences between groups. A further consideration in the present study is that both groups performed additional lower-body training at a variety of loads (30–90% 1RM), so some transfer of training effect was expected between strength gained from the other training performed and strength gained in the machine hack-squat.

In terms of the relationship between change in strength and change in sprint times, our results support the findings of Cronin et al. (11), who reviewed training studies that assessed strength effects on sprint times and concluded that, for highly trained athletes, moderate to large (ES = 0.71–1.2) squat strength changes (~12%) may be needed for moderate (ES = 0.74–0.94) changes (> −2.0%) in sprint time. The decreases in sprint times for both groups (approximately −1.83%, ES ≈ −0.49) and increased machine hack-squat 1RM (12.7 ± 8.5%, ES ≈ 0.70) are similar to the ratio proposed by Cronin et al. (11). However, a surprising finding is that despite maximal strength increases, all of the kinetic/kinematic outputs decreased during the training period, a result difficult to explain. It may be postulated that "biological noise," in terms of fatigue and/or a decreased effort in the posttraining testing occasion, was at least partially responsible for the decreases. Given the strength and speed improvements observed at the posttraining tests, it seems unlikely that biological noise was a contributing factor. Perhaps the subjects experienced a plateau in power owing to a relatively long cycle of training without change in stimuli, or because they had achieved optimal adaptation in the early pretraining familiarization phase. Certainly, it would seem that advanced athletes are more challenging to condition that their less experienced counterparts, and they may require more frequent periodization of program variables (20).

Practical Applications

The reader needs to be cognizant of the limitations of this study when interpreting the results, some of which have been outlined previously (18). Briefly, these are that the resistance exercise (machine hack-squat) used a purely bilateral, acyclical, vertical expression of force, and the kinetic/kinematic variables were assessed over the concentric phase of the movement, only possibly reducing face validity to sprinting ability. Nonetheless, given the propensity of practitioners to use squats and derivatives in training, investigation of such an exercise would seem worthwhile. There are further limitations for consideration within this study. First, statistical power was compromised by the relatively low number of subjects. It should be noted that the subject group used in this study was the entire available group from the target population–that is, the top training squad of an elite rugby league team. Increasing subject numbers by including subjects other than the elite training squad with the intention of providing greater statistical power would have compromised the validity of the study in terms of extrapolating findings to other similar athletes. Also, because of the ethical issues in relation to using professional athletes as subjects, no nontraining control group was allocated. In spite of this, we were able to compare one training modality vs. the other, with all other training exactly the same between groups. Second, the total volume of the training intervention performed by either group constituted a relatively low portion (approximately 20%) of total lower-body training performed by the subjects over the training period. It is entirely conceivable that the other training exercises and drills performed by each group were partly responsible for any observed changes in strength, kinetic/kinematic outputs, and speed, but to gain access to a group of professional athletes and perform experimentation, we were ethically obliged to minimize disruption to normal prescribed training. Also, to allow a mechanical analysis, it was important to control for as many variables as possible; thus, the study design defined specific but limited differences in training interventions between groups. Finally, tracking percent changes in strength and power outputs to percent changes in sprint times and performing a correlational analysis is attenuated by error of measurement, yet such an approach surely provides greater insight into which variables are related to sprint ability and, subsequently, which are worth developing in programs.

It is impossible to disentangle the aforementioned limitations of this study from the practical applications. However, it seems that training at the load that maximizes individual peak power output for this particular exercise with a sample of professional team sport athletes was no more effective for improving sprint ability than training at heavy loads, and the changes in power output were not usefully related to changes in sprint ability. The preoccupation of training with loads that maximize power output in machine squat jumps with the intention of improving sprint ability may be misplaced. Biomechanical specificity to the functional task would seem a fundamental tenet of training adaptations. A detailed investigation of the adaptive associations between strength and power outputs in other commonly prescribed exercises and sprint performance would be most useful.

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