DOES POWER OUTPUT VARY ACCORDINGLY WITH HIGH LOAD RESISTANCE TRAINING? A COMPARATIVE STUDY BETWEEN BULK-UP AND STRENGTH-UP RESISTANCE TRAINING

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Abstract

The objective of this study is to investigate the effects of six weeks of high-intensity resistance training on the power output of 14 university basketball players. The subjects were randomly divided into two groups: a hypertrophy-oriented group (bulk-up) and a neuromuscular improvement oriented-group (strength-up). The bulk-up group performed three sets of squat exercises at 75% of 1RM with 10 repetitions and 1-minute rest period between sets. The strength-up group performed six sets of squat exercises at 90% of 1RM with four repetitions and 3-minute rest period between sets. Both groups performed the squat exercises twice a week over a period of six weeks. The one repetition maximum (1RM) and muscle power of the squat were measured before training (0-wk), after three weeks of training (3-wk), and after six weeks of training (6-wk). The thigh circumference of each subject was measured at 0-wk and 6-wk. It is found that the 1RM of the squat increases significantly after the training period for both groups, and the rate of improvement does not differ between the groups at 6-wk (bulk-up group: 13.1 ± 9.3%, strength-up group: 12.6 ± 6.3%). It is also found that there is a significant increase in the thigh circumference ($p < 0.01$) in the left leg for the bulk-up group. In contrast, there is a significant increase in the peak muscle power (POWmax) ($p < 0.05$) for the strength-up group. The rate of increase for POWmax is different even after three weeks of training (bulk-up group: -4.5 ± 9.6%, strength-up group: 13.9 ± 13.6%). The results suggest that the effects of resistance training on the power output and thigh circumference vary according to the training programme even if the total work load remains the same. It is recommended that strength-up resistance training is implemented to increase muscle power.

Keywords: Squat, power, 1RM, hypertrophy, neuromuscular improvement, periodization

Introduction

In general, there is two types of regimen involved in resistance training, each with its own objective: (1) muscle hypertrophy and (2) neuromuscular improvement. These objectives are reflected by the relationships between the quantity of muscles and muscle strength. Even though it is known that muscle strength is proportional to muscle thickness (Ikai & Fukunaga, 1968), it has also been shown that there is an increase in muscle strength even if there is no increase in the quantity of muscles (Ikai & Fukunaga, 1970).

Muscle hypertrophy-oriented (bulk-up) programmes involve moderate intensity exercise (67–85% 1RM) with high repetitions and relatively short rest periods (e.g. 1 minute) between sets (Baechle, Earle, & Wathen, 2008). In contrast, neuromuscular improvement-oriented (strength-up) programmes involve high intensity exercise (85–100% 1RM) with low repetitions and relatively long rest periods (e.g. 3 minutes) between sets (Baechle et al., 2008). Chestnut and Docherty (1999) compared muscle hypertrophy-oriented and neuromuscular improvement-oriented programmes and found that there are no differences in the effects of these training programmes on both muscle mass and muscle strength (Chestnut & Docherty, 1999).

Athletes generally undergo resistance training in order to increase their muscle power since muscle power affects sports performance (Kawamori & Haff, 2004; Newton & Kraemer, 1994). In order to increase muscle power, it is recommended that athletes undergo training at very high loads (80–90% 1RM) which is similar to strength-up programmes (Baechle et al., 2008). Hence, strength-up programmes may be effective to increase muscle power.

Power is expressed by the multiplication of strength and velocity (Kawamori & Haff, 2004; Newton & Kraemer, 1994). Even though it is difficult to increase the maximum velocity, it is possible to increase the 1RM by performing resistance training. Strength increases with muscle hypertrophy, and power may increase with a gain in strength. Hence, muscle power can be increased by performing bulk-up programmes. Kaneko, Fuchimoto, Toji, and Suei (1981) found that that performing elbow flexure exercises at loads such that the force–power curve becomes maximum (30 %MVC) results in a larger increase in the maximum power compared to training at 0, 60 and 100 %MVC. The maximum power for multi-joint exercises occurs at a load of 30–78% 1RM. Bulk-up training loads (67–85% 1RM) are similar to loads at the maximum power and therefore, the maximum power can be increased by performing bulk-up programmes. If the 1RM increases equally, both bulk-up and strength-up programmes may be effective to increase the maximum power. However, to date, none of the previous studies have investigated the effects of bulk-up and strength-up resistance training on the maximum muscle power.

For this reason, the objective of this study is to investigate the effects of bulk-up and strength-up resistance training on the muscle power of athletes. It is hypothesized that both bulk-up and strength-up resistance training are equally effective to increase the muscle power of athletes.

Methods

Subjects

A total of 22 university basketball players participated in this study, and they were randomly divided into two groups: bulk-up group (n = 11, 20.5 ± 1.2 years, 176.4 ± 6.6 cm, 71.9 ± 7.0 kg) and strength-up group (n = 11, 20.5 ± 1.1 years, 176.1 ± 7.2 cm, 72.2 ± 7.4 kg). The subjects were undergraduate students and had resistance training over a period of six months. They were briefed regarding the experimental procedure and the purpose of the study. Following this, each of the subjects was required to sign a written informed consent, which indicates that they fully agree to take part in this study. All of the procedures used in this study were approved by the Institutional Ethics Committee in accordance with the Declaration of Helsinki.

However, it shall be noted that four subjects from each group were unable to complete the programme either because of illness or injury, and they were excluded from the analysis. Thus, only seven subjects from each group completed the six weeks of training. The mean age, height and body mass of these seven subjects are shown in Table 1.

Table 1: Characteristics of subjects before training. The data are expressed in the form of mean ± S.D.

	N	Age [years]	Height [cm]	Body mass [kg]
Bulk-up group	7	20.4 $\pm$ 1.1	175.8 $\pm$ 7.5	70.3 $\pm$ 5.9
Strength-up group	7	20.1 $\pm$ 0.7	175.7 $\pm$ 8.3	70.3 $\pm$ 7.4

Resistance Training

The 1RM of the squat was measured before the training period (0-wk), and the training load was decided based on this figure for each subject. Table 2 shows the load, number of repetitions, number of sets, and the time interval between sets of the training programme for both bulk-up and strength-up groups. The training programmes were designed such that there would be no significant difference in the quantity of training. The 1RM of the squat was measured after three weeks of training (3-wk) and the training load was recalculated and shown to each subject. The subjects underwent the training more than twice a week over a period of six weeks.

Table 2: Training programme for bulk-up and strength-up groups

	Load	Reps/Set	Sets	Rest period
Bulk-up group	75% 1RM	10	3	60 s
Strength-up group	90% 1RM	4	6	180 s

Assessment

The muscle power of the squat was measured before training (0-wk), after three weeks of training (3-wk) and after the training period (6-wk). The thigh circumference (CIR) and 1RM of the subjects were measured at 0-wk and 6-wk.

Power and Velocity of the Squat

A 3-D accelerometer known as myotest (myotestSA, Swiss) was used to measure the muscle power of the squat. The 3-D accelerometer was set on the barbell shaft and the squat was carried out. The weight of the myotest can be neglected in the assessment since it is very light (approximately 60 g). The squat attempts were initiated at 20 kg. The load following the second attempt was determined based on the instructions on the apparatus. The data were recorded using proprietary software (myotestPRO version 1.3.2) and the maximum power estimated from the approximate curve of load–power relations (POWmax), the load at POWmax, and the estimated maximum velocity (Vmax) were analysed. The myotest unit has been proven to be valid for power measurements in previous studies (Comstock et al., 2011; Crewther et al., 2011), and it can be easily used to evaluate power in practice (Rabahi, Fargier, Sarraj, Clouzeau, & Massarelli, 2013; Wyon, Harris, Brown, & Clark, 2013; Casartelli, Müller, & Maffiuletti, 2010). The test-retest reliability for both POWmax (ICC: R = 0.75) and Vmax (ICC: R = 0.72) was measured in our laboratory.

1RM of the Squat

The 1RM load of the squat was determined using the procedure outlined by Stone, Rapaport, Williams, and Chalupa (1981). Each subject performed the squat by flexing the lower limbs until the top of both thighs was parallel to the ground. The subjects were given sufficient rest between exercises to ensure that that they were able to give their maximum effort.

CIR of the Right and Left Legs

The CIR was measured as an index of muscle size, measured 15 cm from the top centre of the patella. The test-retest reliability was measured for the right leg. The intraclass correlation coefficient (ICC) of the right leg was R = 0.9993.

Statistical Analysis

In this study, the data are expressed in the form of mean ± S.D. The differences in the training volume and the rate of increase in POWmax between the bulk-up and strength-up groups were analysed using independent t-test. Statistical evaluation was carried out on the absolute values of POWmax and 1RM for bulk-up and strength-up groups and specific periods of training (0-wk, 3-wk and 6-wk) using repeated measures two-way analysis of variance (ANOVA). When the results of the two-way ANOVA revealed that there was a significant interaction effect, the differences in POWmax was analysed using Tukey's post hoc test. However, when the results of the two-way ANOVA revealed that there was a significant time effect, the differences in the 1RM between specific periods of training (0-wk, 3-wk and 6-wk) were analysed using Student's t-test with Bonferroni correction. The POWmax-Load and CIR for both bulk-up and strength-up groups and specific periods of training (0-wk and 6-wk) were also analysed using repeated measures two-way ANOVA. Similarly, the differences in POWmax-Load and CIR were analysed using Tukey's post hoc test when a significant interaction effect was observed in the results of the two-way ANOVA. The coefficient of correlation between CIR and 1RM at 0-wk was calculated using Pearson product-moment correlation coefficient. It shall be noted that the statistical significance was set at $p < 0.05$ for the two-way ANOVA, Tukey's post hoc test, Student's *t*-test and Pearson product-moment correlation coefficient. However, the statistical significance was set at $p < 0.016$ (0.05/3 = 0.016) for the Student's *t*-test with Bonferroni correction because of multiple comparisons at three time points.

Results

Training Volume

The bulk-up group was trained 2.2 ± 0.2 times per week whereas the strength-up group was trained 2.1 ± 0.4 times per week. With regards to the total lifting volume of the squat (i.e. the total load × repetitions), it is found that there is no significant difference between the bulk-up group (37,840 ± 7,536 kg) and strength-up group (32,583 ± 9,897 kg).

POWmax, Vmax, CIR, 1RM and POWmax-Load

The squat performance and CIR data are summarized in Table 3. It can be seen that there is a significant interaction effect for POWmax, whereby the POWmax increases at 3-wk and 6-wk relative to 0-wk ($p < 0.01$). In contrast, there is no difference in Vmax for both bulk-up and strength-up groups. In addition, the results show that there is no significant interaction effect for the 1RM. There is an increase in the 1RM at 3-wk and 6-wk for both bulk-up and strength-up groups. However, the rate of increase is not significantly different between bulk-up group (13.1 ± 9.3%) and strength-up group (12.6 ± 6.3%) at 6-wk. In addition, there is a significant interaction effect in the POWmax-Load. Even though there is no variation in the POWmax-Load for the bulk-up group (0-wk: 86.0 ± 15.9 kg, 6-wk: 82.4 ± 15.7 kg), there is a significant increase in this variable for the strength-up group (0-wk: 74.6 ± 10.9 kg, 6-wk: 89.3 ± 13.4 kg, $p < 0.05$). The ratio to 1RM for the bulk-up group is 69.6 ± 8.5% and 59.5 ± 10.3% at 0-wk and 6-wk, respectively, whereas the ratio to 1RM for the strength-up group is 64.0 ± 8.3% and 68.5 ± 11.5% at 0-wk and 6-wk, respectively. The results reveal that there is a significant interaction effect in the CIR of the left leg only for the bulk-up group ($p < 0.01$). The percentage increase in POWmax at 0-wk, 3-wk and 6-wk for bulk-up and strength-up groups are shown in Figure 1. It can be seen that there is a significant difference in the POWmax between the bulk-up and strength-up groups at 3-wk and 6-wk.

Table 3: Variations in the POWmax, Vmax, CIR and 1RM during six weeks of training. All of the data are expressed in the form of mean ± S.D. It shall be noted that 0-wk = before training, 3-wk = after 3 weeks of training, 6-wk = after 6 weeks of training, POWmax = estimated maximum power, Vmax = estimated maximum velocity, 1RM = estimated 1RM of the squat and CIR = thigh circumference. '*' indicates a significant difference versus 0-wk ($p < 0.016$). '**' indicates a significant difference versus 0-wk ($p < 0.01$). '†' indicates a significant difference versus 3-wk ($p < 0.016$).

Variables		Group	0-wk	3-wk	6-wk
POWmax (W)		Bulk-up	1381.0 ± 263.7	1311.4 ± 238.0	1437.3 ± 250.1
		Strength-up	1241.7 ± 165.2	1404.9 ± 184.8**	1483.1 ± 237.9**
Vmax (cm/s)		Bulk-up	261.1 ± 59.2	242.1 ± 29.4	279.9 ± 33.2
		Strength-up	252.3 ± 29.7	261.0 ± 22.4	253.9 ± 27.8
1RM (kg)		Bulk-up	123.4 ± 15.7	130.2 ± 12.8*	138.7 ± 12.2*†
		Strength-up	117.4 ± 17.6	124.6 ± 20.1*	132.2 ± 20.8*†
CIR (cm)	Right	Bulk-up	52.0 ± 2.4	-	53.4 ± 2.4
		Strength-up	52.5 ± 2.4	-	53.2 ± 1.8
	Left	Bulk-up	51.8 ± 2.5	-	52.9 ± 2.4**
		Strength-up	52.6 ± 1.6	-	52.9 ± 1.5

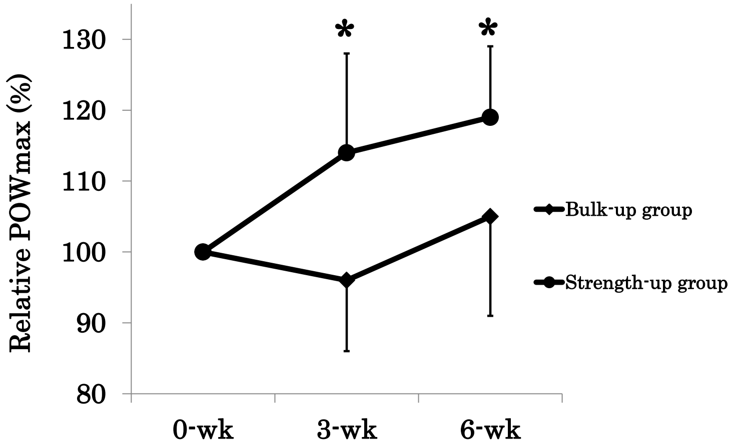

Figure 1: Changes in the relative POWmax for each group before training (0-wk), after three weeks of training (3-wk) and after 6 weeks of training (6-wk). The filled circles and filled diamonds denote the strength-up group and bulk-up group, respectively. '*' indicates a significant difference versus the bulk-up group ($p < 0.05$).

Relationship between CIR and 1RM

It is found that there is a correlation between the CIR of the right leg and 1RM at 0-wk ($r = 0.50$, $p = 0.068$).

Discussion

The results of this study indicate that six weeks of high-load resistance training with the strength-up programme promotes an increase in the maximum power of the squat. Comparison between the strength-up and bulk-up groups reveals that there is a difference in the maximum power between these groups after three weeks of training. Even though there is an increase in the 1RM of the squat for the bulk-up group, there is no variation in the POWmax. This study is the first to investigate the differences in power gain between bulk-up and strength-up resistance training programmes. To date, studies have been carried out to examine training programmes in order to achieve a specific purpose such as increasing muscle mass or increasing the maximum muscle strength. One of the key works in this area is the work of Chestnut and Docherty (1999), in which they compared two training programmes with equal total training volumes. However, none of the studies available in the literature suggest that bulk-up and strength-up resistance training programmes have an effect on muscle power.

In this study, it is found that there is no difference in the total training volume between the bulk-up and strength-up groups. This implies that the results may not be influenced by the quantity of training. In addition, there is no significant difference in the total training volume and therefore, the differences between the bulk-up and strength-up groups are dependent upon the type of programme rather than the quantity of training. Since the effect of training on POWmax is different after three weeks of training, it is imperative to set an appropriate regimen even for relatively short programmes.

The main factor that contributes to the increase in muscle strength may differ between bulk-up and strength-up training programmes. The bulk-up programme aims for hypertrophy whereas the strength-up programme aims for neuromuscular improvement. Even though there is an increase in the 1RM of squat for both bulk-up and strength-up groups, only the bulk-up group experiences an increase in the CIR, specifically in the left leg. It shall be noted that CIR reflects muscle mass (Clarke, 1957) whereas muscle strength is proportional to the thickness of the muscle (Ikai & Fukunaga, 1968). In this study, there is a correlation (r = 0.50, p = 0.068) between the CIR (of the right leg) and 1RM of the squat at 0-wk, and therefore, it is appropriate to use thigh circumference as the index of muscle mass. Increasing muscle strength without muscle hypertrophy requires neuromuscular improvement such as raising the excitation levels of nerves, as well as increasing motor unit recruitment and rate cording (Moritani & deVries, 1979; Sale, 1992). It is perceived that there are similar improvements in the strength-up group investigated in this study.

Strength-up programmes are effective to increase power above medium loads. In this study, it is observed that there is no variation in Vmax in either group. However, there is an increase in POWmax and 1RM in the strength-up group. Since the POWmax-Load increases at 6-wk relative to 0-wk, the force–power curve moves in the upper-right direction. It is found that the POWmax-Load is approximately within 60–70% 1RM in this study. In contrast, previous studies have shown that the POWmax obtained from multi-joint exercises is within 30–78% 1RM (Kawamori & Haff, 2004; Cronin & Sleivert, 2005). Since the values obtained in this study fall within this range, it can be deduced that the evaluation of the POWmax-Load is valid. Some studies have also shown that there is neuromuscular improvement during the initial phase of resistance training (Moritani & deVries, 1979; Sale, 1992). Since the duration of training in this study is set at three (3-wk) and six weeks (6-wk), it is believed that the explosive muscle function of the strength-up group may be improved by neuromuscular improvement.

It is observed that there is no variation in POWmax for the bulk-up group. We suppose that the increase in muscle strength contributes to an increase in power because power is expressed by the multiplication of strength and velocity (Kawamori & Haff, 2004; Newton & Kraemer, 1994). Since POWmax is less than the maximum muscle strength, the mechanism of change may be different from that of the maximum strength. Baker (2003) showed that muscle power decreases immediately after one round of hypertrophy-oriented resistance training. Repeating these types of exercise may not result in any changes in power for the bulk-up programme. There is an increase in 1RM for the bulk-up group and thus, it is possible that this will increase the power output at high loads and low speeds. However, the power output near the 1RM was not measured in this study and therefore, this remains a speculation.

There are two limitations in this study. Firstly, the experiments were carried out over a period of six weeks. However, if the athletes are required to train over a longer period, then periodization needs to be implemented (Bompa, 1999) and the training programme needs to be changed accordingly for each term. Hence, in this study, the effects of long-term training for a period of more than six weeks are not known. It will be necessary to take periodization into consideration if the effects of long-term training are examined. However, the results of this study provide useful information for one to conduct periodization in future studies. Secondly, it is deemed necessary to determine the relationship between high-load resistance training and sports performance. It is indisputable that power is closely linked with various movements. However, sports performance (e.g. sprinting and jumping ability) was not measured in this study and therefore, there is a need to examine the effect of increasing power output on sports performance in future studies.

Conclusion

The effects of high-load resistance training over a period of six weeks on the power output of 14 university basketball players have been investigated in this study, in which the subjects are divided into two groups: bulk-up and strength-up. It is found that the POWmax increases only for the strength-up group whereas the CIR (i.e. muscle mass) increases only for the bulk-up group. Since there is no variation in the maximum power for the bulk-up group, it can be deduced that perhaps it is not possible to gain both muscle mass and power output within six weeks of high-load resistance training. In addition, it is observed that there are differences in the variables between the bulk-up and the strength-up groups after three weeks of training. The results of this study indicate that selection of an appropriate training programme is crucial even if the training term is relatively short.

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