Effect of power training on muscle structure and neuromuscular performance

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Introduction

Although neuromuscular adaptation during power training has received attention in the literature (e.g. Komi et al. 1982; Häkkinen et al. 1985), information is scarce regarding the individual contribution of either muscular or neural alterations to increased power performance. In addition to shifts in isometric force-time and/or force-velocity curves, power training could cause quantitative changes of the neuronal input to the muscle (Moritani and deVries, 1979; Häkkinen et al. 1985) and also a qualitative shifts in the electromyographic (EMG) patterns (Schmidtbleicher and Gollhofer, 1982). Komi (1986) has, however, suggested that the early part of strength training with the increased α-motoneuron excitability (Sale et al. 1983) and increased motor unit synchronization (Milner-Brown et al. 1974) does not only increase muscular force output but may serve as an important stimulus for the hypertrophic factors.

The present study was designed to examine, in more detail, effects of long-term, intensive stretch-shortening cycle (SSC) training on muscle structure, neuromuscular function, physical performance, as well as their interactions.

Methods

13 untrained men (age 24 ± 4 years, height 1.78 ± 0.05 m) and 10 untrained controls (age 25 ± 2 years, height 1.78 ± 0.07 m) volunteered as subjects for the study. All the subjects were informed of the possible risks of the experiment and they gave they written consent to participate. The ethical committee of the University of Jyväskylä, Finland, approved this study.

The experimental group trained twice a week for 15 weeks, which was preceded by a two-week preparatory phase consisting of squats, deadlifts, and abdominal and calf exercises. The training of leg extensor muscles included various types of SSC exercises such as jumping performances with a special sledge apparatus, drop jumps from the heights of 20-70 cm, jump squats (30-60 % from the maximum), one leg and two leg hopping, and hurdle jumps. The jumping performances (5-10 repetitions per set) were performed with a maximal effort to develop explosive force production of the muscles. The overall number of muscle actions increased progressively from 80 to 180 actions per training session throughout the whole training period. Other physical activities such as cycling, walking, and ball games lasted almost 6 h per week for the experimental group and 4 h 30 min per week for the control group.

The experimental group was tested before, after 5, 10 and 15 weeks of training, while the control group was tested only before and after the training period of the experimental group. Testing included maximal voluntary contractions (MVC) for knee extensors and plantarflexors in the isometric conditions, and maximal drop jump exercises.

The parameters included ground reaction forces (GRF) and surface electromyography (EMG) from the vastus lateralis (VL), vastus medialis (VM), gastrocnemius (GA), soleus (SOL) and tibialis anterior (TA) muscles. EMG activity was recorded telemetrically (MESPEC 4000, Mega Eletronics ltd, Finland) with surface electrodes (Beckman miniature skin electrodes, 650437, Illinois, USA) with interelectrode distance of 20 mm. The electrodes were placed longitudinally over the muscle bellies between the center of the innervation zone and the distal tendon of each muscle. The EMG signal amplification was 1000 times (Biotel 99, Glonner, Germany; bandwidth 20-640 Hz / -3 dB; CMRR 110 dB), and it was digitized simultaneously with the force records at a sampling frequency of 1 kHz.

All performances were videotaped at the frame rate of 200 Hz. Reflective markers were placed on the following points: the distal head of the 5th metatarsal bone, the lateral malleolus, the lateral epicondyle of the femur, the greater trochanter and the tragus. These points were digitized for 2-D video
analysis (Peak Performance Technologies, Inc; Motus software, Denver, USA). After filtering with the 4th order Butterworth conditioner with a cut-off frequency of 8 Hz, the digitized and scaled co-ordinates were synchronized with 2-D GRF data for calculating joint moments and powers (Silicon Graphics, USA). In the synchronization of video and analogy data, a circuit to introduce a trigger signal (Fz value of 100 N) to the computer and a flash for a video image was used. Anthropometric data provided by the standards of Dempster (13) were used to determine inertia and mass of the segments.

Before and after the training period, muscle biopsies from the GA muscle were taken for analysing fibre type distribution, fibre area and myosin heavy chain (MHC) composition by using standard procedures.

Results and Discussion

Changes in MVC of knee extensor (KE) and plantarflexor (PF) muscles were not statistically significant during the training period (3598 ± 896 N vs. 4497 ± 1780 N and 3910 ± 1106 N vs. 4241 ± 1071 N, respectively). This was also for the corresponding EMGs. However, the rate of force development of KE increased from 18836 ± 4282 N to 25443 ± 8897 N (p<0.05) during the first 10 weeks of training. In the drop jump exercise, the rising height of the centre of gravity increased from 0.30 ± 0.06 m to 0.37 ± 0.05 m (p<0.01) during the entire training period, while the contact time did not change (0.226 ± 0.090 s vs. 0.231 ± 0.049s). At the same time, knee moment (Mpeak: 377 ± 133 Nm vs. 544 ± 130 Nm, p<0.05) and power (Ppeak: 2093 ± 788 W vs. 3227 ± 919 W in the push-off phase, p<0.01) as well as hip moment and power increased, while the respective values of ankle joint decreased slightly (Figure 1).

![Figure 1](image.png)

Figure 1. Effects of power training on instantaneous joint mechanics in the drop jump. Moment, angle, angular velocity and power curves of the ankle, knee and hip joints were time normalised (% contact time) before (thin line) and after 15 weeks of training (thick line).
In the drop jump test, only small but non-significant changes were observed in muscle activity patterns (Figure 2) and quantitative values of EMGs.

![Figure 2. Effects of power training on muscle activity patterns in the drop jump before (thin line) and after 15 weeks of training (thick line). The vertical dotted line represents the beginning of the contact.](image)

The mean percentage for myosin heavy chain isoforms (MHCI, MHCIIA, and MHCIIX) remained the same: 62.59 ± 13.13 % vs. 65.01 ±14.39 %, 32.56 ± 10.48 % vs. 30.64 ± 11.48 %, and 4.86 ± 7.10 vs. 4.35 ± 5.40 %, respectively. The muscle fibre distributions and areas were also unchanged.

The enhanced performance capabilities in jumping as a result of power training cannot be explained by changes in muscle structure or in neural adaptation of PF. This lack of neural and muscular modification may be due to rather great additional, primarily aerobic type, physical activity performed weekly by the subjects. Similar lack of physiological adaptation to power training has also been observed previously (McBride et al. 2001). Thus, the most important factor for explaining the performance enhancement in this study seems to be some modification in the joint control strategy and/or rate of force development capabilities of KE. This increased use of KE may have resulted in an increase in absorbed negative energy during the braking phase and may have enhanced the respective positive energy in the following push-off phase leading to increased jumping performance.

References

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