Zuerst ersch. in : Strength training for sport, health, aging and rehabilitation, abstracts : 5th International Conference on Strength Training / Aagaard, Per; ... [Eds.]. - Odense : University of Southern Denmark, 2006. - S. 106-107

TASK SPECIFIC CORTICOSPINAL ADAPTATIONS FOLLOWING BALLISTIC STRENGTH TRAINING

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INTRODUCTION

Strength training plays an important role for motor performance in sports and in neurological rehabilitation. The outcomes of rehabilitative interventions as well as the success of physical training programs largely rely on adaptations of the central nervous system. Nevertheless, the sites of neural adaptation and thus the mechanisms of training are still largely unknown. Recent research has focussed on neural correlates like H-reflexes or magnetic evoked potentials to describe neural adaptations following training (Voigt et al. 1998; Aagaard et al. 2002; Carroll et al. 2002; Perez et al. 2004; Jensen et al. 2005). Most of these studies applied isometric voluntary contractions to imitate the functional state. This could be critical because Nielsen and co-workers were able to show that different sub-systems of corticospinal activation were involved during dynamic versus tonic contractions of shank muscles (Nielsen et al. 1993; Nielsen and Petersen 1995). Their studies indicated that fast conducting corticospinal fibres with monosynaptic projections onto spinal motoneurones are involved in the initiation of voluntary leg movements while tonic activation involved other, presumably indirect pathways.

Therefore, we hypothesised that corticospinal adaptations are specific for the motor-task.

METHODS

Subjects: A total of 23 subjects with no history of injuries gave written informed consent to the experiments, which were approved by the local ethics committee. Participants were randomly allocated to a treatment and a control group: Ballistic strength training (BST): 5 women, 7 men: age: 27±6 years; weight: 67±14 kg; height: 1.70±0.1 m, control group (CON): 4 women, 7men: age: 28±5 years; weight: 67±7 kg; height: 1.76±0.1 m.

Training: Training was performed over a period of four weeks, with a total of sixteen training sessions. BST consisted of 4 sets of 10 dorsal and plantar flexions. The contractions were performed in a sitting position against a load of 30 to 40 % of the individual one repetition maximum. Subjects were instructed to concentrate on the next command and contract as fast as possible. BST was characterized by isolated voluntary explosive activations of plantar and dorsal flexors in order to move a light load as fast as possible. The training regimen was reported in detail in a previous study (Gruber et al. 2006).

Motor-tasks: Corresponding to BST, a dorsi-flexing torque was applied at the ankle joint with a motor driven footplate in a sitting position. Subjects were instructed to react as fast and as precisely as possible when performing the compensatory plantar-flexion (PFL). The non-trained task was a backward translation of the feet that was induced whilst standing on a computer driven treadmill. A backward translation between 13-15 cm of amplitude with a peak acceleration of approx. $3m*s^{-2}$ induced body sway (SWAY). Amplitude and peak acceleration were adjusted individually in order to produce equivalent slopes and levels of M. soleus (SOL) EMG activity compared to PFL.

H-reflex (HR): SOL H-reflexes were evoked by a 0.5ms current pulse over the tibial nerve in the popliteal fossa with a constant current square wave stimulator (Digitimer DS7). The sizes of the H-reflex and M-response were measured (4 kHz) as peak-to-peak amplitudes. H-reflexes were tested during PFL and SWAY as well as during sitting at rest (REST) and during quiet stance (STANCE).

H-reflex conditioning with TMS (HR_{cond}): TMS was applied with a MagPro200™ stimulator with a pulse width of 200µs. During SWAY, subjects wore a harness which had a dorsal head rest and carried a clamping device to hold the coil (Schubert et al. 1997). SOL H-reflex conditioning with subthreshold TMS was performed according to the protocol established by Nielsen and co-workers (Nielsen et al. 1993; Nielsen et al. 1995).

General experimental procedure: Each subject was tested in three experiments before and after the training:

1.) PFL and SWAY alone to match EMG and determine functional training effects for PFL.

2.) PFL, REST and SWAY, STANCE + electrical stimulation (SOL H-reflex) to assess spinal excitability at active states and during rest.

3.) PFL and SWAY + SOL H-reflex (= test reflex) + subthreshold TMS (= conditioning stimulus) to assess the contribution of direct corticospinal pathways during the trained as well as a non-trained motor-task.

RESULTS

Maximum RFD during PFL improved after BST. Soleus H_{max}/M_{max}-ratios remained unchanged after training. HR_{cond} revealed modulation of fast direct corticospinal projections in a task-specific manner with an *increase* of HR facilitation in the untrained condition (SWAY: 4.7±0.5% of M_{max}; $p<0.05$) whereas HR_{cond} facilitation was *diminished* in the trained motor-task (PFL: - 4.1%±0.5 of M_{max}; $p<0.05$). Reductions in HR_{cond} were correlated with increases in maximum RFD following BST (r^2=0.55). Controls did not show significant effects.

DISCUSSION

This is the first investigation that showed training effects on direct corticospinal projections to leg muscles in man. These findings are noteworthy because these projections are probably unique to high primates and humans (Jankowska et al. 1975). Cortically conditioned H-reflex facilitation was diminished in the trained motor-task while it was increased in the untrained motor-task. On a functional level it was shown that BST increased RFDmax and that improvements were correlated with reductions in corticospinal excitability. Functional improvements in line with unaltered H_{max}/M_{max}-ratios and reduced corticospinal excitability indicated that neuromuscular control shifted with increased task automaticity from predominantly cortical sites towards subcortical areas in the trained motor-task (cp. Floyer-Lea & Matthews 2004).

CONCLUSION

Ballistic strength training affected fast direct cortico-motoneuronal projections. Activity was up- or down-regulated depending on the interaction of training and motor-task. Accordingly, the present results emphasise the necessity to consider the interaction between training and task when assessing neural plasticity. From a functional point of view this study provides further evidence for the context-sensitivity of ballistic strength training.

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