Laboratory setup for studying sudden loading of the low back
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Introduction
Epidemiological and biomechanical studies indicate that sudden loading events (SLE) may be a risk factor for low back injuries among health care workers (Owen and Damron, 1984, Smedley et al., 1995, Magnusson et al., 1996, Lavender et al., 1989). Laboratory setups for studying the reaction to SLE typically make use of a load exerting a strong impact on the subject, either when dropped in a basket held by the subject or through a wire transmitting the impact to the upper part of the trunk (Wilder et al., 1996, Lavender et al., 2000). In this study the objective is to construct an experimental setup capable of generating a sudden change in loading of the low back without an initial impact, which is not considered to be characteristic for the types of SLE occurring during patient handling.

Methods
The central part of the setup is a load fitted with an electromechanical gripping device through which the load momentarily can be attached to a wire. The wire is running over a wheel hereby transmitting the gravitational force on the load to a horizontal force applied to the upper part of the subject’s body (fig. 1 and 2). The movement of the body is indirectly measured by a potentiometer mounted on the wheel. Prior to the SLE the subject is able to make normal postural movements. The setup is controlled by a computer, which triggers the SLE either according to request by the investigator or at a random time unknown for both the subject and the investigator. The computer also records the position and the signals from a number of EMG electrodes on the subject. EMG recordings from positions on the trunk very often suffer from strong interference by ECG signals. In order to avoid such interference, ECG signals are monitored during the experiment and the SLE is triggered shortly after the occurrence of a QRS-wave in the ECG signal. The Labview software is used for the computer programming.

Results & Discussion
The system generates a SLE to the subject by virtue of a vertical force momentarily increasing from 3 N to 60 N. In order to get accurate reaction time measurement, the onset time of the SLE should be precisely defined, requiring that the resonance frequency of the load/wire system is considerably higher than the resonance frequencies of the trunk (in the range 1-10 Hz). The resonance frequency of the system is measured to 13.5 Hz, however, it is considered to increase this frequency by further stiffening the mechanical system. By the computer program the SLE is scheduled to be triggered approximately 0.2 seconds after the occurrence of a QRS-wave, which typically ensures 0.5-0.7 seconds of EMG recordings without interfering ECG signals (fig. 3). The system can be reloaded for a new SLE within 10 seconds.

Conclusion
The setup proved to be a flexible system able to generate sudden loading events characterized by a sudden increase in the load of the low back without an initial impact. The method used proved very effective to avoid interference by ECG signals in the reaction time analysis of the EMG recordings.

References
Figure 1: Setup for generating a sudden forward pull to the upper part of the subject’s trunk. The wire is fastened to a rigid bar at the back by means of a harness attached to the upper part of the trunk. The movement of the trunk is measured by a potentiometer mounted on a wheel.

Figure 2: Device for generation of sudden loading events. a – cylinder, b – disk shaped load, c – gripping device, d – solenoid for activating gripping device, e – holding magnets, f – load-bearing construction, g – wire, h – wheel with potentiometer.

The wire is kept tightened by the cylinder (a - weight 0.3 kg), which is able to move freely in a vertical direction allowing the subject to make normal postural movements. The computer activates the solenoid (d) causing the gripping device (c) to fix the load (b) to the cylinder (a). Simultaneously the holding magnets (e) are activated and the load (b) is released causing the weight of the load applied to the wire to be suddenly increased from 0.3 kg (a) to 6 kg (a+b+c+d).
Figure 3: An example of recorded data from a sudden loading experiment. The figure shows 2 seconds of EMG data from right and left erector spinae recorded at the level of L3 and the movement of the trunk measured by the potentiometer. The sudden loading is triggered at the time 0. ECG signals are found in the EMG recordings approximately at time –0.9, –0.2, and 0.6 and do not interfere with the reading of the reaction time (approximately 100 ms). The maximum forward movement of the trunk is 4.2 cm at the time 0.47 s.