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Lifting up and laying down a weight causes high spinal loads

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ABSTRACT

Lifting up weights from a cupboard or table and putting them back are activities of daily living. Patients with spinal problems want to know whether they should avoid these activities. However, little is known about the spinal forces during these activities and about the effect of level height.

Loads on a telemeterized vertebral body replacement were measured in 5 patients. The effect of level height when lifting or setting down weights of 0.01, 1.5 and 3.0 kg in a standing posture were investigated. Furthermore, these weights were lifted and set down with a stretched arm while sitting at a table. No instructions were given on how to perform the task.

For these activities, forces as high as 5 times the value for standing alone were measured. In 2 patients, implant loads decreased with increasing level height. In the other patients the effect of level height was small. Lifting a weight from a table with a stretched arm while sitting led to a strong increase of the maximum implant force. Setting down the weight usually caused a slightly higher maximum implant force than lifting it.

Forces on a vertebral body replacement during lifting and setting down a weight varied strongly when no precise instructions were given on how to perform the activity. Thus, the measured forces are representative for such activities performed in daily life. This, however, led to wide variations in measured data. Compared to the value for standing, 5 times higher forces were measured for lifting and setting down of weights. This suggests that these activities should be avoided by patients who have spinal problems.

1. Introduction

Weights of up to a few kilograms often have to be lifted or set down during daily life, for example, when taking something out of a cupboard or when reaching for a coffee pot while sitting at a table. The level at which the weight has to be placed may vary and can be even above head height. After spinal surgery, patients often want to know whether they are allowed to perform these activities and which ones should be avoided. Little information exists about the spinal loads during such activities.

The pressure in a lumbar disc has been measured by several groups (Nachemson, 1981; Sato et al., 1999; Wilke et al., 2001). But to our knowledge, no such measurements were performed during lifting up and setting down weights at different heights.

In vivo measurements of skeletal loads during lifting and setting down of weights only exist for the shoulder joint. Westerhoff et al. (2009) measured the loads in this joint during lifting and setting down a coffee pot (1.5 kg) while sitting at a table as well as during lifting up and setting down a weight of 2 kg from or onto a shelf up to head height while standing. For the lifting tasks, they measured shoulder joint contact forces which were approximately that of the body weight. The shoulder joint forces were about 20–30% higher for setting down the weight than they were for lifting it. Higher forces were measured for picking up and setting down a weight at head height compared to belt height.

Measurement of the complete spinal loads is not yet possible. However, the loads on telemeterized vertebral body replacements (VBR) have been measured during physiotherapeutic exercises, sitting on different seats, during changing body positions, and during whole body vibration (Rohlmann et al., 2008, 2010, 2011).

The aim of this study was to measure the loads on a vertebral body replacement during the lifting up and setting down of different weights. The effects of the magnitude of the weight and the lifting height (hip, shoulder, head, and above head level) were to be determined. The loads should be measured under ordinary daily life conditions.

2. Material and Methods

2.1. Instrumented implant

To measure the forces and moments transferred by a VBR, the clinically proven implant Synex (Synthes Inc. Bettlach, Switzerland) was modified. Six semiconductor strain gauges, a 9-channel telemetry unit and a coil for the inductive power supply were arranged in a cylindrical tube with an original endplate on the lower side (Fig. 1). An adapter plate was welded onto the upper side of the tube. During surgery, an endplate of selectable height was screwed onto the adapter plate to achieve the

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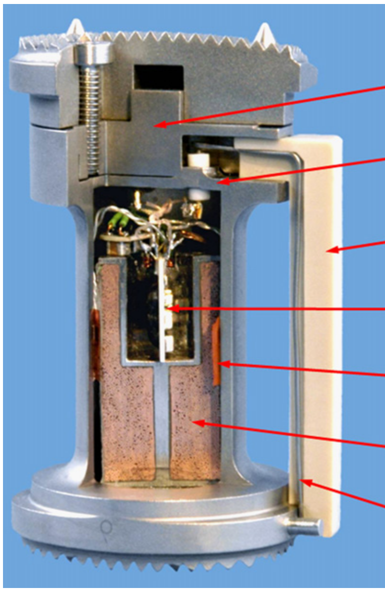

Fig. 1. Cut model of the instrumented vertebral body replacement.

Table 1
Data on patients and surgical procedures.

Parameter	Patient				
	WP1	WP2	WP3	WP4	WP5
Age at the time of surgery (years)	62	71	69	63	66
Height (cm)	168	169	168	170	180
Body mass (kg)	66	74	64	60	63
Gender (M/F)	M	M	F	M	M
Fractured vertebra	L1	L1	L1	L1	L3
Level of internal fixation device	T12-L2	T12-L2	T11-L3	T12-L2	L2-L4
Time between implantation and measuring session (months)	12	10	6	13	6

appropriate implant height. The instrumented implant allows the measurement of all 3 forces and 3 moment components.

Each implant was calibrated and an accuracy test was performed prior to implantation. Related to the maximum applied forces (3000 N) and moments (20 Nm), the average errors were below 2% for force and 5% for moment components. The sensitivity of the instrumented implant is smaller than 1 N and 0.01 Nm. More detailed information about the implant, the external equipment and the telemetry has already been presented elsewhere (Graichen et al., 2007; Rohlmann et al., 2007).

2.2. Patients

Five patients with an A3 type compression fracture (Magerl et al., 1994) participated in this study. Four (WP1 to WP4) had a fracture of the vertebral body L1 and one patient (WP5) a fracture of L3. They were aged 62–71 years. The fractures were first stabilized with internal spinal fixation devices, implanted from the posterior. In a second surgery, parts of the fractured vertebral body and the adjacent discs were removed, and the instrumented implant was inserted into the corpectomy defect. Autologous bone material was added to the VBR in order to enhance fusion of the adjacent segments. Table 1 provides data on patients and surgical procedures.

The Ethics Committee of our hospital approved clinical implantation of the modified implant in patients, and they gave their written consent to implantation of the instrumented VBR, subsequent load measurements, and publishing of their images.

2.3. Activities investigated

While standing, the five patients lifted and set down weights of 0.01 kg (sheet of paper), 1.5 and 3 kg on a shelf at hip, shoulder, head, and above head levels. The patients were also sitting at a table and lifted these weights which were placed close to the upper body; they then put the weight down back onto the table with a stretched arm. After that, all sequences were performed in reversed order. These measurements were performed in a measuring session at least half a year after surgery (Table 1). The patients repeated each activity once. Since we wanted to measure the loads as they occur during daily life, no additional instructions were given on how to perform the activities.

Table 2
Median values of the forces in (N) for standing and for sitting relaxed for the measuring day.

Patient	Standing	Sitting
WP1	95	112
WP2	251	432
WP3	56	54
WP4	188	313
WP5	78	166

2.4. Evaluation of data

The resultant forces (geometrical sums of the 3 components) on the VBR were determined. The peak values of the resultant force for the investigated activities were calculated relative to the value when standing relaxed with the arms hanging down (set to 100%) in one and the same patient, measured on the same day. The resultant implant forces for standing and sitting are given in Table 2. In the diagrams shown here, the mean values of the peak forces and the range of the forces are presented. Not all patients agreed to perform all activities. Therefore, only descriptive statistics were applied in this study.

3. Results

The maximum resultant force during the different exercises always acted when the weight in the hand had the largest lever arm relative to the lumbar spine. For the activities studied, this was the case immediately before setting down or shortly after lifting the weight.

3.1. Activities while standing

Setting down a weight of 3 kg at different levels of a shelf caused implants forces which were always much higher than those for standing (Fig. 2). In patient WP1, forces on the VBR of even 5 times the value for standing were measured. However, there was a large variation of the maximum force for the different patients. The measured forces decreased with increasing level height in 2 patients (WP1 and WP5). No clear trend could be observed in the other 3 patients. Similar dependencies of the force involving the shelf height were found for the other weights studied and when lifting up a weight at different levels instead of putting it down[1].

As expected, the maximum resultant implant forces increased with increasing weight in all patients when setting the weight down (Fig. 3). However, the amount of force increase was seen to be different in all of the 5 patients.

3.2. Activities while sitting

When lifting a weight from a table with a stretched arm while sitting, implant forces of 5 times the value for standing were measured. The maximum resultant implant force increased with the magnitude of the weight (Fig. 4). This force increase differed among patients and was most pronounced in patient WP1. Also

[1] Videos and data files containing all force and moment components for different activities and subjects can be downloaded from www.OrthoLoad.com.