# MUSCULOSKELETAL LOADING DURING SHOVELING TASKS

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## INTRODUCTION

Numerous studies have highlighted the issue of musculoskeletal loading during manual lifting. To date, very little is known about the loading during shoveling activities. Shoveling differs from lifting and carrying by the fact that the load is low in weight but is manipulated at some distance from the body by means of the shovel. In addition, shoveling always entails movements with extensive reach. The aim of the present study was to implement a three-dimensional inverse dynamics approach in order to determine the musculoskeletal loading during shoveling tasks.

## METHODS

A standard shovel was prepared with two six-axis load cells (IF-628 and IF-205, FTSS, Plymouth, Michigan). The support forces of the handle on the thigh were measured by a specially designed pressure mat (Paromed, Neubeuern, Germany). The motion of the shovel and the human body (15 segments) were captured by means of a VICON system (8 cameras). All data were sampled synchronously at 100 Hz. The hand forces were calculated based upon an inverse dynamics model of the shovel. Net joint moments of the upper limbs and trunk were determined by inverse dynamics (top-down approach). The associated compression forces at L5/S1 were calculated by means of the biomechanical model "The Dortmunder" [1].

The measurements were performed in a realistic work situation and under laboratory conditions. Five skilled and healthy workers from different areas of the construction sector practiced their favorable shoveling technique during different work tasks (short/long distance; on level/upwards 1.2 m) with five different bulk products. The workers shoveled continuously for 20 repetitions at their preferred speed. In total, almost 1200 shoveling cycles have been analyzed.

## RESULTS AND DISCUSSION

On average, one shoveling operation associated with a bulk load of 7.0 kg (SD 1.3 kg) lasted 2.1 s (SD 0.5 s) from loading until unloading. The maximum force of the hand close to the blade reached, on average, approx. 260 N (SD 48 N), and the hand at the far end reached approx. 210 N (SD 56 N). An average maximum bearing force of the handle on the thigh of 200 N (SD 85 N) was recorded. The maximum sagittal extension moment at L5/S1 reached an average of 150 Nm (SD 19 Nm). Considerable lateral flexion moments of 85 Nm (SD 41 Nm) were observed and the maximum torsion moment amounted on average to 16 Nm (SD 18 Nm) (Figure 1). The peak compression force at L5/S1 was estimated at approx. 3.5 kN (SD 0.4 kN). An exceptional case was found to be a compound floor layer performing piece work (bulk: sand). One shoveling operation lasted only approximately 1.1 s, and the maximum compression force increased up to approx. 6.5 kN.

## CONCLUSIONS

Shoveling is an extensive spatial motion task associated with multi-axial external and internal loadings. The handle support on the thigh during insertion and lifting of the shovel plays a major role in reducing the lumbar loading. Nevertheless, shoveling must be considered a physically demanding task. Further efforts are necessary in developing recommendations and training programs for ergonomic shoveling techniques.

## ACKNOWLEDGEMENTS

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## REFERENCES

1. Jäger M, et al.: *SAE Digital Human Modeling Conference*, Arlington, Virginia, U.S.A., 2001.

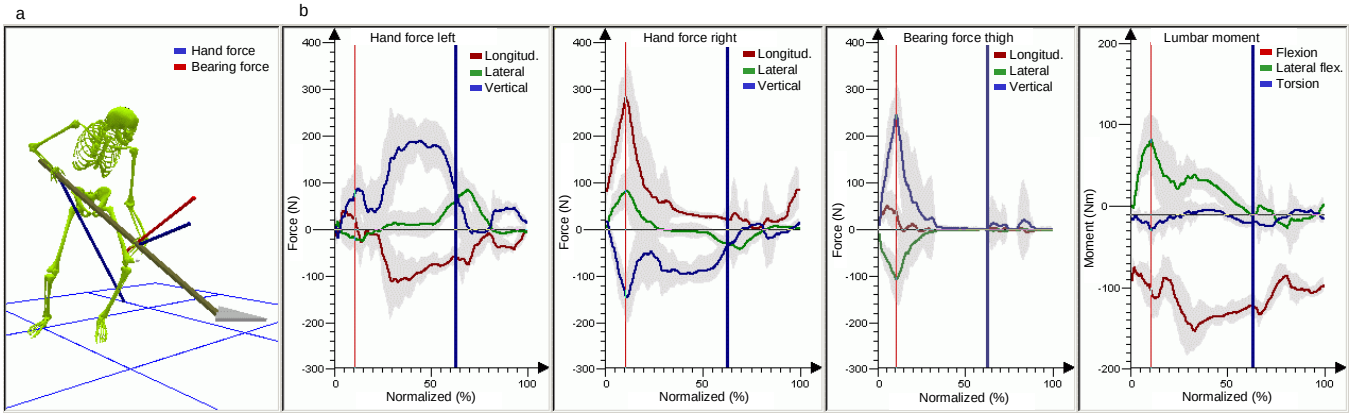


**Figure 1**: Typical loading situation during shoveling by one worker. (a) Force vector graphics at shovel insertion (t = 11 % cycle time) and (b) corresponding averaged time courses of the external forces and the lumbar moment (SD shaded area) of 20 consecutive shoveling cycles normalized to cycle time. Unloading of the shovel at approx. 60 % cycle time (vertical bar).