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PREVENTION OF LUMBAR OVERLOAD FOR HEALTH-CARE WORKERS DURING PATIENT-TRANSFER ACTIVITIES

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ABSTRACT

Diseases of the muscular and skeletal systems are one of the most frequent causes for health-related absenteeism in the workplace. In particular in occupational fields associated with handling heavy objects – like care-activities with patient transfer – the risk of spine diseases in the lumbar region is increased.
Hence, laboratory investigations were conducted regarding the mechanical load on the lumbar spine of health-care workers. The examinations of patient-transfer activities mainly refer to such tasks, which presumably result in high lumbar loads. The aim of the study was to describe quantitatively subject's spinal load by several indicators, to support the assessment of work-related prerequisites in occupational-disease evaluations, to examine various measures for work design, and to derive potentialities for a biomechanically substantiated prevention.
Lumbar-load indicators – such as compressive and shear forces at the lumbosacral disc – were determined for several patient-transfer activities within the bed, between the bed and a chair, on the floor, and at the bathtub by applying a previously developed validated three-dimensional multi-segmental dynamic biomechanical model, *The Dortmunder*. The forces acting between nurse and patient were recorded indirectly with the help

of newly developed force detection devices like “measuring bed” or “measuring chair”. Postures of health-care worker and patient were captured via an optoelectronic “position sensor system” in combination with several video cameras.
In summary, the analyzed patient-transfer activities, if performed in a “conventional” execution mode, cause intensive lumbar load for the health-care workers, which frequently exceeds recommended limits for the assessment of manual materials handling activities (e.g. *Dortmund Recommendations*). A considerably lower lumbar load can be achieved using an “optimized” execution of the activities in many cases. The testing of “small aids” (e.g. “sliding mat” or “handle belt”) shows that lumbar load can furthermore be lowered in order to support health prevention in nurses' everyday working life, especially for elderly persons.

1. INTRODUCTION

Manual materials handling activities are connected with a high risk for the development of diseases related to the intervertebral discs (Videman et al. 1984, Luttmann et al. 1988, Riihimäki et al. 1989, Hofmann et al. 1995). Furthermore, diseases at the muscular and skeletal systems are one of the most frequent causes for health-related absenteeism in the workplace (European Communities 2002, BKK 2008). Similarly, care-activities with patient transfer may lead to high load on the spine and may accelerate the development of degenerative disc-related diseases in the long run of occupational life (Videman et al. 2005).

In this context the spinal load of health-care workers (HCW) was examined for 16 typical patient-transfer activities. The selected care activities are presumably accompanied with a biomechanical overload of the lumbar spine. For these activities the load of the nurses was described quantitatively and evaluated regarding their potential overload risk (Jäger et al., 2005).

For conventionally executed tasks, the actually collected data replaced previously used values in the German regulation regarding the intervertebral-disc related occupational disease “no. 2108” (Kuhn et al., 2001; Theilmeier et al., 2006a).

As a consequence of the very high spinal load determined in case of a commonly used “conventional” task execution, options for prevention were examined. In addition to conventional, so-called “optimized” transfer activities and the usage of “small aids” were analyzed with regard to the corresponding spinal load.

2. METHOD

With the help of several measuring-based devices, characteristic values for spinal load were gathered in laboratory examinations. The movements, performed by the patient and the health-care worker, were documented with an optoelectronic measuring system (signals from infrared markers were received by infrared cameras) and video recordings from several lines of vision (cf. figure 1, Jordan et al., 2003).

The action forces exerted by the health-care worker during moving a patient in the bed were determined with regard to magnitude, direction and bilateral distribution using a common hospital bed that was equipped with an additional framework attached to the bedstead and connected to the bedspring frame via tri-axial force sensors at the four bed corners (figure 1).

Two different “measuring chairs”, a “measuring floor” and a “measuring bathtub”, constructed analogously, enabled the analysis of transfers such as placing the patient in a chair, raising a lying patient from the floor, or moving the patient into the bathtub and vice versa (Theilmeier et al., 2003a,b).

Based on the recorded posture and force data, biomechanical simulation calculations were accomplished applying the three-dimensional dynamic computerized biomechanical model *The Dortmunder* (Jäger et al., 2001a). Hence, time courses for several lumbar-load indicators were calculated, in particular, for the compressive force at the lumbosacral disc (lowest disc of the spine, L5-S1). For an adequate description of rather asymmetry-induced load, further characteristic values – like lateral shear forces and lateral bending and torsional moments of force at the L5-S1 disc – were determined (Jäger et al., 2003; Luttmann et al. 2007).

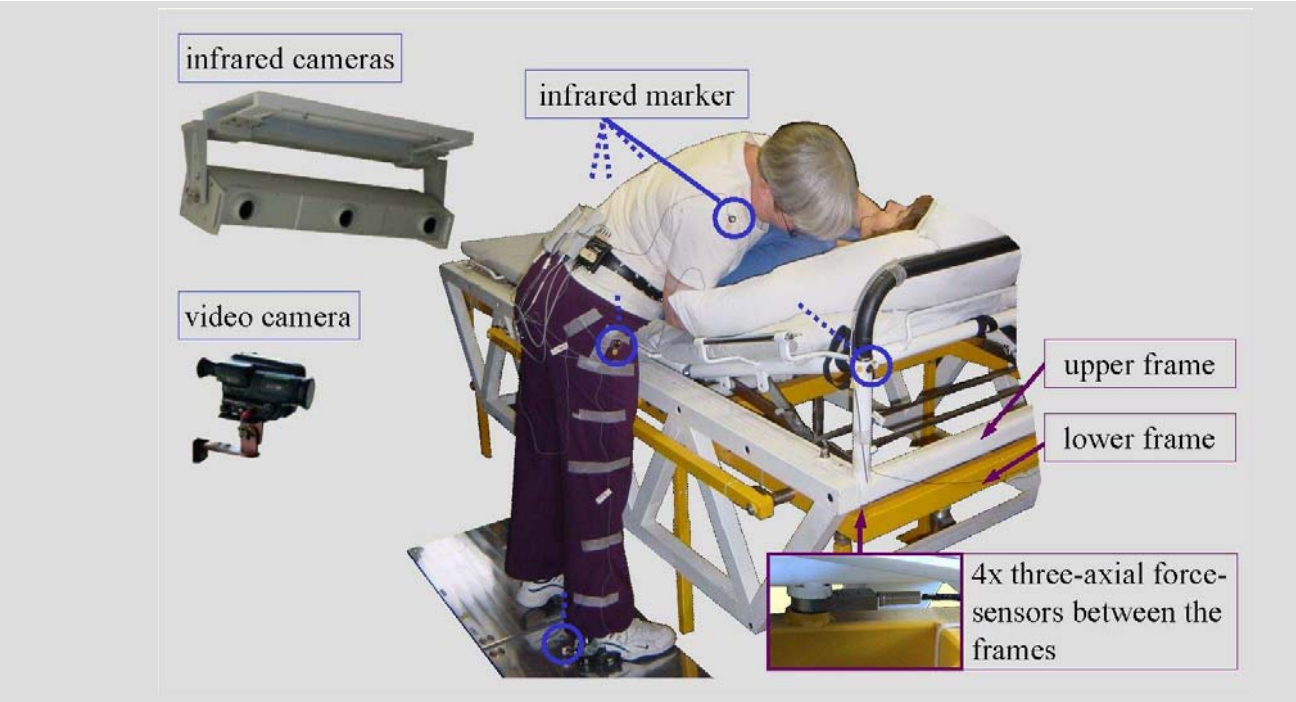

Figure 1:
Capturing of action forces via different measuring systems like the "measuring bed" (sketched here) and capturing of nurse's postural data via an optoelectronic system and video recordings in the Biodynamics Laboratory at the IfADo

The study comprises the analysis of 16 different care activities with systematic changes in the experimental conditions under investigation (2 professionally experienced health-care workers and 2 patients [weight: 60 kg or 80 kg]; patient's degree of mobility: active or passive; conventional or optimized execution and use of small aids) with up to 13 measuring repetitions.

The conventional transfer execution means a technique that is usually used in every day life in the nursing practice. A so-called optimized activity means the conscious usage of measures on biomechanical grounds like "small weights", "short lever arms" or "upright standing". The "small aids" are tools that support the nursing person, for example, . by the reduction of the friction between patient and beds' surface (like the "sliding board" or the "sliding mat") or that allow a better grasping of the patient (like the "handling belt").

In total, time courses of action force and postural indicators were gathered for approximately 1000 task executions. By means of the characteristics "typical posture and motion" and "typical action force", 162 representative transfers for the subsequent simulation calculations were selected. To evaluate the lumbar load the corresponding "force-or-posture time courses" were divided into more then 1000 sections. For each section the time courses of the above-mentioned lumbar-load indicators were computed (Jordan et al., 2005, 2006; Theilmeier et al., 2005, 2006b; Wortmann et al. 2007).

3. RESULTS

In Figure 2, the mean values and the ranges of the commonly used lumbar-load indicator "compressive force on the lowest disc of the lumbar spine" for 16 activities are demonstrated. Red columns refer to the conventional execution mode, yellow to the optimized mode and the green ones to the application of small aids. The values shown in figure 2 are based on the peak values of the respective time courses for the compressive force during the individual task execution. Comparison of the findings reveals a high influence of the tasks and of the performed transfer mode. The disc compression for the health-care workers varies in a wide range between 1½ to 9 kN.

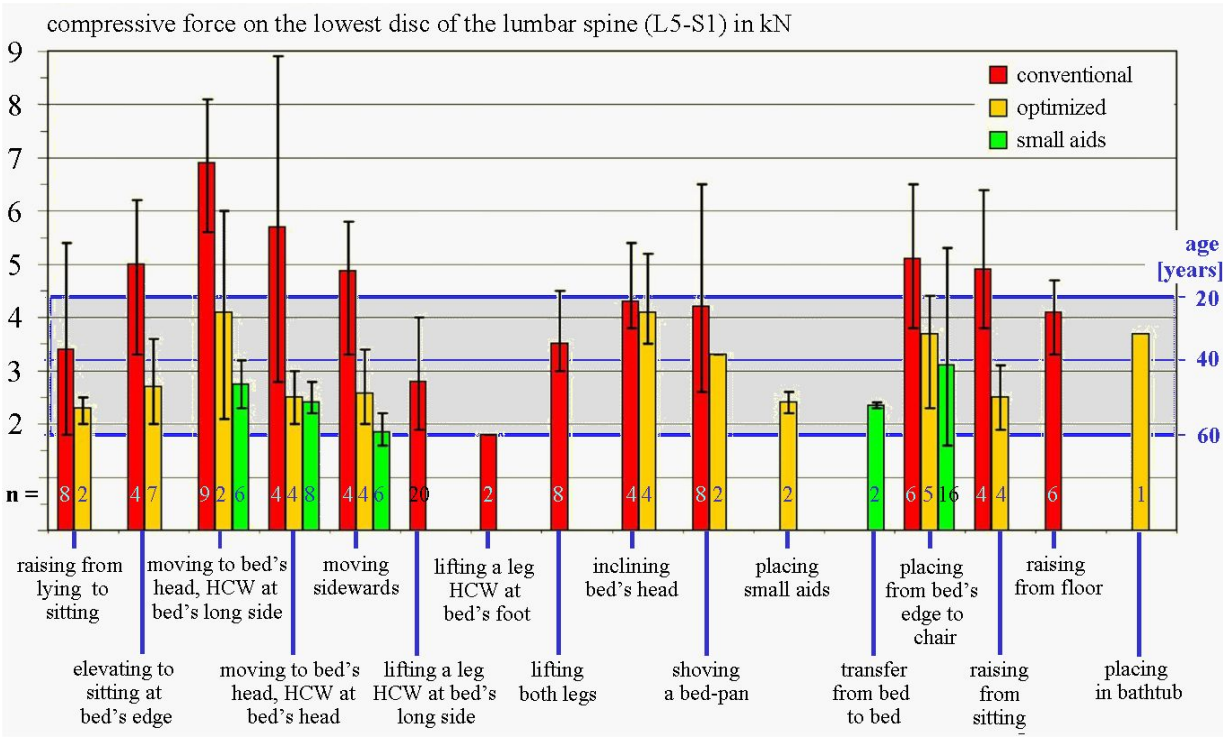

Figure 2:
Load on the lumbar spine for the health-care workers (HCW) during various patient-transfer activities: Mean values (columns) and ranges of the compressive-force values (maximum within the respective time course) for 16 care activities, partly performed in 3 modes (conventional, optimized, using small aids). Dark area: "Dortmund Recommendations" for female persons, compare table 1

Thus for example, as presented in figure 2, compressive-force values (peak values in the respective time course) of up to 8 kN (average 6.9 kN, n = 9) resulted for the conventional execution of the activity "moving a patient towards the bed's head (health-care worker at bed's long side)". When the same activity was performed in an optimized execution manner, the mean lumbar load was reduced by about 40% to approximately 4 kN. An averaged compressive-force value of less than 3 kN was reached by the application of small aids, i.e. to a value which is 60% less than the compressive force for conventional execution mode.

For other activities, represented in figure 2, a similar result was found: A 60% reduction of disc compressive forces was accomplished for "moving a patient towards the bed's head (health-care worker at bed's head)" in an optimized version and for the execution with small aids; reductions of approximately 50% (optimized) and 60% (small aids) were attained for "moving the patient in bed sidewards". A decrease of the compressive force of 30% and 40%, respectively, was found for "placing a patient from sitting at bed's edge in a chair".

For the assessment of lumbar load during patient-transfer activities, recommended limits for the maximum lumbar-disc compression forces of female and male persons at an age of 20 to 60-some are presented in table 1. The table shows the *Dortmund Recommendations* for the assessment of manual materials handling activities with regard to potential biomechanical overload for the lumbar-spine elements. These age-and-gender specific maximum lumbar-disc compressive forces were determined on the basis of the ultimate compressive strength of lumbar-spine autopsy material from a sample of 776 trials in 25 different studies (Jäger et al., 2001b).

The interpretation of the load values demonstrate that conventionally executed activities usually cause compressive forces at the lumbar disc L5-S1 which clearly exceed limits for ergonomic work design shown in table 1.

With regard to different age and gender of the respective health-care worker, in table 2 the necessity for redesign for four examined care activities is shown: with "low risk for biomechanical overload" only the use of small aids lowers the lumbar load into a range within which the activity should be achieved by female and/or older employees.

Table 1: Age-and-gender specific "Dortmund Recommendations" for the assessment of manual materials handling activities: Maximum lumbar-disc compressive forces for female and male persons at an age between 20 and over 60 years.

Dortmund Recommendations ***Max. lumbar load [kN]***					
Age [years]	**20**	**30**	**40**	**50**	**≥60**
female	4.4	3.8	3.2	2.5	1.8
male	6.0	5.0	4.1	3.2	2.3

In addition, the "compression-related load partition" was frequently overlaid by load portions representing asymmetry (lateral shear forces and bending or torsional moments) to a relevant degree. Those loadings result from the lateral action-force components of the health-care worker, from unequally exerted vertical forces of the right and the left hand or from an asymmetrical posture concerning to the body's median plane. For example high asymmetrical loads were determined for activities in conventional mode like "elevating the patient to sitting at the bed's edge" (lateral moment M_{lat} = 90 Nm, torsional moment M_{tors} = 90 Nm, n = 12) or "moving the patient to the bed's head, HCW at the bed's long side" (M_{lat} = 100 Nm, M_{tors} = 170 Nm, n = 11). On the other hand a lateral moment and a torsional moment each with about 20 Nm (n = 18) shows that activities like "lifting a leg of the patient, HCW at the bed's long side" are rather symmetrical load cases. The results are completely represented at Jäger et al. (2008a).

Table 2: Age limit starting from a redesign is necessary for the three examined execution modes

patient-transfer activity	**Age limit in years starting from redesign is necessary** (female / male)		
	convent.	optimized	small aids
moving towards bed's head - nurse at long side	-	20 / 40	40 / 50
moving towards bed's head - nurse at bed's head	- / 20	50 / 50	50 / 50
moving sidewards	- / 30	40 / 50	50 / 60
placing from the bed's - edge in a chair	- / 20	30 / 40	40 / 40

4.DISCUSSION

In the present study the use of a three-dimensional and time-variant analysis lead to an adequate description of the lumbar load, mostly indicated by the compressive force on the L5-S1 disc. The procedure also makes statements possible about the load aspects regarding shear, bending and torsional load at the lower spine, which requires special attention to avoid the development of diseases.

Contrary to the commonly used lumbar-load indicator “compressive force on the lowest disc of the lumbar spine” in the literature no evaluation criteria are available for asymmetry indicators like lateral shear force or torsional moment. Nevertheless more probably than not they increase the load of the spine in addition to a high compressive force or they cause a overload risk despite low compressive force (Theilmeier et al. 2006c).

The methodology used for the described studies, however, is accompanied by a high level of personnel effort for gathering and evaluation of the data, and therefore it is less suited for larger subject groups. The disadvantages of evaluating a partly low number of task executions could be reduced by a careful selection of typical tasks from the pool of the totally collected data (Jäger et al. 2008b, Theilmeier et al. 2008).

In summary, patient-transfer activities executed in the conventional mode cause intensive lumbar load for health-care workers. This results in frequent exceeding of recommended limits for maximum lumbar load, such as the *Dortmund Recommendations* for the assessment of handling activities. In many cases optimized transfer techniques resulted in considerably lower lumbar load. The usage of small aids shows that lumbar load can furthermore be lowered in order to support health prevention in nurses’ everyday working life, especially for elderly persons. In consequence, optimized handling modes should be trained and small aids should be provided to the health-care workers from the preventive point of view.

5. SUMMARY

In this paper information is provided about the determination of lumbar load in care activities with patient transfers. The aim was to support the assessment of work-related prerequisites in occupational-disease evaluations, to examine various measures for work design and to derive potentialities for a biomechanically substantiated prevention.

Various lumbar-load indicators were determined for several patient-transfer activities within the bed, between the bed and a chair, in a bathtub and on the floor by applying a comprehensive biomechanical model.

In a conventional execution mode the analyzed patient-transfer activities cause intensive lumbar load for the nurses, which frequently exceed recommended limits for maximum lumbar load. Optimized transfer techniques resulted in considerably lower lumbar load in many cases. The usage of small aids shows that lumbar load can furthermore be lowered in order to achieve health prevention in nurses’ everyday working life.

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REFERENCES

BKK (2008). Seelische Krankheiten prägen das Krankheitsgeschehen. In Bundesverband der Betriebskrankenkassen (Ed.), BKK Gesundheitsreport, Essen: Bundesverband der Betriebskrankenkassen.

European Communities (2002). European social statistics, accidents at work and work-related health problems. In Européennes, O.D.P.O.D.C. (Ed.), Luxem-bourg.

Hofmann, F., Michaelis, M., Siegel, A., Stößel, U. & Stroink, U. (1995). Bandscheibenbedingte Erkrankungen der Wirbelsäule - Untersuchungen zur Frage der beruflichen Verursachung. In D. Wolter, K. Seide (Eds.), Berufskrankheit 2108, Kausalität und Abgrenzungskriterien (pp. 47–61). Berlin: Springer.

Jäger, M., Luttmann, A., Göllner, R., & Laurig, W. (2001a). The Dortmunder – Biomechanical model for quantification and assessment of the load on the lumbar spine. In Soc. Automotive Engineers (Ed.), SAE Digital Human Modeling Conf Proc. (9 pp. 201-01-2085). Arlington VA: Soc. Automotive Engineers Inc..

Jäger, M., Luttmann, A., Göllner, R. (2001b). Analysis of lumbar ultimate compressive strength for deriving recommended lumbar-load limits. In: R. Müller, H. Gerber, A. Stacoff (Eds.), Int. Soc. Biomechanics, Book of Abstracts (pp. 263-264). ETH Zürich, Laboratory for Biomechanics.

Jäger, M., Jordan, C., Theilmeier, A., & Luttmann, A. (2003). Dortmunder Lumbalbelastungsstudie 3: Ermittlung der Belastung der Lendenwirbelsäule bei ausgewählten Pflegetätigkeiten mit Patiententransfer. Teil 1: Entwicklung und exemplarische Anwendung der Methodik. Aachen: Shaker.

Jäger, M., Theilmeier, A., Jordan, C., & Luttmann, A. (2005). Dortmunder Lumbalbelastungsstudie 3: Ermittlung der Belastung der Lendenwirbelsäule bei ausgewählten Pflegetätigkeiten mit Patiententransfer. Teil 2: Belastungskennwerte von sicher gefährdenden Tätigkeiten im Sinne der Berufskrankheit 2108. Aachen: Shaker.

Jäger, M., Jordan, C., Theilmeier, A., & Luttmann, A. (2008a). Dortmunder Lumbalbelastungsstudie 3: Ermittlung der Belastung der Lendenwirbelsäule bei ausgewählten Pflegetätigkeiten mit Patiententransfer. Teil 3: Biomechanische Beurteilung von Tätigkeiten im Gesundheitsdienst hinsichtlich der Möglichkeit zur Prävention von Gefährdungen der Wirbelsäule. Aachen: Shaker.

Jäger, M., Theilmeier, A., Jordan, C., Wortmann, N., Kuhn, S., Luttmann, A., & the DOLLY Group (2008b). Biomechanical analysis of patient-transfer activities for the prevention of spine-related hazards of healthcare workers. In Healthcare Systems Ergonomics and Patient Safety: Strasbourg: HEPS.

Jordan, C., Theilmeier, A., Luttmann, A., & Jäger, M. (2003). Lumbar load during care-activities with patient transfer. Part 1: Determination of postures and movements. In D. de Waard, W.A. Brookhuis, S.M. Breker, W.B. Verwey (Eds.), Human Factors in the Age of Virtual Reality (pp. 235–238). Maastricht: Shaker.

Jordan, C., Theilmeier, A., Luttmann, A., & Jäger, M. (2005). Erfassung der Lendenwirbelsäulenbelastung bei Kranken- und Altenpflegetätigkeiten mit Patiententransfer. In Th. Brüning, V. Harth, M. Zaghow (Eds.), Dialog zwischen betrieblicher Praxis und arbeitsmedizinischer Wissenschaft (pp. 429–433). Stuttgart: Gentner.

Jordan, C., Theilmeier, A., Luttmann, A., Jäger, M., & DOLLY Group (2006). Lumbar-load analysis for health-care workers during patient transfer activities. In R.N. Pikaar, E.A.P. Koningsveld, P.J.M. Settels (Eds.), Meeting Diversity in Ergonomics. Amsterdam: Elsevier.

Kuhn, S., Baumann, W., Lang, R., & Wortmann, N. (2001). MDD-Pflege – Vorläufige Dosisberechnung >(Gesundheitsdienst). In BG für Gesundheitsdienst und Wohlfahrtspflege (Ed.). Hamburg: BGW.

Luttmann, A., Jäger, M., Laurig, W. & Schlegel, K.F. (1988). Orthopaedic diseases among transport workers. Int. Arch. Occup. Environ. Health, 61, 197-205.

Luttmann, A., Theilmeier, A., Jordan, C., Wortmann, N., Kuhn, St., Nienhaus, A., Jäger, M. (2007). Posture and action-force measurements for health-care workers during patient handling supporting lumbar-load quantification. In Hellenic Institute for Occupational Health and Safety (Ed.), Risks for health care workers: prevention challenges (p. 473). Athens: ISSA.

Riihimäki, H., Wickström, G., Hänninen, K., Mattson, T., Waris, P. & Zitting, A. (1989). Radiographically detectable lumbar degenerative changes as risk indicators of back pain, a cross-sectional epidemiologic study of concrete reinforcement workers and house painters. Scand. J. Work Environ. Health, 15, 280-285.

Theilmeier, A., Jordan, C., Jäger, M., & Luttmann, A. (2003a). Lumbar load during care-activities with patient transfer. Part 2: Measurement of applied forces. In D. de Waard, W.A. Brookhuis, S.M. Breker, W.B. Verwey (Eds.), Human Factors in the Age of Virtual Reality (pp. 239–242). Maastricht: Shaker.

Theilmeier, A., Jordan, C., Jäger, M., & Luttmann, A. (2003b). Measurement of exerted forces during patient transfer for determining lumbar load. In H. Strasser, K. Kluth, H. Rausch, H. Bubb (Eds.), Quality of Work and Products in Enterprises of the Future, (pp. 1006–1009). Stuttgart: Ergonomia.

Theilmeier, A., Jordan, C., Luttmann, A., & Jäger, M. (2005). Messtechnisch gestützte Erfassung von Körperhaltungen und Aktionskräften zur Erhebung der Wirbelsäulenbelastung bei Pflegetätigkeiten. Zeitschrift für Arbeitswissenschaft, 59, 162–171.

Theilmeier, A., Jordan, C., Wortmann, N., Kuhn, St., Nienhaus, A., Luttmann, A., & Jäger, M. (2006a). Belastung der Lendenwirbelsäule von Pflegepersonen bei Patiententransfers – Kennwerte zur Nutzung in BK-Feststellungs-verfahren. Zentralblatt für Arbeitsmedizin, Arbeitsschutz und Ergonomie, 56, 228–251.

Theilmeier, A., Jordan, C., Luttmann, A., Jäger, M., & DOLLY Group (2006b). Measurement of exerted forces for determining nurses' lumbar load during patient transfers. In R.N. Pikaar, E.A.P. Koningsveld, P.J.M. Settels (Eds.), Meeting Diversity in Ergonomics. Amsterdam: Elsevier.

Theilmeier, A., Jordan, C., Luttmann, A., Jäger, M. (2006c). Wirbelsäulenbelastung durch Pflegetätigkeiten mit Patiententransfer bei asymmetrischer Körperhaltung und Krafteinwirkung. In Gesellschaft für Arbeitswissenschaft (Ed.), Innovation für Arbeit und Organisation (pp. 663-666). Stuttgart: GfA-Press.

Theilmeier, A., Jordan, C., Wortmann, N., Kuhn, St., Luttmann, A., Jäger, M. (2008). Risk prevention for health-care workers by reduction of lumbar load during patient-transfer activities. In P. Mondelo, M. Mattila, W. Karwowski, A. Hale (Eds.) Sixth International Conference on Occupational Risk Prevention. La Coruña, Spain.

Videman, T., Ojajärvi, A., Riihimäki, H. & Troup, J.D. (2005). Low back pain among nurses: A follow-up beginning at entry to the nursing school. Spine, 30 (20), 2334-41.

Wortmann, N., Luttmann, A., Kuhn, St., Jäger, M. (2007). Evaluation of compressive forces at the lumbosacral disc in healthcare – Effects on rehabilitation and prevention. In: Hellenic Institute for Occupational Health and Safety, Athens, Greece (Ed.), Risks for health care workers: prevention challenges (p. 173). Athens: ISSA.