Development of a method for evaluating the supposed causal link between disc herniation and manual materials handling

— The *'Mainz-Dortmund Dose Model'* inspired by the *German Occupational Disease No. 2108* and enhanced by the *'German Spine Study'*

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The Occupational Disease No. 2108

After the political re-unification of the two parts of Germany in 1990, the former German Democratic Republic in the Eastern part and Federal Republic of Germany in the Western part, the contradictory conditions and possibilities for workers compensation with regard to severe low-back diseases induced by high physical exposure were harmonised. An occupational disease OD (no. 2108) was enacted in 1992 as the final result of an intensive discussion via a regulatory directive in the corresponding disease list for potential workers compensation: "Intervertebral-disc related diseases of the lumbar spine caused by lifting or carrying heavy objects over many years or caused by activities in an extremely trunk-flexed posture over many years that have forced the person to discontinue all activities which have caused or could have caused the onset, the worsening or the recurrence of the disease" (BMA 1992). The topic of deriving distinct medical and physical criteria for an adequate assessment of individual disease expressions in combination with individual loading profiles became obvious in the following years. According to the occupational-disease definition, disc herniation and severe disc narrowing are discussed not separately in the following, if possible.

The "Mainz-Dortmund Dose Model MDD"

To enable the recognition of a subject's injury as an occupational disease in suspicion of the newly defined German OD 2108, the medical conditions were harmonised by a

national interdisciplinary consensus group initiated by the German Social Accident Insurance (Bolm-Audorff et al. 2005 a+b). In comparison, the physical exposure is commonly evaluated by applying the so-called *Mainz-Dortmund Dose Model – MDD* (Hartung et al. 1999, Jäger et al. 1999, HVBG 2003) in principle, which was proposed by an interdisciplinary working group of scientists and technical experts or jurists of statutory accidents insurancies as a uniform procedure of load evaluation and assessment. However, after respective investigations to substantiate the supposed causal link between lumbar disc herniation or severe disc narrowing, on the one hand, and cumulative lumbar-load dose through manual materials handling and extremely bent postures, on the other hand, within the so-called *German Spine Study – EPILIFT* (Bolm-Audorff et al. 2007), few adaptation criteria seem necessary to be considered.

The German approach takes into account the complex of problems at assessing a subject's occupational-life risk for biomechanical overloading the skeletal low-back structures that lifting or carrying activities and working in certain postures without exerting positioning forces usually occur in combination of various intensities due to different object weights, action frequencies and durations under diverse task conditions. Therefore, the *Mainz-Dortmund Dose Model* follows the idea to transform each potential overloading exposure through manual handling or posture into measures replicating the resultant biomechanical load on the skeletal structures in the lower back. Thereby, in analogy to work-design analysis in ergonomics and occupational physiology, the low-back load of a potential overloading action is described by the task-specific ”situational lumbar load” characterised by the peak compressive force on the lumbosacral disc as well as that action's duration and frequency of occurrence. By contrast, as integrative measures of repeated loading situations, the ”cumulative lumbar load” is characterised by the dose of typical shifts – by summing up all the situational lumbar doses within the respective typical workday – and summarising the shift doses over the individual exposure time up to the total occupational lifetime dose. The resultant lifetime dose must reach a characteristic value to enable the recognition of a medically verified disease as occupationally caused. Corresponding to the definition of the German OD 2108 itself and the official annotations in the corresponding code of practice (BMA 1993, modified by BMAS 2006), thresholds had also to be derived to signify the terms ”heavy objects”, ”extreme trunk bending”, ”many years” and others.

On those presumptions of OD 2108, the *Mainz-Dortmund Dose Model* was therefore developed based on a retrospective load estimation of occupational activities accompanied with an increased risk of intervertebral-disc related diseases of the lumbar spine. Loadings during a shift due to lifting, carrying and trunk inclination are accumulated with a linear as well as squared weighting of disc compression force relative to the situation's

duration. Following experimental findings of lumbar-spine strength during repetitive force application and, therefore, according to the higher overload risk of high forces compared to lower forces of longer cumulative duration, superproportional weighting rather than proportional is preferred in this approach.

The following criteria for data gathering are used in the *Mainz-Dortmund Dose Model*: Activities resulting in lumbosacral-disc compressive forces of 2.5 kilonewtons (1 kN = 10^3 N) or more in the case of women or 3.2 kN for men are considered only, which are induced by lifting a mass of 10 or 20 kg, respectively. Activities without object handling or force exertion, but characterised by an "extremely" trunk-flexed posture of 90 degrees or more, are considered by a disc-compressive force of 1.7 kN and their respective durations. Based on cumulative dose estimations for nursing, construction or dockwork, the minimum dose per shift was set to 3.5 kilonewton-hours (1 kNh = 10^3 Nh) assuming females and 5.5 kNh for males. With respect to epidemiological findings, gender-specific recommended minimum life-time expositions are proposed representing the lower risk limit for generating disc-related lumbar diseases caused by heavy lifting, carrying or activities with the trunk extremely bent forward: 17 meganewton-hours (1 MNh = 10^6 N) regarding female persons and 25 MNh for males.

NOTE: The abovementioned *MDD*-related threshold values were questioned by a subsequent investigation sketched in the following, which is currently not finished in all details (Bolm-Audorff et al. 2007); for the meantime, supported by the Federal Court of Justice for Social Affairs, the compressive-force criterion for males was lowered to 2.7 kN, and the daily-dose criteria were intermitted.

Applying the *Mainz-Dortmund Dose Model* in occupational-disease procedures, in a first step, a pre-selecting criterion is checked whether the exposure fulfill a minimum amount of intensity, so that a risk of hazard is not assumed if the criteria regarding the mass of objects being lifted or carried, the handling frequencies and annual shifts of relevant exposure are not reached. In case of reaching or exceeding these minimum exposure values, in a second step, lumbar load is quantitatively described as precisely as possible with respect to disc-compressive force, action duration and frequency as well as cumulative shift dose. If the circumstances of exposure are uncertain, for example the working site is closed in the meantime, for the purpose of approximation, simplifying estimation equations for compressive-force prediction were proposed for totally six modes of lifting or carrying. Finally, the work-related presuppositions in OD-2108 procedures can be examined and assessed by means of a standardised manner applying the *MDD*.

The ”German Spine Study EPILIFT”

The authors of the *Mainz-Dortmund Dose Model* stated that appropriate knowledge on associations between physical work and severe spine-diseases in the lower back, which are really verified by an increased risk compared to a control group, was very limited at model-derivation time and that knowledge was restricted to few occupational fields only: construction, healthcare and longshoremen‘s work. Therefore, intensive research to both the exposure and the risk for the development of lumbar diseases in order to question or to substantiate the supposed dose-response relationship and to increase the quantitative data base was considered necessary. In this context, a population-based case-control study was performed in the years 2002 to 2007 (e.g. Bolm-Audorff et al. 2007; Seidler et al. 2009; Jäger et al. 2011) in order to investigate the hypothesis whether persons being exposed to manual material handling or awkward postures show a significant higher risk for developing disc herniation or disc-space narrowing in the lumbar region in comparison to the German standard population, i.e. males, or females. Furthermore, the basic criteria were questioned which are provided in the occupational-disease definition or in the transformation procedure *Mainz-Dortmund Dose Model*. Therefore, the minimum physical-load thresholds with respect to object mass, disc-compressive force, trunk inclination, daily dose and other items were varied by defining 10 shift-dose model in total, so that ”best fitting” models could be identified.

Case and control persons (915 vs. 901 subjects) were prospectively recruited in four regions of Germany to consider regional differences in the work content and intensity, for example, so that a couple of centres for data collection and evaluation were involved. Odds ratios were adjusted for age and study region, and further specific adjustments were performed according to a-priori defined biologically plausible factors**.** As the main result, a higher odds ratio for exposed persons than for ”non-exposed” was found for each of the four case groups (herniation/narrowing among males/females), ranging between 1.3 and 3.9 in the respective dose category. Statistical significance was justified for the majority of exposure categories among the four case groups, but not for all. A positive dose-response relationship with a monotonous increase with lifetime dose, which was categorised in tertiles in addition to a ”non-exposed” class, was established among female disc-herniation patients and male disc-narrowing cases. In contrast, the two other configurations show lower odds ratios for the highest exposure category, compared to the second-highest dose category. Even not statistically significant, this specific result might be interpreted as a healthy-worker effect, in particular, among male prolapse patients where the size of an additionally split-off ”high-dose category” is really small. With regard to the mathematical fitting of the supposed causal link of physical exposure and herniation or space-narrowing, the dose models with the best goodness of

fit consider lower thresholds for disc compressive force reflecting the object mass during manual handling and lower thresholds for trunk inclination reflecting awkward postures in comparison with the actual occupational-disease definition or, equivalently, the transformation procedure ”MDD”. Furthermore, these models are characterised by a missing daily dose threshold, and, besides lifting and carrying of objects, other types such as pulling and pushing or throwing and catching were included.

Specific analyses have shown that disc herniation was, on average, developed considerably earlier than severe symptomatic disc-space narrowing (Jäger et al. 2011); furthermore, the level of working intensity, i.e. the dose per year or decade seem to codetermine the type of disease, i.e. herniation or narrowing. In earlier years, a higher risk is provided among herniations. If, however, the worker was meanwhile spared of herniation diseases, disc-space narrowing becomes more likely when working intensity exceeds the level of population controls. In order to investigate the threshold behaviour regarding the impact on the supposed causal dose-response relations, the so-called ”German Spine Study 2” was initiated in 2009 which will be terminated presumably in 2012.

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References

BMA, The Minister for Labour and Social Policy (1992) Second Enactment for modifying the Regulation of Occupational Diseases. Bundesgesetzblatt I, Nr. 59, 2343-2344
[in German: Bundesminister für Arbeit und Sozialordnung, Zweite Verordnung zur Änderung der Berufskrankheiten-Verordnung]

BMA, The Minister for Labour and Social Policy (1993) Code of practice for the medical examination regarding no. 2108. Bundesarbeitsblatt 3, 50-53
[in German: Bundesminister für Arbeit und Sozialordnung, Merkblatt für die ärztliche Untersuchung zu Nr. 2108]

BMAS, The Ministry for Labour and Social Affairs (2006) Code of practice regarding ocuupational disease no. 2108 of annex to occupational-disease regulation . Bundesarbeitsblatt 10), 30-35
[in German: Bundesministerium für Arbeit und Soziales, Merkblatt zu der Berufskrankheit Nr. 2108 der Anlage zur Berufskrankheiten-Verordnung]

Bolm-Audorff U, Brandenburg S, Brüning T, Dupuis H, Ellegast R, Elsner G, Franz K, Grasshoff H, Grosser V, Hanisch L, Hartmann B, Hartung E, Hering KG, Heuchert G, Jäger M, Krämer J, Kranig A, Ludolph E, Luttmann A, Nienhaus A, Pieper W, Pöhl K-D, Remé T, Riede D, Rompe G, Schäfer K, Schilling S, Schmitt E, Schröter F, Seidler A, Spallek M, Weber M (2005) Medical evaluation criteria for occupational diseases of the lumbar spine related to the intervertebral disc (Part 1+2). Consensus

recommendations for assessing the interrelationship as proposed by the interdisciplinary working group established by the HVBG. Trauma und Berufskrankheiten 7, 211-252 (Part I) and 320-332 (Part 2)
[in German: Medizinische Beurteilungskriterien zu bandscheibenbedingten Berufskrankheiten der Lendenwirbelsäule (I+II): Konsensempfehlungen zur Zusammenhangsbegutachtung der auf Anregung des HVBG eingerichteten interdisziplinären Arbeitsgruppe]

Bolm-Audorff U, Bergmann A, Ditchen D, Ellegast R, Elsner G, Geiß O, Grifka J, Haerting J, Hofmann F, Jäger M. Linhardt O, Luttmann A, Michaelis M, Nübling M, Petereit-Haack G, Schumann B, Seidler A (2007) Epidemiologic case-conrol study for examining the dose-response relationships regarding occupational disease no. 2108 – The German Spine Study EPILIFT. Scientific Report. Hauptverband der gewerblichen Berufsgenossenschaften, Sankt Augustin http://www.dguv.de/inhalt/versicherung/bk/wirbelsaeule/index.jsp
[in German: Epidemiologische Fall-Kontroll-Studie zur Untersuchung von Dosis-Wirkungs-Beziehungen bei der Berufskrankheit 2108 - Deutsche Wirbelsäulenstudie. Abschlussbericht]

Hartung E, Schäfer K, Jäger M, Luttmann A, Bolm-Audorff U, Kuhn S, Paul R, Francks H-P (1999) The Mainz Dortmund Dose Model (MDD) for assessing the load on the lumbar spine caused by lifting and carrying heavy objects or by work with the trunk fully inclined in suspicion of occupational disease no. 2108. Part 2: Suggestion for the assessment of work-related prerequisites in occupational disease evaluation. Arbeitsmed Sozialmed Umweltmed 34, 112-122
[in German: Mainz-Dortmunder Dosismodell (MDD) zur Beurteilung der Belastung der Lendenwirbelsäule durch Heben oder Tragen schwerer Lasten oder durch Tätigkeiten in extremer Rumpfbeugehaltung bei Verdacht auf Berufskrankheit Nr. 2108. Teil 2: Vorschlag zur Beurteilung der arbeitstechnischen Voraussetzungen im Berufskrankheiten-Feststellungsverfahren]

HVBG, Federation of Institutions for Statutory Accident Insurance and Prevention (2003) OD-Report 2/03: Spinal diseases (OD Nos. 2108 to 2110). Sankt Augustin
[in German: BK-Report 2/03: Wirbelsäulenerkrankungen (BK-Nrn. 2108 bis 2110)]

Jäger M, Luttmann A, Bolm-Audorff U, Schäfer K, Hartung E, Kuhn S, Paul R, Francks H-P (1999) The Mainz Dortmund Dose Model (MDD) for assessing the load on the lumbar spine caused by lifting and carrying heavy objects or by work with the trunk fully inclined in suspicion of occupational disease no. 2108. Part 1: Retrospective load estimation for risky jobs. Arbeitsmed Sozialmed Umweltmed 34, 101-111
[in German, Mainz-Dortmunder Dosismodell (MDD) zur Beurteilung der Belastung der Lendenwirbelsäule durch Heben oder Tragen schwerer Lasten oder durch Tätigkeiten in extremer Rumpfbeugehaltung bei Verdacht auf Berufskrankheit Nr. 2108. Teil 1: Retrospektive Belastungsermittlung für risikobehaftete Tätigkeitsfelder]

Jäger M, Bergmann A, Bolm-Audorff U, Ellegast R, Grifka J, Hofmann F, Michaelis M, Seidler A, Voß J, Luttmann A (2011) Occupational low-back exposure of persons with or without lumbar disc-related diseases - Selected results of the German Spine Study EPILIFT. In: Grieshaber R, Stadeler M, Scholle H-C (Eds.): Prävention von arbeitsbedingten Gesundheitsgefahren und Erkrankungen. Jena: Verlag Bussert & Stadeler, 341-365

Seidler A, Bergmann A, Jäger M, Ellegast R, Ditchen D, Elsner G, Grifka J, Haerting J, Hofmann F, Linhardt O, Luttmann A, Michaelis M, Petereit-Haack G, Schumann B, Bolm-Audorff U (2009) Cumulative occupational lumbar load and lumbar disc disease – results of a German multi-center case-control study (EPILIFT). BMC Musculoskeletal Disorders 10, 48-60