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Editorial

Spine loading and deformation – From loading to recovery

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1. Introduction

There is ample evidence in the literature of a strong association between low back disorders and spine loading and deformation that are present particularly during repetitive heavy lifting and awkward postures (NIOSH, 1997). The human spine has the fundamental function of the support, control and transmission of upper trunk loads (i.e., body weight, loads carried in hands and on shoulders, inertial loads) while performing tasks and movements common in daily recreational, sport and workplace activities. Peak and repetitive loads and deformations at levels approaching tissue injury thresholds, jerky movements and sudden unforeseen perturbations regularly put this function (i.e., the resistant, reflex response, control and system stability) to the test. Acute or accumulated tissue injuries, degenerations, contaminations in neural network, deformities and instability likely increase the risk of further deteriorations and pain. Adequate knowledge of spine loading and deformation in various conditions and mechanical environments remains hence crucial for effective risk evaluation, workplace safety, prevention programs, rehabilitation, tissue regeneration, tissue replacement and surgery of the human spine.

From early attempts on measurement of the intradiscal pressure (e.g., Nachemson and Morris, 1964), spinal shrinkage (e.g., Eklund and Corlett, 1984), intra-abdominal pressure (e.g., Davis, 1959), muscle electromyography activity (e.g., McGill and Norman, 1986) to more recent ones using instrumented vertebral implants (Rohlmann et al., 1999), researchers have aimed to estimate mechanical loading on the human spine in various activities. In parallel, in vitro studies have for long (e.g., Hirsch and Nachemson, 1954; Roaf, 1960) shed light on the passive resistance and failure mechanisms of the spinal components and tissues. While the foregoing measurements have substantially improved our understanding of the functional biomechanics of the spine in normal and injured conditions, it has long been recognized that they alone are not sufficient to quantify the complex mechanisms in action prior, during and subsequent to injuries. Computational models have hence been employed (e.g., Belytschko et al., 1974) with the expectation to accurately determine the spatial and temporal variations of stresses, strains, fluid flow, cell viability and solute transport throughout the spinal tissues (see review paper; Schmidt et al., 2013). It has never been as evident that further meaningful progress in this field can only materialize through complementary investigations taking full consideration of all these tools.

2. Berlin workshop

After about a year of its inception, the current workshop on spine loading and deformation, organized by Hendrik Schmidt and Aboulfazl Shirazi-Adl, took place with 75 participants from 14 countries around the globe at Julius Wolff Institute of Charité–Universitätsmedizin in Berlin during 3 days of July 2–4, 2015; http://workshop.spine-biomechanics.com/.

The workshop aimed to gather researchers working in different disciplines and fields of application in health care, biological science, biomechanics and ergonomics together in order to share, discuss and re-examine the potentials of their recent works on the spine. Research topics covered trunk loads and motion measurements (imaging, sensors and video camera) and predictions during static and dynamic tasks with focus on the lumbar and thoracic spines.

More than 50 renowned experts in the field were initially contacted. Submitted abstracts were evaluated and authors of accepted ones were invited to present their work at the meeting and submit an original paper for consideration in this special issue of the Journal of Biomechanics. In total 33 works were presented and 22 research papers finally accepted after peer review for inclusion in the current issue. The meeting ended with a round table discussion on four topics chosen based on relevance to the materials presented at podium; (1) What does the medical devices industry expect from spine biomechanists? Appropriateness of testing criteria and their dependence on the patient age, condition and lifestyle were discussed as related to the evaluation of relative

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safety and effectiveness of products. (2) How accurately should we replicate in vivo physiological conditions in vitro? Issues on suitability of animal models, intact normal specimen versus degenerate and injured ones, preconditioning and specific objective of in vitro tests were debated. (3) What is the role of the disc annulus interlaminar interface in disc function and failure? The crucial effects of ageing, disc-endplate interface, fluid content and nucleus pressurization were discussed. (4) How to make full subject-specific trunk musculoskeletal models? Different aspects, from kinematics to material/structural properties and geometry besides the potential of various established and emerging technologies in providing the datasets needed both as input and for validation were discussed.

and loads on vertebral replacements. Various musculoskeletal models are also presented and discussed in details with attention on their assumptions and validation (Dreischarf et al., 2016b).

The fluid content, inflow, outflow and pressure distribution are crucial parameters that govern the time-dependent response of intervertebral discs in loading and unloading periods and as such should be accurately represented in vitro if in vivo physiological conditions are to be replicated (Schmidt et al., 2016; Vergroesen et al., 2016). Concerns on the accuracy of intradiscal pressure measurements using sensors with different sizes are examined in vitro in two species (Bashkuev et al., 2016). The beneficial effect of vertebroplasty in restoring geometry and reducing creep in fractured vertebrae is demonstrated in vitro (Luo et al., 2016).

Photos of some participants during the workshop.

3. Special issue content

The issue begins with two review papers. The first one focuses on what has been learnt regarding the fundamentals of spinal biomechanics in the past 25 years and challenges that lie ahead in future (Oxland, 2016). The second one reviews earlier attempts to estimate spinal loads with focus on measurements of the intradiscal pressure

Compression fatigue fracture strength of 41 lumbar functional spinal units is found in vitro to be related primarily to the endplate area and bone mineral density (Huber et al., 2016).

Lifting from the floor while anchoring one hand on the thigh is recommended as a technique to reduce loads on the back (Kingma et al., 2016). Using an instrumented vertebral replacement system in 4 patients, the effect of lifting techniques on the measured loads on implants is investigated (Dreischarf et al., 2016a). Inertial sensor and force plate measurements are used in 60 subjects to explore the likely effects of age on kinematics and moment demands during lowering and lifting a 4.5 kg weight (Shojaei