DEVELOPMENT OF AN EXPERIMENTAL HIP IMPACT MODEL TO TEST HIP PROTECTORS

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KEY WORDS: HIP, PROTECTION, FALL ACCIDENTS, SENIORS, TEST APPARATUS

INTRODUCTION

HIP FRACTURES, which represent a severe health problem for the elderly, typically result in sideways falls with a direct impact to the hip (Kannus et al. 1999). One possibility to prevent hip fractures is the use of hip protectors. At present, mainly two types of products, namely energy-absorbing soft pads and energy-shunting hard shells are used to protect the hip from impact loads in the area of the trochanter major. Mechanical testing is an important tool to assess the efficacy of hip protectors, and to support the development and optimisation of protector materials and designs. In testing systems used so far (Parkkari et al. 1995; Robinovitch et al. 1995; Mills 1996; Nabhani and Bamford 2002) the mechanical and geometrical properties of the human hip were strongly simplified, so that neither practical wearing conditions of hip protectors nor their deformation and distribution of impact forces could be simulated realistically.

MECHANICAL HIP AND FINITE ELEMENT MODEL

AN EXPERIMENTAL TEST DEVICE was developed which consists of anatomically shaped structures that represent the hard and soft tissues of the femur and the hip (Figure 1). Hip protectors and accessory underwear can be placed correctly or out of position for impact testing. A flesh surrogate (silicone) extending from the thigh to the waist area provides a realistic distribution of applied impact forces. A steel femur with a geometry based on a standard femur proposed by (Viceconti et al. 1996) is embedded in the flesh surrogate. A tri-axial load cell positioned in the femur neck detects the load transmitted. Hence the loading pattern of different hip protector designs as well as their benefit can be assessed.

![Fig. 1 – Femur and pelvis (a), FE stress analysis (b) and drop test with hip protector (c).](image-url)
In parallel to the development of the experimental set-up, a finite element model of the device was established. On the one hand the model was used during the design process to investigate several design aspects like the positioning of the load cell or the choice of materials for the soft tissue surrogate. On the other hand, as the final model matches exactly the test device, it was used to study different hip protector design strategies and can serve as a design tool for the development of new hip protectors.

RESULTS

BY MEANS OF FINITE ELEMENT MODELLING, a detailed stress analysis of the device under impact was performed to ensure that the tri-axial load cell of the experimental set-up was positioned reasonably, i.e. at the position where the maximum stress can be expected in the femoral neck (Figure 1b). The mechanical hip model was used to investigate ten different types of hip protectors, including three energy-shunting systems with hard shells and seven energy-absorbing systems consisting of soft foam pads. Results of drop tests using an impact energy of 49.1 J (mass of 10 kg dropped from a height of 0.5 m) are shown in Figure 2.

![Graph showing forces recorded from different hip protectors](image)

The forces recorded indicate that hip protectors can reduce the femur neck loading by 50% to 70%. In terms of calculated stresses in the femoral neck, there are considerable differences in the effectiveness of current products. No general advantage was found for one of the two investigated categories of hip protectors.

CONCLUSIONS

THE ANATOMICALLY SHAPED HIP MODEL which was developed in this study is suitable to investigate the effect of hip protectors with respect to femoral neck loading. Different design strategies of hip protectors as well as different positioning (out-of-position problem) can be analysed. Hence it is possible to use the test device plus a standardised test procedure as basis for a quality assessment scheme to rate the performance of commercially available hip protectors. In addition, the device is helpful for the optimisation and development of future protectors. Correlating the load recorded to the actual risk of sustaining femoral neck fractures, a Swiss certificate will be issued which allows the consumer to assess the protective potential of a hip protector. Further applications of the test device like in pedestrian impact testing are to be discussed.

REFERENCES


