DESIGN OF LOW STIFFNESS FLOORS FOR PREVENTING HIP FRACTURES IN HIGH RISK ENVIRONMENTS: COMPARISON OF FORCE ATTENUATION AND INFLUENCE ON BALANCE

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INTRODUCTION

The prevention of hip fractures in the elderly is a public health priority. 90% of fractures are due to falls, and low stiffness flooring may be an effective means for preventing fractures in high-risk environments. However, this would only be true if such floors can attenuate impact force sufficiently, without impairing balance so much that falls would be more likely. Previous studies have shown that padded carpeting can attenuate peak impact forces by 15%, without causing a measurable impairment in balance (Gardner et al., 1998, Maki and Fernie 1990, Dickinson et al. 2002). In the current study, we extended this line of enquiry to examine the effect of a wider range of floor stiffness on (a) peak impact force during a simulated sideways fall on the hip, and (b) measures in healthy elderly women of postural stability during daily activities.

METHODS AND PROCEDURES

We used a hip impact simulator, consisting of an impact pendulum and surrogate pelvis (Laing et al., 2006), to measure the attenuation in peak force applied to the femoral neck provided by each floor, for impact velocities of 2, 3, and 4 m/s (simulating falls of low, medium, and high severity, respectively).

We also acquired measures of balance from fifteen healthy elderly women (mean age = 75.0 (8.1) yrs) on each floor. These included Get Up and Go (GUG) test time (Podsiadlo and Richardson, 1990), postural sway during quiet stance (quantified by range and velocity of the centre-of-pressure in the anterior-posterior direction), and success in recovering balance in five repeated backwards floor translations. We also used a questionnaire to acquire participant ratings of balance confidence and practicality for each floor.

RESULTS

We investigated five floors. The ‘Rigid’ floor was a 2 mm thick layer of dense natural rubber used in institutional settings. The SmartCell anti-fatigue mat (2.54 cm thick) and SofTile playground surface (10 cm thick) are composite rubber floors comprised of a continuous surface layer bonded on elastic columns. The Firm Foam (density = 32.0 kg/m³) and Soft Foam (density = 22.2 kg/m³) floors consisted of 10 cm thick open-cell polyurethane foams of the type commonly used in gymnasium mats.

The mean attenuation in peak femoral neck force ranged from 24.5% by SmartCell to 76.6% by Firm Foam (Table 1). When compared to the Rigid floor, the SmartCell and SofTile caused no impairments in ability to recover balance and GUG time, and were ranked as high for balance confidence and practicality. While all floors affected postural sway during quiet stance, the effect was most dramatic for Firm Foam, which caused more than a doubling in sway range and velocity.
DISCUSSION

Our results suggest that currently available flooring systems (e.g. the SofTile playground system) can attenuate peak femoral impact force by up to 47%, while causing only minimal effects on postural stability in elderly women. Further reductions in floor stiffness, while leading to greater force attenuation, caused substantial negative effects on postural sway, balance recovery ability, and balance confidence.

The force attenuation provided by the floors we studied was significantly larger than the 4–15% observed for carpet (Gardner et al., 1998, Maki and Fernie, 1990), and the 12-24% observed for wearable hip protectors tested on our hip impact simulator (Laing et al., 2006). In addition to attenuating force more effectively than hip protectors, low stiffness floors are not dependent on user compliance, and likely reduce the risk of fall-related upper extremity fractures and head injuries, in addition to hip fracture.

SUMMARY

Two of the four floors we examined substantially reduce the force applied to the hip during simulated sideways falls, and are unlikely to increase fall risk compared to typical rigid floors. Furthermore, these floors were rated as practical by a sample of elderly women. A simple cost-benefit analysis projects a pay-off period of 1.5 years for installing such floors in high-risk areas of nursing homes, assuming a direct cost of $26,500 CAD per hip fracture (Wiktorowicz et al., 2001), differential material costs of $134 CAD/m² and a 50% reduction in hip fracture incidence. Overall, this comprehensive biomechanical study supports the value of low stiffness floors for preventing hip fractures in high risk environments.

REFERENCES


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