Biomechanical Study of an Anthropometrically Designed Hip Protector for Older Chinese Women

Pan-ching Sze, MPhil, Wing-hoi Cheung, PhD, Ling Qin, PhD, Kam-fai Tam, PhD, Wai-kin Ng, BSc, and Kwok-sui Leung, MD

Biomechanical properties and compliance are 2 essential properties of hip protectors (HPs) that determine their clinical efficacy. This study describes the development of a HP that was anthropometrically designed according to anthropometric data from 68 older Chinese women and with attention paid to the biomechanical properties of the device. A simulated mechanical fall test using a drop weight and a force plate were set up to test the force attenuation properties of the HP. The HP attenuated up to 93% of the impact force, and the remaining force was 2 standard deviations below the mean fracture threshold of the proximal femur. The HP was effective in force attenuation, and the anthropometric data obtained provides important information for the development of HPs adapted for a Chinese population. Further study on the compliance and clinical efficacy of this HP is underway. (*Geriatr Nurs* 2008; 29:64-69)

A hip protector (HP) is an external device that provides protection from fractures to the hip due to falls.[1] An HP usually consists of a pair of hard, energy-shunting pads that cover the area around the greater trochanter and are held in place by a pair of specially designed pants. Whether HPs are effective in the prevention of hip fractures is controversial.[2-4] A recent meta-analysis of evidence from more than 9,000 subjects in 11 clinical trials showed that use of HPs reduces the incidence of hip fracture by 23%.[4] The effectiveness of HPs was more obvious among institutionalized elderly, reducing hip fractures by up to 80%.[5-8] However, another pooled analysis of 6,000 subjects from 7 clinical trials did not show any beneficial effects of HPs.[3] The majority of trials involved in this meta-analysis were conducted among community-dwelling elderly, who may be healthier and have a lower incidence of hip fracture; thus the treatment effect of HPs might not be easily detected in this population.[9-12]

Poor subject compliance is the major obstacle to the effectiveness of HP.[13] A previous study showed that all the hip fractures found in the intervention group occurred when HPs were not being used.[9] Major challenges have been identified in the use of HPs; these include complaints of bulky pads and of the devices being uncomfortable, tight, and awkward to wear.[13] In particular, devices that did not fit well or were too tight were significantly correlated with noncompliance and dropouts.[14-15] A few studies showed that HPs made of softer materials designed with sewn-in pads could encourage better compliance.[16-17] The force attenuation properties of these devices has often been questioned.[12,18] However, hip fractures seldom occur if a subject wears an HP[2-4] if it provides adequate force attenuation to reduce the impact of falls to a level below the fracture threshold of the proximal femur.[19]

Currently available HPs, which are designed for Caucasians, are not suitable for the Chinese population,[20,21] who require a different fit because of ethnic differences in anthropometry.[22] Designing an HP that fits well is crucial to enhance compliance. Furthermore, wearing tight pants in hot, humid places such as Hong Kong is also uncomfortable and challenging. Therefore, selection of fabrics with properties that disseminate heat and humidity is also crucial to design a good HP. In light of the increasing numbers of older adults with osteoporosis and subsequent hip fractures in China,[23] development of an effective HP has significant clinical implications. This study describes the development of an HP for Chinese elderly and reports the initial test on its force attenuation properties.

Methodology

Anthropometric Measurement

The study included 68 ambulatory women with mean age of 75.4 (± 6.2), recruited from an elderly hostel, who underwent anthropometric measurement to design pants made to fit the bodies of older Chinese women. The reason for including only women in the study was because women have a higher risk of hip fracture than men.[23] The measurements included waist, hip, and thigh size (circumference of first round) and vertical distances between the greater trochanter and waist, the hip and waist, and the first round (proximal thigh near to groin) and waist. Each measurement was performed 3 times with tape measures. The mean values of the 3 measurements were used for calculation. All measurements were performed by a well-trained research staff. The Clinical Research Ethics Committee of the Chinese University of Hong Kong approved this study (Ref. No.: CRE-2004.331).

Design of the Pants

Mean values of the anthropometric data were used to determine the cutting and sizes of the pants. Consultation with the Institute of Textiles and Clothing of the Hong Kong Polytechnic University were made on the selection of fabric for the pants. Knitted fabric (93% cotton, 7% Lycra) was selected because of its satisfactory and balanced properties in terms of texture, air permeability, water absorbance, strength, and dimensional stability.

Design of the Pads

Semiflexible thermal plastic, Orfit (ORFIT Industries, New York), which is an allergy-free plastic appropriate for direct application to skin,[24] was used to make the plastic shield of the pad. Low-density silicon was padded along the edge of the plastic shield (Figure 2) to provide better cushioning for the users to avoid discomfort caused by pressure from the pads.[25] The maximum width and length of the pads were 9 cm and 14 cm, respectively, which is sufficient to cover the greater trochanter of older Chinese women.[26] The maximum height of the pad was 2.5 cm, including a 1.5-cm gap between the inside of the pad and the skin, which was recommended for safety.[18]

Figure 1. Composition of the hip protector pads.

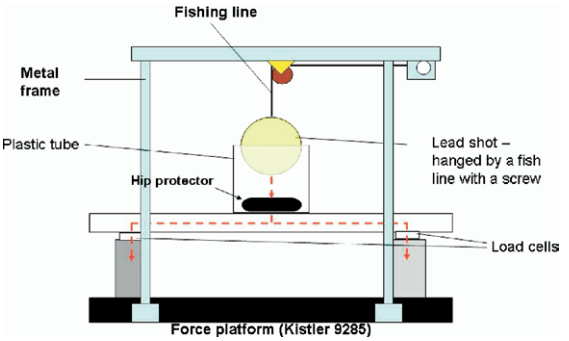

Figure 2. Mechanical test set up for the hip protector pads.

Mechanical Test of the Pads

A drop-weight test consisting of a force platform (Kistler 9285, Kistler Instrument, New York) and a 7-kg lead shot was set up to test the force attenuation properties of the pads (Figure 1). The lead shot was performed by a fishing line from a height of 0.15 m to provide an impact of approximately 7,000 N and 0.25 m to provide 10,000 N, which respectively simulate the amount of impact of a fall under a low-impact condition with the muscle in a relaxed state and a high-impact condition with the muscle in an active state.[18]

The sampling rate of the force platform was set to 2000 Hz so that it would have adequate sensitivity to record the impact force with a duration of impact estimated to be in milliseconds.[27] A lead shot was used because a sphere would provide the same impact even if the orientation of the lead shot was different at the moment of release. This was important to ensure the test-retest reliability and minimize systemic error. Five identical samples were tested in each of the impact conditions. Five successive drops were performed to ascertain the variation of force attenuation among successive impacts.