Are hip protectors correctly positioned in use?

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Abstract

There are many designs of hip protectors ranging from small elliptical shaped hard shell designs to large circular soft pads. They are held in position usually by being contained in a close fitting pocket on a garment that patients wear all the time they are at risk of sustaining a fracture of the hip if they fall onto the area of the greater trochanter (GT). It is important for the function of the hip protector that the pad element is positioned over the GT when the subject falls onto a surface such as the floor so as to provide the maximal protection by reducing the large forces transmitted to the femoral neck that lead to the fracture of the bone. In this study, anatomical measurements show where the GT is relevant to the centre of the hip protector, and position and movement studies have shown that generally the hard shell design of the hip protector lies posterior and proximal to the GT both for erect and flexed positions of the hip. The position of the GT relevant to the anterior superior iliac crest was established using ultrasound examinations on control and patients admitted with a fracture of the hip due to a fall. The diagonal surface distance for the three groups of test subjects was approximately 12 cm and a template was developed that could be used to locate the GT. A ‘zone’ of GT position and movement has been established relative to the anterior superior iliac crest, and designers of garments should ensure that this zone is within the area of protection provided by their hip protector pad design.

Keywords: hip protectors, hip fracture, older people, elderly, undergarment design, greater trochanter, soft tissue thickness, hip protector movement, elderly

Introduction

Falls resulting in fracture of the hip in elderly people pose a major health problem worldwide. These fractures can result in long term care requirements, morbidity and disability, and an increased risk of premature death [1]. It has been forecast that as the population ages, the number of hip fractures occurring throughout the world each year will rise from 1.66 million in 1990, to 6.26 million by the year 2050 [2]. A sideways fall on the hip is certainly highly likely to produce the energy to fracture the proximal femur in young healthy men [3] which is greater than the energy to create a fracture in the elderly.

Sufficient kinetic energy is produced in a fall from a standing position to fracture a bone, even in young healthy persons [4]. This falling mechanism and the energy absorption of the trochanteric soft tissue are the main determinants of hip fracture, rather than bone density loss [5]. Impact testing of various designs of hip protectors in undergarments show that some designs have little effect on reducing the peak force on the hip during a simulated fall [6]. Biomechanical testing of both hard shell and soft padded designs of hip protectors has shown that hard shells positioned on the greater trochanter (GT) and the anterior superior iliac crest (ASIC) could be used for energy and force shunting [7]. However, there is no indication in their study as to how the hip protectors were positioned relative to the GT during testing. Derler et al. [8] tested their hip protectors placed centrally over the GT, and then displaced them 3 cm anterior to the GT and repeated the impact test. This showed a considerable difference between individual hip protectors in their effectiveness to reduce the impact force on the femur. All pads are effective only if they are always covering the GT, especially the designs incorporating a hard shell and utilising the force-shunting mechanism. Hard shell designs in which the edge is located over the GT may give rise to high interface pressures and the force-shunting mechanism is compromised [6]. We felt it was important to investigate how the pads were located within the garments relative to the GT on a range of subjects of different age and build.

In many subjects the location of the greater trochanter is hard to define. For accurately determining the positions of
the GT and the ASIC, ultrasound imaging was considered the most appropriate medium to use. Ultrasound has the attraction of being non-invasive, quick and accurate at determining the position of the bony tissue under the skin.

Patient compliance is still a debated issue and a hard shell protector design in two trials appear to show that making these hip protectors available to a group at high risk did not reduce the rate of hip fracture [9, 10]. The use of hip protectors on patients to prevent a second hip fracture showed no benefit [11]. Compliance issues may be due to hip protectors being uncomfortable, a poor fit, too tight and proving difficult to lie down with at night [12, 13]. Hip protectors that are soft appear to be more comfortable and compliance may rise with protectors based on a soft energy-shunting padding [14], or energy-absorbing padding [15]. Also, if there is a structured education programme and free provision of hip protectors to the elderly at risk, the claim that hip fracture incidence can be reduced will be justified [16].

The purpose of this study was to determine where the GT was in relation to the ASIC, where various designs of hip protectors and their associated garments were positioned relative to the GT which is the area needing maximum protection from impact forces generated from a sideways fall.

**Hip Protector Designs**

The current designs of hip protectors either incorporate a thin preformed shell within a softer layered material [17], an oval or circular pad of curved dense foam, or a two part rigid oval polypropylene grill that is attached by sandwiching the pants-type garment in between the shells.

Except in the last design, the pads are held in position by being incorporated into a garment that is supposed to keep the pad in the right location with respect to the GT that is just below the surface of the skin. Some garments have an open pocket in which the pads are located, and three designs have the pads sewn into the undergarment and the pads are not removable. The pads located in an open pocket may also be subjected to movement within the pocket which increases the likelihood of malpositioning of the pad relative to the GT while the subject is moving/sitting or lying on the pad area. Also, the pads may not be in the correct position when a patient falls.

**Experimental Methods**

**Movement studies**

Female SafeHip hip protector garments of three sizes (4 small, 4 medium and 1 large) was used in the study with 9 female nurses with an average age of 50, average weight of 64 kg and average height of 162 cm. A 15 mm diameter hole was carefully punched through the geometrical centre of the hip protector shell and the garment’s inner and outer surfaces on both sides so that the skin could be marked using coloured felt tip pens from the outside.

The centre of both GTs were located by palpation of the bony prominence when standing upright, which may have to be confirmed by flexing the hip and visually cross referencing the temporarily marked palpated position with the centre of movement during flexion when viewed laterally, the GT centre being 2 cm below the instant centre of the hip joint. The confirmed position was then marked with a horizontal/vertically aligned black cross. The ASIC was also located by palpation and the anterior border of the crest marked around its periphery. The subject was then asked to lie on her side with the hip flexed to 90 degrees and the centre of the GT was then marked with a red cross.

Following waist measurements taken for each subject, the appropriate sized garment was used. After pulling the garment on to the resting position at the waist whilst standing, a black circle was drawn on the skin through the hole in the pad (Figure 2—on the SafeHip pad). Subjects were then asked to walk around, sit down and arise from a seat twice before a green circle was made on the skin through the central hole. The subject was then asked to lie on their side with the upper hip flexed to 90 degrees and a red circle drawn on the skin through the pad hole.

Polaroid photographs were taken with centimetre spaced grid film, initially with skin-mounted scales to confirm the effect of oblique views on the distance measurements compared to the flat in-plane grid. Since the skin markings were within the plane of the film, there was little out-of-plane error in the distances between the marks (Figures 1(a)).

**Pad position studies**

A medium sized female torso made from moulded expanded Polystyrene (Donated by Tytex A/S, Ikast, Denmark) was used to study the position of the pad relative to the GT. From anatomical studies it was established that the centre of the GT relative to the distal extremity of the crotch area in the coronal plane was 6 cm, and a removable guide was made to locate the position of the GT outside the garment. This was confirmed as being a median position from the movement studies using the SafeHip pad, whose centre was on average 2 cm above the GT in the coronal plane and was observed as similar on the torso model (Figure 2).

Nine medium-sized brands of commonly used hip protectors were placed on the torso model to assess their position in the garment relative to the GT using the removable guide. Four hard shell pads and five soft pads were evaluated for their position relative to the 6 cm datum established from the hard shell SafeHip movement studies performed (Figure 2).

**Ultrasound studies**

Twenty female patients \( (n = 20 \text{ hips}) \), admitted for a fracture of their hip and twelve female patients \( (n = 24 \text{ hips}) \) admitted for elective hip or knee replacement acting as the control group, had the location of their GT and the confirmed and measured using an ultrasound transducer. The mean age of the control group was 79 years (69–88) and of the...
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The contra-lateral hip in the fracture group was measured (11 left, 9 right), while both hips were measured in the control group.

A Sonosite Titan machine using a 5 mHz linear array flat transducer which is 5 cm long, was traversed over the bony prominence of the ASIC and the GT. In the transverse and coronal plane using gel on the skin, the centre of the GT and the most anterior aspect of the ASIC were marked where the minimum skin thickness was noted, and the images recorded with the transducer held in the vertical and horizontal position. The dimensions X, Y and D (Figure 1) were measured over the skin surface for all the subjects in this study and the results are shown in Table 1. Body mass index (BMI) was calculated for these subjects by measuring their weight (kg) and height (m). The statistical analysis was performed using SPSS version 12.

Results

The distance of the GT from the initial pad centre was 2.65 cm (SD 2.0) posterior, 2.07 cm (SD 2.1) proximal which results in a diagonal distance of 3.36 cm (SD 2.5). Only 0.45 cm posterior movement of the pad centre was seen after the subjects walking and sitting. The pad centre only moved 0.64 cm when the hip was flexed from full extension to 90 degrees of flexion.

![Figure 1](https://academic.oup.com/ageing/article-abstract/36/2/140/41110)

Figure 1. (a) View of the markings made on the skin of a subject. (b) GT centre guide (hole) on a SafeHip garment used in the position study. (c) Front and lateral view of the dimensions measured.

The mean distance over the surface from the ASIC to the GT centre for the nurse volunteers was an average of 12.03 cm although they were younger (50 years) than the ultrasound control group which had an average of 11.97 cm, that of the hip fracture group being slightly smaller at 11.48 cm (Table 1). The BMI for the fracture group was significantly lower than for the younger control group because they were smaller in height which may explain the proportional smaller value for the distance between the ASIC and the GT in the fracture group. A mean position of 12 cm diagonal and 8 cm posterior was considered an accurate value for the relationship between the ASIC and the GT and a likely range of 1.5 cm about these values would encompass most subjects that are likely to be using hip protectors.

![Figure 1](https://academic.oup.com/ageing/article-abstract/36/2/140/41110)

The soft tissue thickness over the ASIC was half that measured over the GT (13.3 mm and 27.9 mm respectively in the control group and 9.2 mm and 18.1 mm in the fracture group). This suggests that the ASIC is a better bony landmark to locate than the GT in these subjects.

The use of a GT centre location gauge 6 cm above the plane of the garment crotch on the torso model appears to be confirmed when compared with the GT position on the in vivo movement tests (Figure 1(b)).

We used this location method on the torso model to assess how eight other designs of pads were positioned relative to the GT in their associated undergarment. Three out of four of the hard shell designs appear to cover the GT, in one design (Remploy Caresse) the GT centre appears close to the shell edge (Figure 2). Two of the soft pad designs appear not to cover the GT on the torso model.

Although the nurses used in this study were younger than the users of hip protectors, one can assume that between 50 and 70 years, the female form around the torso area does not change dramatically in time with regards to the distance of the GT from the pelvis centre line and the transverse bony margins around the crotch area. The position of the SafeHip pad in the undergarment relative to the GT was consistently always posterior and in most cases above the GT centre. When the undergarment was pulled onto the torso model and the pad centre determined relative to the GT, the same pad displacement was seen, confirming that 6 cm above the most distal transverse margin of the crotch centreline and central to the torso in the coronal plane, was a reasonable estimate of the GT centre.

Discussion

We have demonstrated that hip protector position for nine commonly used designs is highly variable.

Displacement of the pad centre away from the GT centre is more of a protection issue with hard shell designs as the risk of the raised periphery overlying the GT reduces their force/energy-shunting capabilities and increases the potential for high interface pressure over the GT whilst lying laterally directly onto the pad [5]. A hard shell protector does not need to be so large as to overlie the ASIC. This will decrease the convenience and hence the compliance with
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Table 1. The horizontal and diagonal dimensions and BMI for the three groups measured

<table>
<thead>
<tr>
<th>Groups</th>
<th>Xcm (1 SD cm)</th>
<th>Ycm (1 SD cm)</th>
<th>BMI Kg/m² (1 SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurses</td>
<td>7.62 (1.19)</td>
<td>12.03 (1.91)</td>
<td>24.4 (4.8)</td>
</tr>
<tr>
<td>Control</td>
<td>8.26 (1.27)</td>
<td>11.97 (0.56)</td>
<td>29.1 (4.5)</td>
</tr>
<tr>
<td>Fractures</td>
<td>7.38 (0.72)</td>
<td>11.48 (0.65)</td>
<td>22.6 (4.8)</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.01 level (2-tailed).

Figure 2. Position of the GT marker on the top row-hard shells (from left to right): Remploys Caresse, FallGuard, KPH, SafeHip. Bottom row-soft pads (from left to right) HipShield, HipSaver, PoseyHipsders, Lyds, Sanavida.

wearing this form of protector. However, the reach of the lateral part of the iliac crest with hard shell hip protectors is important because, if the hard shell protector lies only over the GT, the energy shunting is not so effective if the protector reaches the lateral part of the iliac crest as well. Most of the undergarments have a leg portion extending 2–4 cm below the plane of the crotch so a useful design feature from this study may be that the distal edge of the pocket holding the pad should be aligned with the distal edge of the undergarment. This would ensure that if the pads have a vertical length greater than 16 cm and wider than 6 cm about the coronal plane centreline, the pad centre is highly likely to be close to the GT centre. This is more critical for the hard shell designs for the reasons given above. The effect of flexing the hip shows little displacement of the skin over the GT of not more than 1 cm, but this appears to be increased a further centimetre by the relative movement of the garment surface over the skin. Consequently, a maximum of 2 cm anterior movement of the pad relative to the GT appears to occur at 90 degrees of hip flexion, and this should be taken into account when determining the width of the pad. We suggest that a soft padding with a horizontal width of at least 10 cm should be used; anything larger may impinge on the anterior groin fold risking buckling of the soft pad or rising away from the skin during extremes of hip flexion such as sitting down. It may also be a relevant issue if the hip is flexed at the point of impact with the GT on the ground. Atrophy of the gluteus muscles among older people leads to a more prominent GT. Among these individuals, a wider and flatter hard shell protector may pivot on the GT allowing only limited shunting of the impact force to the surrounding tissues. Conversely, any protector that is designed to work as a ‘ring’ around the GT for this group with a prominent GT may also not be effective at transferring the impact force through the ring material. To be more effective, a hard shell design should be narrow, sufficiently concave and correctly positioned to utilise its full force and energy shunting effect.

The soft tissue cover over the ASIC is significantly thinner than over the GT being half the value in both groups of subjects using ultrasound. As a consequence we feel the ASIC is a good and easy bony marker to detect accurately, especially in women, in whom the ASIC is more prominent.
and sharply curved to palpate. The position of the GT centre relative to the ASIC lay within a small ellipse 3 by 4 cm for all the subjects studied, centred 12 cm diagonally and 8 cm posterior along the skin surface. From this data, a position template was designed and produced to guide nursing staff and the designers of the undergarment as to where the centre of any hip protector form should be relative to the more easily identified ASIC (further information on this can be obtained from the first author). Because the dimensions are the same for both sides, a universal template was produced that could be rotated through 180 degrees to locate the GT centre on the opposite side.

It is clear that the position of these hip protectors relative to the GT is highly variable and in some cases does not cover the GT at all. The hard shell devices certainly need to be located over the ASIC also, on their proximal edge to fully utilise the energy and force shunting effects. Positioning of hip protectors has a large influence on their mechanical effectiveness [8]. Consequently, positioning during impact testing is vitally important, and should reflect the position of these devices in clinical use when performing biomechanical testing.

Key points
- Hip protector design
- Protector pad position
- Greater trochanter position
- Protector garment movement

Conflicts of interest
None of the authors have a Conflict of Interest with any of the products tested having received no payment/fee/honoraria from any of the manufacturers of the Hip Protectors tested.

References