Frequently Asked Questions Regarding Hip Axis Length (HAL)

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1. What is Hip Axis Length?

Answer: Hip axis length is the distance along the femoral neck axis, extending from the bone edge at the base of the trochanter to the bone edge at the inner pelvic brim.

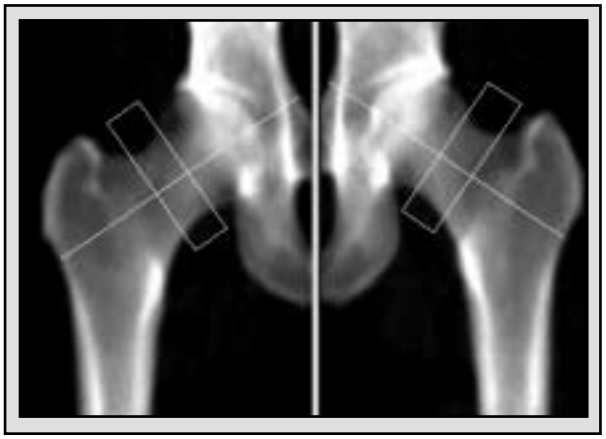
2. Has HAL been shown to predict fracture?

Answer: Yes. However, it is a moderate to weak predictor, as compared to BMD at the hip.

HAL has shown positive results relating to hip fracture in several prospective studies. Most studies where HAL was properly measured have reported a positive association, but the magnitude varies from weak (relative hazard per SD increase of 1.2 to 1.3) to strong (relative hazard of 1.8 to 2.0). At this point, it appears that HAL has some significant association with hip fracture risk, but it is weaker than the relationship of BMD with fracture. HAL has been studied only for short-term (2 year) fracture risk – long-term fracture risk relationships have not been reported. HAL has shown no association with other fractures, such as spine, rib, or forearm.

3. How does a long HAL increase risk for fracture? What is the "mechanism"?

Answer: The precise mechanism is not known but thought to be related to bone size, bone shape, and potential for impact to the hip during a fall.



According to engineering principles, the strength of an object is a function of other properties besides the mass and density of the material present. Strength depends on (1) the mechanical properties of the materials, (2) the object's geometry and shape, and (3) the loading conditions, in terms of magnitude, rate, and direction, of force applied to the object. If the geometry of the hip is related to fracture risk, geometric measurements might be used together with densitometric measurements for a better assessment of hip fracture risk than might be obtained from just a density measurement alone.

While the exact mechanism of how an increased HAL predicts fracture is not known, several possible explanations have been proposed, including the concept of HAL coinciding with the femoral moment arm. HAL may also be a measure of the degree to which the femur extends beyond the pelvis, increasing risk for impact. Unfortunately, the exact mechanism for HAL may never be known, due to the complex interaction of femoral forces, hip geometry, and fall dynamics.

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4. If we do not understand why HAL predicts fracture, is it wise to use it as a risk factor?

Answer: HAL should be used only in combination with BMD and not as the sole basis for risk assessment.

Without knowing the mechanism, it is possible that the measurement is a surrogate marker for some underlying risk factor. This same situation exists for other risk factors as well. Nonetheless, the published associations still exist, even if it is a surrogate marker. Because of the lack of definitive evidence regarding HAL, it is not recommended to use HAL alone – it should only be used in conjunction with BMD and considered a significant risk factor for patients with clearly long (12 cm or more) measurements.

5. We cannot change a patient's HAL – so why measure it?

Answer: Many other risk factors are non-modifiable (such as age), yet they have important use for identifying high risk patients.

HAL is a non-modifiable risk factor, such as age, previous fractures, and family history of osteoporosis. Although these factors cannot be modified, they help identify patients at risk that can benefit from methods to reduce fracture risk targeted toward the modifiable risk factors (such as reducing falls and preventing bone loss).

6. Is HAL a surrogate marker for something else? Height? Ethnicity?

Answer: HAL may be a surrogate marker for other unknown factors, just as BMD is a surrogate for bone strength.

HAL is weakly related to body size, thus it is reported on the Prodigy as a height and weight adjusted value. When HAL is corrected for height, the predictive power of HAL improves. HAL also differs among ethnic groups, which is likely related to height differences in these groups. When height adjusted HAL is compared in ethnic groups, differences still exist which may provide a partial explanation for ethnic differences in hip fracture rates. It has been suggested that HAL is a marker for the protrusion of the trochanter beyond the pelvis, resulting in a susceptibility to impact at the trochanter rather than the iliac crest. Trochanter area has been shown to predict hip fracture, and HAL does have a weak relationship to trochanter area.

7. How can such a small difference in HAL (1 cm) cause such a large difference in fracture risk?

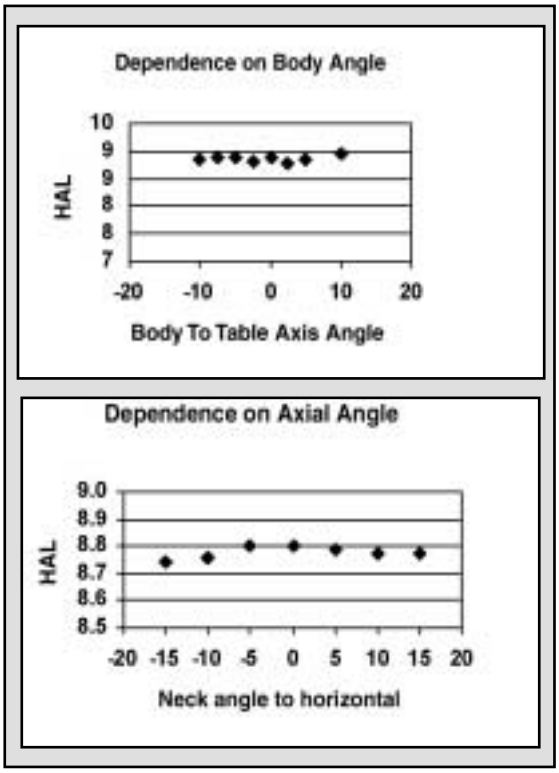
Answer: A 10% difference in HAL increases risk 50% to 80%. This is similar to other risk factors and less strong then BMD.

In clinical practice, small differences in risk factors often have a profound influence on risk. For example, a 10 to 15% decrease in femoral neck BMD increases the risk for hip fracture by 160%. For HAL, a 10% increase (1 cm) increases fracture by only 50 to 80%. So the predictive power is comparable to other risk factors.

8. Is HAL sensitive to positioning and femur rotation?

Answer: Yes, but the influence with Prodigy is very small.

Studies performed using excised bones have shown the measurement to be relatively insensitive to these effects. Rotation of the femur about its head resulted in an average change in HAL of less than 0.01 cm for any measurement angle between



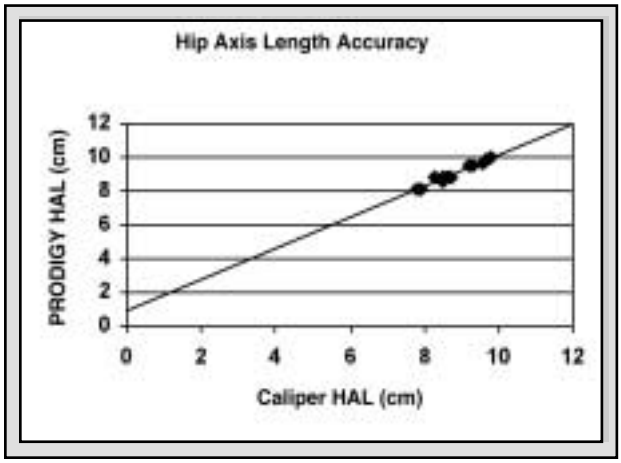
+15° and –15°. Differences related to neck angle were not significant. HAL was not affected by the angle of femur relative to the table axis.

9. What is the precision and accuracy of HAL on the Prodigy?

Answer: Precision in healthy subjects was 0.67%. Accuracy error was less than 1 mm.

HAL was measured by software using two or three scans from 43 different subjects. Precision was calculated as %CV. Precision error (%CV) was 0.67%.

To evaluate accuracy, ten excised femur bones were used. Prior to acquisition, the femurs were placed in an in-vitro pelvis to simulate the in-vivo configuration. For each femur, five scans were acquired. Tissue thickness was simulated with 15cm of lucite. A calibrated caliper was used to measure HAL five times. HAL values measured by Prodigy software were virtually identical to HAL values measured by the caliper. The percent difference was less than 0.5% (less than 1 mm) with $R^2 = 0.99$.



10. How should HAL be used for assessing fracture risk? Can it be used alone, or should it be used with BMD?

Answer: HAL should be used in combination with BMD and other risk factors.

HAL is an ancillary risk factor that is properly used in conjunction with BMD and other risk factors. Risk and treatment decisions based on HAL alone are not appropriate. Yet, in patients with low BMD, HAL may be useful to determine if treatment is warranted.

11. Why does it appear that HAL predicts fracture when femur neck length does not? What is the significance of the pelvic portion of HAL?

Answer: Of all the geometric measurements investigated, HAL (which includes the pelvis) has the strongest evidence for predicting fracture. The significance of the pelvic portion is not known.

The HAL measurement includes both the length of the femur and a portion of the pelvis. Femur neck length is defined as the femoral portion of HAL, excluding the pelvis. Originally, the pelvic portion was included to simplify determination of the measurement using software. Early densitometers did not include enough scan field to measure the complete HAL, and several papers reporting results on HAL were actually measuring femur neck length.

Research has shown that the pelvic portion may be important to the fracture risk relationship of HAL. Data from pelvic radiographs have shown that the pelvic portion alone (called the acetabular width) is related to fracture. Of the studies looking at femur neck length, the relationship with fracture risk is usually not as strong as for HAL. When measuring HAL, it is important that the measurement include the pelvic portion. The significance of the pelvic portion is not known, though it may relate to pelvic structure and the ability of the pelvis to absorb the impact of a fall.

12. What do we know about treating people with long HAL? For example, has it been shown that giving antiresorptive therapy to patients with long HAL and normal BMD can prevent fracture?

Answer: Treatment efficacy in long HAL patients has not been shown.

It has not been shown that treating individuals with long HAL and normal BMD with an antiresorptive can prevent fracture. Because HAL is believed to indicate risk for impact, or the ability to absorb an impact at the hip, it is conceivable that patients with long HAL would be best treated with fall prevention measures or possibly hip pads. However, this is not known.

13. Can any densitometer measure HAL?

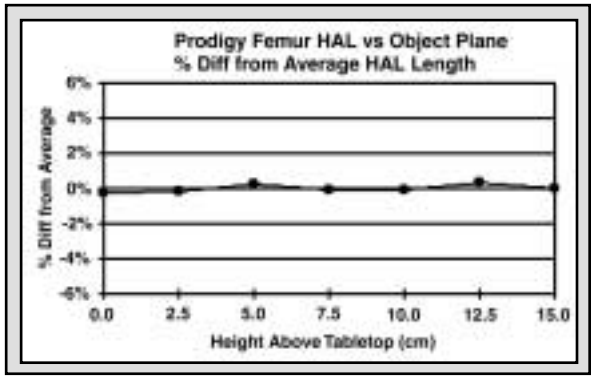
Answer: HAL can only be accurately measured on pencil beam systems or fan beam systems with corrections for magnification error.

HAL is a linear measurement and can be accurately determined on any system that can accurately gauge linear distance. Pencil beam systems and narrow-angle fan beam systems are best suited for the measurement, as they do not have magnification errors associated with wide-angle fan beam geometries. If HAL is measured on a fan beam system, it is important to verify that there is no relationship of HAL to table height or the height of the femur on the table (due to variations in body size).

14. Is the Prodigy fan beam sensitive to table height? Magnification error?

Answer: On the Prodigy, HAL was not influenced by table height or magnification error.

HAL was measured three times at each of seven positions ranging from 0 to 15 cm above the tabletop. HAL ranged from 10.74 to 10.80 cm with no significant trends related to distance above the tabletop ($p = 0.94$). There was no object plane dependency above the tabletop.



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