

## Estimating Living Stature from Skeletal Remains

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### İSKELET KALINTILARI YARDIMIYLA KİŞİNİN HAYATTAKİ BOYUNUN HESAPLANMASI

#### Özet

İskelet kalıntılarının ölçümü yapılarak kişinin ölmeden hemen önceki boyunun hesaplanmasında genellikle matematiksel yöntemler kullanılır ve özellikle *Trotter-Gleser* (5,6) formüllerinin önemi büyüktür. *Trotter-Gleser* eşitliklerinin kullanımının, örneğe özgü ya da topluma özgü olduğuna ait görüşler vardır (13-16). *Boldsen* (18) ise, *Trotter-Gleser* eşitliklerinin Avrupa toplulukları için de kullanılabilirliğini ve doğru sonuçlar elde edilebileceğini savunmaktadır.

Tamama yakın bir iskeletin elde edilebildiği koşullarda yapılacak boy hesaplaması için *Fully*'nin anatomik yöntemi (8, 21), matematiksel yöntemle tercih edilmelidir (12,20,22).

Eksik kısmı bulunan uzun kemik parçalarından yararlanarak boy hesaplamak çok risklidir. *Steele* eşitliklerinin (24) kullanıldığı çalışmalarda sonuçlar bile, *Trotter-Gleser* formülü ile birlikte ele alındığında, birbirlerinden oldukça farklı bulunduğu tesbit edilir. Bu tür çelişkiler, verilerin gruplandırılmasında boy ölçümlerinden yararlanmayı önemli ölçüde kısıtlar.

Hesaplanan boy, bilinmeyen kişiye ait iskelet kalıntılarının fiziksel tanımında çok önemli bir komponenttir. Bu işlem yalnızca bir hesaplama olmasına rağmen, eğer uygun yöntemlerle ve dikkatli bir biçimde yapılmışsa, elde edilen verilerin, taranacak bilgi alanlarını azaltmada büyük yardımcı olur.

#### Summary

The mathematical method in general, and *Trotter and Gleser*'s (5,6) formulae in particular, is the most used method for estimating living stature, estimation equations are sample or population specific (13-16), *Boldsen* (18) has shown that *Trotter and Gleser*'s equations may be suitable for use in certain European populations.

In cases where one has a nearly complete skeleton, *Fully*'s anatomical method (8, 21) is preferable to the mathematical method for estimating living stature from skeletal remains (12, 20, 22).

Attempting to provide a precise estimate of living stature from incomplete long bones is fraught with hazards.

Even *Steele*'s (24) equations, when they can be used, provide very wide estimates when used in conjunction with *Trotter and Gleser*'s formulae. This reduces considerably the effectiveness of utilizing stature as a sorting tool.

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Estimated stature is an important component of the physical description of unknown skeletal remains. And while it is only an estimate, if done carefully using accepted methods, estimated stature can greatly aid in narrowing down the field of possible matches.

Keywords : *Skeletal remains - Estimating living stature - Mathematical methods - Anatomical methods - Anatomical vs mathematical method*

## INTRODUCTION

The discovery of human skeletal remains poses many questions, and police investigators, prosecutors and the courts look to the forensic anthropologist and/or pathologist for answers. One of the questions to be answered is: "*How tall was this person in life?*"

Estimating stature from skeletal remains seems to have been first addressed in the literature by *Sue* (1), and today we have reliable methods available to estimate living stature. The most common method is termed the mathematical method, where the lengths of long limb bones for an individual are mathematically regressed against the recorded antemortem height or in some cases, cadaver lengths. With a sample of such individuals, one can calculate equations for estimating stature from long bones. The work of *Rollet* (2), *Manouvrier* (3), *Pearson* (4) and more recently, *Trotter* and *Gleser* (5, 6) is based upon this method.

Another method, termed the anatomical method by *Dwight* (7) and *Fully* (8), prescribes the measurement of the height of the skeleton to which is added a correction factor for the soft tissues of the scalp, soles of the feet and cartilage of the joints.

These two methods for estimating living stature from skeletal will be discussed in more detail.

## MATHEMATICAL METHOD

Today, the mathematical method is the primary method for estimating living stature. In this method, stature estimation formulae are calculated by mathematically regressing the lengths of individual long limb bones or long bones selected in combinations against living height or cadaver length. In Europe, several workers have calculated equations using this method, including *Rollet* (2), *Manouvrier* (3), and *Pearson* (4) as well as *Brietinger* for German males (9), and *Telkka* for Finns (10). The largest study of the mathematical method was undertaken by *Trotter* and *Gleser* (5, 6) using a sample

of American military casualties from World War II and the Korean War. To calculate the equations, the lengths of long bones were mathematically regressed against the recorded antemortem height for each identified serviceman. Non-military remains were also included in their study.

Presently, *Trotter* and *Gleser*'s equations are available for American White and Black males and females, Mongoloid males, and Mexican males (11). To use the *Trotter* and *Gleser* equations, one simply measures the length of the particular long bone(s) in the manner prescribed (5), and inserts the resulting length into the equation listed for that bone under the proper racial group and sex. The calculated stature and its standard error of the equation provide an estimated living height within one standard deviation. *Stewart* (12) has suggested that the standard error be doubled when using *Trotter* and *Gleser*'s formulae.

The advantage of the mathematical method is that it is a quick and straightforward technique, requiring only an osteometric board for measuring the lengths of the long bones. Its major drawbacks are that it is based upon the relationship of long bone length to total living height or cadaver length and, thus, does not always reflect the variability in body proportions when applied to an unknown skeleton. Further, in 1929, *Stevenson* (13) pointed out that stature estimation equations are accurate only in the population from which they were calculated. This warning has been echoed by *Stewart* (12), *Lundy* (14, 15), *Lundy* and *Feldesman* (16), *Feldesman* and *Lundy* (17) and even by *Trotter* and *Gleser* (6). However, a recent study by *Boldsen* (18) suggests that *Trotter* and *Gleser*'s equations may be suitable for use in some European populations. Another possible source of error in the use of *Trotter* and *Gleser*'s formulae is the unknown reliability of the antemortem military height data. We do not know if all service inductees were measured in the same manner on the same type of equipment or if those taking the measurements were all trained in the same manner.

## ANATOMICAL METHOD

The term, anatomical method, was first coined by *Dwight* (7). His anatomical method entailed laying out the skeleton in anatomical position using clay or similar material to articulate the bones and substitute for the cartilage at the joints. The length of the articulated skeleton was then measured, yielding an estimated living stature. A variation of *Dwight*'s (7) method was introduced by *Fully* (8) in 1956. *Fully*'s method was also termed the anatomical method, but rather than laying out the skeleton in anatomical position, *Fully* prescribed measuring the skeletal components and then adding a correction factor for the soft tissues.

To use *Fully*'s method, one measures the basi-bregmatic height of the cranium (Fig.1) as described by *Hrdlicka* (19), the maximum anterior height of each vertebrae

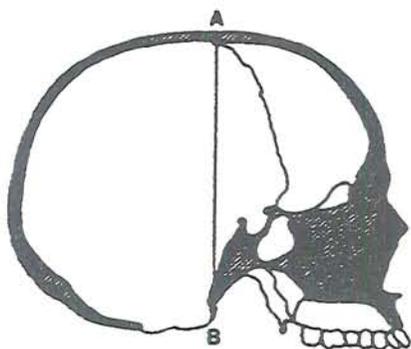


Figure 1. Basi-bregmatic height of the cranium.

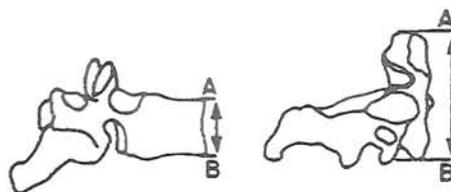


Figure 2. Maximum anterior heights of the presacral vertebrae.

C2 through S1 (Figs.2,3), the bicondylar or physiological length of the femur (Fig.4) (19), the length of the tibia (Fig.5) without spines which is the bicondylar length of *Hrdlicka* (19), and the articulated height of the talus and calcaneus (Fig.6) (8). The height of each vertebra is taken with a sliding caliper. In the case of C2, the height is taken from the most superior point on the odontoid process to the inferior margin of the anterior portion of the corpus, thus including C1 in the measurement (8). I have found the measurement of the articulated talus and calcaneus most easily taken on a mandible board (14, 20). Figures 1 through 6 illustrate how these measurements are taken. These measurements are then added to obtain a "skeletal height". Once the skeletal height is calculated, a correction factor for soft tissues is added (8, 21). For skeletal heights of 153.5 cm or less, add 10.0 cm to the result. For skeletal heights of 153.6 to 165.4 cm, add 10.5 cm, and for skeletal heights above 165.5 cm add 11.5 cm to the result.

The obvious advantage of *Fully's* method (8) over *Dwight's* (7) is that one need not articulate the skeleton to obtain a skeletal heights. Thus, *Fully's* method is convenient in both the field and the laboratory.

In a 1960 paper, *Fully* and *Pineau* (21) described a variation of *Fully's* (8) anatomical method which provided a stature estimate formulae based upon the tibia and the five lumbar vertebrae.

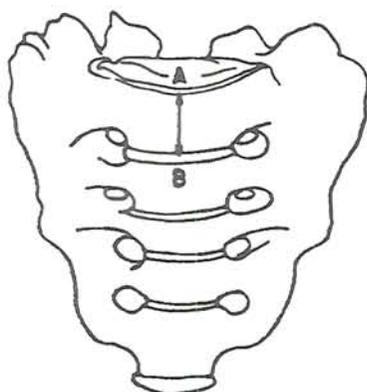
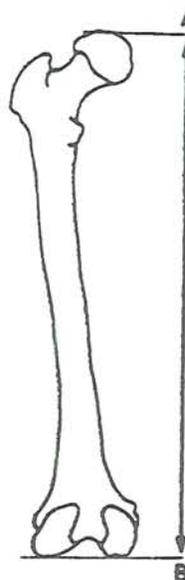


Figure 3. (Top). Maximum anterior height of sacral segment 1.

Figure 4. (Right). Physiological (bicondylar) length of femur.



## ANATOMICAL versus MATHEMATICAL METHOD

Both *Stewart* (12) and *Lundy* (20) have advocated the anatomical method over the mathematical when enough skeletal material is present. *Lundy* (22) has also shown the anatomical method to be as accurate, and in one case, more accurate, than the *Trotter* and *Gleser's* (5, 6) formulae in a small sample of American servicemen.

The mathematical method has the advantage of being simple to use and does not require a complete skeleton. It does not, however, reflect the variability in skeletal proportions in all cases, following the suggestions of using two standard errors for *Trotter* and *Gleser's* (5, 6) formulae renders stature less useful for sorting, and *Trotter* and *Gleser's* equations are not accurate in many populations (13, 14, 16).

The anatomical method is more time consuming and requires a nearly complete skeleton to use, a circumstance rare in forensic cases. However, because one measures the skeletal components directly, it more accurately reflects skeletal and body proportions. Further, since one directly measures the individual skeleton, it is applicable in all populations. The correction factor for soft tissues put forth by *Fully* (8) has been shown to be accurate in other populations as well (14-16).

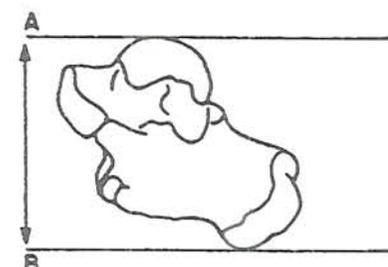


Figure 5. (Left). Bicondylar (physiological) length of the tibia without spines.

Figure 6. (Top). Articulated height of the talus and calcaneus.

### INCOMPLETE LONG BONES

One problem facing the forensic anthropologist is the estimation of living stature from skeletal remains where the long limb bones are incomplete. *Steele* and *McKern* (23) and *Steele* (24) have addressed the issue of estimating stature from incomplete long bones, and *Steele* (24) has calculated formulae, using anatomical landmarks on the bones, for estimating total bone length from incomplete long bones. Once the total bone length has been estimated, the length is then used with *Trotter* and *Gleser*'s (5, 6) stature estimation formulae. The standard error of *Steele*'s equations must be combined with the standard error of *Trotter* and *Gleser*'s formulae, giving any stature estimate a very large degree of possible error. Further, when working with burned or highly eroded material, *Steele*'s landmarks are very difficult to find, rendering their locations highly subjective.

Another technique applied to incomplete long bones is to compare the incomplete bone to several other like bones of varying length to get an idea of how long the bone may have been. Again, this technique is highly subjective and inaccurate, and should only be utilized to determine if the bone is from someone who appears tall, medium or short in height based upon the comparisons. When confronted with incomplete long bones unsuitable for use with *Steele*'s (24) method, it is far better to err on the side of conservatism and offer no estimate of living stature. An honest "I don't know" is always preferred to what might amount to a wild guess.

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