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Body length estimation during the post mortem interval: preliminary study

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Abstract: *Purpose.* Body height represents an essential parameter in forensic cases. Moreover, the evaluation of stature could be helpful also in malpractice lawsuits. The reliability of cadaver length can be influenced by several factors and the difficulties in obtaining data upon precise living stature are well-known.

Methods. We prospectively evaluated 100 cadavers. The cadavers were admitted to the mortuary within 2 hours of death. The body length was measured using a portable stadiometer, in three different post-mortem intervals: within the first 2 hours (T0), at 4-6 hours (T1) and after 20-24 hours (T2).

Results. Showed that at T1 there was a lengthening of the cadaver by almost 1 cm while there was a small decrease in the following hours. Thus, we can state that nearly 24 hours postmortem cadaver length increases slightly (0.6 cm) from the measurement taken 2 hours postmortem, and this is very close to the estimated living height.

Conclusion. Variation of body size during post mortem interval has not been fully explored despite its important implication in forensics. The findings here observed, even considering the limitation exposed in the study, do not support the theory that there is a great difference in cadaver stature postmortem.

Key Words: Living stature, cadaver length, postmortem interval, portable stadiometer.

INTRODUCTION

The estimation of stature is crucial in different research areas in biological anthropology including forensic anthropology and cadaver measurements are a routine part of the external inspection performed before autopsy. The medico - legal value of these data may be essential in many fields of forensic science. Body height is an important parameter that is widely used to identify a person. For example, the increasing frequency of mass disasters, when only fragments of bone or human remains are still available, has created problems in body identification. In such cases, the use of regression ratios in estimating living stature involves the addition of measurements of the skull, longitudinal assembled bones of the vertebral column and long bones of lower limbs length (1-7).

Ante - mortem or living stature estimation is also useful in other deaths when the height of the victim is an important factor in reconstructing a crime. For instance, it may be necessary to place the perpetrator or the victim in a crime scene involving the trajectory of a bullet, or moreover, stature may be important in evaluating the traumatic impact mechanism in some types of injuries. A difference in stature of a few centimetres in such cases can represent a discordant element to be discussed during a trial. In cases of robbery, there may be the need to identify a masked perpetrator from videos, and if he dies without an accurate estimation of his living stature it is difficult to put the face, exclusively used in such 3-D engineering reconstructions, in the right position to be sure of robber identity (8-16).

Furthermore, the evaluation of stature also can be important in some cases of malpractice, for example when the body mass index (BMI) is a rigid parameter for the correct administration of drugs (17).

Estimating height after death can be challenging. The first issue is with regard to the inaccuracy of living data,

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often obtained from official documents such as identity cards or driving licenses. Height is not always measured by the officers in charge of issuing these documents; therefore, it is often overestimated according to what applicants or costumers have reported (18-20). The second concern is with regard to the postmortem body length.

A difference has been reported in living people between standing free stature and the measurement taken when the body is lying down. However, it is still not clear if there is any difference between postmortem height and cadaver length.

The cadaver length must be measured from heel to crown. However, it is not unusual in daily practice for the technician or pathologist to use different tools for evaluating the body length (tape measure, portable stadiometer, and folding measuring stick) and it is sometimes measured from toe to crown which can result in a significant difference compared with the living standing height. Furthermore, according to Knight, post - mortem height may differ from known height by several centimetres because of several opposing causes of variation, such as muscle flaccidity and rigor mortis (21).

Therefore, if body length measurement in autopsy report does not align with the living record, the value of this data may be questioned, even from a forensic standpoint.

MATERIALS AND METHOD

Enrolled Subjects

We prospectively evaluated 100 cadavers who died at University Hospital of Bari. In all cases, brain death was legally certified and then cadavers were admitted at the mortuary of Local Department of Legal Medicine within 2 hours of death, waiting for autopsy or funeral.

The exclusion criteria were vertebral column or lower limb fractures.

The body length of each cadaver was measured using a portable stadiometer in three different post - mortem intervals: within the first 2 hours (T0), at 4-6 hours (T1) and nearly after 20-24 hours (T2). The measurement was taken by the same forensic pathologist under control of two other specialists. This control warrants accuracy of the detected lengths and improves the repeatability of the measurement technique. The cadavers were measured lying down to reduce the influence of postmortem phenomenon such as rigor mortis on measurements.

A data collection card was made for each of cadaver, which contained information on: gender, height, time of death. The cards were entered into a database created with FileMaker Pro software and the data were analyzed with STATA MP11 software.

Statistical analyses

Categorical variables were expressed as percentages and continuous variables were reported as mean with indication of the standard deviations. In order to compare length average in the different measurements in both sexes was Student's t-test was used us for unpaired samples. In order to study the role of gender and death time in height variations a repeated measure ANOVA was used (22).

To evaluate all the variables related to the postmortem stature in the interval considered multiple logistic regression models were used. Significance was claimed at a value of $p < 0.05$.

Cadaver characteristics are listed in Table 1.

Table 1. Patient characteristics

Parameter	Value
Number of patients	100
Gender (M/F)	57/43
Age (years)	72.7 ± 15.6
Age M (years)	70 ± 17
Age F (years)	76.1 ± 12.9
T0 (< 2 hrs P.M.) length (cm)	163.9 ± 10.3
T0 (< 2 hrs P.M.) M length (cm)	168.9 ± 9.3
T0 (< 2 hrs P.M.) F length (cm)	157.2 ± 7.5
T1 (4 - 6 hrs P.M.) length (cm)	165.0 ± 10.6
T1 (4 - 6 hrs P.M.) M length (cm)	170.1 ± 9.6
T1 (4 - 6 hrs P.M.) F length (cm)	158.3 ± 7.8
T2 (20 - 24 hrs P.M.) length (cm)	164.4 ± 10.4
T2 (20 - 24 hrs P.M.) M length (cm)	169.4 ± 9.5
T2 (20 - 24 hrs P.M.) F length (cm)	157.7 ± 7.6

RESULTS

The study population consisted of 57 males (57%) and 43 females (43%), with a mean age of 72.7 ± 15.6 years. The males mean age was of 70 ± 17 years; the females mean age of 76.1 ± 12.9 years. The mean body length within 2 hours post mortem (T0) was 163,9 ± 10.3 cm ($t = 6.8$; $p < 0.0001$); male mean was 168.9 ± 9.3 cm, female mean was 157.2 ± 7.5 cm (Fig. 1). The mean length 4 – 6 hours post mortem (T1) was 165.0 ± 10.6 cm ($t = 6.5$; $p < 0.0001$); male mean was 170.1 ± 9.6 cm, female mean was 158.3 ± 7.8 cm. The mean length 20 – 24 hours post mortem (T2) was 164.4 ± 10.4 cm ($t = 6.6$; $p < 0.0001$); male mean was 169.4 ± 9.5 cm, female mean was 157.7 ± 7.6 cm.

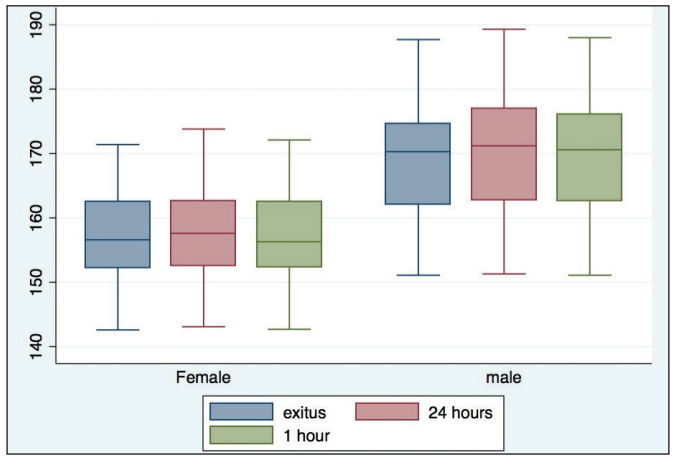

Figure 1. Length variation.

The ANOVA model for repeated measures shows that the differences observed in the various measurement times depends both on time ($F = 183.9$, $p < 0.0001$) and gender ($F = 44.1$, $p < 0.0001$). The multiple logistic regression model showed that the height after 4 - 6 hours (T1) depends on the length at T0 (coef = 1.3; t = 119.6, $p < 0.0001$), sex (coef = -0.42: t = -2.69; p = 0.008) and age (coef = -0.01, t = -2.29; p = 0.024) and does not depend on the time of death ($p > 0.05$). The length after 20 - 24 hours (T2) is rather influenced by length at T0 (coef = 0.41; t = 7.3, $p < 0.0001$), length at T1 (coef 0.58; t = 10:56; $p < 0.0001$) but it is not influenced by sex, age and time of death ($p > 0.05$).

The cadaveric length increased by a mean of 1.1 cm 4 – 6 hours post mortem (T1); male subjects increase during this interval by 1.2 cm, female subjects increasedby 1.1 cm on average. At 20 - 24 hours post mortem (T2) the cadaveric lengths increased if compared with T0 by 0.5 cm on average (in both male and female subjects), although they are 0.6 cm shorter than at T1 (0.6 cm in female subjects and 0.7 cm in male subjects).In the sample considered we observed 12 cadavers under 50 years-old, with a mean age of 34 years. Considering only this sample we observed that cadaveric length increased by 1.7 cm at T1 while after 24 hours we noted just a slight increase (0.1 cm) compared with the study population examined (Table 2).

Table 2. Post-mortem interval and length variation

Post - morteminterval	Variation
T0 – T1 (4 – 6 hours)	+1.1 cm
	+1.7 cm (Under 50 age)
T1 – T2	-0.6 cm
	-1.1 cm (Under 50 age)
T0 – T2 (20 – 24 hours)	+0.5 cm
	+0.6 cm (Under 50 age)

DISCUSSION

The observations detailed here have demonstrated that body length increases slightly during the first 24 hours postmortem, from the measurement taken within 2 hours of death.

These preliminary results seem not to support the theory of such a great postmortem differential in cadaver stature. Moreover, if we have no data with regards to the cadaver's living stature we can speculate that the measurement taken 24 hours postmortem is very close to the estimated living height.

The goal of postmortem stature estimation is to obtain the smallest range of error compared with actual living height of an individual.

The importance of cadaver length is potentially useful in forensic casework of crime investigation but in daily practice only a forensic anthropologist can use analytical methods to estimate the stature from intact bones. With the increase in malpractice lawsuits a difference of a few centimetres between living and cadaver stature can significantly change the formulae for properly administering drugs.

Recently, Mc Cormack and colleagues explored the possible correlation of cadaver measurements (including body length) perturbations from their corresponding pre-mortem values on heart weight interpretation (23).

Wilson and colleagues examined the difference between Forensic stature (FSTAT) and measured stature (MSTAT), commonly used in regression analyses. They revealed many of confounding factors, personal and environmental, that can influence the evaluation of living stature (18, 24-27).

Hence the current literature clearly demonstrates the limited value of self-reported stature such as on driver's license when measured stature is unavailable. The reason for the inaccuracy of any ante-mortem record is generally related to the trend in people to overestimate their stature (25).

Cadaver measurement of body length is a routine part of the external inspection performed before autopsy, however, it is usually taken by technicians and some flaws were generally noted.

As reported by Knight, it is possible that the attendant does not take the height form toe to crown due to the plantar flexion of rigor.

Bidmos underlines the need to place the plantar surface of the feet as well as the neck in the right position and these elements, coupled with the lack of standard measuring instrument, may contribute to error in the final measurement (19, 28-30).

In consideration of these issues, we used a portable stadiometer with one fixed plate, generally placed on the foot and another sliding plate which are connected by a rod marked with a measuring scale. Only one forensic pathologist provided all the measurements to be sure that the same method was used in placing the stadiometer but two other pathologists checked the properness of the procedure.

Nevertheless, there are some limitations of this study that deserve to be mentioned and are strictly related to the sample examined.

The choice to evaluate people who died in the Hospital was due to the possibility of measuring the body length at T0 which was not possible in forensic cases. Therefore, we were not able to choose the sample, and the old average age analysed is in accordance with the Hospital data.

It is well-known that the aging process influences measured statures; however, the aim of our study was not to examine how height metrically decreases in old people but the difference, if any, of presumed living stature during a 1 day postmortem interval (24, 31).

The findings here observed seem to correlate the slight increase of cadaver's length to the postmortem phenomena. It is possible that in the first 6 hours after death muscle flaccidity allows joints to relax and then the

cadaver will be influenced by the progressive increasing degree of rigor mortis. We have to consider also the supine compared with standing position and the role of flattened intervertebral discs and vertebral bodies, kyphosis and other degenerative vertebrae diseases that could be represent in the sample. This is considered an important limitation (3, 28-32). Gender and sex do not influence the stature variation in postmortem interval.

Interestingly in the small sample of people under 50 here considered we observed an increase of 1.7 cm in the first 6 hours while after 24 hours the range of cadaver length was rather the same compared with the whole study population. This "young" sample is too small to draw a definitive conclusion and further studies are needed.

CONCLUSION

The current study contributes substantially to our knowledge of postmortem variation of cadaver length during the first 24 hours. Even considering the limitations of the sample here observed we demonstrated that cadaver length increases slightly when compared with the measurement taken within 2 hours of death.

Conflict of interest. The authors declare that there is no conflict of interest.

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