Tuttle N. A comparison of methods used for measuring popliteal height. *Ergonomics Australia*. 2004;18:14-18.

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ABSTRACT

Popliteal height is the main anthropometric dimension used in school chair design and specification to determine appropriate seat height. Three methods of measuring popliteal height — anatomical, table (weight-bearing) and knee-crease methods were investigated in a sample of 10 university students measured twice by each of two observers. Inter- and intra-observer repeatability for each method was good with the exception of inter-observer repeatability for the knee-crease method which was poor. The knee-crease method was not considered repeatable enough for it to be of practical use. Popliteal height measurement obtained using the table method was significantly greater than the other two methods by between 63 and 89 mm (3.7% - 5.3%) of stature). In this small sample no variation was detected in the difference between the methods in relation to the size of the individual. Implications for specification of school chairs are discussed.

INTRODUCTION

Popliteal height is the main anthropometric dimension used in school and other chair design and specification to determine appropriate seat height. In designing a chair to suit a population, the popliteal height is used to ensure that members of the population are able to sit with their feet supported on the floor, and without undue pressure behind the knees. Likewise, comparing the popliteal height of an individual to the seat height of the available chairs can assist in selecting the most suitable size for that individual. Popliteal height can be measured using different methods. The majority of anthropometric data on popliteal height data has been produced using an anatomically based method of measurement (Pheasant, 1992), however there are questions as to whether this is the best method on which to base seat height of a chair. A weight-bearing "table" method of measuring popliteal height has been advocated as providing a more functional indication of appropriate seat height (Molenbroek, Kroon-Ramaekeres, & Snijders, 2003). Alternatively, the height of the crease at the back of the knee in standing has been proposed as an easier method for use by teachers untrained in anthropometric measurement to assign the appropriate size chair for school children. Measurements taken using these different methods are all called popliteal height and have been referred to as if all were measurements of the same parameter. The different methods of measurement however measure different things and the values obtained are potentially quite different.

In order to better understand the relationship between measurements taken by the three methods and the usefulness of each method, a small pilot study was undertaken to determine the following:

- 1. the inter- and intra-observer reliability of the three methods;
- 2. whether there is a significant bias (consistent difference) between the three methods;
- 3. if there is a bias, whether it is constant or varies with the size of the individual.

METHOD

The sample consisting of ten volunteer university students (4 male, 6 female; mean weight = 65 kg, SD =12 kg; mean stature = 170 cm, SD = 8 cm), had their popliteal height measured on a single day by two observers, one a Musculoskeletal Physiotherapist and the other a secondary school student. Each observer measured the unshod right leg of each subject using each of the three methods – anatomical, table, and knee-crease methods, and then repeated the three measurements on that subject. Although blinding is not possible for one observer performing repeated measures, an attempt was made to minimise the likelihood of observer bias by each measurement being recorded on a separate sheet and each observer taking measurements of the same subject using the two other methods before repeating any measurement.

For the anatomical method, the popliteal height was measured with the subject in an upright sitting position as the vertical distance from the insertion of the biceps femoris tendon to the floor (Pheasant, 1992). Variations of this method have been reported in the literature including that used by Parcells et al. (1999) and Legg et al. (2003) who measured to the less clearly defined "posterior surface of the knee or popliteal space". For the table method, subjects were seated on a horizontal table with the back of their knees near the edge and their lower leg vertical. A second horizontal surface was raised until the subject's foot was resting on it. The measurement was taken as the vertical distance from the tabletop to the horizontal surface under the subject's foot (Molenbroek et al., 2003). For the knee-crease method, the subject was standing next to a sheet of paper taped to a wall. The height of the knee-crease on the lateral side of the knee was marked on the paper and the distance from this mark to the floor was recorded.

For assessment of reliability, each measurement was treated individually resulting in 20 repeated measures. The inter- and intra-assessor reliability was assessed by two methods. Intra-class correlation coefficients (ICC) were performed to give an indication of the degree of correlation between repeated measures. Intraclass correlation coefficients however do not indicate the bias or the size of the difference resulting from measurements by the two methods. To indicate the size of the bias between the two repeated measures, repeatability coefficients (Bland & Altman, 1999) were also calculated. The repeatability coefficient (Equation 1) indicates the range within which 95% of repeated measurements would be expected to lie and is expressed in the same units as the original measurement.

Equation 1

95% repeatability coefficient = 1.96 $\sqrt{2}$ 2xS = 2.77S Where S is the within subject standard deviation

For comparing the three methods the averages of the two repeated measures for each method by each observer were used for analysis again making a total of 20 measurements for each method. Means and standard deviations for popliteal height in millimetres as well as a percentage of stature were calculated for each method of measurement and Student's t-tests were used to compare the groups. The approach of Bland and Altman (1999) was also used to compare the methods of measurement as it is able to provide an indication of the size and uniformity of differences between methods. Using this method the difference between measurements of the same subject by the two methods is calculated. The mean of these differences is the bias or how much the measurements by one method vary from those of another. The standard deviation and 95% confidence interval of the mean can then be applied to the bias giving the interval within which we can reasonably expect the actual bias to lie. It is important to note that the confidence interval is difference between a pair of measurements (no bias would usually be expected between the means of repeated measures using the same method). The difference between the measurements by each pair of methods can then be plotted against other factors which might influence the size of the bias in this case popliteal height (expressed as the average of the two methods) or stature. If the difference between the two methods appeared to be related to popliteal height a regression analysis would be performed to quantify the relationship. Statistical analysis was performed using SPSS v.12.0 with significance levels were set at .05 for all tests.

RESULTS

Correlation coefficients and inter- and intra-observer repeatability coefficients for each method are shown in Table 1. All three methods demonstrated good inter-observer reliability with the anatomical method being superior to the other two. Both the anatomical and table methods also showed good intra-observer repeatability with the anatomical method again being superior. The knee-crease method however showed poor intra-observer repeatability coefficient of nearly half the measured popliteal height.

	Inter-observer		Intra-observer	
Method	Repeatability coefficient	ICC (F-test value)	Repeatability coefficient	ICC (F-test value)
Anatomical method	$\pm 25 \text{mm}$.91 * (14.2)	± 51mm	.98 * (60.7)
Table method	$\pm 51 mm$.86 * (7.3)	± 99mm	.97 * (31.1)
Knee-crease method	± 57mm	50 (.7)	± 210mm	.96* (22.0)

Repeatability coefficient indicates the range within which 95% of repeated measures would be expected to lie. *indicates significant correlation (p < .05)

Table 1: Inter- and intra-observer repeatability coefficients and correlation coefficients for each measurement method

The means and standard deviations for each method of measurement expressed in millimetres and as a percentage of stature are shown in Table 2. A comparison between the anatomical method and the other two methods showing the bias and the 95% confidence interval of the bias is shown in Figure 1. The popliteal height measured using the anatomical method was less than that measured by the anatomical method by 76 mm (95% confidence interval 63 - 89 mm) or 4.5 percent of stature (95% confidence interval 3.7 - 5.3 %) while the anatomical method was 19 mm (95% confidence interval -3 mm - 41 mm) or 1.2% (95% confidence interval -0.1% - 2.5%) less than the knee-crease method. No significant differences were detected in the bias in relation to popliteal height or stature.

Method	Popliteal Height (SD)	Popliteal Height as percentage of stature (SD)
Anatomical method Table method Knee- crease method	443 mm (36 mm) 519 mm (49 mm) * 462 mm (48 mm)	26.2% (1.4%) 30.7% (1.9%) * 27.4% (2.5%)

* Table method was significantly different from both anatomical and knee-crease methods (p<.05) when expressed either in millimetres or as a percentage of stature.

Table 2: Popliteal heights for each measurement method







Figure 1: Comparison of popliteal height measured by the anatomical and the table methods and anatomical and knee-crease methods. The difference between the measurement obtained by the two methods is plotted vs the mean of that pair of measurements. The mean of the differences is the bias between the two methods of measurement. The 95% confidence interval is the range within which one can expect the actual bias to lie. Although the number of samples is small there is no apparent variation in the size of the bias with increasing popliteal height.

DISCUSSION

This study set out to clarify the usefulness of three methods of measuring popliteal height. In order for a measurement to be useful, it must not only be reproducible, but also be relevant to the objective for which the measurement is being used. The knee-crease method was included in this study as it had been proposed as a simple means to assess students for appropriate chair size by school staff who are untrained in anthropometric measurements. The intra-observer repeatability however was unacceptable. A possible reason for the larger variation in the measurements taken using the knee-crease method is that it may be difficult for observers without training to determine the point of the knee crease from which to take the measurement. The knee-crease is not horizontal, but rather is typically higher laterally than medially and may continue beyond the posterior surface of the knee. Although the mean for the knee-crease method was not significantly different from the anatomical method, the high variability of the knee-crease method combined with its lack of relation to a functional dimension would indicate that it would not be useful as a quick method for untrained personnel to use for assessing popliteal height in the school setting.

The remainder of the discussion will thus concentrate on the two remaining methods — the anatomical and table methods. The repeatability for both of these methods of measurement was good, with the anatomical method demonstrating better repeatability for both inter- and intra-observer comparisons. The bias of 63 mm to 89 mm between these two methods is surprisingly large considering that the average popliteal height measured by the anatomical method was less than 450 mm⁴.

One would expect this bias between the two methods of measurement to vary with the size of the individual e.g. to be longer in taller individuals. For this small sample size of skeletally mature subjects, however there was no detectable variation in the bias with increasing height. Other factors that were not included in this study could also affect the difference between the methods of measurement. An individual of the same height with a higher body mass index would be unlikely to have a different reading using the anatomical method, but may, as a result of having thicker thighs have a lower measurement on the table method. Further data with a larger sample size over a greater range of ages and sizes would be necessary in order to clarify the factors affecting the bias or to determine if it is possible to accurately convert a measurement by one method to the equivalent of that taken using another method.

The question remains as to which method of measurement is more useful for determining the appropriate seat height for a population or the fit of an individual to a fixed height chair such as a school chair. The anatomical method has good repeatability as the location of the insertion of the biceps femoris used for the anatomical method provides a distinct landmark and is easy to access on the outside of the leg. It is less clear what relevance this point has for determining the appropriate seat height. The biceps femoris tendon is not the first part of the posterior thigh to contact a chair seat, as the tendons on the medial side of the knee are lower. Neither is the biceps femoris tendon particularly sensitive to pressure or compression. A seat height such that biceps femoris insertion is contacted by the front of a chair would not produce compression of the nerve or vascular structures in the popliteal space, but it is not clear how much higher the seat could be before such compression occurred.

The table method on the other hand relates directly to the function of seating by measuring the maximum height of a flat seat that will enable the user to sit with their heels on the floor (if the seat is flat and extends to immediately behind the knees). Sitting in this way, however would produce undue pressure on the nerve and vascular structures in the popliteal space. In practice and according to the current and proposed Australian standards for school chairs the front edge of the seat is rounded and seats do not extend to immediately behind the knee. The maximum height of the front of a seat that would enable an individual's feet to reach the floor would therefore be somewhat different from the height measured by the table method. In spite of this the table method of measuring popliteal height would seem to provide the best starting point from which to determine the maximum allowable seat height for school chairs. A correction factor would need to be applied to the popliteal height measured by the table method to ensure prevention of unwanted pressure in the popliteal space and to allow for the effects of shorter rounded seats used in the actual school chairs.

While it is not possible to determine the maximum front of seat height directly from any of the popliteal height measurements, for a particular individual the table method provides an approximation of the maximum height of the front of a seat. The appropriate seat height would also be affected by factors including the body mass index of the individual and the angle, depth and contour of the seat and can probably only be accurately determined by an individual sitting in a particular chair.

CONCLUSION

The knee-crease method of measuring popliteal height did not demonstrate the level of repeatability necessary for it to be a useful method. The anatomical and table methods demonstrated good repeatability, but produced quite different measurements of popliteal height.

The different methods of measuring popliteal height are not interchangeable and further data would be necessary to be able to convert a measurement taken using one method to its equivalent using another method. The table method would appear to have face validity as the most appropriate method on which to base dimensions for sizes of school chairs. Measurements of populations or individual students taken using any of the methods however may not provide sufficient information to adequately specify the most appropriate seat height.

'The reader can appreciate the size of the difference on themselves. Sit on a table or desk with the back of your knees near the edge

and your feet unsupported and your heel against the table leg. Lift one knee until the biceps femoris tendon — the hamstring tendon on the lateral side of your knee — just lifts off the table. The distance your heel has moved is the difference between the popliteal height measured by the table and anatomical methods.

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