

GUIDELINES FOR MEASUREMENT OF AMPUTATION STUMP LENGTH

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INTRODUCTION

Accurate measurement of limb length before amputation surgery aids the surgeon in the election of the amputation site. Postoperatively, accurate measurement of stump length assists the clinician in the definition of remaining musculature, intact tendinous insertions, joint integrity, and the functional lever by which the stump can control a prosthetic device. This information leads to the selection, fitting, suspension, and alignment of a prosthesis.

For any measurement to be reliable, it must be capable of being repeated on separate occasions, under similar conditions, by several different evaluators. However, because of typical variables such as human error, external conditions, and slight inaccuracies in the measuring instruments (e.g., ruler or tape), a precise measurement is difficult to obtain. The introduction of other variables, such as non-standard reference points and methods of measurement, will only serve to compound the problem of attaining reliable, accurate information.

Stump length measurements, in particular, should be standardized to avoid interdisciplinary misunderstanding and misinterpretation. It is understood that variations from these standards may be necessary when measuring for specific purposes, for unusual or difficult cases, or when the "standard" landmarks are unavailable or difficult to palpate.

The purpose of this paper is to review currently accepted guidelines for measuring amputation stump length and the rationale for using the named techniques and reference points, and to present those variations which may be considered acceptable.

THE DEVELOPMENT OF THE PRESENT SYSTEM

Prior to 1920, amputation stumps were classified according to site, with stump lengths grossly categorized into upper, middle, and lower thirds

(1). These classifications were arrived at by rough, "eye" estimates; no specific measurements were recorded. The expanded numbers of amputee veterans produced by World War I directed attention to the need for exact measurements and resulted in the adoption of standards for measurement in Europe. Specific locations based on easily palpated structures served as reference points; these landmarks varied somewhat, as did the methods of measurement. As will be noted, these landmarks were somewhat vague and indefinite.

In London, the Ministry of Pensions adopted a system of landmarks for measurement (1) that resembles the present system:

- shoulder—tip of acromion
- elbow—olecranon, with forearm flexed to 90 deg.
- hip—tip of greater trochanter
- knee—tibial plateau (preferably medial)

A separate system of landmarks was indicated for the measurement of sound limbs:

- humerus—lateral condyle
- ulna—styloid process
- femur—lateral condyle
- tibia—medial malleolus

Exact points on these landmarks were not identified; one examiner might have chosen the superior aspect of the olecranon, for example, while another examiner might have chosen the apex.

Also, in London in 1923 Ernst (2) interchanged the use of the "hip joint" and the perineum as proximal reference points. His definition of a landmark for the "hip joint" is unclear.

In Geneva, stump length was measured from "below the nearest joint" (3).

During the 1930's, A.A. Marks (4) in the United States described the "point of the shoulder" and axilla as landmarks for *both* above-elbow and below-elbow amputees, and the perineum as a reference point for *both* above-knee and below-knee amputees. No distal reference points were specified.

Interest in prosthetics remained relatively static until World War II (5), when a tremendous influx of amputee veterans created an upsurge of concern for these individuals, and a more scientific field of prosthetics was initiated. As authorities in the various medical and paramedical fields developed increased prosthetic knowledge and skill, specific measurements became necessary.

With the numbers of amputee veterans to be evaluated and fitted with prosthetic devices, and with the increased interest and concern for prosthetics as a science, research, medical, and educational programs realized

the need for reliable data. The prosthetic and orthotic professions developed and became respected members of the paramedical community. The establishment of the American Board for Certification in 1948 (6) led to the adoption of standards for prosthetic-orthotic professional practice and ethical conduct. The ABC examination for prosthetic certification utilizes those standards which are accepted and taught by universities with prosthetic-orthotic programs.

The introduction and development of such concepts as total contact, the suction socket, and patellar-tendon-bearing prostheses in the 1950's and 1960's reemphasized the need for exact stump measurements. Fitting and fabrication manuals, published by various institutions and professional organizations, noted specific locations and techniques for stump and sound extremity length measurements adopted and published for educational purposes. These reference points and techniques were based on the standards taught by the universities and recognized by the American Board for Certification (Fig. 1, 2, and 3).

It is anticipated that unusual or difficult cases may preclude the use of these particular landmarks and techniques. Alternatives that meet the following criteria should be noted and the particular variation recorded along with the measurement.

CRITERIA FOR MEASUREMENTS

Several factors are considered in the standardization of landmarks and limb positions used for measuring stump length:

1. The landmark should be a readily palpable structure.
2. The landmark should whenever possible be a *bony* structure, eliminating any possible variables resulting from soft tissue changes.
3. The landmark should be anatomically suitable for the particular segment that is being measured.
4. The landmark should be located at, or in proximity to, the most distal intact joint.
5. The extremity should be positioned in such a way as to minimize or eliminate external influences, such as muscular contraction or stump angulation, which may obscure the true stump length.
6. Proximal-to-distal measurement should be taken in a straight line, avoiding incorrect measurements from an obliquely placed ruler, tape, or caliper.

With these criteria in mind, the following methods of measuring stump lengths and their corresponding anatomical reference points are reviewed. Variations from these methods are included, with the stipulation that they meet the aforementioned criteria.

UPPER-EXTREMITY MEASUREMENT CHART

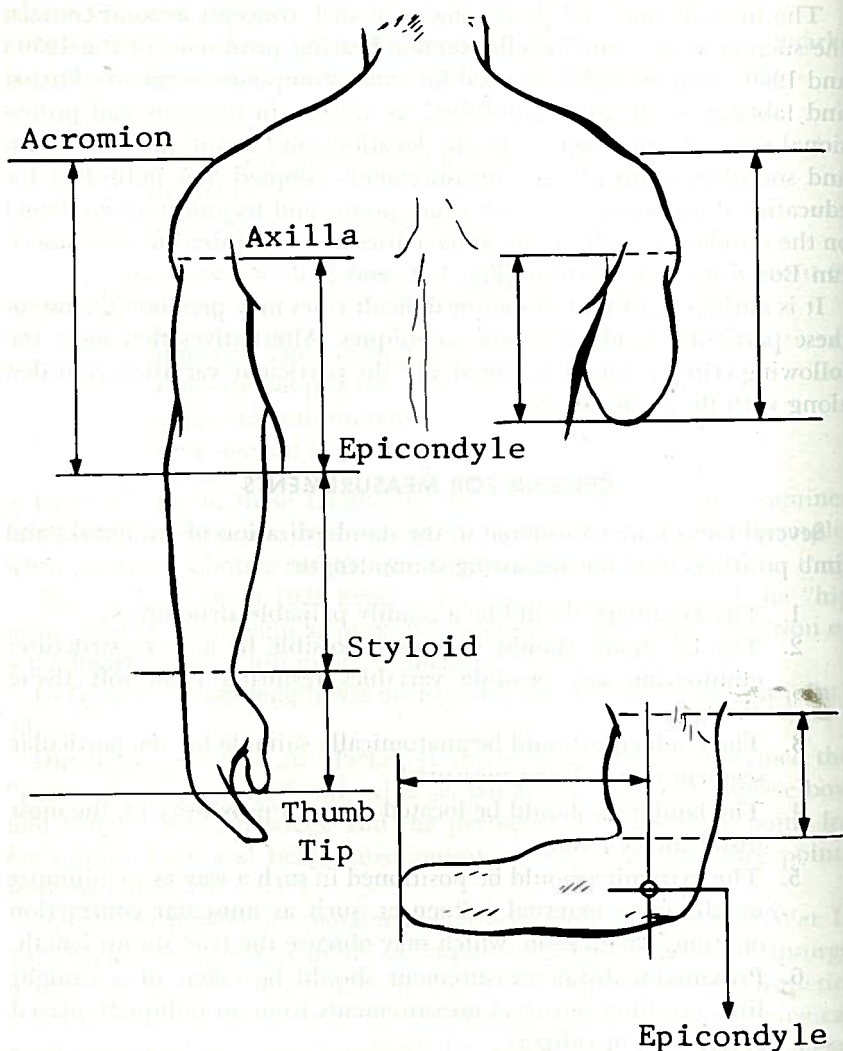


FIGURE 1.—Upper-extremity measurement chart—all length measurements should be taken twice: to bony end for *functional* stump length and to fleshy end for *actual* stump length. (Adapted from a form developed at UCLA.)

PROSTHETIC INFORMATION - ABOVE-KNEE PROSTHESIS
B. PROSTHETIC MEASUREMENTS

RIGHT OR LEFT AMPUTATION _____ PROSTHETIST _____

FIGURE 2.—Lower-extremity (above-knee) measurement chart—Note that *two* measurements are taken: “Stump Length” indicates the *actual* length (to fleshy end) and “femur length” indicates *functional* length (to bony end). (Adapted from a form developed at UCLA.)

PROSTHETIC INFORMATION
BELOW-KNEE PROSTHESIS

B. PROSTHETIC MEASUREMENTS

FITTING AIDS: () PLASTER CAST OF STUMP

() TRACINGS: NORMAL SIDE : LATERAL AND ANTERIOR VIEWS
AMPUTATED SIDE: ANTERIOR VIEW

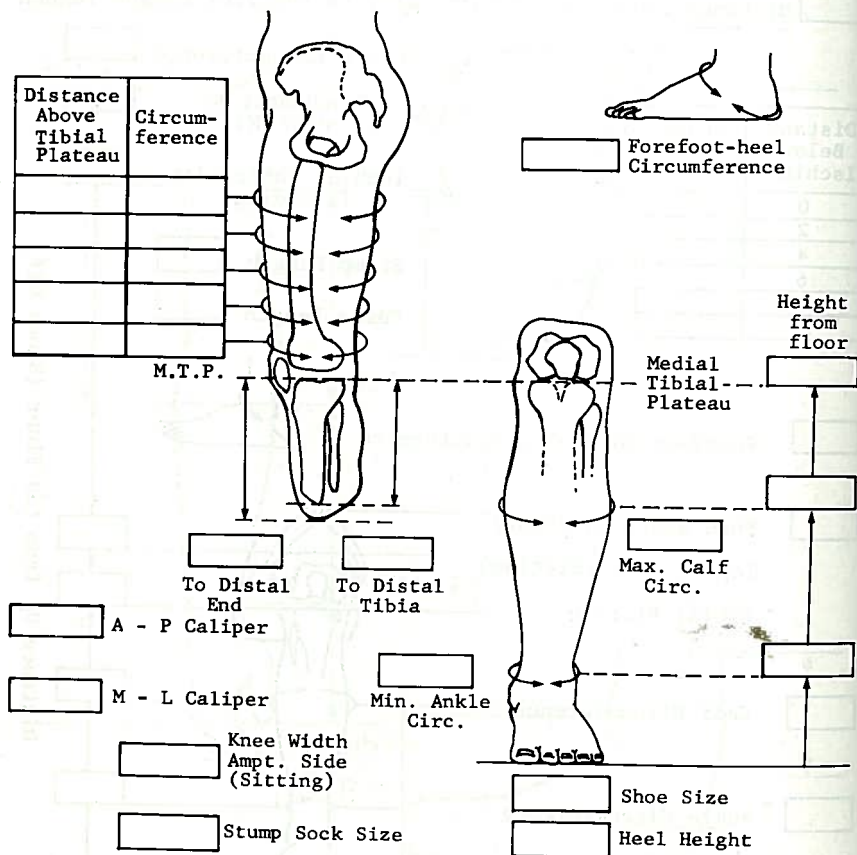


FIGURE 3.—Lower-extremity (below-knee) measurement chart—Note that *two* measurements are taken: to “distal end” (fleshy end) for *actual* length and to “distal tibia” (bony end) for *functional* length. (Adapted from a form developed at UCLA.)

UPPER EXTREMITY

Figure 1 illustrates the standard measurements for stump and sound extremity lengths and circumferences for both above- and below-elbow

amputees. In both cases, measurement of the length of the sound upper extremity is extremely important for proper prosthetic fitting and sizing.

It is important to distinguish between the stump as a total structure (to the fleshy end) and the stump as an "effective lever" (7) or *functional* structure (measured to the bony end). Redundant tissue, although it must be considered to describe *actual* stump length, does not contribute to *functional* stump length. Therefore, two measurements should be taken—one to the fleshy end for *actual* length and the other to the bony end (firm pressure applied to stump end) for *functional length*.

Above Elbow

The most desirable surface bony landmark in the region of the shoulder joint is the *acromion process*. Ideally, either the glenoid fossa or the head of the humerus would be the more desirable, as they are the portions of the scapula and humerus that form the shoulder joint itself. These structures, however, are not palpable in the normal shoulder joint because of muscle bulk and a ligamentous sleeve which encapsulates the joint. The tip of the acromion is readily palpable and, therefore, is used.

Measurement of the stump from this landmark does not provide the prosthetist with adequate information. An additional measurement is therefore taken from the axilla to the end of the bone. These two measurements establish the *functional* stump length, which demonstrates the effective lever of the stump (e.g., a patient may have some intact portion of the humerus; however, if this stump does not extend beyond the axillary fold, it is classified as a shoulder amputation and therefore an ineffective lever). The axilla-to-stump-end measurement is especially important for prosthetic fitting.

We therefore have four measurements for above-elbow stump length: Tip of acromion to fleshy end and axilla to fleshy end for *actual* stump length, and tip of acromion to bony end and axilla to bony end for *functional* stump length (Fig. 4).

Below Elbow

The elbow is a multi-facet joint consisting of the trochlea and capitulum of the humerus, the trochlear notch of the ulna, and the head of the radius.

Although the olecranon process of the ulna appears to be a suitable reference point by its readily palpable nature, it is anatomically situated posterior to the elbow joint; its position changes in relation to the elbow joint (moving in a posterior direction in reference to the humerus) during flexion-extension motions of the forearm. Therefore, the olecranon is not usually used as a proximal landmark for measuring the below-elbow stump. This rule does not remain firm, however. For instance, the Northwestern University self-contained, self-suspended below-elbow

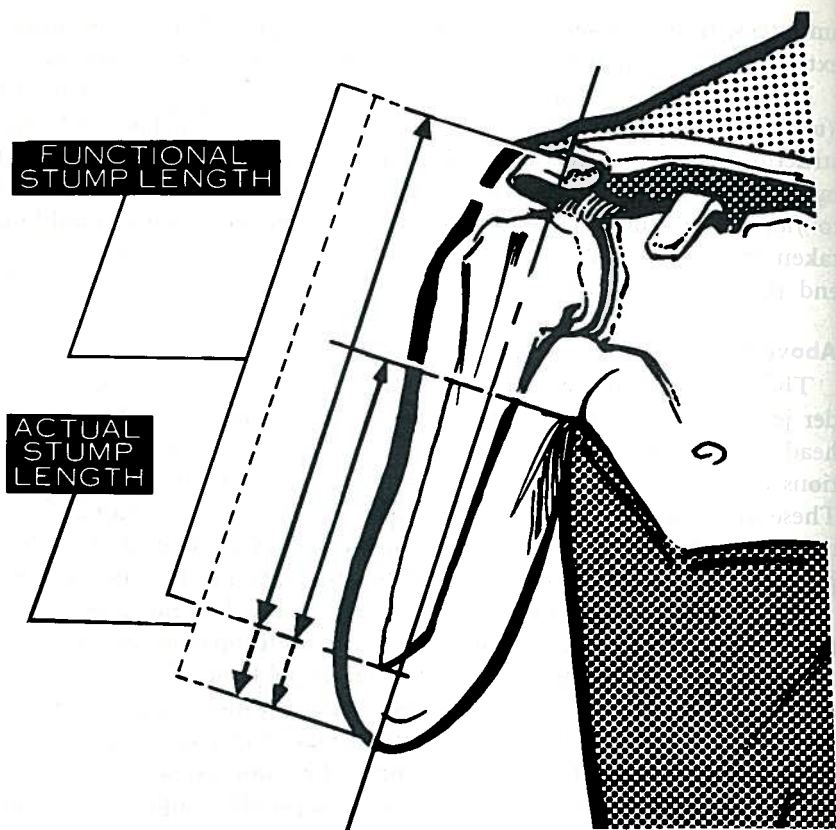


FIGURE 4.—Above-elbow stump length measurements: Note that there are four measurements. The above-elbow stump should be held in slight passive abduction.

prosthesis (described in BPR 10-14) utilizes the olecranon for suspension. The olecranon-to-stump-end length is thus essential to determine adequate suspension. In rare cases where the humeral epicondyles are absent, the olecranon may be used. In any case, the alternatives should be noted next to the measurement.

The medial and lateral epicondyles of the humerus, which extend slightly above the anatomical elbow joint, are prominent and easily palpated through the skin. Both are palpated with equal facility. However, the use of the *lateral* epicondyle places the measuring instrument in a more accessible position.

A major factor in measuring the forearm is its anatomical structure, which dictates the need for especially accurate methods of measurement. Brunnstrom (8) indicates that the trochlea of the humerus extends more distal than the capitulum. As a result, if the forearm is held in an extended and supinated position, the forearm tends to deviate "laterally

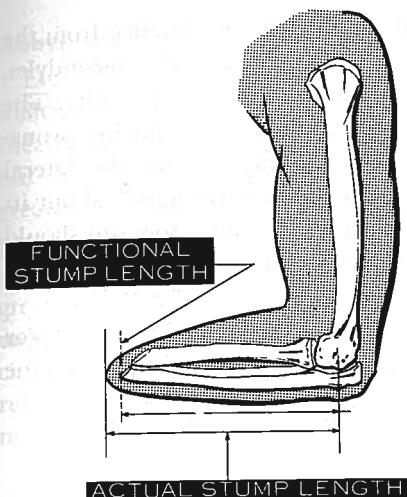


FIGURE 5.—Below-elbow stump length measurements: The forearm should be held in a flexed, mid-pronated (neutral) position.

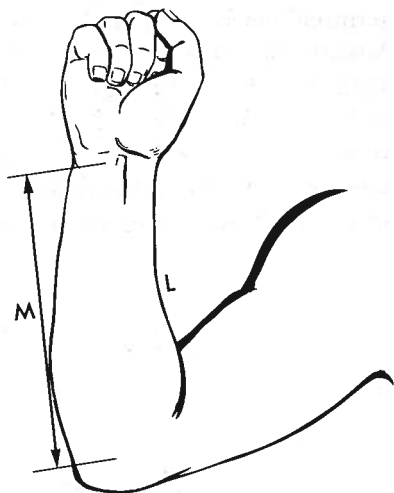


FIGURE 6.—Position of the forearm for medial epicondyle-to-ulnar-styloid measurement (alternative measurement).

in relation to the humerus, which accounts for the *carrying angle* or cubital angle" (8). Hence, to avoid this angulation, the below-elbow stump should be measured in a flexed, mid-pronated (neutral) position (Fig. 5). With the forearm in this position, the measuring instrument would be difficult to read if the medial epicondyle were used. The only other position which would give an accurate measurement from the medial epicondyle would be with the forearm flexed and mid-pronated, with the olecranon held against a table (Fig. 6). When either medial epicondyle-to-ulnar-styloid or to-stump-end measurement is desired, this position should be adopted. As stated previously, efforts should be made to avoid a measurement produced by an obliquely placed ruler, tape, or caliper.

Two measurements should be recorded for below-elbow stump length: Lateral epicondyle to fleshy end for *actual* stump length, and lateral epicondyle to bony end for *functional* stump length. These measurements should be taken with the stump held in a flexed, mid-pronated position (Fig. 5). If medial epicondyle-to-stump-end (or ulnar styloid) measurements are taken, the stump (or sound limb) should be held in a flexed, mid-pronated position with the elbow resting on a table or similar surface (Fig. 6).

The Sound Limb

Measurements of the sound limb are extremely important to insure proper prosthetic fitting and sizing. Distally, the thumb tip is occasionally used when the projected total length of the prosthesis, including the

terminal device, is desired. More often required is the distance from the lateral epicondyle to the ulnar styloid. As is the case with the epicondyles, both styloids (medial and lateral) are palpated with equal facility. The radial styloid (lateral), however, rotates about the ulna during pronation and supination. As a result the measurement from the lateral epicondyle to the radial styloid changes as the forearm moves about its transverse axis. Measurement of the length of the sound forearm should therefore be taken from the lateral epicondyle to the *ulnar* (medial) *styloid*.

Therefore, the acromion to lateral epicondyle to ulnar styloid (or thumb tip) measurement is the most appropriate measurement for the sound limb (Fig. 7).

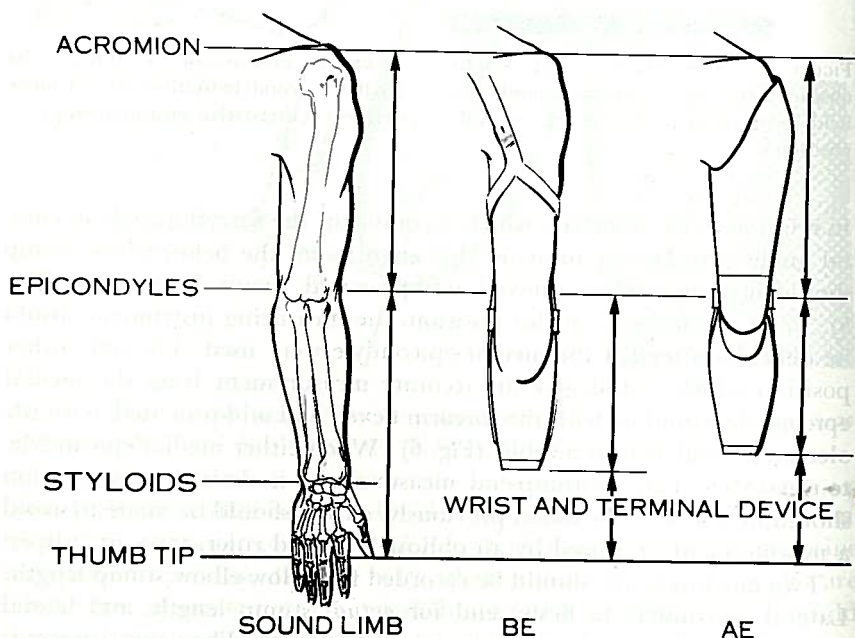


FIGURE 7.—Length measurements of the sound upper extremity for prosthetic fitting and sizing. The distal landmark may be the ulnar styloid or the thumb tip. (Adapted from "Manual of Upper Extremity Prosthetics," UCLA, 1958.)

LOWER EXTREMITY

Figures 2 and 3 illustrate those measurements for stump and sound extremity lengths and circumferences that are considered standard. As indicated for upper-extremity measurements, it is important to distinguish between *actual* stump length and *functional* stump length.

Above Knee

Location of anatomically suitable landmarks about the hip joint is a difficult task because of the usual amount of soft tissue in that area. Ideally, the hip joint itself would be the most desirable reference point, but its location makes it a non-palpable structure. Traditionally, the greater trochanter of the femur has been used as an approximate counterpart to the hip joint. In extremely obese or muscular individuals, however, the greater trochanter may be difficult to locate. Although the greater trochanter meets the criteria for a suitable landmark, it is not the most desirable because of potential difficulties in its palpation. If unusual circumstances necessitate the use of the greater trochanter as a proximal reference point, the *tip* should be used and this landmark should be noted with the measurement.

The ischial tuberosity is located distal to the hip joint at approximately the level of the lesser trochanter. It is best palpated below the gluteal fold when the gluteus maximus and hamstring muscles are relaxed (8). This bony prominence and its surrounding soft tissue provide the weight-bearing surface for above-knee quadrilateral sockets, below-knee ischial-weight-bearing corsets, and some weight-bearing orthoses. The ischial tuberosity-to-stump-end or to-floor measurement is thus critical in determining socket fit and correct prosthesis length. The ischial tuberosity may be somewhat obscured by soft tissue; however, this may be a factor in increasing socket comfort due to increased pressure distribution (Fig. 8), and should therefore be considered during the measurement process.

Care should be taken to position the stump in the midline (avoid flexion, extension, abduction, or adduction) to eliminate placement of the measuring instrument in an oblique direction. Remember to take *two* measurements—for *actual* and *functional* stump lengths (Fig. 9).

Below Knee

The knee joint is a complex structure involving articulations between the femoral and tibial condyles, with intervening menisci. The patella is a sesamoid bone, which is imbedded in the quadriceps tendon, functioning as a pulley to facilitate quadriceps action. The head of the fibula articulates with the tibia and is not an integral part of the knee joint.

The tibial plateaus are easily palpated when the knee is held in a *slightly flexed position*. The *medial tibial plateau* is used as the standard landmark by virtue of its easy palpation just distal to the medial femoral condyle. The lateral tibial plateau may also be used; it is, however, less distinct and is somewhat obscured by surrounding soft tissue and the head of the fibula. The patella is *not* a satisfactory landmark, as it shifts with quadriceps action and knee motion (9, 10).

The patellar ligament is a soft tissue structure and, although its fibers



FIGURE 8.—X-ray demonstrating distance between the ischial tuberosity and the ischial seat of an above-knee prosthesis (weight-bearing). [Note: The prosthesis was well-fitted and the patient was comfortable.] (Courtesy of Veterans Administration Prosthetics Center.)

permit relatively little extensibility (11), it does not meet the criteria stated earlier. The tibial tuberosity, which serves as the insertion for the quadriceps tendon (patellar ligament), could be considered as a variation from the standard. However, its location distal to the knee joint does not ideally meet the criteria for anatomic placement.

Hence, there are two below-knee stump length measurements—medial tibial plateau to bony end (*functional* stump length) and medial tibial

Ross: Stump Length Measurement

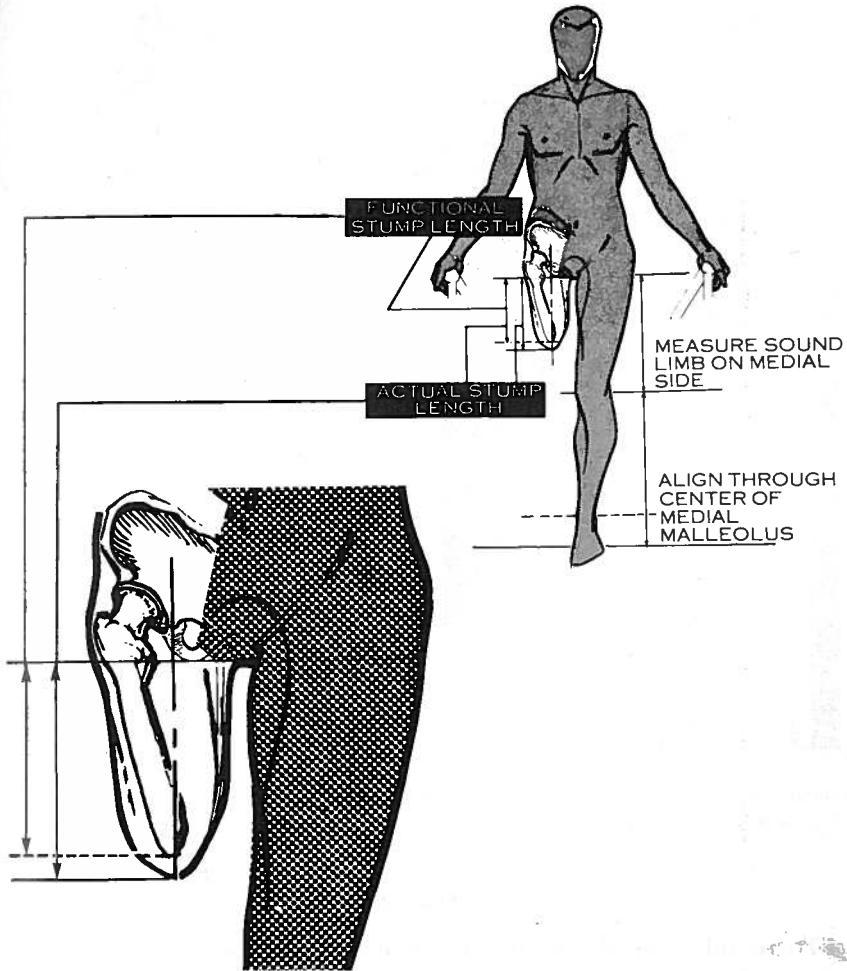


FIGURE 9.—Sound lower-extremity and above-knee stump length measurements. Stump should be positioned in the midline, avoiding flexion, extension, abduction, or adduction.

plateau to fleshy end (*actual* stump length) (Fig. 10). Alternative reference points should, of course, be recorded with the measurement.

The Sound Limb

To ensure uniformity, measurement of the sound limb should coincide with measurement of the amputated limb. If ischial tuberosity or medial tibial plateau to stump end measurements are taken for the amputated side, then ischial tuberosity (reference line) to medial tibial plateau to the floor on the medial side (with reference line through the medial malleolus) should be recorded for the sound lower extremity (Fig. 9).

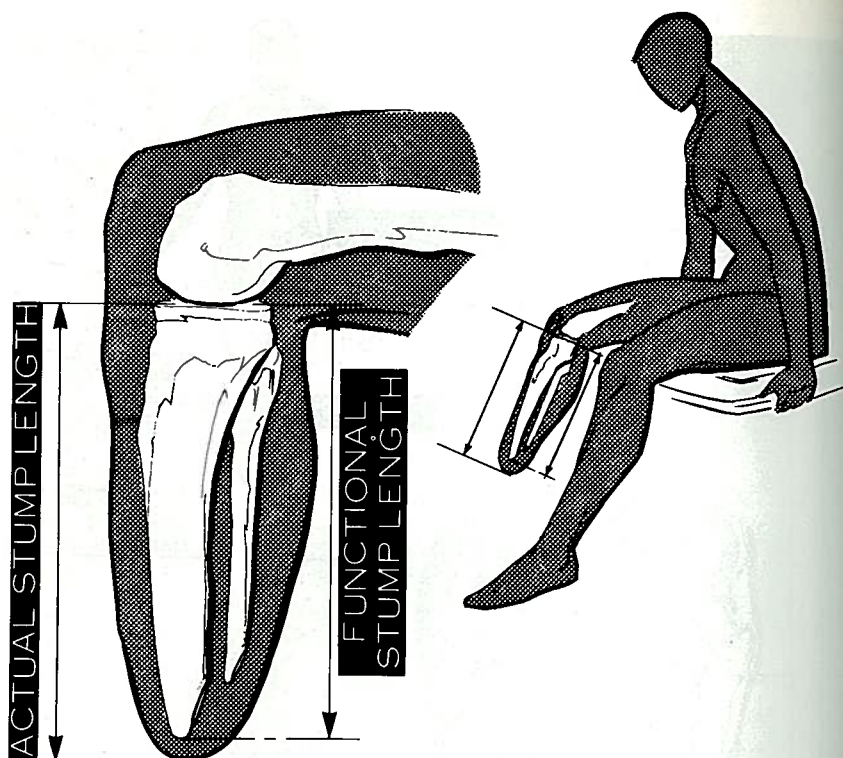


FIGURE 10.—Below-knee stump length measurements. The stump should be held in a slightly flexed position.

SUMMARY

To recapitulate, the measurement of amputation stump length has been a step in the process of patient evaluation that has been taken for granted. Although the universities, fitting and fabrication manuals, and the American Board for Certification teach and expect certain standards, various other reference points are occasionally used and interchanged without regard to the need for consistency.

Guidelines for proximal and distal landmarks and for positions of the extremities during measurement have been presented; they are outlined in Table 1.

It is anticipated that unusual cases might preclude the use of the standard reference points; in these cases, the alternative landmarks should be recorded. Acceptable alternatives are presented in Table 1.

TABLE 1.—Guidelines for Measuring Stumps and Sound Limbs

Upper Extremity	Stump length measurement		Measurement of sound limb	Position for measurement
	Actual	Functional		
Above elbow	Acromion to fleshy end Axilla to fleshy end	Acromion to bony end Axilla to bony end	—	Arm in slight passive abduction
	Lateral epicondyle (olecranon; medial epicondyle *) to fleshy end	Lateral epicondyle (olecranon; medial epicondyle *) to bony end	—	Forearm in flexed, mid-pronated position
Sound limb	—	—	Acromion to lateral epicondyle to ulnar Styloid (or thumb tip *) (Medial epicondyle to ulnar styloid ^a)	Arm in slight passive abduction, forearm flexed in mid-pronated position
Lower Extremity				
Above knee	Ischial tuberosity (or greater trochanter *) to fleshy end	Ischial tuberosity great- er trochanter *) to bony end	—	Neutral position, midline (avoid flexion, extension, abduction, or adduction)
Below knee	Medial (lateral *) tibial plateau to fleshy end	Medial (lateral *) tibial plateau to bony end	—	Knee in flexion
Sound limb	—	—	Ischial tuberosity to medial tibial plateau to floor on medial side of foot (ref. line through medial malleolus)	AK—Standing with knee of sound limb extended (not hyperextended) BK—Sitting with knee flexed at “90°”

* Recommended alternatives—if used, must be noted on measurement chart.

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