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THE SEGMOMETER: REPLACEMENT OF THE CLASSICAL ANTHROPOMETER TO OBTAIN SEGMENTAL LENGTHS

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Abstract: *A new commercially available instrument, the Rosscraft Segmometer, is proposed as a replacement for the classical anthropometer of the Martin type for obtaining segmental lengths. The evolution of the new instrument, and its design features and details of manufacturing are discussed in chronological sequence. The technical error of measurement on bilateral replicated measures involving 30 young gymnasts showed technical errors of measurement less than 1 percent that compared favorably to those obtained using the Segmometer 2 in group deployment and to those of the Segmometer 1 used to compare measures to those obtained by the classical anthropometer.*

Key words: *Anthropometry, anthropometer, instrument design, segmental lengths, segmometer, technical error of measurement.*

Introduction

Marshall McLuhan the Canadian media prophet remarked that "We observe the present through a rear-view mirror. We march backward into the future." The first automobile was simply a "horseless carriage". Perhaps because the early cars were notoriously unreliable the design was practical. The shouts of derision "get a horse" was often the expedient solution to the problem of transportation.

In the design of anthropometric instruments, the anthropometer, a device for measuring projected and derived lengths, has been virtually unchanged for 70 years. The illustration Fig. 1. shows Rudolf Martin's classical instrument (Martin, 1928). An updated instrument, with square magnesium sections and plasticized coating is still manufactured by GPM, Gneupel, Switzerland and marketed by Siber-Hegner Inc.

The senior author (WDR) was introduced to the original stainless steel anthropometer by Howard V. Meredith whom James Tanner designated as the greatest anthropometrist of his generation. Realizing that instability of the anthropometer caused untoward error, WDR designed a plastic foot-base attachment in the early 1970's that has been widely emulated.

The design faults of the classical instrument became evident from heavy student use at Simon Fraser University. The disarticulated pieces were not exactly compatible or interchangeable. The end branch and the broached plastic sliders occasionally were broken. The disarticulated end section when used as a wide sliding caliper had the tendency to bind. Pressure at the end of the long branches made this inevitable. Moreover, the use of recurved branches to obtain anterior-posterior chest breadth was never really satisfactory. The tendency to bind did not easily permit small excursions in locating the spinous process of the vertebra at the level of the mesosternale.

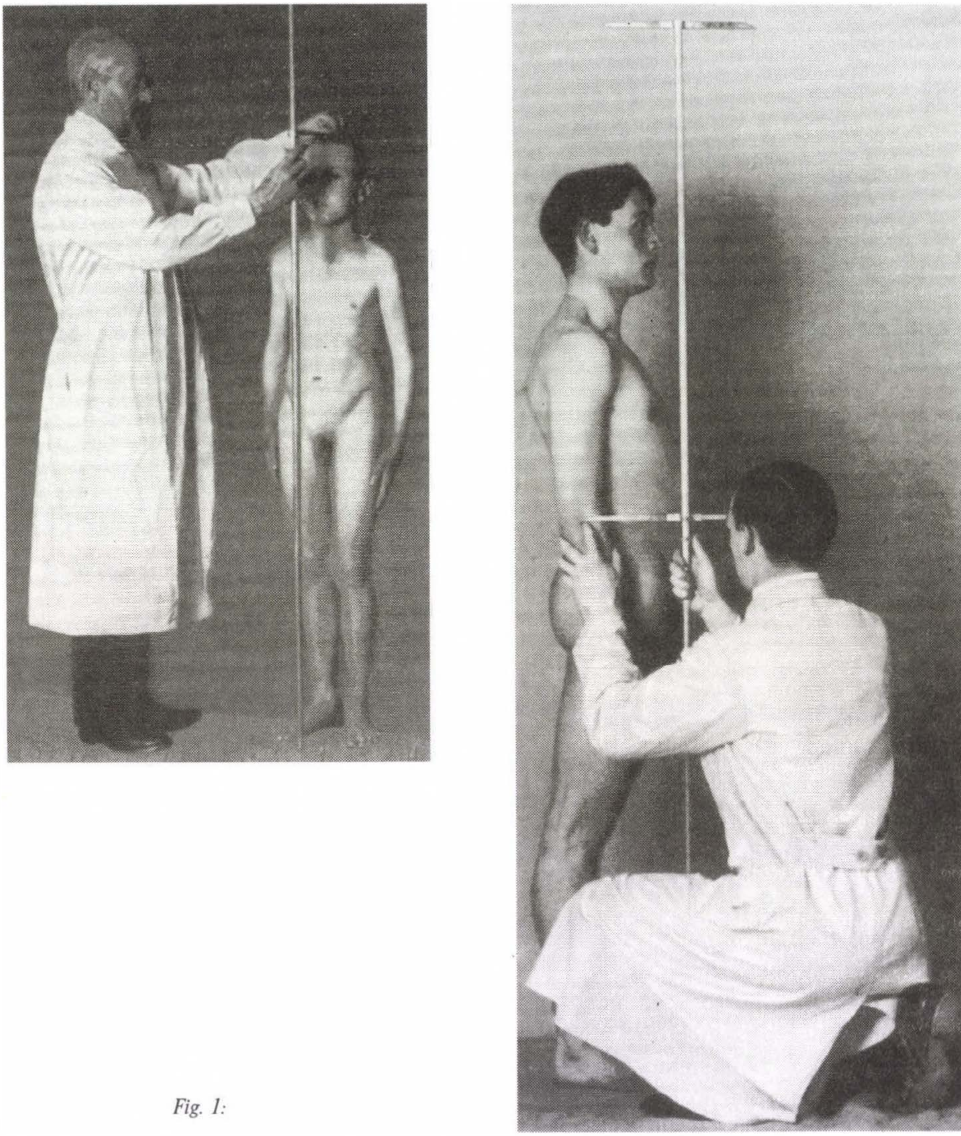

Fig. 1:

The cost of the instrument created a problem for investigators as well as for the senior author whose requests for replacement of used instruments seemed always to have a low priority in the Department of Kinesiology. Necessity, being the mother of invention, resulted in the design of a new anthropometer that could be easily replicated in non-specialized machine shops (Ross, 1985).

In 1988, Linda Blade, then a graduate student was scheduled to join her husband, an agricultural scientist in Nigeria. Her intent was to initiate studies, in particular to look at proportional segmental lengths in African children to determine if systematic differences were similar to those found in comparing black and white Olympic athletes (Ross et al., 1984). We thought of using pointers affixed to a retractable carpenter's tape to measure segmental lengths. In order to demonstrate the principle, Linda used filed cotter pins. The end pointer was fixed to the stub end of the tape by 5 minute epoxy glue. Another pointer at the housing end was secured by an elastic band as shown in Fig. 2. We tested the prototype instrument and found that it was as accurate or more accurate than the classical anthropometer (Carr et al, 1993).

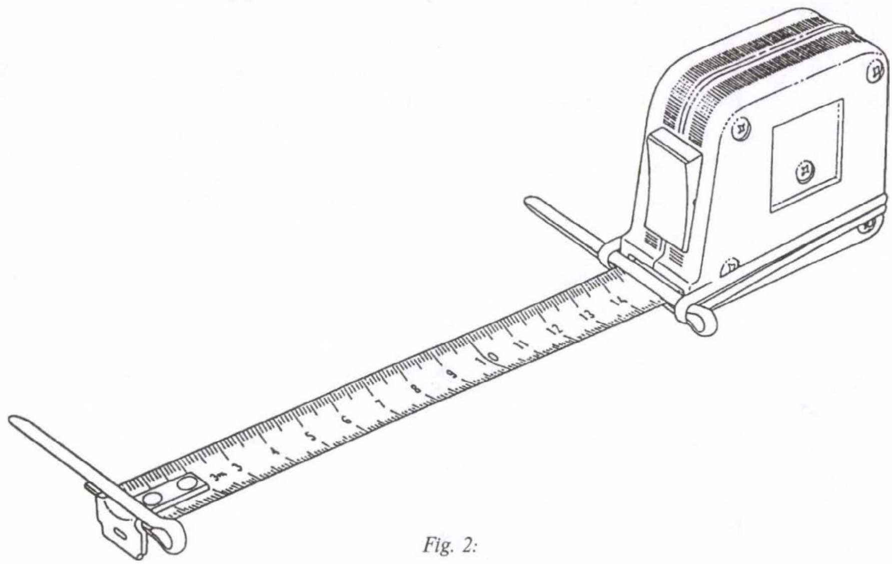

Fig. 2:

Some improvement of the design was made in the Machine Shop of the Department of Human Movement Studies of the University of Western Australia. Essentially, as shown in Fig. 3, this was to stabilize the passage of the tape in the tape housing. The new segmometers were used in Perth in 1991 in the Kinanthropometric Aquatic Sports Project (KASP) reported by Carter and Ackland (1994). The specification of techniques and obtained technical errors of measurement from replicated measurement by different measurers are included in Appendix B of the report by Ross et al. (1994).

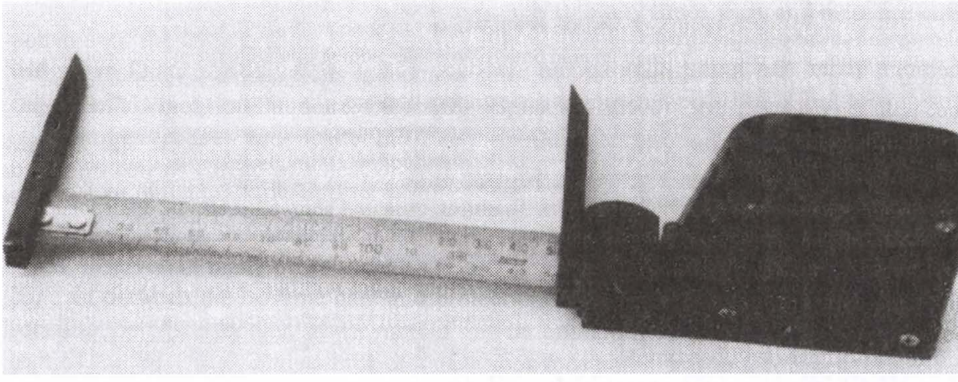

Fig. 3:

Segmometer 3

In the expansion of Rosscraft, a science and technology transfer company since 1981, the segmometer was redesigned and manufactured by T.E. and B. Ross. The new instrument, was designated as the Segmometer 3, the first being the Blade model and the second, the adapted version designed at the University of Western Australia and used in KASP.

The Segmometer 3, dispensed with the tape housing and featured machined end- and sliding-pointers as shown in Fig. 4. A blue tape at the inside edge right angles to the scale provides for measures of direct segmental lengths, and a laser engraved scratch line on the viewing glass provides for reading of projected heights. The parts are tumbled to achieve a satin finish for black anodizing. A machined track with Teflon insert and a fiber adjustment screw ensures smooth passage of the tape without lateral play. Ostensibly simple, the manufacture of the Segmometer 3 requires 13 milling, 7 drilling, 5 tapping, 2 riveting, 2 tumbling, 2 anodizing, 2 laser and 10 assembly operations on each instrument.

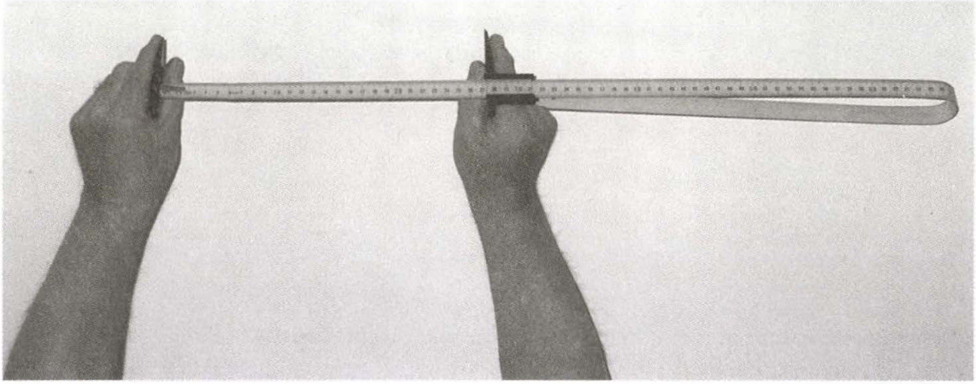

Fig. 4:

Subjects

One of the first applications of the Rosscraft Segmometer 3 was in team deployment of anthropometrists in a pilot project for a proposed longitudinal study of gymnasts at Western Washington University. Thirty young girl gymnasts were studied using single and on occasion double replicated measures bilaterally of the following segmental lengths: arm (acromiale-radiale), forearm (radiale-stylion), hand (midstylion-dactlion), thigh (trochanterion-tibiale laterale), and tibia (tibiale mediale-sphyrion tibiale).

Methods

The techniques used with the exception of ulna length were similar to those reported by Ross, et al. (1994) and Ross (1996), and those endorsed for the national standardization scheme in Australia as specified in the new textbook an Anthropometria (edited by Norton and Olds, 1995). The techniques are also specified in addenda files with the software for the O-Scale Physique Assessment System (Rosscraft course 2000 version).

Analyses

The data were analysed using the technical error of measurement (TEM) advocated by Dahlberg (1940), Johnston et al. (1972), Mueller and Martorell (1988) and Knapp (1992). Precision from replicated measures was expressed as follows: TEM = (sum d^2/2n)^.05, where (sum d^2) is the sum of the square of the differences between the first and a replicated measurement, and (n) is the number of comparisons.

Table 1 shows summary data using Segmometer 1 by Carr (1994), Segmometer 2 in the team deployment in KASP (Ross et al. 1994), and Segmometer 3 in the present study. The obtained values in KASP using the Segmometer 2, were obtained by different measurers. Although acceptable, especially in comparsion with technical errors using the classical anthropometer, they were not as precise as those obtained by Carr using the Segmometer 1. Clearly, the technical errors by Carr using Segmometer 3 defines new levels of precision attainable for segmental lengths by a single measure (Fig. 5).

Table 1: Precision summary of three segmometers

Segmental Lengths:	arm	forearm	hand	thigh	tibia
Segmometer 1					
Mean R	33.67	28.86	18.89	45.23	39.60
SD	2.80	2.53	1.57	3.67	3.34
SE	0.13	0.04	0.08	0.18	0.17
TEM	0.24	0.19	0.19	0.28	0.19
N*	165	165	165	165	165
Segmometer 2					
Mean R	33.97	25.9	19.63	44.64	38.74
SD	2.66	2.08	1.55	3.22	3.08
SE	0.31	0.24	0.18	0.36	0.35
TEM	0.28	0.35	0.24	0.40	0.20
N	76	75	75	79	79
Segmometer 3					
Mean R	26.83	20.32	15.60	36.35	32.31
SD	3.15	2.31	1.37	3.74	3.23
SE	0.41	0.30	0.18	0.48	0.42
TEM	0.09	0.09	0.10	0.12	0.06
N	30	30	30	30	30
Segmometer 3					
Mean L	26.68	20.23	15.68	36.18	32.26
SD	3.11	2.30	1.36	3.79	3.32
SE	0.40	0.30	0.18	0.49	0.43
TEM	0.13	0.09	0.10	0.12	0.10
N	30	30	30	30	30

*N = 1-2, 2-3, 1-3; other 1-2

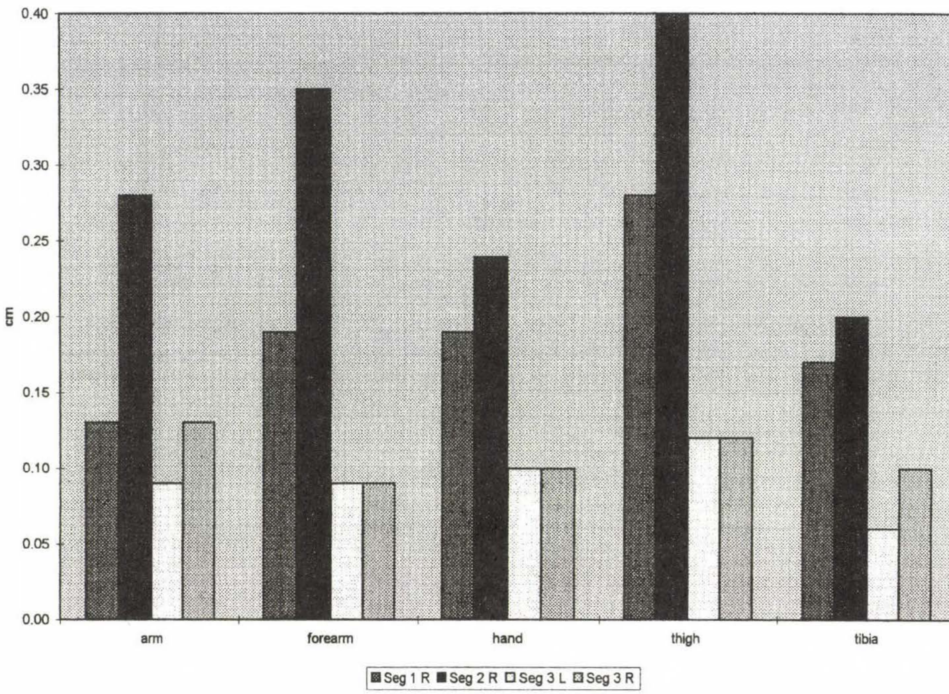

Fig. 5:

Discussion and Conclusions

In a previous paper by Carr (1993) we demonstrated that the rustic segmometer using filed cotter pins affixed with exoxy glue to an end pointer and an elastic band to the housing of a retractable carpenter's tape was a viable alternative to using the classical anthropometer. An ostensibly improved segmometer used in KASP in a team deployment yielded less precise values than those in the first study. One might attribute some of the difference to the precision of the team compared to Carr. Clearly, however, in the most recent study using the commercially available machined Segmometer 3, Carr was able to demonstrate new standards of precision for segmental lengths.

For those wishing to replace the anthropometer with segmometers as discussed in this paper, we have included a full description of techniques in Appendix A. We trust the information will encourage the measurement of long bone growth that heretofore may have been discouraged by the cost of anthropometers used for this purpose.

Acknowledgments: Rosscraft for instruments used in the preliminary studies of a longitudinal study of gymnasts at Western Washington University. Precision data for the Segmometer 2 was from the Kinanthropometric Aquatic Sports Project supported by grants from the Australian Sports Commission, Western Australian Ministry of Sport and Recreation, Eceed Sports Nutritionals Company, the Department of Human Movement Studies of the University of Western Australia and institutions of the international measurement team. We recognize too the contribution of Wayne Wilson in the studies related to the first segmometer.

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Appendix A

Measurement of Lengths

The landmarks for marking and measuring subjects in a comprehensive measurement protocol such as that in KASP are as follows:

Landmarks (including those used for measuring lengths)

Landmarks are defined points on the body used for reference for the application of instruments. Location of landmarks is a crucial part of the technique for obtaining accurate and precise measurement. A fineline felt or ball point pen with washable ink enables the anthropometrist to identify the underlying skeletal structure. In order to avoid ambiguity in the text or identifying the anthropometrist by a sexist pronoun, or awkward non-sexist phases, we address the reader as YOU and couched the text in a how-you-do-it style. We specify each landmark or technique tersely in an incomplete sentence. The general procedure for identifying a landmark is: (1) locate, (2) release and relocate, (3) mark, (4) check. The technique requires the use of the lateral nail of the thumb and distal nail of the index fingers of both hands. Cut and file your nails so they extend only slightly when you apply pressure to the fleshy portion of your thumb and index fingers. This assures subject comfort. Moreover, with properly groomed nails, landmarking and measuring can be done wearing rubber gloves without appreciable loss in accuracy as determined in student experiments.

With practice the following landmarks can be obtained very rapidly and accurately. The releasing, relocating and checking is automatic, assuring the surface of the skin does not distort the location of the landmark. Both hands are used in the process. We have included some nuances in how-to-locate landmarks on atypical subjects. Do not use these except when necessary. Normally, the sequencing in landmarking is unvaried with minimum manipulation and posing of the subject.

Do not innovate or teach nondescript anthropometry. If you propose an alternate procedure for location of a landmark or technique, provide the rationale and assemble the evidence. Petition the Chairman of the ISAK Working Group on Standards and Instrumentation for a considered opinion. Present the case formally, report the technical error of measurement on your proposed procedure and the standard procedure, and show the systematic difference between median values of each. This was done for the use of the segmometer and direct length procedures in this chapter, approved on the basis of economy, ease and precision, and later reported in the literature by Carr et al. (1993). In other instances, the proposition may be accepted as a "nuance" or occasional augmentation such as the hip manipulation to locate the trochanterion, recumbent position for measuring abdominal skinfold, and a double grasp for the measurement of front thigh skinfold.

(Note: Dr. J.E.L. Carter, San Diego, is the current Chairman of the Working Group on Instruments and Standardization of the International Society for the Advancement of Kinanthropometry.)

Acromiale: the point at the superior and external border of the acromion process of the scapula. (1) Place your pencil alongside the external border of the scapula to identify the superior margin. (2) Locate the most superior lateral margin with the left side of your left thumb. (3) Release and relocate with your left index finger nail. (4) Mark with a small horizontal line. (5) Check with the left side of your left thumb nail while your right thumb nail locates the radiale.

Radiale: The point at the upper and lateral border of the head of the radius. (1) Using your right thumb nail palpate downward in the lower portion of the lateral dimple of the elbow to locate the head of the radius. (2) Release and relocate with left index finger (a slight pronation/supination of the subject's forearm is reflected by a rotary movement of the head of the radius). (3) Mark. (4) Check using the side of the nail of your left thumb while you use the nail of your right thumb to locate the stylion.

Stylion: The most distal point on the processus syloidus radius. This is located in the so called "anatomical snuff-box" identified when the thumb is extended and adducted. (1) Place your right thumb nail in the box defined by the tendons (of the extensor carpi radialis longus and the adductor policus longus). Locate the stylion, the most distal tip of the radius. (2) Release and relocate with the nail of your left index finger. (3) Mark. (4) Check with the nail of the thumb of your left hand, freeing your right hand to start to locate the mesosternale.

Note: The stylion is the landmark for obtaining forearm length. We prefer a direct measure of hand length from the mid-stylion point to the dactlyion using the segmometer rather than deriving hand length from projected lengths of the stylion and dactlyion (Carr et al. 1993).

Mesosternale: The point on the corpus sterni at the intersection of the midsagittal and horizontal planes, at the mid-level of the fourth chondrosternal articulation. (1) A two-handed palpation method provides for rapid location of the landmark. You place your index fingers on the clavicles on either side of the manubrium sternum while your thumbs locate the first costal spaces, thus encompassing the first ribs. (2) Then move your index fingers to replace the thumbs that are lowered to the second intercostal spaces to identify the second ribs. (3) You repeat the procedure for the third and fourth ribs. (4) Mark the mesosternale that is at the mid-point of the sternum at the level of the center of the articulation of the 4th rib with the sternum.

Iliospinale: The most inferior tip of the anterior superior iliac spine. (In matters of adjusting for clothing, point to the site and tell the subject you wish to make a mark. Men invariably pull down their shorts, some women do, but mostly women and children pull up on the leg of their shorts). (1) Grasp the subject's left hip about the inquinal level with your left hand, use your thumb to palpate anteriorly to locate the undermost point of the anterior superior iliac spine. Occasionally, you will find it difficult to locate. Ask the subject to stand on his or her left foot, raise the heel of the right foot and rotate inwards and outwards on the ball of the right foot. The movement of the sartorius muscle can be traced to its origin at the site of the landmark. (2) As usual, release and relocate with the nail of the index finger. (3) Mark using a small cross mark. (4) Check using the nail of your left thumb.

Trochanterion: The most superior point on the greater trochanter of the femur. Location of this landmark requires a persistent technique. The subject takes a short stride forward resting the right foot on a raised object about 15 cm high. Stand behind the subject and locate and mark the trochanterion as follows: (1) Stabilize the subject's left hip with your left hand, (2) Palpate using the thenar eminence of your right palm (i.e., pad on the thumb side) by pushing on the lateral aspect of the subject's gluteal muscle to locate the right trochanter that is on a line with the long axis of the femur. (3) Identify the uppermost part by firm downward pressure of your hand. (4) Then have subject carefully assume the erect stance with weight equally distributed on each foot, and the toes pointing directly forward. (5) Use the side of your right thumb as a wedge to palpate anteriorly and upward on the head of trochanter to locate the most superior point. (6) Release the pressure and reapply with the nail of your left thumb or index finger. (7) Mark the site on the relatively undistorted skin surface. (8) Check with the right thumb assuring the site is directly over the trochanterion. Occasionally, in locating the landmark, you can ask the subject to extend his or her hip laterally, or, bend the knee and move the thigh forward and backward. If you are still doubtful, relocate the landmark when subject is recumbent on a table lying on the left side and facing away from you.

Tibiale Laterale: The most proximal point of the margo glenoidalis of the lateral border of the head of the tibia. It is often easier for you to locate the landmark by having the subject flex his or her leg at the knee, or sit down. The tibiale laterale is located as follows: (1) Find the depression or dimple in the knee, bounded by a triad of promenences: epicondylar femur, anterolateral portion of the head of the tibia, and the head of the fibula. (2) From this orientation, press inward using the side of your right thumb as a wedge, locate the border of the tibia, and palpate posteriorly until you locate the landmark, which is the most superior point. This is at least one-third of the anterior posterior distance. (3) Release, relocate with the nail of the index finger and mark. (4) Check pressing downward using the nail of your right thumb. (The tibiale laterale is approximately in the same transverse plane as the tibiale mediale.)

Tibiale Mediale and *Spherion Tibiale:* These landmarks define the length of the tibia. The subject sits and crosses his right leg over the left thigh presenting the medial side of the tibia. (1) Locate the proximal border of the tibia with the nail of your right thumb. (2) Release and relocate with the nail of your left index finger. (3) Mark. (4) Check using the nail of your left index finger pushing downward to the bony margin while searching for the spherion tibiale with your right thumb nail. (5) Locate the spherion tibiale, the most distal point on the tibia (not the lateral protuberant malleolare) with your right thumb nail. (6) Release and relocate with the nail of your left index finger. (7) Mark. (8) Check with the nail of your right thumb by pushing upwards to the designated landmark.

Mid-Acromiale-Radiale: A line is marked horizontal to the long axis of the humerus at the mid-acromiale-radiale distance, as determined by an anthropometric tape. (1) Wrap the anthropometric tape around the arm at the level of the mark, pinning the tape with your left thumb. (2) Mark horizontal lines at the level of the mid acromiale-radiale mark on the posterior and anterior surfaces of the surface of the arm. (3) With the subject having pendent arms with the hands along the high, make a vertical line at the most posterior surface to intersect with the horizontal line to mark the site where the triceps skinfold is raised. (4) With the subject very slightly rotating the hand outward, make a vertical line at the most anterior surface directly over the belly of the biceps brachaii to identify the site where the biceps skinfold is raised.

Mid-Stylion Line: The subject flexes at the elbow and presents the right wrist, palmar surface upward. (1) Wrap the tape around the wrist pinning it distal to the stylion ulnare and stylion radiale on the dorsal surface with your left thumb and second digit (it is not necessary to hold the case). (2) Draw a small line on the palmar surface at the proximal border of the tape in the mid portion of the wrist. (3) Release the tape and estimate the mid portion of the subject's wrist and make a cross on the previous line. (4) Check that the cross is in the mid portion and in line with the dactilion, the most distal point on the terminal phalanx III when the hand is extended with the fingers together.

Mid-Thigh: There are several methods for locating the mid-thigh. One is to use half the measured distance in a seated subject from the inguinal line at mid-thigh to the anterior margin of the patella. This is consistent with the technique for estimating the site for obtaining mid-thigh skinfolds. For girth measurement we prefer defining the mid-thigh as half the measured distance from the previously located trochanterion to the tibiale laterale when the subject stands erect. (1) In identifying this level you place anthropometric tape zero indicator on the marked site on the trochanterion and pin it there with pressure from the third digit of your left hand. (2) Let the tape hang freely and hold it to the thigh with your outstreched left thumb. (3) Extend the tape downwards and note the distance to the previously marked tibiale laterale. (4) Estimate half the distance on the tape held in place with your third finger and thumb and mark the lateral thigh at this level.

Lengths

Lengths (direct segmental or projected). Instructions for direct segmental and projected lengths (heights) are organized under two headings: Instruments and Techniques, as follows:

(1) Instrument: Rosscraft Segmometer is a replacement instrument for the anthropometer for obtaining direct segmental lengths and projected lengths (heights) from a measuring box. The segmometer consists of a base pointer and a sliding pointer on a flexible 105 cm tape. The indicator permits reading to 0.1 cm. The Segmometer 3, represents further refinement earlier versions designed to replace the traditional anthropometer (Carr et al. 1993, Ross et al. 1992, Norton et al. 1996, and Ross 1996). The recent version

features a looped tape with machined end- and sliding-pointers ans illustrated. Direct lengths are measured from the internal edge of the sliding pointer. Projected length, from a box top are measured at the laser engraved scratch line that subtracts the thickness of the base pointer. In manufacturing, the pinters are tumbled to achieve a satin finish for black anodizing. A machined track with Teflon insert and a fiber adjustment screw ensures smooth passage of the tape without lateral play. Ostensibly simple, the manufacture of the Segmometer 3 requires 13 milling, 7 drilling, 5 taping, 2 riveting, 2 tumbling, 2 anodizing, 2 laser and 10 assembly operations on each instrument (see <Segmometer 3> Fig. 4.).

(2) Technique: During direct and projected measures on the upper extremity, the subject stands erect with arms at the sides, and palms against the thighs. The segmometer sliding pointer is held in the left thumb and index fingers as one would hold a pencil. The pointer end is similarly grasped by the right thumb and index fingers. In the direct length technique, the upper landmark is approximated by the index finger of the left hand which anchors to the skin surface, stabilizing and protecting against penetration by the pointer. The sliding pointer is extended by the right hand to the lower site. In all direct measurements, the reading is made from the inside edge of the sliding pointer (not the scratch line that is used for projected measurements).

ACROMIALE-RADIALE LENGTH (arl). The distance from the acromiale to the radiale. The subject stands erect with arms extended downward and palms pressed against the side of the thigh. The anthropometrist anchors the end pointer with the index finger and rotates the pointer to the acromiale. The sliding pointer is placed on the radiale. Reading is from inside edge.

RADIALE-STYLION LENGTH (rls). The distance from the radiale to the stylion. The subject maintains the same position as for the acromiale-radiale lenght. The end pointer is placed on the radiale and the sliding pointer on the stylion. The orientation of the tape is such that it parallels the long axis of the radius. Reading is from inside edge.

MIDSTYLION-DACTYLION (dsl). The shortest distance from the midstylion line to dactylion III. The subject extends the right hand supinated (palms up), fully extending the fingers. The end pointer is place on the marked midstylion line, the sliding pointer held in the right hand is then applied to the dactylion, the most distal point of the third digit. Reading is from inside edge.

ILIOSPINALE HEIGHT (ish). Projected height from the box to the iliospinale. The subject stands the feet together facing the box, heels together with feet on either side of a corner of a box. The end pointer is placed flush on the box and the sliding pointer extended vertically upward to the marked iliospinale landmark. Reading is from the scratch line.

TROCHANTERION HEIGHT (tro h). Projected height from the box to the trochanterion. The subject stands with the feet together and facing away from the anthropometrist with the side of the right lower extremity against the box. The end pointer is placed flush on the box and the sliding pointer extended vertically upward to the marked trochanterion site. Reading is from the scratch line.

TROCHANTERION-TIBIALE LATERALE LENGTH (tr-tll). Distance from the trochanterion to the tibiale laterale. The subject stands on the box with feet together with the lateral surface of the right lower extremity facing the anthropometrist. The end pointer is anchored by the left index finger to the marked trochanterion site. The sliding pointer is extended with the right hand to the marked tibiale laterale. Reading is from inside edge.

TIBIALE LATERALE HEIGHT (til). Box to the tibiale laterale. The subject stands on box as above. The end pointer is placed flush on the box and the housing pointer extended vertically upward with the right hand to the marked tibiale laterale site. Reading is to the marked scratch line. Reading is from inside edge.

TIBIALE MEDIALE-SPHYRION TIBIALE (ti-sp). Direct length from tibiale mediale to sphyrion tibiale. The subject sits on the box and crosses the right leg over the left leg to present a horizontal medial surface of the leg. The end pointer is applied to the tibiale mediale site by firmly anchoring the left index finger to the proximal tibia border and placing the end pointer on the marked site. The sliding pointer is extended to the marked sphyrion tibiale, the most distal point on the medial malleolus, anchoring the right index finger slightly distal to the landmark and manipulating the sliding pointer to the exact site. Reading is from inside edge.

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