HAB718 Spor Biyomekaniğinde Hareket Analizi

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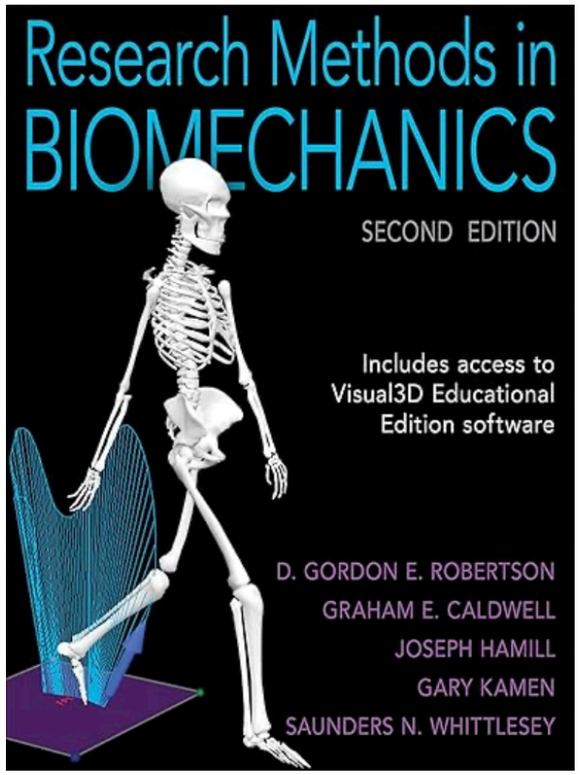
#6

- Body Segment Parameters



Chapter 3

Body Segment Parameters

D. Gordon E. Robertson

Anthropometry is the discipline concerned with the measurement of the physical characteristics of humans. Biomechanists are mainly interested in the inertial properties of the body and its segments, a body segment parameters. Before a kinetic analysis of human movement is possible, each segment's physical characteristics and inertial properties must be determined. The relevant characteristics are the segmental mass, locations of the segmental centers of gravity, and segmental mass moments of inertia.

Body Segment Parameters

12th April **1961** the Russian Cosmonaut Yuri Gagarin was the first human to make it past our planet's atmosphere and out into open space.

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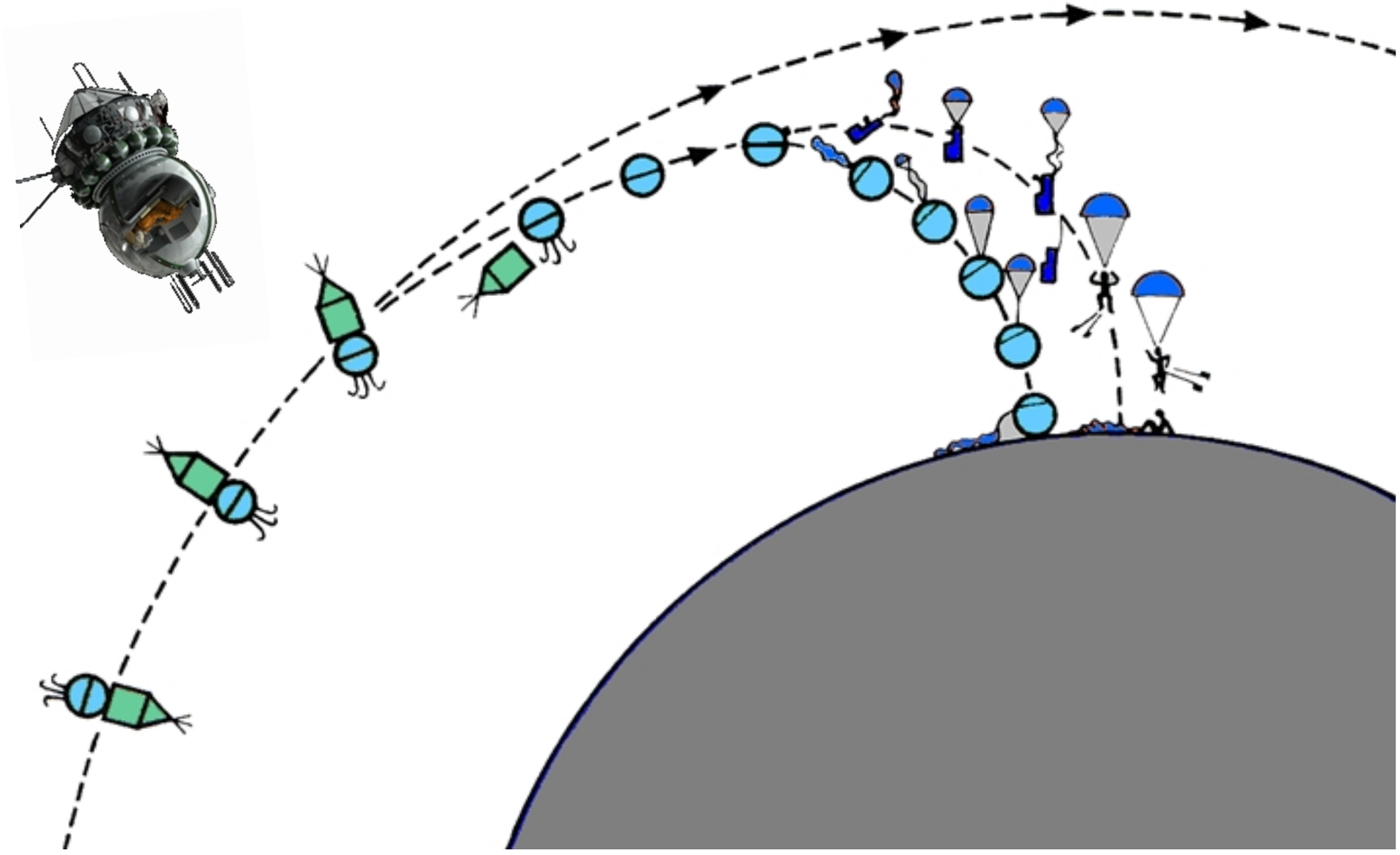
Body Segment Parameters



His entire journey in the Vostock 1 Rocket lasted 108 minutes (less than 2 hours) during which time he took off from the Baikonur Cosmodrome in the Southern deserts of Kazakhstan, orbited once around the Earth and landed safely back on land in Northern Russia.

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Body Segment Parameters

SPACE REQUIREMENTS OF THE SEATED OPERATOR

Geometrical, Kinematic, and Mechanical Aspects of the Body
With Special Reference to the Limbs

WILFRED TAYLOR DEMPSTER

UNIVERSITY OF MICHIGAN

JULY 1955

AERO MEDICAL LABORATORY
CONTRACT No. AF 18(600)-43
PROJECT No. 7214

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Body Segment Parameters

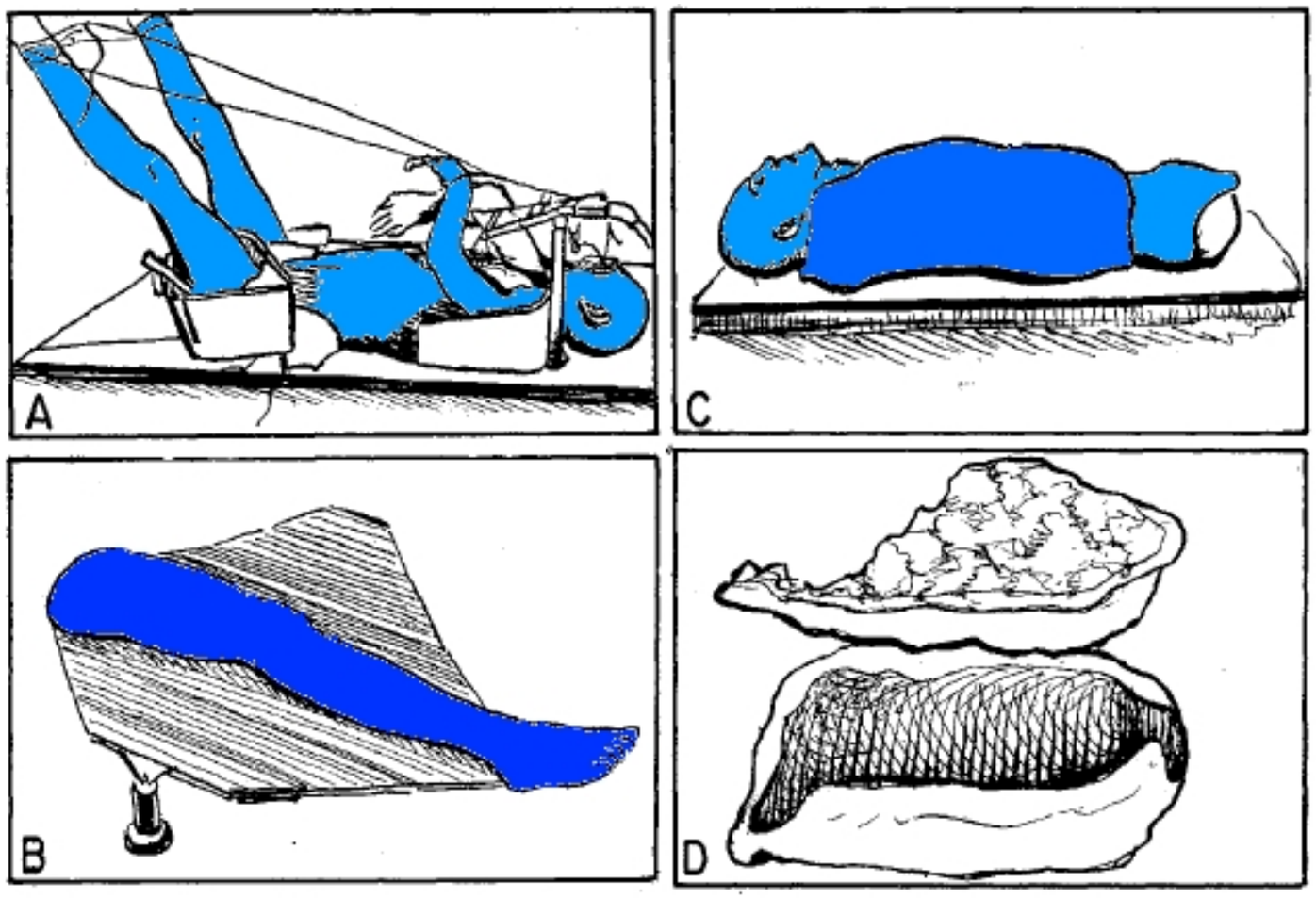

Figure 21. Procedures Associated with Cadaver Dismemberment. A—The cadaver was lashed on a work board with the hip and shoulder fixed at mid-range positions. Joints were frozen solid by dry ice in metal containers. B—Balance plate for determining the level of center of gravity of the lower limb. C—Preparation of plaster of Paris mould of the shoulder region. D—The shoulder mass, frozen solid, is shown lifted away from the plaster of Paris shoulder mould.

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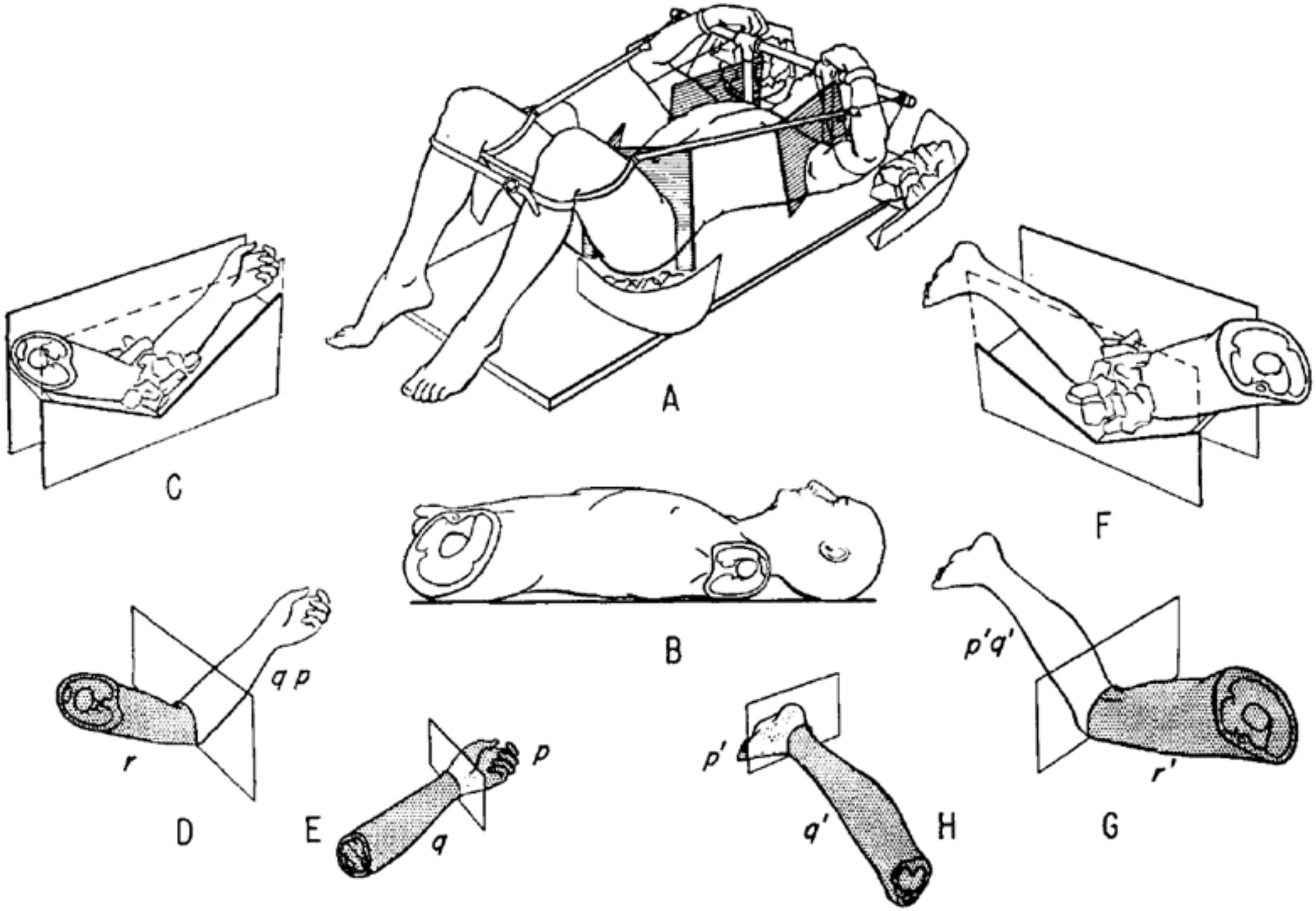
Body Segment Parameters



Body Segment Parameters

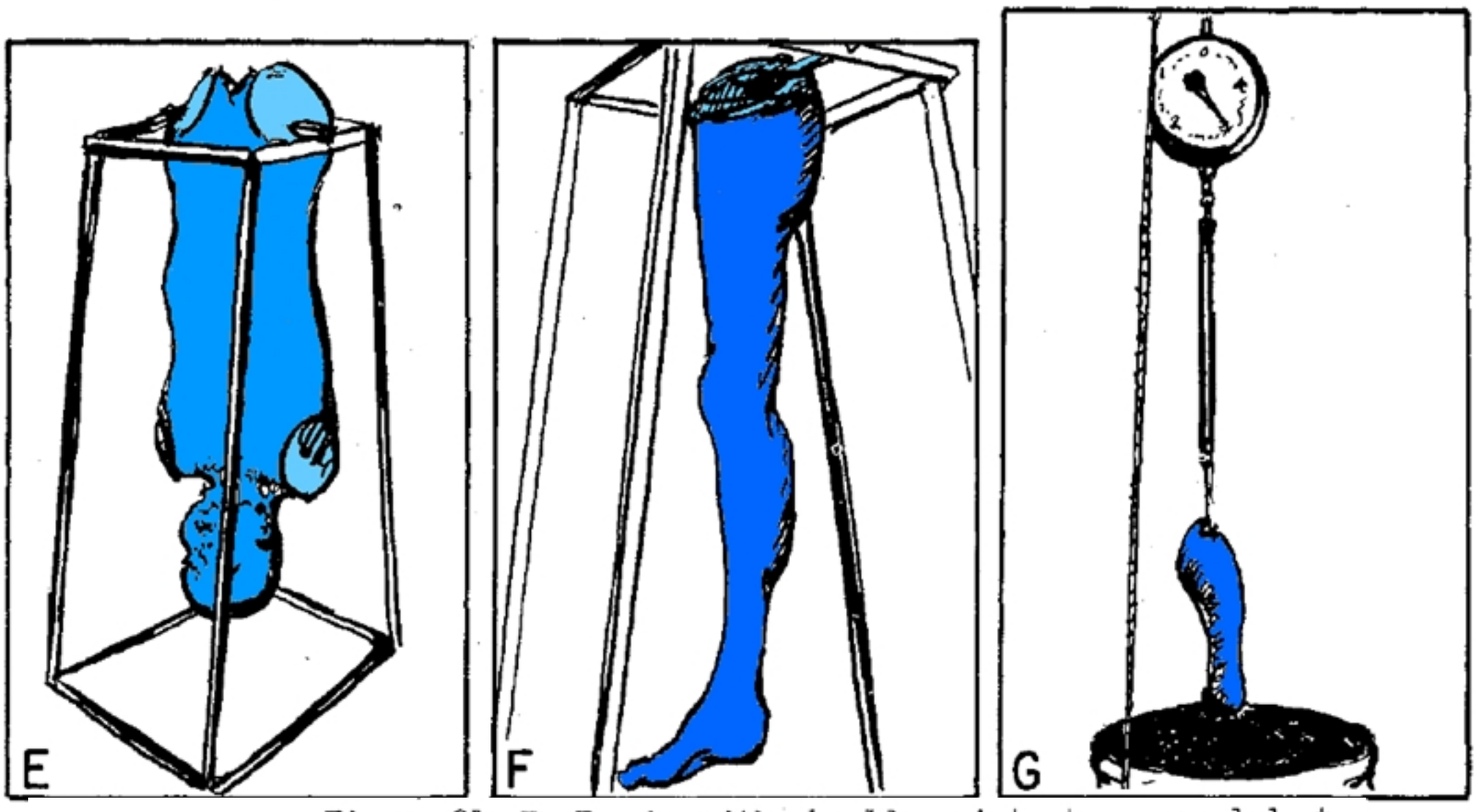


Figure 21. E—Trunk, with shoulders intact, suspended at the acetabula on knife edges for determination of oscillation time, a method associated with experimental determination of moment of inertia. F—Lower limb has been supported on knife edges for determination of the moment of inertia. G—Upper limb segment suspended from a scales prior to immersion in the tank of water below — for determination of the mass of water displaced (i.e., volume).

Body Segment Parameters

Dempster's Body Segment Parameter Data for 2-D Studies[1]

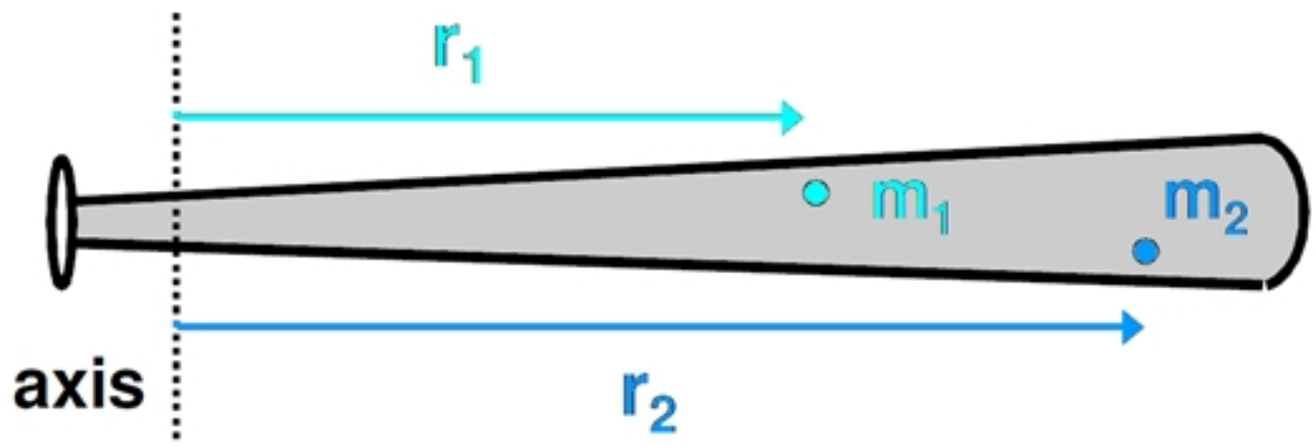
Segment name	Endpoints (proximal to distal)	Seg. mass /total mass (P)	Centre of mass /segment length ($R_{proximal}$)	(R_{distal})	Radius of gyration /segment length (K_{cg})	($K_{proximal}$)	(K_{distal})
Hand	wrist axis to knuckle II third finger	0.0060	0.506	0.494	0.298	0.587	0.577
Forearm	elbow axis to ulnar styloid	0.0160	0.430	0.570	0.303	0.526	0.647
Upper arm	glenohumeral joint to elbow axis	0.0280	0.436	0.564	0.322	0.542	0.645
Forearm & hand	elbow axis to ulnar styloid	0.0220	0.682	0.318	0.468	0.827	0.565
Upper extremity	glenohumeral joint to elbow axis	0.0500	0.530	0.470	0.368	0.645	0.596
Foot	lateral malleolus to head metatarsal II	0.0145	0.500	0.500	0.475	0.690	0.690
Leg	femoral condyles to medial malleolus	0.0465	0.433	0.567	0.302	0.528	0.643
Thigh	greater trochanter to femoral condyles	0.1000	0.433	0.567	0.323	0.540	0.653
Leg & foot	femoral condyles to medial malleolus	0.0610	0.606	0.394	0.416	0.735	0.572
Lower extremity	greater trochanter to medial malleolus	0.1610	0.447	0.553	0.326	0.560	0.650
Head	C7-T1 to ear canal	0.0810	1.000	0.000	0.495	1.116	0.495
Shoulder	sternoclavicular joint to glenohumeral joint	0.0158	0.712	0.288			
Thorax	C7-T1 to T12-L1	0.2160	0.820	0.180			
Abdomen	T12-L1 to L4-L5	0.1390	0.440	0.560			
Pelvis	L4-L5 to trochanter	0.1420	0.105	0.895			
Thorax & abdomen	C7-T1 to L4-L5	0.3550	0.630	0.370			
Abdomen & pelvis	T12-L1 to greater trochanter	0.2810	0.270	0.730			
Trunk	greater trochanter to glenohumeral joint	0.4970	0.495	0.505	0.406	0.640	0.648
Trunk & head	greater trochanter to glenohumeral joint	0.5780	0.660	0.340	0.503	0.830	0.607
Head, arms & trunk	greater trochanter to glenohumeral joint	0.6780	0.626	0.374	0.496	0.798	0.621
Head, arms & trunk	greater trochanter to midrib	0.6780	1.142	-0.142	0.903	1.456	0.914

[1] Adapted from D.A.Winter, *Biomechanics and Motor Control of Human Movement*, Second edition. John Wiley & Sons, Inc., Toronto, 1990.

Body Segment Parameters

Radius of Gyration

$$I_{AXIS} = \Sigma m_i r_i^2$$



$$I_{AXIS} = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + ... + m_n r_n^2$$

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Body Segment Parameters

Radius of Gyration

A more practical approach:

$$I_{AXIS} = m_{BODY}k^2$$

k indicates radius of gyration, which is an experimentally determined length that applies to the whole object at once k depends on the location of the axis and location of the mass.

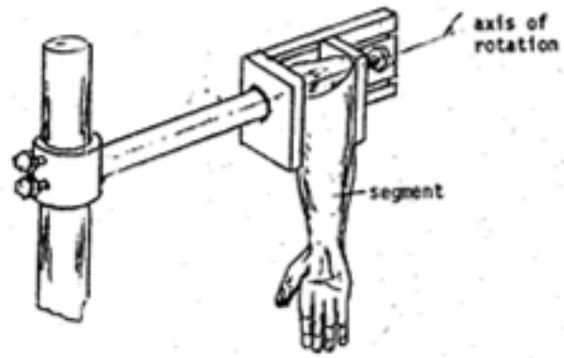

Figure 3-4. Determination of segment moment of inertia of oscillation.

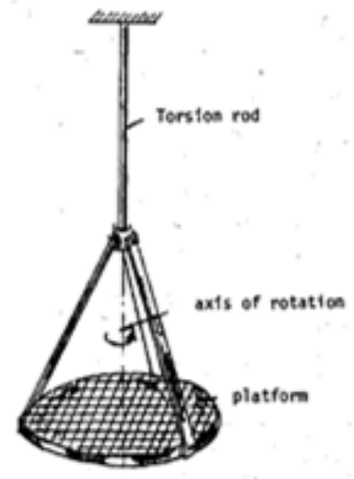

Figure 3-5. Torsional pendulum for determination of moment of inertia of segments.

Body Segment Parameters

Radius of Gyration

• Radius of gyration is the distance a particle with the same mass as the segment would need to be from the axis of rotation to have the same moment of inertia (angular inertia) as the segment

• Radius of gyration is really just a convenient way of “packaging” mass moment of inertia information

• In anthropometric data sets, k is often expressed relative to segment length

Mass Moment of Inertia

For a three dimensional object there will be 3 moments of inertia, typically expressed about the 3 principle axes of the segment For human limb segments, I_X and I_Z will be similar, I_Y will be much smaller

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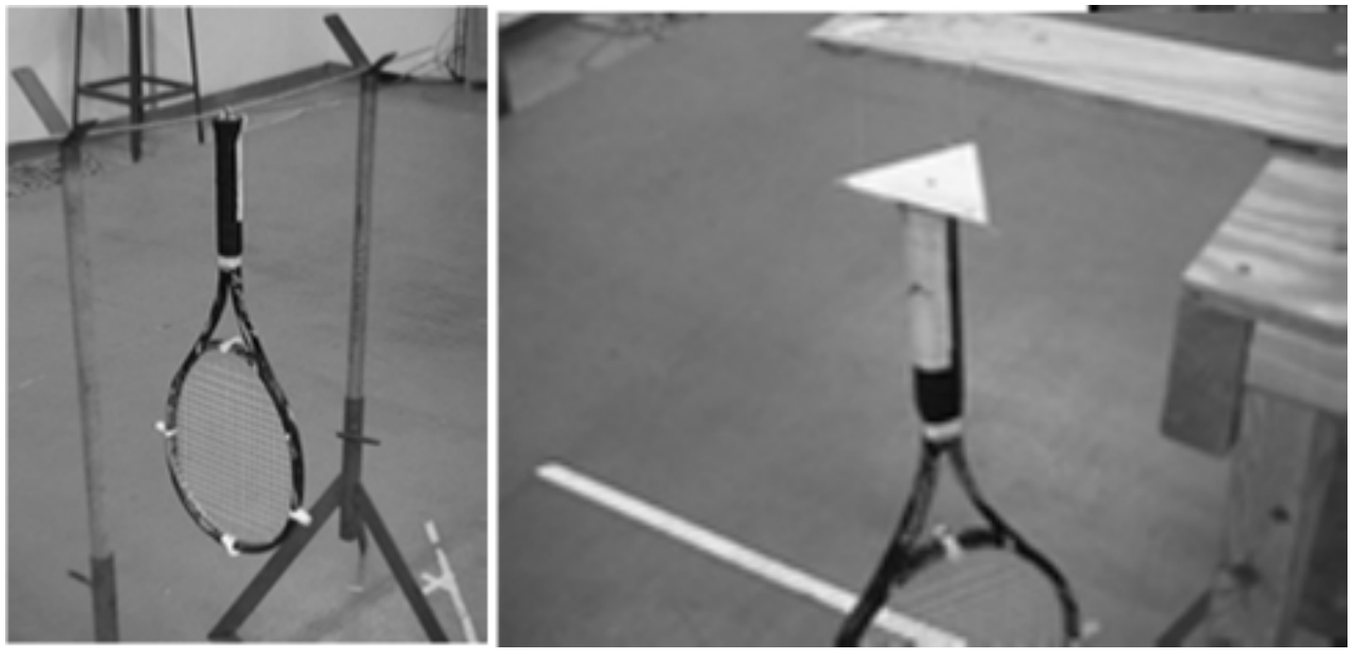
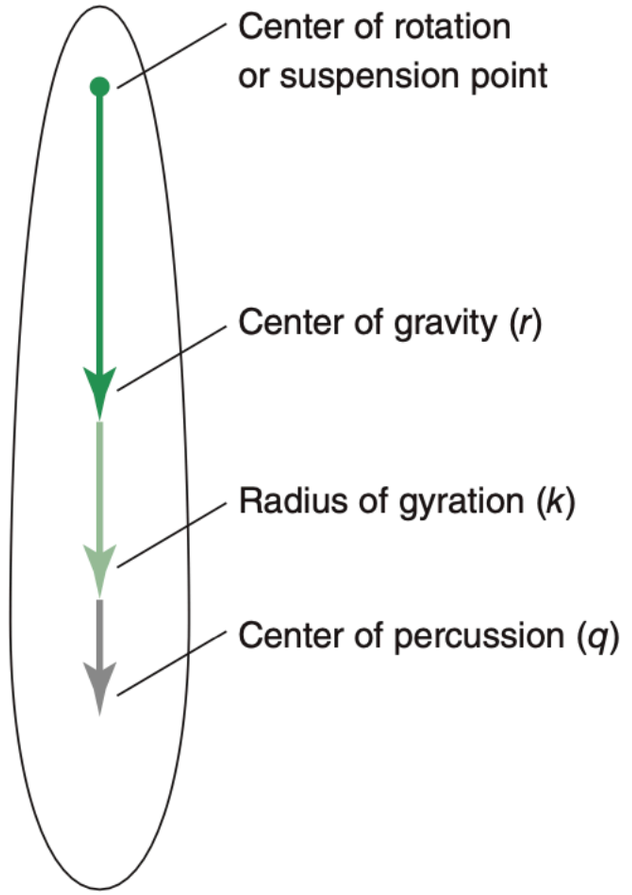
Body Segment Parameters

Center of Percussion



The **center of percussion** is not strictly speaking a body segment parameter. It is usually associated with sporting implements, such as baseball bats, rackets, and golf clubs.



▲ **Figure 3.7** Relative locations of the center of gravity *(r)*, radius of gyration *(k)*, and center of percussion *(q)*.

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Body Segment Parameters

Volume Calculations

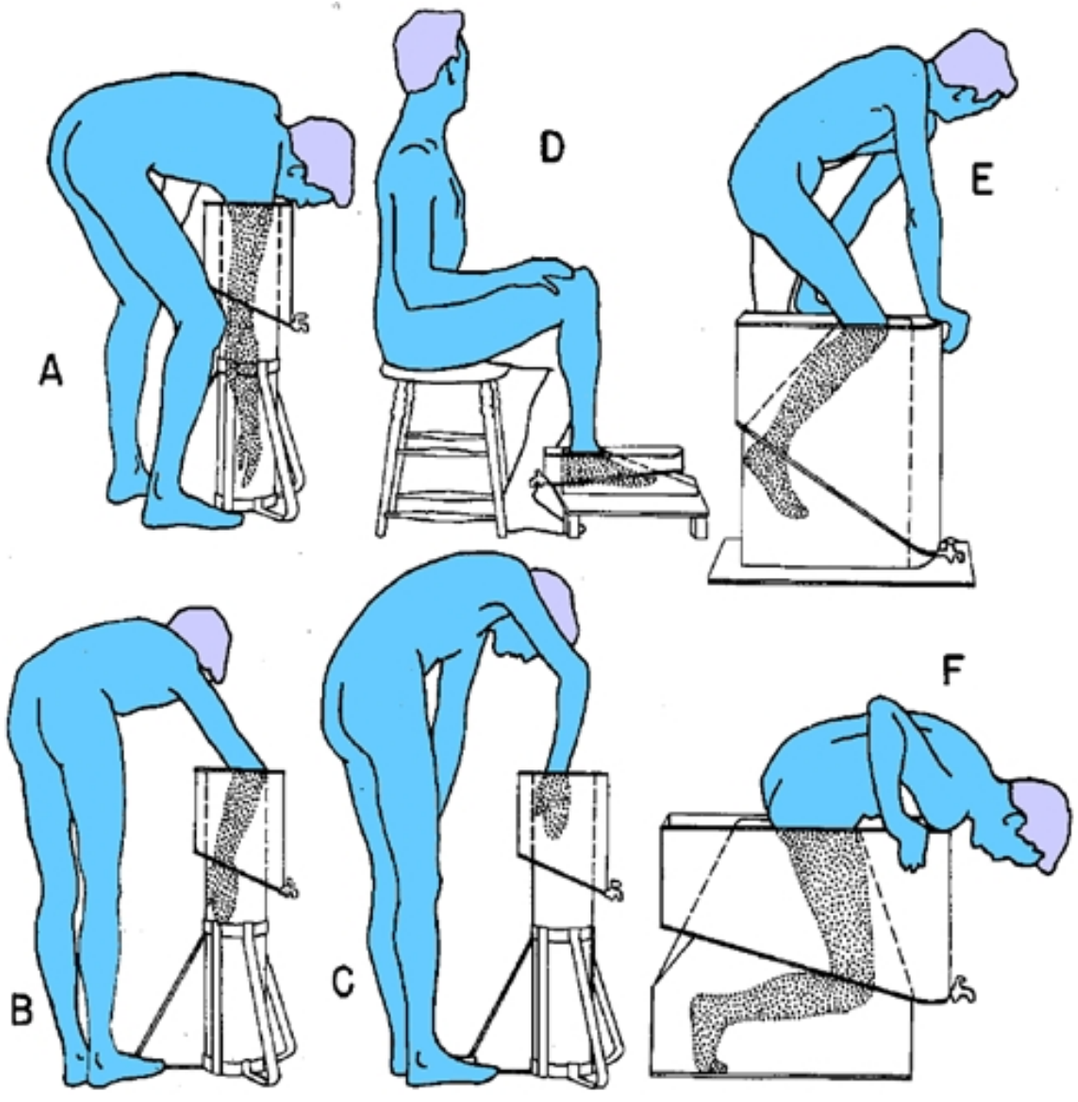
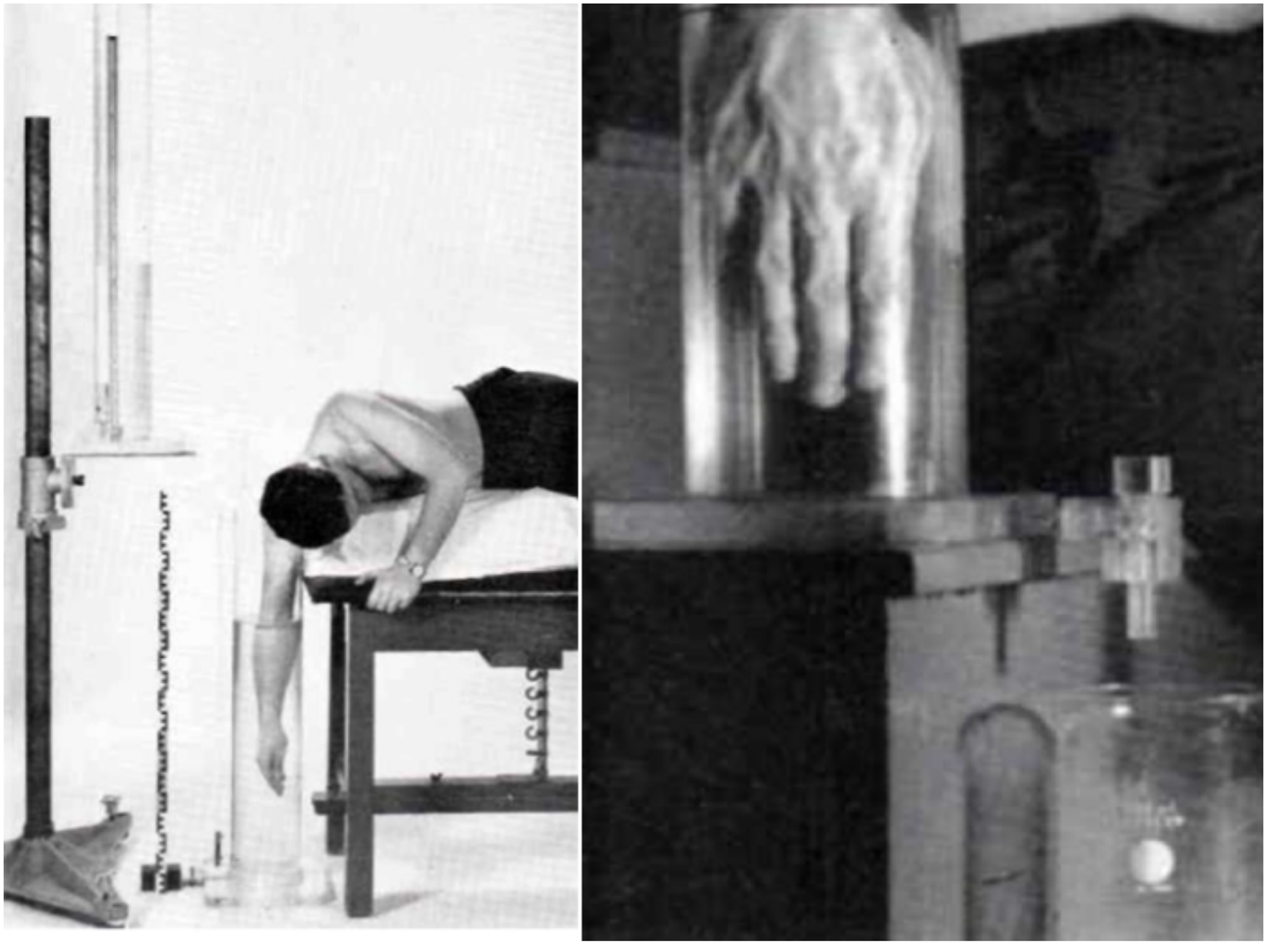


Figure 23. Segment Volume by Water Displacement. Methods of determining volumes of limb segments on living subjects by water displacement.

Body Segment Parameters

Volume Calculations



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Body Segment Parameters

WEIGHT, VOLUME, AND CENTER OF MASS OF SEGMENTS OF THE HUMAN BODY

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AUGUST 1969

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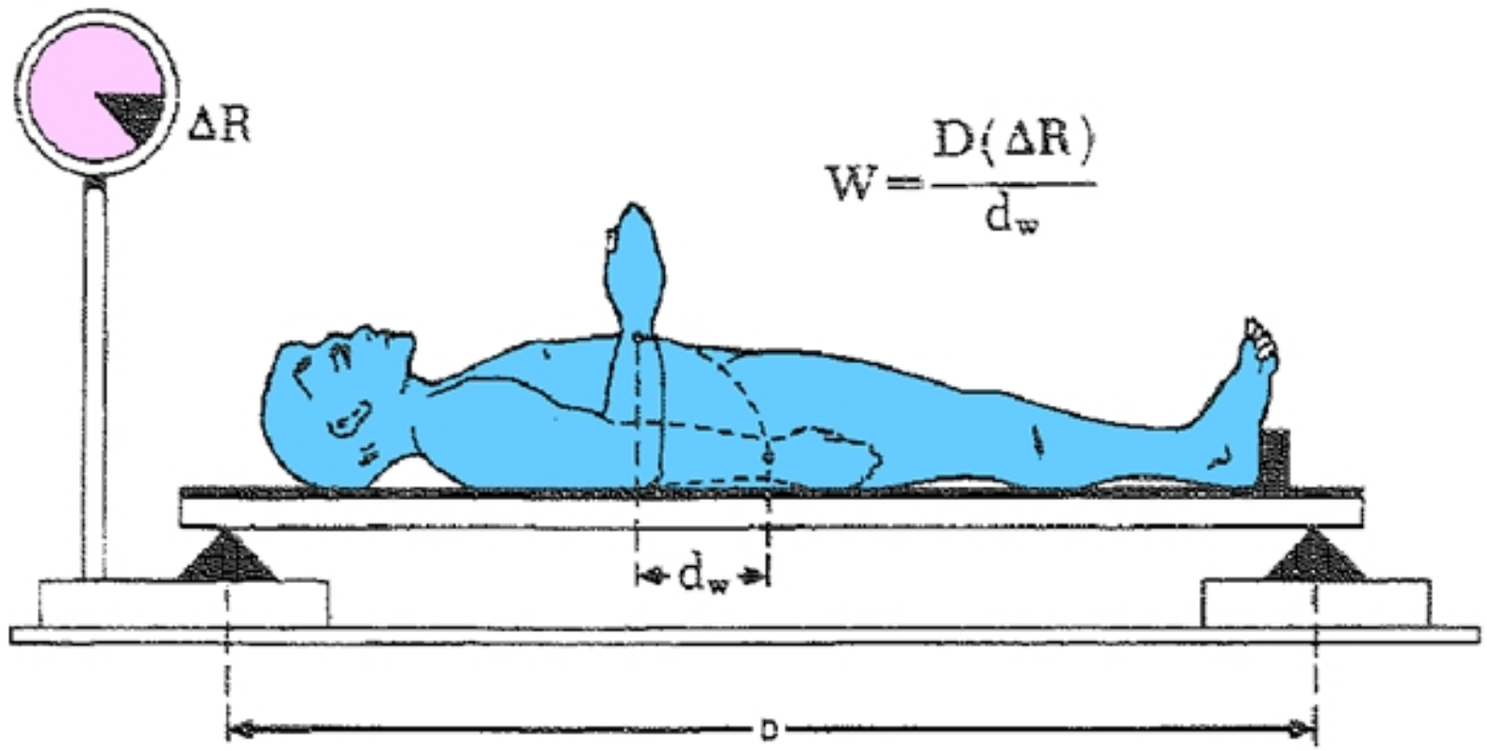
Body Segment Parameters



Determination of Forearm-Hand Weight

W - Weight of Forearm-Hand

ΔR - Difference Between Scale Readings

D - Distance Between Supports

d_w - Displacement of Center of Mass of Forearm-Hand

Figure 1. Estimation of a Segment's Weight by the Method of Reaction Change.

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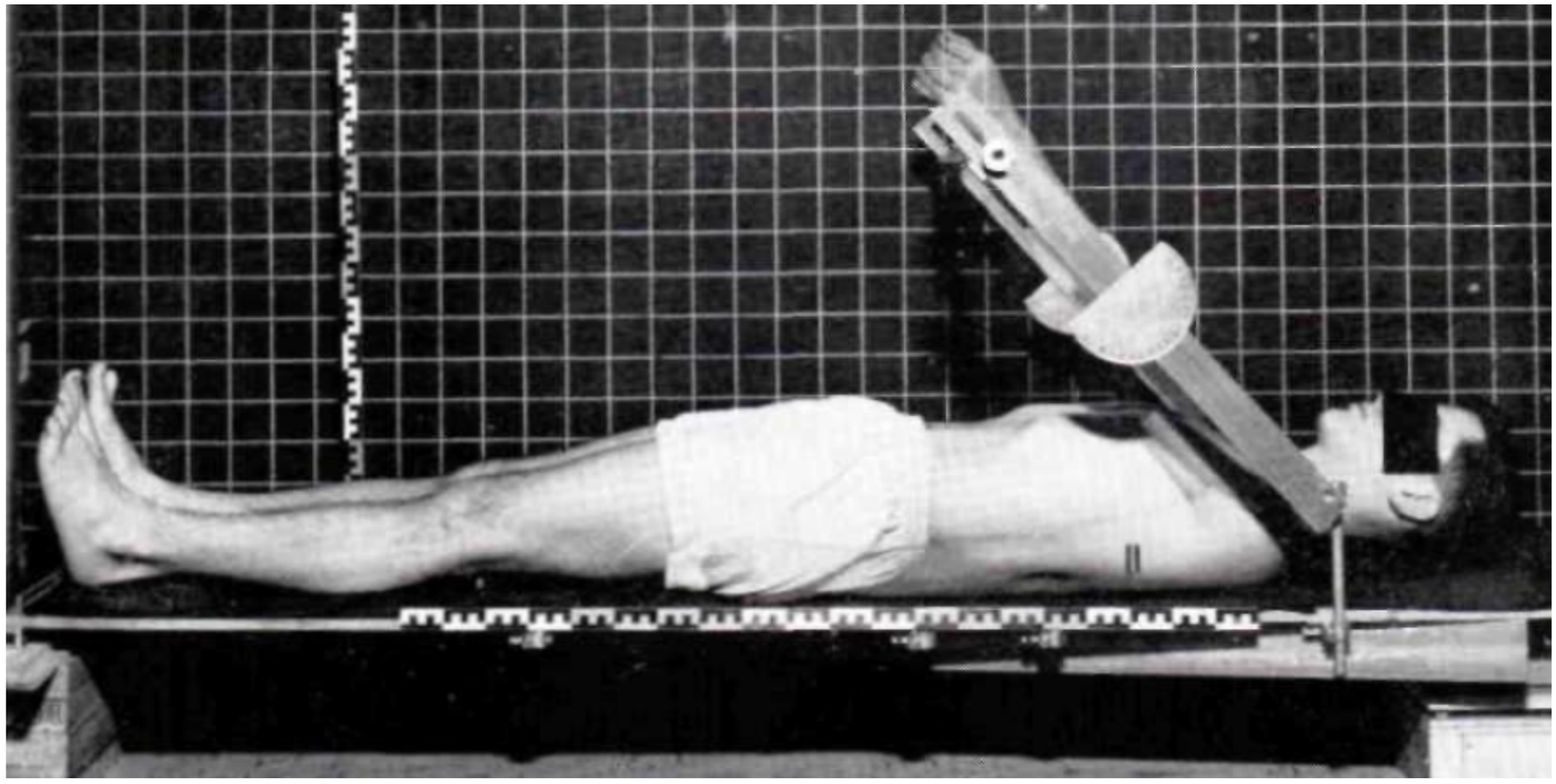
Body Segment Parameters



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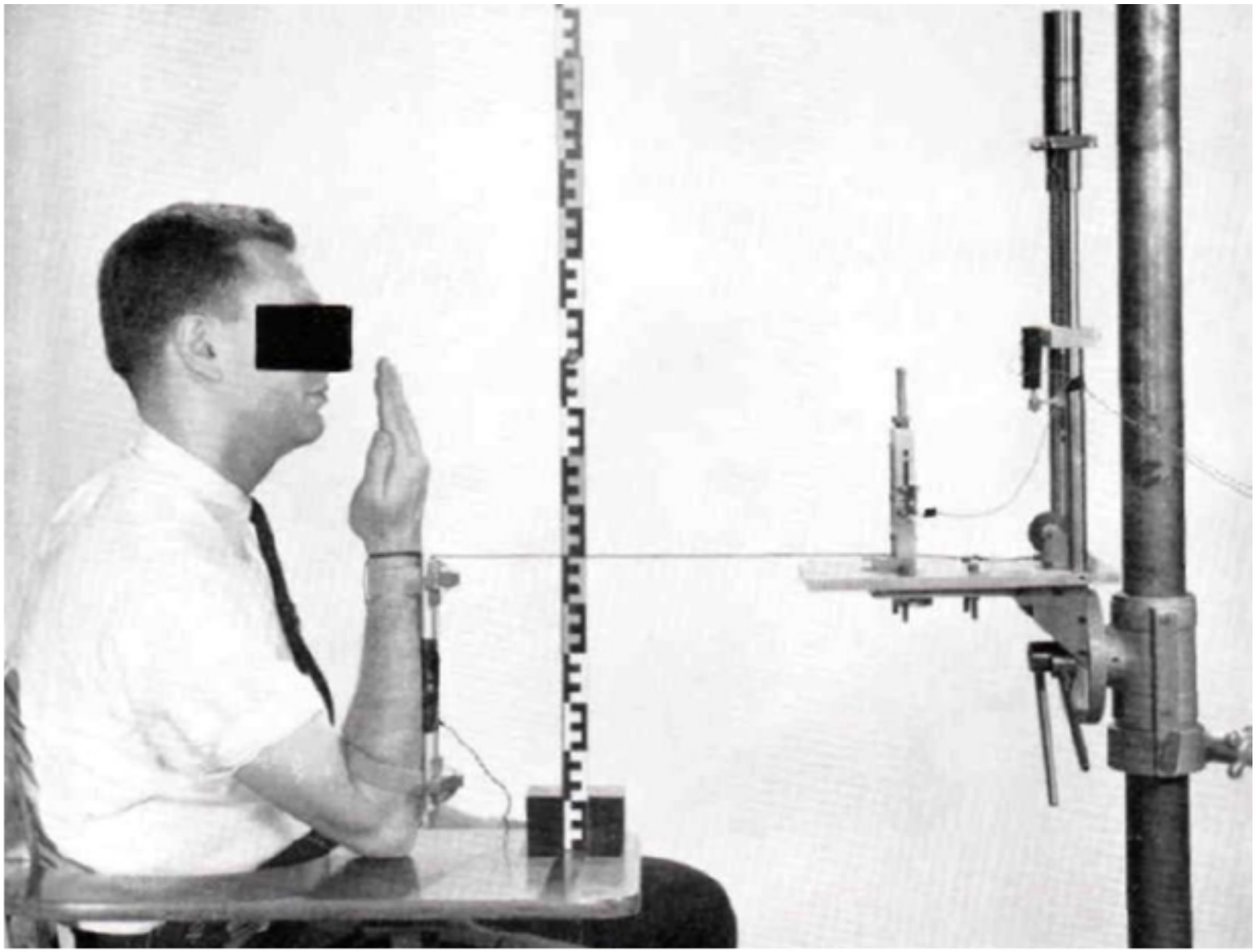
Body Segment Parameters



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Body Segment Parameters

Clauser's et al. Body Segment Parameters for 2-D Studies[1]

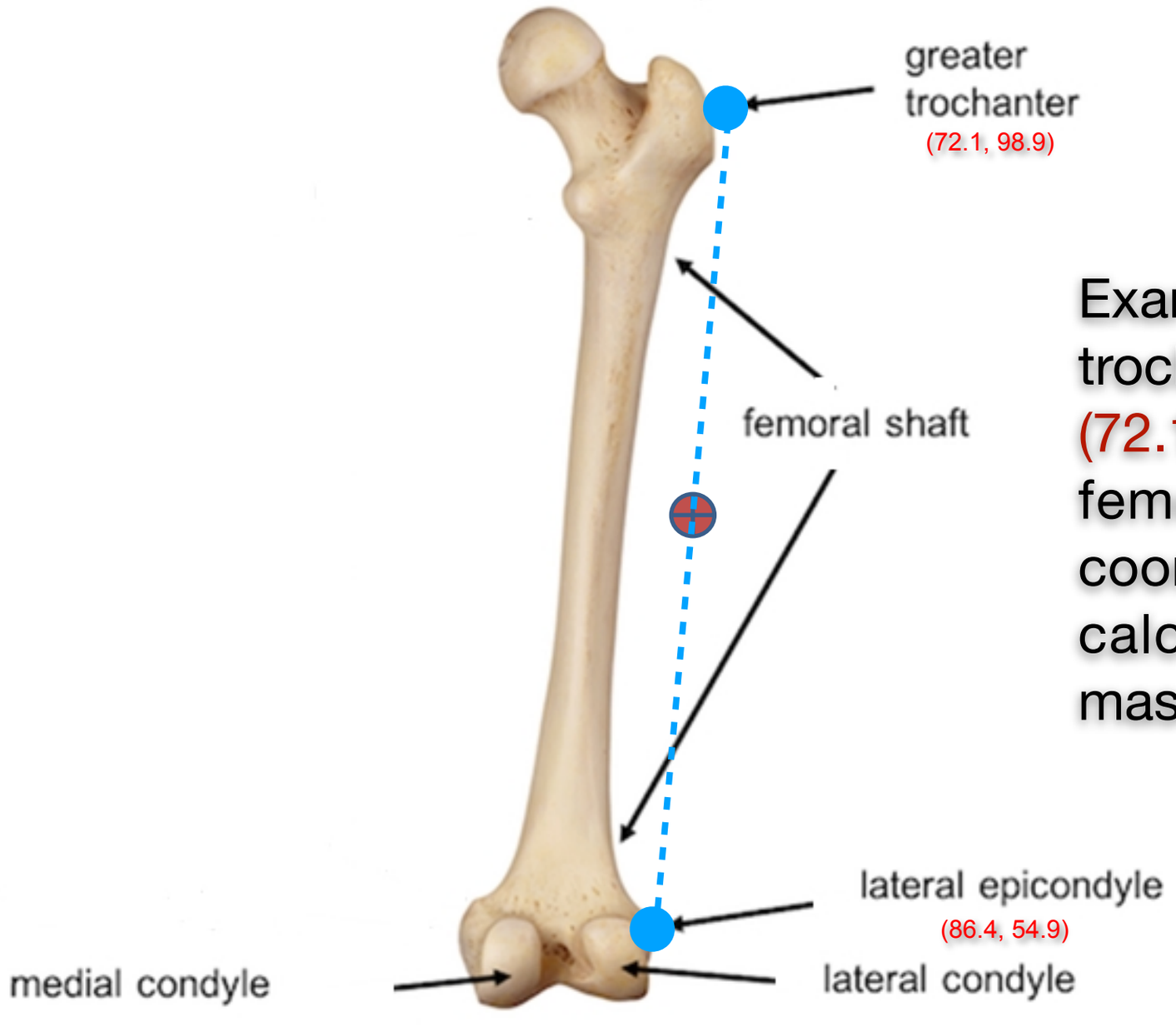
Segment name	Endpoints (proximal to distal)	Seg. mass /total mass (P)	Centre of mass /segment length ($R_{proximal}$)	(R_{distal})	C. of mass to ant. A/P size	Radius of gyration /segment length (K_{cg})	($K_{proximal}$)
Hand	stylion to metacarpale III	0.0065	0.1802	0.8198	0.5613	0.6019	0.6283
Forearm	radiale to stylion	0.0161	0.3896	0.6104	0.4863	0.3182	0.5030
Upper arm	acromion to radiale	0.0263	0.5130	0.4870	0.5100	0.3012	0.5949
Forearm & hand	radiale to stylion	0.0227	0.6258	0.3742	0.5240		
Upper extremity	(regression equation)[2]	0.0490	0.4126	0.5874			
Foot	heel to tip longest toe	0.0147	0.4485	0.5515		0.4265	0.6189
Foot	sphyrion to sole of foot	0.0147	0.4622	0.5378			
Leg	tibiale to sphyrion	0.0435	0.3705	0.6295	0.4247	0.3567	0.5143
Thigh	trochanter to tibiale	0.1027	0.3719	0.6281	0.5335	0.3475	0.5090
Leg & foot	tibiale to floor (sole)	0.0582	0.4747	0.5253	0.3325		
Lower extremity	trochanter to floor (sole)	0.1610	0.3821	0.6179	0.6313		
Trunk	chin-neck int.[3] to trochanter	0.5070	0.3803	0.6197		0.4297	0.5738
Head	top of head to chin-neck int.	0.0728	0.4642	0.5358		0.6330	0.7850
Head	glabella to occiput	(c. of m. to occiput/head length)			0.3996		
Trunk & head	chin-neck int.[3] to trochanter	0.5801	0.5921	0.4079			
Total body		1.0000	0.4119	0.5881		0.7430	0.8495

[1] From Clauser, McConville and Young, Weight, volume and centre of mass of segments of the human body, AMRL-TR-69-70, 1969 and Chandler, Clauser, McConville, Reynolds and Young, Investigation of inertial properties of the human body, AMRL-TR-74-137, 1975 both Wright-Patterson Air Force Base.

[2] regression equation for arm: length = 1.126 (acromion to radiale distance) + 1.057 (radiale to stylion distance) + 12.52 (all distances in centimetres.)

[3] chin-neck intersection: the point superior to the coracoid cartilage at the level of the hyoid bone. Marker should be placed level with the intersection but at the lateral aspect of the neck.

Body Segment Parameters



Example: If the greater trochanter has coordinates (72.1, 98.9) and the lateral femoral epicondyle has coordinates (86.4, 54.9), calculate the center of mass of the thigh.

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Body Segment Parameters

Table 3.4 Clauser and Colleagues' Body Segment Parameters

Segment	Endpoints[a] (proximal to distal)	SEGMENTAL MASS/TOTAL MASS	CENTER OF MASS/SEGMENT LENGTH		RADIUS OF GYRATION/ SEGMENT LENGTH	
		$(P)^b$	$(R_{proximal})^c$	$(R_{distal})^c$	$(K_{cg})^{d,e}$	$(K_{proximal})^d$
Hand	Stylion to metacarpale III	0.0065	0.1802	0.8198	0.6019	0.6283
Forearm	Radiale to stylion	0.0161	0.3896	0.6104	0.3182	0.5030
Upper arm	Acromion to radiale	0.0263	0.5130	0.4870	0.3012	0.5949
Forearm and hand	Radiale to stylion	0.0227	0.6258	0.3742		
Upper extremity	Regression equation[f]	0.0490	0.4126	0.5874		
Foot	Heel to toe II	0.0147	0.4485	0.5515	0.4265	0.6189
Foot	Sphyrion to floor	0.0147	0.4622	0.5378		
Leg	Tibiale to sphyrion	0.0435	0.3705	0.6295	0.3567	0.5143
Thigh	Trochanter to tibiale	0.1027	0.3719	0.6281	0.3475	0.5090
Leg and foot	Tibiale to floor	0.0582	0.4747	0.5253		
Lower extremity	Trochanter to floor (sole)	0.1610	0.3821	0.6179		
Trunk	Chin-neck intersection to trochanter[g]	0.5070	0.3803	0.6197	0.4297	0.5738
Head	Top of head to chin-neck intersection	0.0728	0.4642	0.5358	0.6330	0.7850
Trunk and head	Chin-neck intersection to trochanter	0.5801	0.5921	0.4079		
Total body		1.0000	0.4119	0.5881	0.7430	0.8495

[a]Endpoints are defined in table 3.3.

[b]A segment's mass as a proportion of the total body mass.

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Body Segment Parameters