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International Symposium on *In Vivo* Body Composition Studies

Program and Abstracts

Sept. 28-Oct. 1, 1986

Brookhaven National Laboratory
Upton, Long Island, New York

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PROGRAM

INTERNATIONAL SYMPOSIUM ON IN VIVO BODY COMPOSITION STUDIES

Brookhaven National Laboratory, Upton, New York

September 28 - October 1, 1986

Monday, September 29, 1986
Body Composition I; G.B. Forbes and L. Burkinshaw, chairpersons
Hamilton Conference Rm, Chemistry Bldg.,
9:45 A.M. - 12:30 P.M.

8:45		ANNOUNCEMENTS
9:00	A 1.	MODELS OF THE DISTRIBUTION OF PROTEIN IN THE HUMAN BODY. L. Burkinshaw. University of Leeds, U.K.
9:25	A 2.	CLINICAL BODY COMPOSITION ASSESSMENT USING IN VIVO NEUTRON ACTIVATION ANALYSIS (IVNAA). A.H. Beddoe, University of Auckland, New Zealand.
9:50	A 3.	BODY COMPOSITION IN ACROMEGALY BEFORE AND AFTER THERAPY. R.J.M. Brummer, B.A. Bengstsson, B. Isaksson, Sahlgren's Hospital, Gothenburg, Sweden.
10:05	A 4.	ONE YEAR FOLLOW-UP OF WEIGHT, TOTAL BODY POTASSIUM (TBK) AND TOTAL BODY NITROGEN (TBN) IN OBESE ADOLESCENTS TREATED WITH THE PROTEIN SPARING MODIFIED FAST (PSMF). E.H. Archibald, V.A. Stallings, P.B. Pencharz, J.E. Harrison, L.E. Bell. University of Toronto and Research Institute, Hospital for Sick Children, Toronto, Canada.
10:20		COFFEE BREAK
10:40	A 5.	EXPERIENCE IN THE USE OF BODY COMPOSITION STUDIES IN GASTROENTEROLOGY. L.M. Blendis, J.E. Harrison, J.R. Mernagh, K.N. Jeejeebhoy, K.G. McNeill, University of Toronto, Canada.
11:05	A 6.	RAPID ESTIMATION OF LEAN BODY MASS BY MEASUREMENT OF TOTAL BODY ELECTRICAL CONDUCTIVITY. T. Van Itallie, K.R. Segal and M.U. Yang, St. Luke's-Roosevelt Hospital Center and Mt. Sinai Hospital, New York, NY.
11:30	A 7.	THEORY AND VALIDATION OF THE TETRAPOLAR BIOELECTRICAL IMPEDANCE METHOD TO ASSESS HUMAN BODY COMPOSITION. H.C. Lukaski and W.W. Bolonchuk, Human Nutrition Research Center, Grand Forks, ND.
11:45	A 8.	LEAN BODY MASS AND TOTAL BODY FAT BY DUAL-PHOTON (^{153}Gd) ABSORPTIOMETRY. C. Hassager, A. Gotfredsen, C. Christiansen, Glostrup Hosp., U. Copenhagen, Denmark.
12:00	A 9.	INFANT BODY VOLUME MEASUREMENT BY ACOUSTIC PLETHYSMOGRAPHY. H.-P. Sheng, T. Dang, R. Schanler and C. Garza, Baylor College of Medicine, Houston, Texas.
1:00-4:00		**POSTER SESSION, TOURS OF BROOKHAVEN NATIONAL LABORATORY, Berkner Hall**
4:00-5:00	A10.	**KEYNOTE ADDRESS**: NEW CONCEPTS OF BODY COMPOSITION. S.H. Cohn, Woodside, CA
6:00		COCKTAILS, Brookhaven Center
7:00		BANQUET, Brookhaven Center

Tuesday, September 30, 1986
The Skeletal System; J.E. Harrison and S.H. Cohn, chairpersons
Conference Rm, Medical Dept.,
8:45 A.M. - 12:35 P.M.

8:45		ANNOUNCEMENTS
8:55	B 1.	TOTAL BODY CALCIUM AND OTHER BONE MINERAL STUDIES IN EDINBURGH. P. Tothill, University of Edinburgh, U.K.
9:20	B 2.	NON-INVASIVE TECHNIQUES FOR QUANTITATING BONE MASS: FACT OR FANCY? C.H. Chesnut III, University Hospital, U. Washington, Seattle, WA.
9:45	B 3.	OSTEOPOROSIS IN PATIENTS WITH INFLAMMATORY BOWEL DISEASE. J.E. Compston, W.D. Evans, E.O. Crawley, D. Judd, C. Evans, J. Rhodes, U. Wales College of Medicine and University Hospital of Wales, Cardiff, U.K.
10:00	B 4.	BONE LOSS IN RHEUMATOID ARTHRITIS. A. Gotfredsen, O.S. Als, C. Hassager, C. Christiansen, University of Copenhagen, Glostrup Hospital, Denmark.

10:15 B 5. ACCURACY AND PRECISION IN THE *IN VIVO* DETERMINATION OF BONE MINERAL CONTENT USING THE ATTENUATION OF A CONTINUOUS X-RAY SPECTRUM. R. Jonson, B. Roos, T. Hansson, and S. Mattsson, University of Gothenberg, Sweden

10:30 COFFEE BREAK

10:50 B 6. BONE CHANGES OCCURRING SPONTANEOUSLY AND CAUSED BY OESTROGEN IN EARLY POSTMENOPAUSAL WOMEN: A LOCAL OR GENERALISED PHENOMENON? C. Christiansen, A. Gotfredsen, B.J. Riis and C. Hassager. University of Copenhagen, Glostrup Hospital, Denmark.

11:15 B 7. AN EVALUATION OF CENTRAL SKELETON: NEUTRON ACTIVATION ANALYSIS FOR THE ROUTINE DIAGNOSIS OF OSTEOPENIA. J.E. Harrison, K.G. McNeill, N. Patt, C. Mueller, R. Chow and BMG, University of Toronto, Canada.

11:40 B 8. BONE MINERAL MEASUREMENTS AND THE PATHOGENESIS OF OSTEOPOROSIS. J.F. Aloia, A.N. Vaswani, K.J. Ellis, S.H. Cohn, Winthrop University Hospital, Mineola, NY and Brookhaven National Laboratory, Upton, NY.

12:05 B 9. SEQUENTIAL AND POPULATION BMM STUDIES USING DUAL ENERGY (SPINE) AND SINGLE ENERGY (FEMUR AND FOREARM) PHOTON ABSORPTIOMETRY. E.G.A. Aird, Newcastle General Hospital, U.K.

12:20 B10. ULTRASONIC STUDIES OF THE OS-CALCIS *IN VIVO*. S.B. Palmer and C.M. Langton, University of Hull, U.K.

1:00-3:30 **POSTER SESSION, TOURS OF BROOKHAVEN NATIONAL LABORATORY, Berkner Hall**

Body Composition II; A.G. Beddoe and A. Vaswani, chairpersons
Hamilton Conference Rm, Chemistry Bldg.,
3:30 P.M. - 5:20 P.M.

3:30 C 1. USE OF A PULSED NEUTRON GENERATOR FOR *IN-VIVO* MEASUREMENT OF BODY CARBON. J.J. Kehayias, K.J. Ellis, S.H. Cohn and S. Yasumura, Brookhaven National Laboratory, Upton, NY.

3:55 C 2. LEAN BODY MASS AND FAT: CONCORDANCE AND DISCORDANCE. G.B. Forbes, University of Rochester Medical Center, Rochester, NY.

4:20 C 3. A STUDY OF THE SITES OF BODY FAT LOSS BY NMR IMAGING. M.F. Fuller, S.M. Stratton, P.A. Fowler and M.A. Foster, Rowett Research Institute and University of Aberdeen, U.K.

4:35 C 4. NONINVASIVE BODY COMPOSITION IN HUMANS BY NEAR INFRARED SPECTROSCOPY. J.M. Conway, Energy and Protein Nutrition Lab, ARS, USDA, Beltsville, MD.

4:50 C 5. A CLINICAL FACILITY FOR MEASURING TOTAL BODY FAT. C.B. Oxby, L. Burkinshaw and B. Oldroyd, University of Leeds, U.K.

5.05 C 6 TISSUE LOSS DURING SEVERE WASTING IN LUNG CANCER PATIENTS. T. Preston, I. Robertson, B.W. East, Scottish Universities Research and Reactor Centre, East Kilbride, Glasgow; K.C.H. Fearon and K.C. Calman, University of Glasgow, U.K.

6:00 COCKTAILS AND BUFFET, Berkner Hall

8:30 **CONCERT:** DORIAN WIND QUINTET, Berkner Hall

Wednesday, October 1, 1986
Trace Metals: K. Jones and L. Wielopolski, chairpersons
Hamilton Conference Rm, Chemistry Bldg.,
8:45 A.M. - 12:05 P.M.

8:45 ANNOUNCEMENTS

8:55 D 1 *IN-VIVO* MONITORING OF TRACE ELEMENTS IN MEDICINE AND RESEARCH. D.R. Chettle, M.C. Scott, University of Birmingham, U.K., K.J. Ellis, Brookhaven National Laboratory, Upton, NY, and W.D. Morgan, Swansea, U.K.

9:20 D 2. X-RAY FLUORESCENCE TECHNIQUE FOR *IN-VIVO* ANALYSIS OF "NATURAL" AND ADMINISTERED TRACE ELEMENTS. S. Mattsson, J.-O. Christoffersson, R. Jonson, University of Goeteborg, Sweden.

9:45 D 3 *IN-VIVO* MEASUREMENTS OF PT AND PB IN PATIENTS UNDERGOING CIS-PT CHEMOTHERAPY. W.D. Morgan, M. Jaib, C.J. Evans and S. Cobbold, A. Sivyer, B.N.C. Littlepage, J. Dutton, Singleton Hospital and University College of Swansea; A.M. El-Sharkawi, Singleton Hospital, Swansea, Wales, U.K.

10:00 D 4. X-RAY FLUORESCENCE OF LEAD *IN VIVO*: SIMULTANEOUS MEASUREMENT OF A CORTICAL AND TRABECULAR BONE IN A PILOT STUDY. L.J. Somervaille, D.R. Chettle, M.C. Scott, G. Krishnan, C.J. Browne, A.C. Aufderheide, L.E. Wittmers, and J.E. Wallgren, University of Birmingham, U.K.

10:15 D 5. A LINEAR MODEL DESCRIBING THE KINETICS OF LEAD IN OCCUPATIONALLY EXPOSED WORKERS. J.O Christoffersson, L. Ahlgren and S. Mattsson, Lund University, Malmo, Sweden; A. Schuetz, S. Skerfving, University Hospital, Lund, Sweden.

10:30 COFFEE BREAK

10:55 D 6. A LONGITUDINAL SURVEY OF EXPOSURE TO CADMIUM FUMES - PRELIMINARY FINDINGS FROM *IN-VIVO* BODY BURDEN MEASUREMENTS. D.M. Franklin, C.J.G. Guthrie, M.C. Scott, D.R. Chettle, H.J. Mason, N.J. Smith and M. Blindt, University of Birmingham, U.K.

11:10 D 7. *IN-VIVO* F-19 MAGNETIC RESONANCE SPECTROSCOPY IN HUMANS. M.S. Silver, M. Albright, Siemens Medical Systems, Iselin, NJ; W. Wolf, USC, Los Angeles, CA; R. Sauer, University of Erlangen, West Germany.

11:25 D 8. BODY LEAD BURDEN, II: ENVIRONMENTAL LEAD AND END-STAGE RENAL DISEASE. R.P. Wedeen and V. Batuman, V.A. Medical Center, East Orange, NJ; K.W. Jones and G. Schidlovsky, Brookhaven National Laboratory, Upton, NY; M.E. DeBroe, F. Van de Vyver and W.G. Visser, University of Antwerp, Belgium.

11:40 D 9. BONE ALUMINUM MEASUREMENTS IN PATIENTS WITH END-STAGE RENAL DISEASE. K.J. Ellis, Brookhaven National Laboratory, Upton, NY and S.P. Kelleher, SUNY-Stony Brook, NY

Water and Electrolytes; P. Tothill and H.P. Sheng, chairpersons
Hamilton Conference Rm, Chemistry Bldg.,
1:00 - 3:05 P.M.

1:00 E 1. THE QUALITY OF THE LEAN BODY MASS. METHODS OF MEASUREMENT: IMPLICATIONS FOR CLINICAL MEDICINE. R.N. Pierson, Jr., and J. Wang, Columbia University-St. Luke's Hospital, New York, NY.

1:25 E 2. MEASUREMENT OF TOTAL BODY WATER BY ISOTOPE DILUTION: A PRIMER FOR CALCULATIONS. D.A. Schoeller and P.H. Jones, University of Chicago, IL.

1:50 E 3. HYDRATION OF FAT-FREE MASS IN PROTEIN-CALORIE MALNOURISHED INFANTS. C.R. Fjeld, D.A. Schoeller, K.H. Brown, University of Chicago and Instituto de Investigacion Nutricional, Lima, Peru.

2:05 E 4. BODY COMPOSITION CHANGES IN ESSENTIAL HYPERTENSION BEFORE AND AFTER TREATMENT. T. Fulop, Jr., I. Worum, J. Csongor, L. Ujhelyi, G.Y. Kurta, G. Foris, University Medical School of Debrecen, Hungary.

2:20 E 5. DEUTERIUM AND OXYGEN-18 ISOTOPE DILUTION SPACES IN NORMAL ADULTS. W. Wong, W. Cochran, L. Lee, W. Klish and P. Klein, Baylor College of Medicine, Houston, TX.

2:35 E 6. BODY WATER, EXTRACELLULAR WATER, BODY POTASSIUM AND EXCHANGEABLE SODIUM IN BODY BUILDERS USING ANABOLIC STEROIDS. J. Wang, E.D.W. Colt and R.N. Pierson, Jr., Columbia University, New York, NY.

2:50 E 7. DIRECT MEASUREMENTS OF TOTAL BODY OXYGEN IN BODY COMPOSITION STUDIES. B.W. East, T. Preston, I. Robertson, Scottish Universities Research and Reactor Centre, East Kilbride; D.L. Davies and G. Herd, Western Infirmary, Glasgow, Scotland, U.K.

POSTER SESSIONS
Berkner Hall
Monday, September 29, 1986 1:00 - 4:00 P.M.
Tuesday, September 30, 1986 1:00 - 3:30 P.M.

P 1. ANTHROPOMORPHIC MODELS FOR THE CALIBRATION OF EQUIPMENT FOR *IN-VIVO* NEUTRON ACTIVATION ANALYSIS D.K. Bewley Hammersmith Hospital, London, England.

P 2. RELATIONSHIP BETWEEN DENSITY AND BODY WEIGHT IN PREMATURELY BORN INFANTS RECEIVING DIFFERENT DIETS. R.B. Dell, Y. Aksoy, S. Kashyap, M. Forsythe, R. Ramakrishnan, C. Zucker, W.C. Heird, Columbia University, NY, NY.

P 3. A NEUTRON ACTIVATION ANALYSIS TECHNIQUE FOR THE MEASUREMENT OF PHOSPHORUS IN SECTIONS OF THE HUMAN BODY D. Glaros, J. Xatzikonstantinou, J. Leodiou and J. Kalef-Ezra, University of Ioannina, Greece.

P 4. BODY COMPOSITION IN INFANTS BY DUAL-PHOTON ^{153}Gd ABSORPTIOMETRY. A. Gotfredsen, S. Pedersen, C. Hassager, C. Christiansen, University of Copenhagen, Glostrup, Denmark.

P 5. *IN-VIVO* MEASUREMENTS OF NITROGEN USING A NEUTRON ACTIVATION TECHNIQUE. L. Larsson, M. Alpsten, J. Tolli, N. Drugge and S. Mattsson, Sahlgren Hospital, Gothenberg, Sweden.

P 6. MEASUREMENTS OF BODY PROTEIN FOR CLINICAL INVESTIGATION. J.R. Mernagh, J.E. Harrison, M.G. McNeill, K.N. Jeejeebhoy, S.S. Krishnan, University of Toronto, Canada.

P 7. THE DESIGN AND CONSTRUCTION OF A NEW INSTRUMENT FOR MULTI-ELEMENTAL IVNAA. S.J.S. Ryde, W.D. Morgan, A. Sivyer, C.J. Evans, J. Dutton, University College of Swansea, Swansea, Wales, U.K.

P 8. A NEW MULTI-ELEMENT ANALYSIS SYSTEM USING ^{252}Cf CALIBRATION AND PERFORMANCE. S.J.S. Ryde, W.D. Morgan, C.J. Evans, J. Dutton, A. Sivyer, E. McNeil and S. Sandhu, Singleton Hospital and University College of Swansea, Swansea, Wales, U.K.

P 9. ANALYTICAL SIGNALS FROM CANCER PATIENTS FOLLOWING RADIATION TREATMENT. L. Wielopolski, Brookhaven National Laboratory, Upton, NY, A.G. Meek, L.E. Reinstein, University Hospital, Stony Brook, NY.

P10. DETERMINATION OF BODY COMPOSITION IN ELDERLY SUBJECTS SUFFERING FROM DIABETES MELLITUS AND ARTERIOSCLEROSIS. I. Worum, T. Fulop, Jr., L. Ujhelyi, J. Csongor, University Medical School of Debrecen, Hungary.

P11. BODY COMPOSITION CHANGES IN CONGESTIVE HEART FAILURE BEFORE AND AFTER TREATMENT. T. Fulop, Jr., I. Worum, T. Szabo, J. Csongor, G. Forris, A. Leovey, University Medical School of Debrecen, Hungary.

P12. AGE-RELATED VARIATIONS IN THE BODY COMPOSITION OF PATIENTS IN MAINTENANCE HEMODIALYSIS. T. Fulop, I. Worum, J. Csongor, T. Szabo, University Medical School of Debrecen, Hungary.

P13. BODY FLUID COMPARTMENTS, HYPERTENSION AND RENIN-ANGIOTENSIN-ALDOSTERONE SYSTEM (RAAS) IN HEMODIALYSED PATIENTS. I. Worum, T. Fulop, J. Csongor and T. Szabo, First Department of Medicine, Debrecen, Hungary.

P14. BODY COMPOSITION STUDIES IN AGING RATS. S. Yasumura, SUNY-Health Science Center, Brooklyn, NY; K.J. Ellis, A.F. LoMonte, R. Zhang, K. Yuen, and S.H. Cohn, Brookhaven National Laboratory, Upton, NY; G.M. Kiebzak, NIA/NIH, Baltimore, MD.

P15. *IN-VIVO* CALCIUM DETERMINATION OF SMALL SAMPLES USING ^{252}Cf NEUTRON ACTIVATION FACILITY. S.S. Krishnan, J. Song, M.T. Bayley, S.C. Lin, A.J.W. Hitchman and J.E. Harrison, University of Toronto, Canada.

P16. AN INSTRUMENT FOR *IN-VIVO* DETERMINATION OF BONE MINERAL CONCENTRATION BY COHERENT-COMPTON SCATTERING. U. Nilsson, L. Ahlgren and S. Mattsson, Malmo General Hospital and Sahlgren Hospital, Goteborg, Sweden.

P17. PRE-RECONSTRUCTION DUAL-ENERGY X-RAY COMPUTERIZED TOMOGRAPHY (CT) THEORY, IMPLEMENTATION, RESULTS AND CLINICAL USE. W.T. Oravez, Siemens Medical Systems, Iselin, NJ.

P18. *IN-VITRO* COMPARISON OF DE-QCT PARAMETERS WITH THE COMPRESSIVE STRENGTH OF CANCELLOUS BONE. W.T. Oravez, Siemens Medical Systems, Iselin, NJ; D.D. Robertson, Brigham and Women's Hospital, Boston, MA.

P19. CYPROTERONE ACETATE, AN ALTERNATIVE GESTAGEN IN POSTMENOPAUSAL ESTROGEN GESTAGEN THERAPY. B.J. Riis, J. Jensen and C. Christiansen, Glostrup Hospital, Glostrup, Denmark.

P20. CALCIUM REQUIREMENT AND FACTORS INFLUENCING THE SKELETAL STATUS IN MAN. H. Spencer, VA Hospital, Hines, IL.

POSTER SESSIONS (Continued)

P21. CARBONATED BEVERAGE CONSUMPTION AND BONE FRACTURES. G. Wyshak, R.E. Frisch, N.L. Aibright, T.E. Albright, I. Schiff, and J. Witschi, Harvard Center for Population Studies, Cambridge, MA.

P22. A FEASIBILITY STUDY FOR THE *IN-VIVO* MEASUREMENT OF BERYLLIUM BY PHOTONUCLEAR ACTIVATION. P.A. Ali, J. Dutton, C.J. Evans, W.D. Morgan and A. Sivyer, University College of Swansea and Singleton Hospital, Wales, U.K.

P23. *IN-VIVO* MEASUREMENT OF ORGAN MERCURY BY PROMPT GAMMA ACTIVATION ANALYSIS USING A MOBILE NUCLEAR REACTOR. P.-S. Chang, Kaohsiung Medical College, Taiwan, Republic of China; C. Chung, National Tsing Hua University, Taiwan, Republic of China.

P24. THE *IN VIVO* MEASUREMENT OF SILICON IN THE LUNG AND OTHER BODY ELEMENTS USING FAST NEUTRON INELASTIC SCATTERING REACTIONS. J. Dutton, C.J. Evans, A. Kacperek, University College of Swansea, Swansea, U.K.; A. Sivyer and W.D. Morgan, Singleton Hospital, Swansea, U.K.

P25. BODY LEAD BURDEN I: VALIDATION OF RAPID, NON-INVASIVE, *IN-VIVO* BONE LEAD DETERMINATION BY X-RAY FLUORESCENCE. K.W. Jones and G. Schidlovsky, Brookhaven National Laboratory, Upton, NY; R.P. Wedeen and V. Batuman, VA Medical Center, East Orange, NJ.

P26. THE *IN-VIVO* ASSESSMENT OF INHALED IRON-BEARING LUNG CONTAMINANTS USING (i) FAST NEUTRON INELASTIC SCATTERING AND (ii) REMANENT MAGNETIC FIELD MEASUREMENTS. A. Kacperek, D. Rassi and C.J. Evans, University College of Swansea, Swansea, U.K.

P27. A LONGITUDINAL STUDY OF EX-EMPLOYEES OF A Ni-Cd BATTERY COMPANY. W.D. Morgan, S. Cobbold, S.J.S. Ryde, R.R. Ghose, P.A. Ali, J.L. Birks, S. Sandhu, I. Hainsworth, Singleton Hospital and University College of Swansea, U.K.; R. Braithwaite, Dudley Road Hospital, Birmingham, U.K.

P28. *IN-VIVO* MEASUREMENT OF Li. D. Vartsky, Soreq Nuclear Research Center, Yavne, Israel; A. LoMonte, K.J. Ellis, S. Yasumura and S.H. Cohn. Brookhaven National Laboratory, Upton, NY.

P29. PARTICLE-INDUCED X-RAY EMISSION ANALYSIS OF TRACE ELEMENTS IN HUMAN BRAIN TUMORS. C.-C. Wei, Tsing Hua University, Taiwan, Republic of China; S.Y. Chen, M. Castro-Magana, Nassau County Medical Center, East Meadow, NY; M.-J. Chou, Harvard University, Boston, MA; C.-H. Chien, Kaohsiung Medical College, Taiwan, Republic of China.

P30. ESTIMATION OF TOTAL BODY POTASSIUM IN THE PRESENCE OF INTERFERING RADIO-ISOTOPES. G.I. Lykken, K.K. Speaker and A.K. MacKichian, University of North Dakota and USDA/ARS Human Nutrition Research Center, Grand Forks, ND.

P31. TOTAL BODY WATER MEASUREMENT BY ISOTOPIC WATER IN VERY YOUNG ANIMALS. H.-P. Sheng, W. Wong, C. Garza and P. Klein, Baylor College of Medicine, Houston, TX.

P32. COMPARISION OF TOTAL BODY WATER DETERMINATION IN LACTATING WOMEN BY ANTHROPOMETRY, WATER DISPLACEMENT, AND DEUTERIUM ISOTOPE DILUTION. W. Wong, N. Butte, L. Lee, C. Garza and P. Klein, Baylor College of Medicine, Houston, TX.

P33. THE INFLUENCE OF PHYSICAL ACTIVITY ON THE METABOLISM AND THE TOTAL BODY CONTENT OF SODIUM AND POTASSIUM IN THE RAT. J.K. Yeh, S. Yasumura and J.F. Aloia. Winthrop-University Hospital, Mineola, NY and Brookhaven National Laboratory, Upton, NY.

P34. EXPERIENCE WITH BIOELECTRICAL IMPEDANCE DETERMINATIONS IN YOUNG CHILDREN: SOURCES OF VARIABILITY. C. Barillas, C. Vettorazzi, S. Molina, O. Pineda, National Committee for the Blind and Deaf of Guatemala, Guatemala City, Guatemala.

P35. SEGMENTAL BIOELECTRIC IMPEDANCE MEASURES OF BODY COMPOSITION. W.C. Chumlea, R.N. Baumgartner, A.F. Roche, Wright State University School of Medicine, Yellow Springs, OH.

P36. THE USE OF TOTAL BODY ELECTRICAL CONDUCTIVITY (TOBEC) TO DETERMINE TOTAL BODY WATER. W. Cochran, W. Wong, H.-P. Sheng, P. Klein, and W. Klish, Baylor College of Medicine, Houston, TX.

P37. AN EVALUATION OF TOTAL BODY ELECTRICAL CONDUCTIVITY (TOBEC) MEASUREMENTS FOR THE DETERMINATION OF BODY COMPOSITION IN THE HUMAN INFANT. M. Fiorotto, W. Cochran, H.-P. Sheng, and W. Klish, Baylor College of Medicine, Houston, TX.

P38. VALIDATION OF THE TOTAL BODY ELECTRIC CONDUCTIVITY METHOD BY DIRECT CARCASS ANALYSIS OF SWINE. N.L. Keim, S.J. Taylor, P.L. Mayclin and D.L. Brown, ARS, USDA, San Francisco and University of California, Davis, CA.

POSTER SESSIONS (Continued)

P39. A FEASIBILITY STUDY OF *IN-VIVO* BODY COMPOSITION MEASUREMENTS USING A RESONANT AC CIRCUIT. N.H. Saunders, D. Rassi, P. Chadwick, J. Dutton, University College of Swansea; A. Sivyer and W.D. Morgan, Singleton Hospital, Swansea, Wales, U.K.

P40. SOURCES OF VARIABILITY IN BIOELECTRICAL IMPEDANCE DETERMINATIONS IN ADULTS. R. Elsen, M.-L. Siu, O. Pineda, N. Solomons, National Committee for the Blind and Deaf of Guatemala, Guatemala City, Guatemala.

P41. ACCURACY AND PRECISION OF BIOELECTRICAL IMPEDANCE AND ANTHROPOMETRY TO ESTIMATE BODY COMPOSITION. T. Gonzalez-Cossio, E. Diaz, H. Delgado, INCAP, Guatemala City, Guatemala.

P42. BODY COMPOSITION DETERMINATIONS BY BIOELECTRICAL IMPEDANCE IN OLYMPIC-CLASS ATHLETES AT THE THIRD CENTRAL AMERICAN GAMES. M.J. Guzman, R. Elsen, A. Padilla, N.W. Solomons, C. Whalen, M.-L. Siu, M. Mazariegos, S. Molina, L. Neufeld, A. Rosas, C. Barillas, D. Canales, C. Vettorazzi, F. Beltranena, O. Pineda, National Committee for the Blind and Deaf of Guatemala, Guatemala City, Guatemala.

P43. EVALUATION THROUGH SEQUENTIAL DETERMINATION OF THE STABILITY OF BIOELECTRICAL IMPEDANCE MEASUREMENTS FOR BODY COMPOSITION ANALYSIS. M.-L. Siu, R. Elsen, M. Mazariegos, N. Solomons, O. Pineda, National Committee for the Blind and Deaf of Guatemala, Guatemala City, Guatemala.

P44. RELATIONSHIP BETWEEN WEIGHT-FOR-HEIGHT INDEX AND BODY COMPOSITION IN CHILEAN ADULTS. M. Vasquez, J. Pena, University of Chile; E. Diaz, Institute of Nutrition of Central America and Panama, Guatemala City.

Models of the distribution of protein in the human body

L. Burkinshaw

Department of Medical Physics, University of Leeds, U.K.

Total body nitrogen (TBN) can be measured by in vivo neutron activation analysis and, assuming that all the nitrogen in the body is in protein at a known and constant concentration, total body protein (TBPr) can be calculated from the measured value. This procedure has been used in several institutions to determine TBPr in healthy volunteers and in patients with a variety of diseases, in order to quantify the changes in TBPr that occur as a result of disease and/or treatment.

Useful though it is to be able to estimate TBPr in this way, the estimate would be even more informative if it were possible to find out also how protein is distributed among the various tissues of the body and whether, when TBPr changes, some tissues gain or lose more protein than others. One approach is to measure, in addition to nitrogen, one or more other substances that are associated with protein, but in different proportions in different tissues. With certain simplifying assumptions the masses of protein in individual tissues can then be derived from the measured amounts of nitrogen and the other substances in the whole body.

The element potassium is one suitable substance. Like nitrogen it is confined to the fat-free tissues, but its concentration varies more from tissue to tissue than does that of nitrogen, being relatively high in cellular tissues such as skeletal muscle. Furthermore, total body potassium (TBK) can be estimated by measuring the natural radioactivity of the potassium in the body.

Two principal models have been described that purport to explain how the distribution of protein between certain tissues can be deduced from measured values of TBK and TBN. One estimates how much protein is intracellular and how much is extracellular, and the other estimates how protein is apportioned between skeletal muscle and 'non-muscle' fat-free tissue. An extension of the latter model also estimates protein in the viscera. The theoretical bases of the two principal models will be discussed and a model consistent with both will be proposed. The usefulness of the models for determining the origin of the protein lost by wasted patients will be assessed by applying them to relevant data.

CLINICAL BODY COMPOSITION ASSESSMENT USING IN VIVO NEUTRON ACTIVATION ANALYSIS (IVNAA)

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A prompt gamma IVNAA facility has been developed in Auckland to study body composition in both the depleted surgical patient and the critically ill intensive care patient (Phys.Med.Biol. 29: 371-383, 1984). The IVNAA method, used in conjunction with the tritium dilution technique, enables total body protein, water and fat to be determined with precisions (sd), based on normal man, of 4.2%, 1.5% and 6.3% respectively, and has been validated by studies of normal volunteers (Metabolism 33: 270-280, 1984 and 34: 509-518, 1985) and analyses of two human cadavers (Am.J.Physiol. 250: E179-186, 1986). Studies of normal volunteers have also provided a data base used to define compositional deficits in patients.

This paper reviews clinical research carried out since late 1982. The protein and hydration status of surgical patients presenting for nutritional support is described (Am.J.Physiol. 249: E227-233, 1985) as are the changes in protein and fat achieved with nutritional therapy in pre- and post-operative patients. Results are also presented of a clinical trial which examines the efficacy of fat and glucose as hypercalorific energy sources. The IVNAA / tritium dilution method has for the first time been applied to document body composition changes in intensive care patients (Metabolism 34: 688-694, 1985), and results on critically ill post-operative septic intensive care patients are discussed (J.Trauma - in press). Data is also presented for patients who have suffered major blunt trauma. Finally the method is contrasted with skinfold anthropometry as a means of determining total body fat (or fat-free mass) and also with conventional nitrogen balance as a means of monitoring crude protein changes in the clinical situation.

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BODY COMPOSITION IN ACROMEGALY - BEFORE AND AFTER THERAPY

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INTRODUCTION

Acromegaly is a disease caused by a benign pituitary tumor producing excess amount of growth hormone. A changed body composition can be a functional parameter of the disorder. Aim of this study is to describe body composition in acromegaly before and after therapy.

METHODS

We studied 87 patients (45♂, 42♀) before treatment (22-75, median 46yrs). The median approximate duration of the disorder before the diagnosis was 8 yrs. In a follow-up investigation 67 patients (33♂, 34♀) were studied (26-74, median 57yrs). In this group 41 patients had undergone pituitary irradiation, 20 patients were pituitary operated by transsphenoidal approach, 1 patient transfrontal, and 5 patients had not got any therapy at all. Between 0.5 and 31 years had elapsed since therapy (median 5 yrs). Of these 62 patients who got therapy, 34 had also been investigated before treatment. In these patients we studied the effect of therapy on body composition by paired observations.

Total body potassium (TBK) was measured as total exchangeable potassium using ^{42}K by dilution technique or by counting gamma radiation from the naturally present ^{40}K in a high sensitivity 3π whole body counter. Total body water (TBW) was determined with an isotope dilution technique using tritiated water as a tracer. The specific activity was measured in urin or plasma.The predicted values for TBK, TBW, and body fat (BF) were calculated by equations using body weight (BW), body height, age and sex as independant variables. The normal values for BW were calculated by using body height and sex as independent variables.

RESULTS

The mean BW before treatment, 84.3kg, was significantly higher than the mean normal BW of 74.5kg ($p<0.001$). In 61 patients with paired data on BW, BW did not changed significantly by therapy (85.1 before to 85.8kg after). The mean TBK of the acromegalic patients before treatment was 4234±141 mmol (mean ±SEM), which is significantly higher ($p<0.0001$) than the the mean predicted value 3870±121 mmol. The TBW before treatment was 55.2±1.6 l, which also is significantly higher ($p<0.0001$) than the predicted TBW 44.7±1.2 l. Consequently BF (15.3±1.3 kg) was significantly lower ($p<0.0001$) than the the predicted BF (23.0±3.3kg). The treated patients in the follow-up group had still a significantly higher TBK as well as TBW than predicted ($p<0.0001$). The paired observations showed a TBK before treatment of 110.7±1.8 % (mean±SEM) of the predicted TBK. After treatment this value was about the same (110.0±1.9 %), whereas TBW decreased significantly from 115.8±2.5 % of the predicted TBW to 109.2±1.9 % ($p<0.05$). Hence BF increased.

The quotients of TBK over predicted TBK and TBW over predicted TBW in each patient in the follow-up group were significantly positively correlated to the serum growth hormone level ($p<0.01$ for TBK and $p<0.0001$ for TBW).

CONCLUSION

Acromegalic patients have related to their body weight, body height, age and sex a significantly increased body cell mass (BCM) and total body water, which consequently result in a increased amount of extra cellular water and a decreased amount of fat. After therapy BCM does not change whereas TBW decreases significantly but still is significantly higher than in a normal populalation. An increased TBK and TBW are both significantly correlated to serum growth hormone level.

ONE YEAR FOLLOW-UP OF WEIGHT, TOTAL BODY POTASSIUM (TBK) AND TOTAL BODY NITROGEN (TBN) IN OBESE ADOLESCENTS TREATED WITH THE PROTEIN SPARING MODIFIED FAST (PSMF). EH Archibald, VA Stallings, PB Pencharz, JE Harrison, LE Bell, Depts of Pediatrics, Nutrition Sciences and Medical Physics, Univ of Toronto, Toronto, Ont. and Research Institute, Hospital for Sick Children, Toronto, Ont.

Seventeen obese adolescents were treated with the PSMF, a high protein (58%), low carbohydrate (7%), low calorie diet (880 cal/d) for approximately 3 months. They were then switched to an iso-caloric diet and re-evaluated at 12 months. Body composition was determined by four skinfolds, TBK and TBN at 0, 3 and 12 months. Twelve subjects returned at one year (71%) and eight of the original seventeen sustained weight loss (48%).

	Weight (kg) (n=12)	FFBM (kg) (n=12)	FAT (kg) (n=12)	TBK (g) (n=11)		TBN (kg) (n=6)	
				Normal	Actual	Normal	Actual
Initial	80.1±6.6	49.7±3.2	30.4±4.7	97.9	111.5±11.8	1.36	1.68±.12
3 mo	66.8±6.3	45.4±3.2	20.8±5.2	98.7	93.1±8.0	1.40	1.52±.08
12 mo	75.2±6.3	49.0±3.9	26.2±4.4	101.5	110.5±15.7	1.41	1.44±.07

The mean weight loss was 4.9 kg ($p < .025$) and mean adipose tissue loss was 4.2 kg ($p < .001$). There was no difference between initial and 12 month fat free body mass (FFBM), TBK, TBK/FFBM or TBN/TBK. There was a significant loss of TBN over the 12 months ($p < .001$). However, measured TBN still remained within the normal (predicted) range.

We conclude that the PSMF is an effective means of reducing body fat while at the same time permitting a preservation of lean tissue.

EXPERIENCE IN THE USE OF BODY COMPOSITION STUDIES IN GASTROENTEROLOGY

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The measurement of total body nitrogen (TBN) as an index of total protein in the body has been performed in a number of different studies.

The in vivo technique is based on the detection and counting of the characteristic nitrogen gamma rays emitted after neutron capture i.e. neutron capture prompt gamma ray anaylsis. The accuracy of the method was estimated as better than 10%, reproducibility was 5.5%. The effective dose equivalent for nitrogen measurement is 50 mrem. TBN was initially measured in 121 volunteers and found to correlate best with the mean of height and arm span (HAS), a better estimate of skeletal size than height alone. This was then used to normalize TBN for body size with the derivation of a Nitrogen Index (NI), with a normal range of 0.8 - 1.2. These measurements were then applied to different patient populations. For example, both patients with anorexia nervosa, a feeding disorder mainly in young women, the average body weight was 60% of normal and TBN and NI were significantly reduced. Similarly in a group of patients with intestinal malabsorption, TBN was an average 68% of normal and in all cases less than 90% of normal.

A select group of 38 malnourished patients were then treated with total parenteral nutrition for periods of 3 to 33 months. This resulted in a weight gain of 10% and a significant increase of 32% in TBN ($P<0.001$). In contrast, increases in lean body mass, measured anthropometrically (AMLBM) and total body potassium (TBK) were only increased 9%, the later two reflecting total and intracellular water respectively, but not protein content. In addition, in acute studies of nutritional replenishment (< 40 days) acute increases in AMLBM and TBK occurred, but not in TBN indicating the rise in lean body weight with short term TPN is in water and potassium, but not nitrogen.

Cirrhotic patients with fluid retention develop massive ascites lose muscle mass and may become resistent to diuretic therapy. One of the modalities of treatment is by the operation of peritoneovenous shunting following which our clinical impression was that patients regained true weight. Body composition studies showed that in the perioperative period both TBN, 1.54 $\pm$ 0.1 Kg and NI 0.74 $\pm$ .04 were reduced. Successful surgery and a marked diuresis resulted in an immediate change in TBN/TBK ratio. The patients regained their appetite and by a mean of 14 months, had a significant increase in both TBN, to 1.84 $\pm$ 0.1 ($P<0.005$) and NI, to 0.88 $\pm$ 0.04 ($P<0.005$).

In conclusion, body composition studies using TBN, NI and TBK have been most useful in the nutritional assessment of different patient groups in gastroenterology and in monitoring their response to treatment with particular reference to changes in body water and electrolytes compared to body protein.

Rapid Estimation of Lean Body Mass by Measurement of Total Body Electrical Conductivity

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Total body electrical conductivity (TOBEC) has been found to provide an accurate index of lean body mass in infants, children and adults. TOBEC can be measured rapidly (within 90 seconds), comfortably and noninvasively, requiring minimal subject effort and operator skill. Indeed, the method is objective, being inherently judgment- and bias-free. Thus, TOBEC has potential value in the nutritional assessment of individuals and groups. It should be particularly useful in the study of people who, because of illness, age or infirmity, cannot tolerate demanding procedures such as hydrodensitometry. The principle on which TOBEC is based; namely, the fact that the electrical conductivities of extracellular water (ECW) and hydrated lean tissue far exceed that of fat, constitutes both an advantage and a disadvantage. In a heterogeneous group of healthy men and women, an excellent correlation ($r = .98$) was observed between TOBEC and densitometrically determined lean body mass (LBMd). Thus, in healthy subjects whose hydration is normal, TOBEC should provide an accurate index of the body's lean mass, excluding such water-poor structures as bone, cartilage and connective tissues. In contrast, in dehydrated subjects or those with an expanded extracellular fluid compartment, TOBEC will provide values that underestimate or overestimate LBM respectively. In fact, the relative contributions of the intracellular and the extracellular compartments to the TOBEC signal are not yet satisfactorily defined. Limited data suggest that the precision with which TOBEC can predict LBM in people who are extremely muscular or extremely obese will be enhanced by use of population-specific regression equations. Recent studies have confirmed that there is a systematic, positive correlation between degree of obesity and the hydration of the lean body. Independent approximation of the severity of the obesity, as can be obtained by anthropometry, should permit application of a prediction equation appropriate for the putative level of hydration. The TOBEC method also can be used to monitor changes in LBM during pathologic or therapeutic weight loss, nutritional rehabilitation and growth. However, disproportionate changes in ECW and intracellular water are likely to distort interpretation of the results. Despite these theoretical problems, preliminary studies of obese patients during weight loss have disclosed an excellent concordance between changes in LBMd and changes in TOBEC. Because the advantages of the TOBEC method, such as rapidity, convenience and objectivity, are so manifest, further assessment of its clinical and investigative usefulness is urgently needed.

THEORY AND VALIDATION OF THE TETRAPOLAR BIOELECTRICAL IMPEDANCE METHOD TO ASSESS HUMAN BODY COMPOSITION. H.C. Lukaski and W.W. Bolonchuk. USDA-ARS, Grand Forks Human Nutrition Research Center, Grand Forks, ND 58202

Routine assessment of human body composition is limited by the availability of a method that is safe, non-invasive, rapid, portable, and inexpensive, and that provides valid and reasonably accurate estimates of fat free mass (FFM) and body fatness (BF). One approach that may meet these criteria is tetrapolar bioelectrical impedance plethysmography which is based upon the conduction of an applied electrical current through the conductive tissues of the body. This method introduces a painless, radiofrequency signal (800 microamps alternating current at 50 kilohertz) through surface electrodes into the deep tissues of the body. Adjacent surface electrodes measure the voltage drop across the body. Phase-sensitive electronics quantitate the impedance to the flow of current into the geometric components of resistance (R) and reactance (Xc). Previous findings from our laboratory demonstrated the reliability and importance of conductance measurements, Ht^2/R, to estimate FFM and demonstrated a small error (3.7%) in predicting FFM in a homogenous sample. To determine the validity and accuracy of this technique for a heterogenous sample, we studied 300 males and females aged 18-61 yr who underwent anthropometric (a), densitometric (d), and bioelectrical impedance (i) determinations. Volunteers were randomly assigned either to a model or a validation group. The model group consisted of 84 males and 67 females aged 27 ± 0.6 yr (mean ± SEM) with a FFMd 59.5 ± 1.3 kg and BFd 20.9 ± 0.6%. The best single predictor of FFMd was Ht^2/R ($r = 0.989$). Multiple regression analysis identified the best prediction equation for $FFMi = -4.033 + 0.734\ Ht^2/R + 0.096Xc + 0.116Wt + 0.878Gender$, $R^2 = 0.983$, SEE = 2.10. This model was cross-validated with an independent sample of 74 males and 75 females aged 35 ± 0.9 yr with a FFMd 59.2 ± 0.9 kg and BFd 23.1 ± 0.8%. FFMi correlated highly ($r = 0.988$; SEE = 2.06) with FFMd. Statistical analyses of the regression line predicting FFMd from FFMi showed that the slope was not different than 1 ($p = 0.61$) and the intercept was similar to 0 ($p = 0.53$). Similarly, BFd and BFi were related strongly ($r = 0.960$, SEE = 2.70). Also the regression line between BFd and BFi was similar to the line of identity. Although both FFMa ($r = 0.974$, SEE = 3.13) and FFMi correlated significantly with FFMd, BFa ($r = 0.902$, SEE = 4.06) was related much less strongly to BFd than was BFi ($p < 0.005$). Anthropometry overestimated ($p < 0.0005$) FFM and underestimated ($p < 0.005$) BF relative to densitometry and impedance methods which yielded similar body composition estimates. These results establish the validity of the bioelectrical impedance method and indicate acceptable errors in the determination of human body composition in a heterogenous group of volunteers.

ABSTRACT

LEAN BODY MASS AND TOTAL BODY FAT BY DUAL-PHOTON (^{153}Gd) ABSORPTIOMETRY.

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We describe a method for measuring the lean body mass (LBM) and total body fat (FAT) by dual-photon (^{153}Gd) absorptiometry (DPA). Lean percent determination on limb phantoms, revealed precision and accuracy errors below 2.0%. The in vivo precision of the LBM of duplicate measurements on five healthy subjects was 2.2%. The accuracy error in vivo of measuring the total mass of soft tissues was 1.4%, thus yielding an overall accuracy error of the LBM of about 2.5%. Measurements on 100 healthy subjects revealed high correlations (r:0.71-0.96) between FAT, FAT% or LBM by DPA versus FAT, FAT% OR LBM calculated from anthropometric measurements (height, weight, age and skinfold thickness). From DPA measurements of 228 normal adults (age:20-72), multiple regression equations of LBM and FAT based on age, height, and weight were computed (r:0.86 -0.95, SEE:2.1-2.9 kg). We conclude that DPA measurements of LBM and FAT in vivo is a reliable estimation of the gross body composition, and that LBM and FAT in normal adults can be calculated solely from age, height, and weight with reasonable accuracy for many purposes.

INFANT BODY VOLUME MEASUREMENT BY ACOUSTIC PLETHYSMOGRAPHY.
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Body volume measurements are essential for the measurement of total body protein and fat stores in infants. To study body composition, various investigators have attempted to measure the body volume of infants. We have developed an acoustic plethysmograph to measure body volume in premature infants. This technique uses the principle of the Helmholtz resonator in which the resonant frequency depends, in part, on the volume of the resonating chamber. Thus, when an infant is placed inside a resonating chamber, the resonant frequency changes in proportion to the body volume of the infant. The prototype system consists of a 20- x 20- x 45-cm plexiglass chamber with a hinged front for access. A loud speaker, driven by a variable frequency tone generator, is aimed at an opening in the top surface of the chamber. The frequency of this tone is controlled by a microprocessor and monitored by a frequency counter for accuracy. The resonant frequency corresponds to the frequency at which the sound level inside the chamber reaches a maximum. This sound level is detected by a microphone in the chamber. The sound pressure level was below 75 dBa. The plethysmograph was calibrated by measuring the resonant frequency when objects of known volume were placed in the chamber. The coefficient of variation of calibration measurements was less than 1%. The coefficient of variation of body volume measurements of anesthetized minipigs was larger than that for inanimate objects, but was less than 2%. Body volumes of 8 minipigs measured by the acoustic method and water displacement differed by less than 1%. The body densities of six 2- to 3-wk-old minipigs calculated from body volumes measured by the acoustic method ranged from 1.02 to 1.07. Preliminary measurements of 3 premature infants (postnatal age 6 to 11 wk; weight 1437 to 2425 g) over a 5-day period gave density values that ranged from 0.99 to 1.04. The acoustic plethysmograph appears to measure the body volume of newborn infants.

New Concepts of Body Composition

Stanton H. Cohn

Abstract

Serious investigation of body composition is very much a product of the twentieth century. Progress in this aspect of physiological research is highly dependent on developments in physics and chemistry, and, more recently, mathematics.

From the start, there have been two avenues of analysis: one, the elemental approach, and the other, the compartmental approach. Early work in the latter avenue of research was carried out by Behnke in the 40's and by Moore in the 60's, both pioneers in this field. Research into elemental body constituents--calcium, potassium, nitrogen, carbon and others--began to move forward in the 70's with the advent of the in vivo neutron activation technique.

Current research is blending the data from these two general areas of investigation to provide a more detailed analysis of the human body. Particular studies, however, may emphasize one approach or the other for specific understanding.

Conceptually, the model of the human body has shifted from the physical view of organs and tissues to the more abstract one of body compartments: skeletal mass, body cell mass, total body fat, extracellular water and intracellular water.

Until fairly recently, data on body composition was derived indirectly. Currently, non-invasive measurements of body compartments provide a more precise picture and lend themselves to models for dynamic representation. New techniques include in vivo neutron activation, photon activation, photon absorptiometry, computed tomography, electrical conductivity (bioelectrical impedance and total body electrical conductivity), ultrasound, roentgenography, NMR, infra-red interactance, coherent Compton scattering, isotope dilution techniques and acoustic plethysmography. Additionally, x-ray fluorescence has been employed for measurements of trace elements. Of the newer techniques, NMR displays a considerable potential which has not, as yet, been exploited.

New developments in the means of detecting elements and body components are providing considerably more insight into the structure and dynamics of the human body. The dynamic inter-relationships among the body compartments have yet to be explored.

The tool that is pre-eminently useful in recording and condensing data and in bringing together data from various sources is, of course, the computer. Computer programs are providing models that are proving extremely useful for discerning diseases and metabolic disturbances that affect body composition and for evaluating the effectiveness of various therapeutic regimens. In addition to the immediate benefit of clinical applications, new understandings of body composition are emerging.

This symposium provides an exciting opportunity to interchange information on the various techniques and concepts used to measure and model body composition and to set general directions and specific goals for further development in this emerging field.

Total body calcium and other bone mineral studies in Edinburgh

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For some years we have used in vivo neutron activation analysis to measure total body calcium (TBCa). The patient was irradiated in a polythene kiosk with neutrons from a cyclotron and the induced calcium-49 measured in a shadow-shield whole body counter (1). Normalisation for size and years post menopause reduced the coefficient of variation for normal subjects to less than 7%. Precision was 1.8% with phantoms and 2.9% in vivo.

Cross-sectional and longitudinal studies have been carried out in a number of diseases. Osteoporotic subjects had a mean TBCa 13% below age-matched normals and a deficit of 31% when normalised for size alone (2). Patients with rheumatoid arthritis treated with non-steroidal anti-inflammatory drugs had a reduced TBCa, with greater reductions for those receiving corticosteroids (3). More recent longitudinal measurements in rheumatoid patients with corticosteroid-induced osteoporosis showed that a control group continued to lose TBCa at an annual rate of 3%, but a group treated with micro-crystalline calcium hydroxyapatite had no such loss. TBCa was normal in patients with primary generalised osteoarthrosis or polymyalgia rheumatica.

A new method was developed of measuring the total bone mineral in the hand by single-photon absorptiometry with iodine-125 radiation (4). Precision is 1.9% and the coefficient of variation of normal subjects 13% after normalising for span and years post menopause.

Theoretical calculations on the precision of dual photon absorptiometry for measuring spine bone mineral had earlier shown that Gd 153 was the best source, but that a combination of Am 241 and Cs 137 should be acceptable (5). The latter pair have now been incorporated into a scanner. Dependence of vertebral bone mineral on size and age was small; after normalisation, the coefficient of variation for normal subjects was 14%.

When TBCa, hand and spine bone mineral were measured in patients with rheumatoid arthritis, it was found that the deficit of hand bone mineral was greater than that of TBCa, but the spine bone mineral was in the normal range.

Steroid-treated asthma patients had a reduced TBCa, but hand and spine bone mineral were normal. In each of these groups the correlation between hand, spine and whole body bone mineral was poor when they were expressed as % of normal.

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NON-INVASIVE TECHNIQUES FOR QUANTITATING BONE MASS - Fact or Fancy

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As bone mass is the principle determinant of fracture, a noninvasive quantitation of bone mass would theoretically be of value in bone-wasting disease in (a) predicting the risk of fracture, (b) quantitating the severity of disease, and (c) following response to therapy. The past 20 years have seen the development of a number of non-invasive procedures, including radiogrammetry (RG) and radiographic photo densitometry (RD), single and dual photon absorptiometry (SPA) and (DPA), computed tomography (CT), and total body calcium neutron activation analysis (TBC); such techniques are capable of quantitating bone mass at those axial, appendicular, and total skeletal sites encompassing the principle areas involved in bone-wasting diseases (i.e., spine, wrist, and hip). In addition, these measured sites exhibit varying proportions of cortical and trabecular bone; trabecular bone appears to be metabolically more active than cortical bone, to be preferentially altered in osteoporosis and other metabolic bone diseases, and to be the type of bone most affected by the majority of medications utilized in the treatment of most metabolic bone disease.

RG, RD, and SPA exhibit a reasonable cost, radiation dosage and precision, but do not quantitate bone mass at the principle sites of the most common metabolic bone disease, osteoporosis. TBC is a precise and accurate procedure and has proven efficacy in monitoring response to therapy; its high radiation dosage, limited availability, expense, and predominantly cortical bone mass measurement is less acceptable. TBC does however provide a unique assessment of net skeletal change: cortical and trabecular compartments. The two comparatively new techniques of DPA and CT are perhaps the most promising of available methodologies, as they quantitate bone mass at two of the principle target organs affected in the most common metabolic bone disease, osteoporosis: the spine and the femur. Cost is reasonable, and radiation dosage is minimal with DPA, although somewhat high with CT. The CT measurement of primarily trabecular bone within the vertebral body is unique. Marrow fat may, however, provide a significant error in accuracy for the single-energy CT. Dual-energy CT may correct such an error, but with a possible decrease in precision. DPA, on the other hand, quantitates bone mass within the entire vertebral body, including transverse and spinal processes, and possibly within surrounding tissues including the aorta (aortic calcification).

No noninvasive technique is currently noted to significantly discriminate between normal and osteoporotic individuals; indeed, it appears unlikely that any single methodology currently quantitating bone mass alone can definitively predict the individual at significant risk for osteoporosis prior to the occurrence of fracture, in part due to the presence of factors (tendency to fall, decreased neuromuscular coordination) other than low bone mass that may contribute to fracture.

In addition, there is increasing concern regarding: 1) the relative amounts of bone present at different skeletal sites (sites of varying amounts of cortical and trabecular bone) and the ability of a measurement of bone mass at one site to predict bone mass at a second site, 2) the relative changes in bone mass at different skeletal sites and the ability of a measurement of bone mass change at one site to predict bone mass changes at a second (and third) sites, 3) a possible heterogeneity of response to various therapies, particularly those for osteoporosis, between different bone sites, such that a measurement of therapeutic response at one site may not predict response at a second site.

In spite of these concerns, however, definite advances have occurred in the field of noninvasive bone mass quantitative techniques over the past 15 to 20 years, and there is no doubt that such techniques have contributed to the overall evaluation of the patient either at risk for, or already with, bone-wasting disease.

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OSTEOPOROSIS IN PATIENTS WITH INFLAMMATORY BOWEL DISEASE

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The prevalence of osteoporosis in inflammatory bowel disease (IBD) has not been accurately established. Using single photon absorptiometry (SPA) and vertebral quantitative computerised tomography (QCT) we measured bone mineral content (BMC) in 75 unselected patients with IBD.

Osteoporosis (BMC >2SD below normal mean) was present in 23 (31%). Seven had cortical and trabecular osteoporosis, 11 cortical only and five trabecular only. Three amenorrhoeic premenopausal females had clinically severe osteoporosis and a further 4 had vertebral crush fractures. The median lifetime steroid dose in osteoporotic patients was significantly greater than in patients with normal BMC ($P < 0.05$); most patients with osteoporosis had small bowel IBD with one or more resections.

Repeat QCT measurements in 18 patients after one year were unchanged in 12, increased in one and decreased between 10 and 37 mg/ml K_2HPO_4 (mean 22.6) in 5 (mean age 38.6 years) of whom four were receiving steroids. Radial BMC decreased in one patient, increased in one and was unchanged in the remainder.

Thus osteoporosis was present in 30% of these patients, with severe clinical disease in three young females. Rapid spinal trabecular bone loss was demonstrated over the course of one year in some patients. Steroid therapy, amenorrhoea and small bowel IBD with resection appear to be important risk factors.

ABSTRACT

BONE LOSS IN RHEUMATOID ARTHRITIS.

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We studied 159 patients with rheumatoid arthritis (RA) treated with a variety of drugs including glucocorticoids, penicillamine, gold, and NSAID. Stratification of the patients was done according to treatment, sex, menopausal state, duration of the disease, and functional impairment (functional class). Forearm bone mineral content (BMC) and total body bone mineral (TBBM) were measured by single and dual photon absorptiometry. Bone turnover was estimated by biochemical markers (BGP, alkaline phosphatase, fasting urinary hydroxyproline, and fasting urinary calcium). All patients had significantly decreased BMC and TBBM compared to normals. Comparing glucocorticoid and penicillamine treatment in premenopausal patients, we found significantly lower BMC and TBBM values in the glucocorticoid treated group. However, no differences in BMC and TBBM values were found in the corresponding postmenopausal groups. In the premenopausal glucocorticoid group the duration of treatment and cumulated dose correlated with BMC, whereas no such correlations were found in the postmenopausal women. In the patients who did not recieve glucocorticoids we found significant relationships between BMC and functional impairment as well as duration of the disease. Indices of bone turnover rose with increasing functional impairment, particularly those of bone resorption.

We conclude that 1) RA is accociated with bone loss, 2) glucocorticoid treatment aggravates the bone loss, 3) bone loss due to glucocorticoid treatment is more marked in premenopausal women, 4) in non-glucocorticoid treated RA patients osteopenia is induced by disability by an increase in the bone turnover, particularly the resorption processes.

Accuracy and precision in the *in vivo* determination of bone mineral content using the attenuation of a continuous x-ray spectrum

R. Jonson, B. Roos, T. Hansson and S. Mattsson

An x-ray technique using a highly stabilized generator and a germanium detector for the *in vivo* determination of bone mineral content in the lumbar vertebra has been described previously from our laboratory. This technique estimates the bone mineral content in presence of fat and lean soft tissue in the path of the x-ray beam.

The prestent investigation was undertaken *in vitro* to determine the accuracy, precision and long term reproducibility of the technique. The ash density of 12 human bone specimens was determined on the basis of ash weight and total volume measurements of each specimen. The result was compared with the measured bone mineral content. The deviation between the result of the attenuation measurements and the weight/volume measurements was (4 ± 0.9 %).

The precision of the method as measured *in vitro* has been determined to be between $\pm$ 1.6% (high bone mineral content) and $\pm$ 2.6 % (low bone mineral content) by repeated measurements on a new type of bone mineral phantom.

The results show that the technique described gives an accuracy and a precision which is of the same order of magnitude as the technique using dual photon energy absorptiometry.

ABSTRACT

Bone changes occurring spontaneously and caused by oestrogen in early postmenopausal women: a local or generalised phenomenon?

Claus Christiansen, Anders Gotfredsen, Bente Juel Riis & Christian Hassager. Department of Clinical Chemistry, Glostrup Hospital, University of Copenhagen, DK-2600 Glostrup, Denmark.

Regional values of bone mineral content and bone mineral density were calculated from total body dual photon absorptiometry scans of 52 early postmenopausal women treated with oestrogen for one year and of 52 similar women treated with placebo. The six regions were head, arms, chest, spine, pelvis, and legs. In addition, bone mineral density of the spine was calculated by dual photon absorptiometry and bone mineral content of the forearm by single photon absorptiometry, using separate special purpose scanners.
All regions were unchanged after one year of treatment with oestrogen, excluding the lumbar spine, for which values rose. Values for all regions except the lumbar spine fell significantly in the placebo group. The rates of loss ranged from 2 to 8%, with no significant differences between the regions.
It is concluded that loss of bone in the early menopause is a generalised phenomenon, affecting all parts of the skeleton. Furthermore, oestrogen prophylaxis for loss of bone is effective in all parts of the skeleton. Finally, it is suggested that the measurement of bone mineral content in the forearm be used for clinical follow up of bone changes, as this method is superior to others in the ratio of change to precision.

An Evaluation of central skeleton, Neutron Activation Analysis for the routine diagnosis of osteopenia.

J.E. Harrison, K.G. McNeill, N. Patt, C. Mueller, R. Chow & BMG, University of Toronto.

At Toronto, NAA is used to quantitate the total bone mineral in the central third of the skeleton and results are expressed as fractions of the mean values for normal young adults (<55 yrs) of the same body size, based on height and arm span. The normal range for this Calcium Bone Index, CaBI, is 0.75-1.20. The CaBI values for 181 patients, investigated for postmenopausal osteoporosis, were compared to spinal x-ray measurements of vertebral deformity. Fractures were defined as vertebral compression > 10% or wedging with anterior/posterior vertebral heights (A/P ratio) <0.67 for thoracic and <0.75 for lumbar vertebrae. The 127 patients without fractures had a mean CaBI = 0.81 ± 0.13 with low CaBI values (< 0.75) in 24% of cases. The 54 patients with fractures had a mean CaBI = 0.67 ± 0.12 with CaBI <0.75 in 80%. Thus our CaBI gives useful separation between these two groups. Furthermore, 10 of the 11 fracture patients with normal CaBI values had only one thoracic fracture and this isolated deformity may not necessarily reflect significant osteopenia: 97% of patients with multiple fractures had CaBI < 0.75. Results by dual photon absorptiometry (DPA) correlate significant (r =0.73) to CaBI values but with a large s ΣΣ (±13.5%) so that the value by one procedure may not predict reliably that of the other.

For over 10 years, the CaBI has been used routinely for the diagnosis of osteopenia and to assess bone changes with progression of disease and in response to treatments. Recently, CaBI values on 42 women, mean age 57 ± 7 yrs., have shown significant correlation (r =0.74) to physical fitness, based on VO_2 max. while correlations to age (r = -0.14) and to years postmenopause (r = -0.25) were not significant. To meet the clinical demand for CaBI, an upgraded hospital facility will be built within the next year.

BONE MINERAL MEASUREMENTS AND THE PATHOGENESIS OF OSTEOPOROSIS

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ABSTRACT

Low bone mass (osteopenia) is a major factor in the development of osteoporotic fractures in women after the menopause. The pathogenesis of postmenopausal osteoporosis has been pursued by dual lines of investigation: (1) development of a model to describe involutional bone loss, (2) identification of those factors which result in some healthy women having a greater risk for osteoporosis than others. Bone mineral measurements have been made using in vivo neutron activation analysis and whole body counting for the measurement of total body calcium (TBCa), single photon absorptiometry for the measurement of bone mineral content of the distal radius (BMC_r) and dual photon absorptiometry for measurement of the bone density of the spine (BD_s). TBCa is higher in men than women and is lost at a slow linear rate in men. Blacks have a skeletal mass about 8-9% higher than Caucasians. Women have a similar slow loss of TBCa to men prior to menopause, but then have an accelerated rate of loss after menopause. The change in bone density of the radius and spine with increasing age is also best described by a 2 phase regression in women, with appreciable loss after age 50 years.

The probability of a woman developing osteoporotic fractures may be estimated through the use of a multiple logistic regression model. For example:

$$TBCa = \text{logit}_p = \ln(p/1-p) = 0.466A + 1.47 \times TBCa/H - 57.17,$$

where A is age (years) and H is height (cm). Construction of receiver operating curves using TBCa, BD_s and BMC_r reveal that TBCa best separates osteoporotic from non-osteoporotic women and the other 2 measurements are comparable. Each 100 gm reduction in TBCa is associated with a 10.7 x increased risk for the development of the vertebral crush fracture syndrome.

Population studies and a case control study have identified the following risk factors for postmenopausal osteoporosis: early menopause, cigarette smoking and low estrogen and calcitriol levels. Exercise is protective in maximizing peak bone mass and preventing postmenopausal bone loss. The importance of exercise was demonstrated by a cross-sectional study of male marathon runners and a prospective study using motion sensors, where TBCa and BD_s were shown to be related to physical activity levels. A prospective study has shown that exercise helps prevent postmenopausal bone loss. We believe that women with low bone mineral measurements at the time of menopause should be given the option of estrogen replacement therapy. Physical exercise and cessation of smoking should be encouraged and an adequate intake of vitamin D should be ensured.

Sequential and population BMM studies using dual energy (spine) and single energy (femur and forearm) photon absorptiometry

E. G. A. Aird

The methods of BMM available in Newcastle will be described briefly. These are:

1. a commercial machine (NOVO) for dual energy, area scanning of the spine;

2. a machine built in Newcastle using fluorescent X-rays, primarily intended for measurement of the femur;

3. a commercial machine (NOVO) for single energy measurement of the forearm.

The long term reproducability for patient measurements will be discussed for all three methods including the impact of new software for the spine machine. The results of population studies of various groups of renal patients and osteoporotic patients will be presented. The results of sequential measurements at all three sites on a group of osteoporotic patients, in which some have been treated with calcitonin, will be discussed.

Initial studies on BMM of patients treated for primary bilary cirrhosis will be presented.

Ultrasonic Studies of the Os-Calcis In Vivo

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It has now been more than two years since the initial report of the relevence of the measurement of the frequency dependence of ultrasonic attenuation of the os-calcis to the trabecular structure of the bone. Since that time we have been engaged in further studies in two directions. Firstly we are examining the underlying physical mechanisms associated with the interaction of the ultrasound with the cancellous bone of the os-calcis. Secondly we have been conducting a series of clinical trials in collaboration with medical centres in the UK. These trials have allowed us to assess the relevence of ultrasonic bone analysis (UBA) to a range of medical conditions, including osteoporosis, and to compare UBA to techniques used at present such as single and dual photon absorption , C.T. scanning and morphology.

This work has been carried out in parallel with developments of the technique itself which have allowed improvements in the speed and reproducibility of the measurement. The presentation will review the progress made to date in these various directions and consider the possible future developments.

* Now with Walker Sonix UK Ltd., Newlands Technology Park, University of Hull UK.

USE OF A PULSED NEUTRON GENERATOR FOR IN-VIVO MEASUREMENT OF BODY CARBON, J.J. Kehayias, K.J. Ellis, S.H. Cohn and S. Yasumura, Medical Research Center, Brookhaven National Laboratory, Upton, New York 11973.

Measurement of total body fat (the body's main energy store) is of importance in studies of nutritional assessment, dietary regimens, and for the management of obesity. In the past, fat has been determined either by anthropometric methods, which introduce high uncertainties, or by model-dependent estimation of fat-free tissue. The validity, however, of the different models in disease is questionable. Total body carbon measurements provide a more direct evaluation of body fat both in normal subjects and in patients. We present here a facility for carbon measurements without the use of a major accelerator. The same facility can be used for the measurement of other major body elements (K,O,N,H) and thus for the evaluation of the body's compartments.

Carbon is measured in-vivo through neutron inelastic scattering, by detecting the 4.44 MeV gamma rays. A miniature (10 cm long) 14 MeV D-T neutron generator is used, which has been developed by Sandia National Laboratories. The neutron generator is pulsed at a rate of 10 KHz and delivers 1000 neutrons/pulse. A target current feedback system regulates the source of the accelerator to assure constant neutron output.

The short half life of the 4.44 MeV state of carbon requires detection of the gamma rays simultaneously with the 10 μs neutron pulse. Generators with low pulsing rate were found inappropriate for carbon measurements because of their low duty-cycle (high neutron output during pulse). The detection system consists of NaI(Tl) detectors and fast electronics for handling the high event rate during the neutron pulse.

Description of the facility and evaluation of the technique will be presented.

LEAN BODY MASS AND FAT: CONCORDANCE AND DISCORDANCE

G. B. Forbes, University of Rochester Medical Center, Rochester, NY

This presentation will compare the changes in LBM and fat produced by various maneuvers, using data from the author's laboratory and from the literature. In certain situations these two body components change in the same direction albeit in variable proportions; in other situations they change in opposite directions.

Concordance. Deliberate overfeeding of normal subjects with normal diets, and rehabilitation of the undernourished produce an increase in both LBM and fat; the relative contribution of each component to the total weight gain determines the energy cost of the weight gain. Spontaneous weight gain also involves both LBM and fat. With but one exception (the hibernating bear) underfeeding results in a fall in both LBM and fat; the ratio of LBM loss to the total weight loss is directly proportional to the degree of the energy deficit and inversely proportional to the initial body fat content.

Established obesity is usually associated with an increase in LBM as well as fat, anorexia nervosa with a decrease in both.

Discordance. Large doses of androgens cause an increase in LBM and a decrease in fat, hypothalamic injury (in animals) a decrease in LBM and an increase in fat. In contrast to normal high energy diets, those which are low in protein cause an increase in body fat without a concomitant increase — or even a decrease — in LBM. Vigorous exercise may decrease body fat and increase LBM to a modest degree, while bed rest does the reverse.

Thus in some situations LBM and fat behave as true companions, in other situations as strangers.

A STUDY OF THE SITES OF BODY FAT LOSS BY NMR IMAGING

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During a period of weight loss, body fat may be mobilised preferentially from particular sites in the body. The contribution of each depot to total fat loss varies with the physiological state and from one individual to another, depending on genetic factors. NMR has been used in Aberdeen to make images of body fat distribution in man and animals. This study was undertaken to assess how well NMR imaging can be used to detect the modest differential losses of fat from various parts of the body that may be of significance during a period of sustained weight loss. A group of 18 women volunteers, members of a slimming club, were studied before, during and after over a period in which they were losing weight by following a diet giving them an average intake of 1400 Kcal/d. At the start of the study their mean age was 35.9 (SD 12.3) years, their mean height 157 (SD 5.2) cm and their mean weight 76.7 (SD 7.5) kg, giving a mean body mass index of 31.1 (SD 2.6). The regional pattern of adipose tissue loss was examined by making images in each of six transaxial planes, two on the thorax, two on the abdomen and two on the thighs. The planes of these images were first determined on each subject from anatomical reference points and images were made at the same planes in each subsequent session. The body girth at every location was measured on each occasion as well as at the conventional bust, waist and hip sites. The instrument used in this study was the Aberdeen MkII imager operating at 3.4 MHz (0.08 Tesia) using pulse sequences based on the Aberdeen spin-warp imaging technique. The pulse sequence used was one in which 90° radiofrequency pulses are applied at intervals of 1s in the presence of a slice selection gradient. Each alternate 90° pulse is preceded by a spin inversion using adiabatic fast passage applied 200ms before the 90° pulse. This modified sequence produces the S2 signal displayed as an inversion recovery image which gave the strongest contrast between fat and other tissues and was used for the estimation of adipose tissue. The area of adipose tissue at each site was estimated both from the areas of the images occupied by the fat depots and by a computer program by which the number of pixels in the image giving a signal corresponding to adipose tissue were counted.

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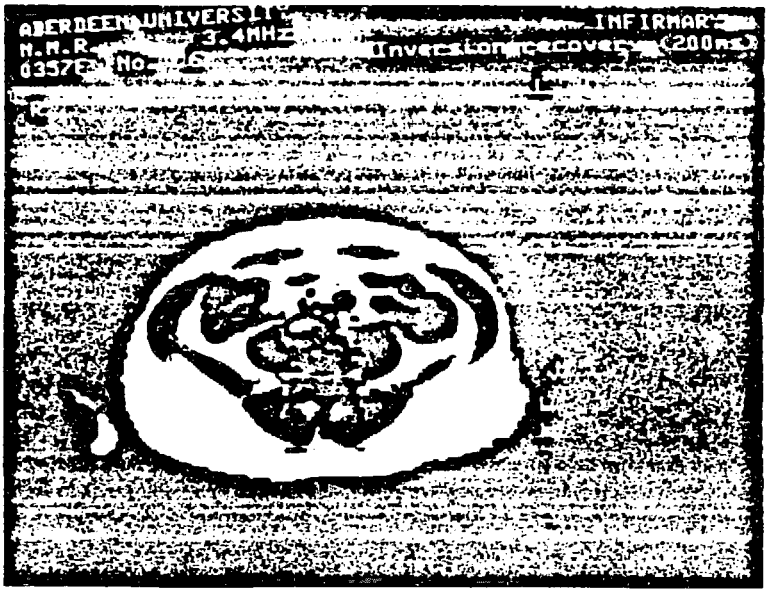

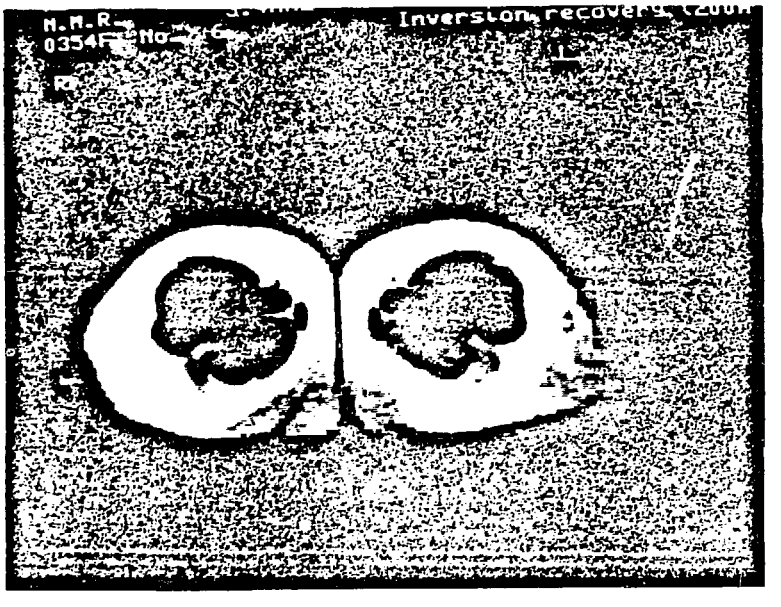

NONINVASIVE BODY COMPOSITION IN HUMANS BY NEAR INFRARED SPECTROSCOPY

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Since 1965, Near Infrared (NIR) Spectroscopy has been used to determine the chemical composition of forage and foodstuffs. Specifically this includes the protein, fat, and moisture content of grains, seeds, fruits, and meat. Fat, moisture, and protein all absorb radiation in the 1 region of the near infrared spectrum. This technology has been applied to the study of human body composition.

Near infrared radiation was introduced into the body at the same sites as typically used for skinfold measurements, triceps, biceps, subscapular, suprailiac, and thigh. NIR penetrates approximately 1 cm., interacts with the tissue, and is scattered back to the surface where the absorbance is measured. This process is called infrared interactance (IRI). Computer assisted spectra were obtained for the five sites (log 1/I [interactance] vs wavelength). The log 1/I at each of these wavelengths for all of the five sites was correlated with body composition estimates from other methods.

In the first study[1], data was collected from 53 adults (23 to 65 yrs). IRI correlated best with results from D_2O, r(±SEE) = 0.94 (3.0).

Body fats of 68 adults (38M,30F), between 20 and 61 years of age and between 4.5% and 39.9% fat were estimated by IRI, D_2O, SF, hydrostatic weighing (UWW) and total body impedance (TBI).[2] Correlation coefficients, r±SEE), were IRI:D_2O = 0.90(3.2); IRI:SF = 0.82(3.9); IRI:UWW=0.85(4.3); IRI:TBI=0.85(3.0).

In order to test the feasibility of developing a low-cost pratical instrument utilizing this technology, a computer simulation was performed to compare the results from the optimized single-term, second derivative data treatment, to the results from wide-bandwidth IRI data in combination with readily available subject parameters. D_2O was used as the reference method and subject parameters tested for inclusion with the IRI data were sex, age, weight, height, race and wrist circumference. Using the optimized second derivative, IRI:D_2O=0.84(4.0). The results for the wide-band width simulation were; 0.77(4.8) for IRI alone; 0.83(4.2) adding weight; 0.92(3.1) adding sex; 0.92(3.0) adding height. Adding wrist circumference, age, and race did not improve the correlation.

Preliminary results indicate that IRI (n=14) is significantly correlated to "actual fat" as determined by a combination of tritiated water and neutron activation.

1.Conway,J.M.,Norris,K.H., and C.E.Bodwell;Amer J. Clin Nutr 40:1123-1130, 1984

2.Conway,J.M., Norris,K.H., and C.E.Bodwell;Amer J. Clin Nutr. 41:839, 1985

A clinical facility for measuring total body fat.

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The paper reviews the progress in the development, design and installation of a clinical facility for measuring the amounts of fat and other body components using the techniques of prompt and delayed in vivo neutron activation analysis. Fat is measured during the neutron irradiation by counting the 4.43 MeV gamma rays from carbon nuclei excited by neutron inelastic scattering. The system consists of a 14 MeV neutron generator in a shielded enclosure with a collimator forming a horizontal beam of neutrons incident upon a lateral side of a supine patient. Collimated 6" x 5" NaI detectors are positioned two above and three below the subject in a mid-saggital plane. The gamma radiations resulting from neutron interaction with the body's hydrogen, carbon and oxygen are clearly observed in the detectors' response and those counts from carbon are used to estimate total body fat. After a neutron irradiation the subject is transferred to a whole body radiation counter consisting of eight 6" x 4" NaI detectors and their response resulting from the radioactivity induced in the body by the neutron irradiation is analysed to give estimates of total body nitrogen, phosphorus, sodium, chlorine and calcium. Accuracy and precisions of the measurements will be reported.

TISSUE LOSS DURING SEVERE WASTING IN LUNG CANCER PATIENTS

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Body composition changes have been measured in a small homogenous group of severely wasted lung cancer patients, as part of an investigation into the mechanism of wasting disease. In vivo neutron activation analysis was used in conjunction with whole body counting to measure the status of the major body elements Ca, N, P, K, Na, and Cl. Measurements from 6 patients who had lost an average of 29% of their pre-illness weight were each compared with 4 carefully-matched controls chosen from a group of several hundred patients with mild hypertension or hospital outpatients.

The mass of major body compartments was calculated in addition to the mass of the major body elements listed above. Total body water was calculated as the sum of intracellular water, measured as the K space, and extracellular water, measured as the Cl space. Fat was derived by difference (weight - lean body mass) after addition of total body water, protein (N * 6.25) and minerals (the sum of the mineral elements) to calculate the lean body mass. In addition, muscle mass changes were calculated by compartmental analysis of changes in total body N and K.

Results show that on average body fat reduction was greater than 80%. Intracellular water reductions were very significant in all patients, but extracellular water mass increased in only 2 patients, the mean change not being significant. Bone minerals decreased significantly in all patients. A major finding of this study was that the significant large reduction of total body N and K in all patients (means of 323 gN and 35 gK) was consistant with the hypothesis that skeletal muscle was the predominant tissue lost from the lean body.

In vivo monitoring of trace elements in medicine and research

D.R. Chettle[1], M.C. Scott[1], K.J. Ellis[2], W.D. Morgan[3]

This paper will survey recent developments in measurements of cadmium and lead in vivo, for which techniques have been available for about a decade, with a view to demonstrating the contribution such studies have made to research in occupational medicine and toxicology. Salient features of contrasting techniques will be drawn out so as to highlight their respective strengths and weaknesses. This will include comparison of neutron activation analysis and x-ray fluorescence for cadmium measurement, together with discussion of the choice of source in neutron activation systems. The different, and sometimes conflicting, claims of precision and accuracy will be discussed. In the case of lead, attention will focus on variations amongst x-ray fluorescence techniques. This will include discussion of the contrasting merits of using K or L series x-rays for lead measurements and comments on the choice of photon source for these measurements.

Recent technical advances which promise to extend the range of elements of interest in occupational medicine accessible to in vivo measurement will be considered. The present status of analytical techniques for mercury, beryllium, silicon and silver will be reviewed, and likely future development discussed.

Amongst other minor, or trace, elements, whose measurement will be discussed, are platinum, iron, copper, lithium and strontium. The varying fields of application for these analyses will be indicated, and the techniques already applied to the in vivo analysis of these elements will be considered.

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X-RAY FLUORESCENCE TECHNIQUE FOR IN VIVO ANALYSIS OF "NATURAL" AND ADMINISTERED TRACE ELEMENTS

During recent years there has been a growing interest to use X-ray fluorescence techniques for the in vivo measurements of trace elements in the body. This has arisen because

a) clinically important amounts of toxic heavy elements (e.g. Pb, Cd, and Hg) can be reached as a result of low-level occupational and environmental exposure

b) there is a possibility to gain additional biokinetic information by quantitative measurements of heavy elements in X-ray contrast agents (I, Ba) and in some modern very promising cytostatic drugs (Pt).

A variety of radionuclide and X-ray sources as well as irradiation and detection geometries have been used.

In practically all in vivo situations one have to measure close to the detection limit of the technique which means that there is a real need to optimize and continuously improve the technique.

The absorbed dose to the patient during a typical measurement which lasts 20-40 minutes is normally very low.

The paper will shortly review the technique and applications used for in vivo studies in man and finally present our recent data from in vivo measurements of platinum following cisplatin therapy.

In-Vivo Measurements of Pt and Pb in Patients Undergoing cis-Pt Chemotherapy

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An apparatus employing the method of X-ray fluorescence analysis has been developed [1] which is capable of measuring the uptake of platinum in the kidneys and superficial tumour sites of patients receiving cis-Pt chemotherapy. This enables pharmacodynamic information to be obtained directly, thereby increasing the potential for improving the effectiveness of drug dosage regimens.

For kidney measurements, a 20mCi (740MBq) ^{57}Co source is directed at the posterior lumbar region and a hyperpure germanium (HpGe) detector positioned laterally records the fluorescent Pt K X-rays emitted at 90° to the incident beam. Depending on the depth and position of the kidney, which is previously determined using ultrasound, the detection limit for a skin dose of 5mGy delivered in a time of 2000s is approximately 20ug g^{-1}. This is considerably less than the platinum concentrations in the kidney during cis-Pt administration, and is less than the amounts typically retained by the kidney after the treatment has been completed. The method therefore offers the opportunity of non-invasively monitoring the distribution and uptake of platinum in the body and relating this to the observed clinical effects.

A pilot study in 20 patients is in progress, in which Pt retention and distribution will be related to mode of administration and indices of nephrotoxicity. In three out of the first 10 patients, lead was also found unexpectedly in the kidney. In two of these cases, the uptake was massive (~ 1000ug g^{-1}) and in the third (in whom no lead had been observed prior to treatment) it was an order of magnitude smaller. All three patients had employment histories involving exposure to lead, although the one with the lowest result was only marginally exposed.

In one of these patients, Pb exposure was confirmed by a tibia measurement kindly undertaken by the Birmingham University Group using their ^{109}Cd system. A value of 95ug g^{-1} was recorded. Subsequently, the tibia Pb was measured in the other high exposure patient by the Swansea group and found to be 30ug g^{-1}.

These findings suggest that body lead stores may be mobilised by cis-Pt chemotherapy and that renal uptake of lead may be a hitherto unrecognised contributory factor to the nephro-toxicity of Pt compounds.

1. Dutton J, Evans CJ, Samat SB, Morgan WD and Sivyer A, 1985. Adv in X-ray Anal 28, 145-154 (Plenum)

X-ray Fluorescence of Lead In Vivo: Simultaneous Measurement of a Cortical and a Trabecular Bone in a Pilot Study.

L.J. Somervaille, D.R. Chettle, M.C. Scott, G. Krishnan, C.J. Browne
A.C. Aufderheide, L.E. Wittmers, J.E. Wallgren.

Following the development and successful application, of an in vivo x-ray fluorescence technique to measure lead in the tibia shaft, the method was extended to include a simultaneous measurement of the lead concentration in calcaneus. This method, in which the 88 keV γ-rays from ^{109}Cd excite the lead K series x-rays, can now be used to obtain the lead concentration in both cortical (tibia) and trabecular (calcaneus) bone.

As with the tibia measurement, the lead x-ray signal is normalised to a concentration in bone by means of the coherently scattered photon signal. The accuracy of this procedure was tested by comparing the results of x-ray fluorescence (XRF) and atomic absorption spectroscopy (AAS) measurements on 44 bone samples - a section of tibia shaft and the calcaneus from each of 22 subjects. The mean differences (XRF-AAS) in lead concentration (μg Pb (g bone ash)$^{-1}$) were; for the tibia -1 ± 2(SEM), and for the calcaneus 2 ± 5(SEM).

Measurements were carried out in a touring caravan, which had been converted for use as a mobile laboratory specifically for in vivo bone lead surveys. The use of the mobile laboratory greatly eases and reduces administrative arrangements entailed by a survey and gives considerable flexibility as to the places at which surveys can be undertaken. In this case 6 demolition workers were monitored on the site at which they were employed at the time. They had had considerable exposure to lead at the site and had escaped routine blood lead monitoring for about 3 years. In the two people with the longest exposure histories (5 and 20 years) the calcaneus lead concentration was high (~ 100 μg (g bone ash)$^{-1}$) and was about double their tibia lead concentrations. This can be seen as consistent with the postulated more rapid build up of lead in trabecular than in cortical bone.

It is concluded that in vivo monitoring of tibia lead can contribute to occupational health monitoring by giving an indication of cumulative

exposure. As had been predicted, the coherent normalisation method made the extension of the existing tibia lead measurement to another bone site technically straightforward. Although few data have yet been collected, the addition of a measurement of lead in a trabecular bone promises useful further information. Finally, the mobile laboratory has proved to be a completely satisfactory and convenient place in which to make in vivo measurements.

J O Christoffersson[1], A Schütz[2], B Ekstrand[2], L Ahlgren[1] and S Mattsson[1].

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A LINEAR MODEL DESCRIBING THE KINETICS OF LEAD IN OCCUPATIONALLY EXPOSED WORKERS.

We have during recent years studied occupationally exposed lead workers. The lead concentration in different tissues, predominantely in bone and blood, has been determined.

Using these data a linear three-compartment model for the kinetics of lead has been developed.

More than 90% of lead in the body is to be found in bone. The kinetics of lead in cortical and trabecular bone differ. Therefore two of the compartments consist mainly of trabecular and cortical bone respectively. The third compartment consists of blood and soft tissues.

Using this model levels of lead in bone and blood can be predicted on a group basis.

A Longitudinal Survey of Exposure to Cadmium Fume - Preliminary Findings from In-Vivo Body Burden Measurements.

D.M. Franklin, C.J.G. Guthrie, M.C. Scott, D.R. Chettle,
H.J. Mason, N.J. Smith, M. Blindt.

Members of a workforce exposed to cadmium fume during the production of brazing alloys had in vivo liver and kidney cadmium measurements made in 1981. The factory was revisited in 1986 when repeated measurements of both liver and kidney cadmium were obtained on 16 individuals; for a further 5 workers repeat measurements of only liver cadmium were acquired.

There had been a variety of exposure patterns in the time between measurements; in particular a number of people had ceased exposure on leaving employment at the factory in 1983.

Analysis of the results lent support to the suggestion made previously that cadmium is redistributed from liver to kidney some time after initial exposure and to the observation of an association between a low ratio of kidney cadmium to liver cadmium and renal dysfunction. The results of the in vivo monitoring also contributed significantly to advice concerning future exposure to those still engaged in the cadmium-silver alloy production.

It is concluded that longitudinal data on cadmium organ burdens, obtained by in vivo neutron activation analysis, are beginning to clarify what had previously only been inferred from cross-sectional studies. It is further noted that in vivo cadmium measurements can contribute to decisions in the area of occupational health in addition to their more established role in toxicological research.

In Vivo F-19 Magnetic Resonance Spectroscopy in Humans

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We have obtained for the first time in vivo F-19 spectra of the chemotherapeutic agent 5-Fluorouracil (5FU) and at least one of its catabolites, α Fluoro- β alanine (FBAL), from the intact liver of several patients undergoing chemotherapy. These results demonstrate the feasibility of in vivo F-19 spectroscopy in studying drug metabolism.

Previous F-19 studies of 5FU have been carried out in vitro or in vivo in animals, and in F-18 studies on patients.

Spectra were obtained using a 1.5 Tesla Magnetom, operating with a resonant frequency of 59.8 MHz. Spectra were collected and signal averaged over an eight minute period, commencing with the administration of the chemotherapy. This was done while the patient was within the magnet. A control spectrum before drug administration was taken to preclude the presence of any residual levels of 5FU. A surface coil 15 cm in diameter was used as a transmitting/receiving coil, and a $\approx 90^{0}$ pulse was optimized for ≈5 cm above the surface of the coil. The patients were positioned face down on the imaging table so that the liver was located directly above the surface coil.

Figure 1 shows several spectra recorded over the liver of patient "WK" (66 years old male). The 5FU peak, at 0.0 p.p.m, is clearly seen and its half life in this patient is 15 min. Within about 5 minutes after infusion of 5FU, at least one peak (FBAL) is seen at -18.9 p.p.m., indicating that the 5FU has been metabolized in the liver.

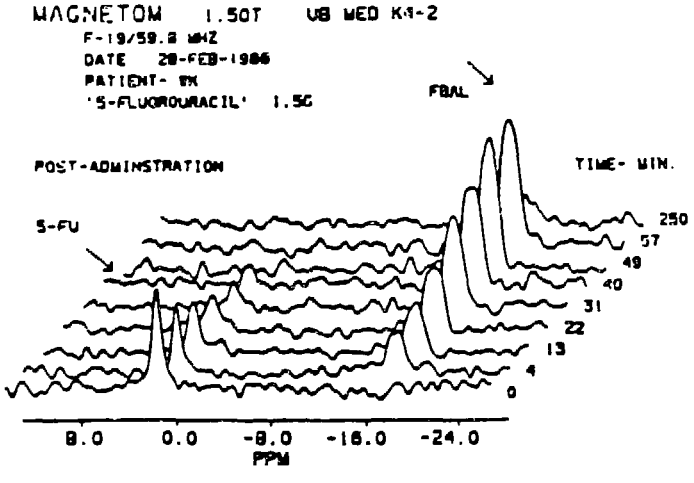

Figure 1

International Symposium on In-Vivo Composition Studies.
Brookhaven National Laboratory, Upton, NY 11973.
Sept.28 - Oct.1, 1986
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BODY LEAD BURDEN, II: ENVIRONMENTAL LEAD AND END-STAGE RENAL DISEASE.

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Approximately 200,000 Americans are currently afflicted with end-stage renal disease(ESRD) at a cost exceeding 2 billion dollars,however,fewer than 10% of ESRD cases are characterized etiologically(1). Among these, lead nephropathy is unique in that it is not only preventable but also reversible by EDTA Pb chelation therapy(2). Since over 95% of body Pb is stored in bone the application of rapid,non-invasive measurement of bone Pb by in-vivo X-ray fluorescence(XRF) offers the opportunity to perform epidemiological studies of the association of body Pb burden with an increased risk of ESRD. Five preliminary studies performed over the past two years in a collaboration of the VA with the University of Antwerp and Brookhaven National Laboratory support the conclusion that tibial XRF of chronic hemodialysis patients and case matched controls can establish the impact of body Pb burden on ESRD. I:5% of European patients have bone Pb levels comparable to those found in occupational Pb nephropathy(152 transiliac bone biopsies measured by atomic absorption spectroscopy(AAS). II:The good correlation between transiliac bone Pb and EDTA-chelatable urine Pb suggests bone XRF will reflect body Pb stores as measured by the EDTA test(17 patients). III:AAS measurements of Pb and Ca in paired iliac crest,transiliac and tibial biopsies from 8 random cadavers demonstrate that reproducible bone Pb values can be extracted from the measured Pb:Ca ratio rather than the absolute measure of Pb.Also,Pb XRF data collected by the BNL group in 6 random cadaver legs closely approximates Pb AAS data obtained by two other laboratories on the same legs. IV:Correlations between known Pb content of plaster of Paris phantoms and values obtained by XRF and AAS indicate that calculations and assumptions inherent in the conversion from XRF to absolute Pb ppm values are fundamentally sound. V:Correlation of Pb values obtained by XRF with those from the EDTA chelation test in renal clinic patients is continuing(22 patients to date)to establish whether bone XRF measurements may be more accurate and/or convenient predictors of renal damage than the urine Pb chelation test.Our current working hypothesis is that evaluation of body Pb burden by tibial XRF will provide the information necessary to make informed public health decisions with respect to the impact of environmental Pb on ESRD in adults.

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BONE ALUMINUM MEASUREMENTS IN PATIENTS WITH END-STAGE RENAL DISEASE.

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Long-term use of aluminum-based phosphate binders and trace aluminum contamination of dialysate solution have led to increased body burden of this metal in patients with end-stage renal disease. Aluminum accumulates in bone and has been associated with the development of a renal osteodystrophy, called "aluminum-induced osteomalacia." At present, bone biopsy is the method of diagnosis of this condition. When examined by quantitative histomorphometry, the aluminum accumulation was reported to correlate with the severity of the osteomalacia. This project was therefore undertaken to investigate the possibility of developing a non-invasive technique using neutron activation analysis for the direct in vivo assessment of bone aluminum levels.

A bilateral exposure (2 min total time, dose < 0.02 Sv) of the patient's hand is performed at the patient port of the Brookhaven Medical Research Reactor. The induced activity is then counted for 5 min using four 4"x4"x16" NaI(Tl) detectors arranged in a quasi-4! geometry. In addition to Al, Ca is also detected and serves as each individual's internal standard for the volume of bone mass irradiated. The Al/Ca ratio provides an index of the amount of elevated aluminum per unit bone mass. When this ratio is multiplied by the total body calcium value, an estimate of total skeletal aluminum is obtained. These measurements will be presented for a pilot study of ten asymptomatic renal patients.

THE QUALITY of the LEAN BODY MASS

Richard N. Pierson, Jr. and Jack Wang

Methods of Measurement: Implications for Clinical Medicine

The concept of isolating the lean body mass by identification of the fat mass has presented severe methodological problems for four decades. The interests of several groups in studying fat, and the increasing sophistication of instruments which induce different signals from fat than from water-containing lean tissues, have set the stage for consistent identification of the lean body from its surrounding and interspersed layers of fat. Several of these methods show promise of providing measurements which are independent of assumptions which, in the history of body composition measurements, have turned out to be dependent on age and sex.

Cellular integrity depends largely on membrane potential, and membrane potential depends principally on sodium and potassium gradients between the cell and its surrounding extracellular fluid. While the particular membrane potential in skeletal muscle, intestinal epithelium, cerebral cortex, and osteoblast varies according to specialized function, and many diseases selectively affect such a small mass of cells that there is no measurable "whole body" distortion of constituents which can only be measured as averaged contents for the whole body, there is a set of diseases, prominent in clinical medicine, where systemic defects in membrane function are associated with "average whole body" abnormalities which turn up in our measurements. Disorders of nutrition are prominent on this list. We will present small sets of data concerning the constituents of the lean body in several conditions and disease states, from which we have developed the concept of the **quality of the lean body mass.**

After adipose tissue has been measured and subtracted from the body weight, and certain adjustments made to allow for the extracellular water obligated by the adipose tissue, the body potassium and sodium contents are considered. In studies where the extracellular and intracellular water are measured, and the average potassium and sodium concentrations in the intracellular water (K_i and Na_i) are available, they are used to define the quality of the lean body. In a larger number of clinical studies, only body potassium and body water measurements are available, and the K/TBW is taken as surrogate for the more complete measurements.

We will review data from our own laboratory and others which include K_i and Na_i and K/TBW, in cohorts of subjects who are normal and super-normal (athletes), and in patients with alcoholism, manic-depressive psychosis, obesity, anorexia nervosa, cardiac failure, and AIDS, which affect water and electrolyte metabolism. These data will establish the correlation of K/TBW with the K_i/Na_i ratio, and will provide a basis for discussion of the concept that the quality of the lean body can be defined with clinical utility in such a one-dimensioned manner.

MEASUREMENT OF TOTAL BODY WATER BY ISOTOPE DILUTION: A PRIMER FOR CALCULATIONS. DA Schoeller and PH Jones, Clinical Nutrition Research Unit, University of Chicago, Chicago, IL 60637.

Water is the major component of the human body and is associated with fat free mass. Measurement of total body water is, therefore, important in the assessment of body composition. This measurement of body water is often performed by isotope dilution using either the stable isotopes deuterium or oxygen-18 or the radioisotope tritium. Although the dilution principle itself is quite simple-ie total body water=dose/concentration-the dynamic nature of water metabolism necessitates corrections for isotope losses or changes in body water that occur during the delay associated with isotope distribution across the body. If the time of the determination is defined as the time of the dose, then the amount of isotope in the body is equal to the dose. However, because the sample is collected at some time after the dose to allow for isotope equilibration, the measured total body water must be corrected for any water entering the body pool between the time of the dose and the time of the sample. If the time of the determination is defined as the time at which the sample is taken, then the amount of isotope in the body is equal to the dose less any isotope that has left the body as either urine or insensible water. There is, however, no new water correction, because the sample is collected at the defined time of total body water determination. In addition to these corrections, further corrections are needed because these isotopes are not perfect tracers for water. These imperfections include exchange of the isotopic tracers with nonaqueous components of the body and isotopic fractionation. Unfortunately, the above sets of corrections are often ignored or abused. Although these corrections are small (1 to 5%), they become quite significant when the purpose of the study is to determine body composition for the purpose of measuring energy stores and changes in those stores over time. (Supported by NIH grant AM 26678)

Hydration of fat-free mass in protein-calorie malnourished infants. CR Fjeld[1,2],DA Schoeller[1],KH Brown[2];[1]U of Chicago,IL USA;[2]Instituto de Investigacion Nutricional, Lima, Peru.

Total body water may be unreliable in single-point measurements of fat-free mass (FFM) in malnourished children because of hydration abnormalities. However, data on hydration of FFM are largely from cadaver analysis leaving uncertainties about body composition of children who survive and particularly about composition of weight gained during recovery.

The objective was to test the hypothesis that the FFM component of weight gain(d FFM) could be measured from change in total body water(dTBW). A predictable relationship between dTBW and d Protein in body mass gained would support the hypothesis. We further tested the hypothesis by comparing energy stored calculated from TBW with that determined by energy balance.

Twelve marasmic children, 9.3 mos height-age, hospitalized in the IIN in Peru were studied when weight was between 70 and 93% expected for height. Seven were studied 2X, 19 studies total. Nutrient requirements for catch-up growth were met or exceeded. Deuterium and oxygen-18 were given day 1,and 7 to 11 days later. Enrichment was measured in urine collected 3 to 6 hrs post dose. TBW was the average of deuterium space/1.04 and oxygen-18 space/1.01. Protein retention (N X6.25) was from 3 to 4 day metabolic collections. From regression, (3.92 X d Protein) - 0.48 = dTBW; ($r=0.64, n=19, p<.001$). This does not differ significantly from the slope calculated from published values for normals of comparable heights(Fomon AJCN 1982 35:1169) suggesting the hydration coefficient of FFM added is normal.

Body composition from dTBW assumed that (d body weight)-(d FFM) = d Fat; d FFM from dTBW used hydration constants for normals of equal height (Fomon,ibid). The energy equivalents were calculated using: Energy stored as FFM = dFFM X %Protein X 5.65kcal; energy stored as fat = Fat,g X 9.4kcal. Energy balance was from energy in and fecal loss by bomb, energy expenditure by doubly labeled water. Average weight gain was 1225 g, 7.6g/kg/d(sd=3.6), 44% of which was water. Sum of calories deposited as new mass calculated from TBW was 47.9 kcal/kg/d (6.3kcal/g gain) and from energy balance, 48.5 kcal/kg/d (6.4kcal/g gain). Although average values are nearly equal, sd of each mean is large, partly because weight gain rates and composition differed between patients, leading to large sd of means of kcal stored/kg/d. However individuals' energy stored, calculated from energy balance, differed significantly from that calculated from d TBW.

The hydration coefficient of FFM gained is predictable so that dTBW is a measure of FFM gained during recovery from marasmus.

BODY COMPOSITION CHANGES IN ESSENTIAL HYPERTENSION BEFORE AND AFTER TREATMENT

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The body composition of 30 elderly (22 females: 78,2+7,6; 8 males: 80,4+5,4yrs) and 38 middle-aged (27 females: 45,5+10,3; 11 males:42,3+8,7yrs) people suffering of essential hypertension, determined by complex clinical and biological examinations (BP: 160-180/100-120 Hgmm), was determined before and after treatment. Most of them (78%) could be reassessed after 3 month of treatment (beta-blocking drugs or diurectics). We also investigated a few numbers (n=10) of patients presenting a hypertensive crisis treated with vasodilatant drugs and diurectics during 1 week of period. The hormonal status of all of them was assessed at the same time. The body composition was determined by multiple-isotope method.

It was found that in the case middle aged patients independently of sexes, either the extracellular volumes (plasma volume PV, interstitial volume ISV) except the extracelllular volume (ECV) or intracellular volumes are enhanced in the case of essential hypertension. In contrast in the elderly, except the enhancement of PV, no significant differences could be demonstrated comparing to healthy age-matched controls. After 3 months of beta-blocking drug treatment in the middle-aged group for females, the PV did not change, total body water (TBW) and intracellular volume (ICV) normalized, as well as ISV. The ECV did not change significantly. In the case of males we observed also a normalization of body compartments, including the PV. After 1 week of treatment for hypertensive crisis (BP>180/140 mmHg) all the body compartments diminished significantly in both sexes, without normalization, except ICV which diminished only moderately comparing to the starting value. In the case of elderly no changes in the body composition could be observed after treatment with beta-blocking drugs comparing to the starting values. In contrast ,if diurectics were used we observed the normalization of PV but also a significant diminution of TBW and ICV comparing to normal values, without marked changes of other compartments. The hormonal values followed sensibly the body composition changes.

We can conclude, that 1. the changes of body composition in essential hypertension are different in middle-aged and elderly persons; 2. with beta-blocking drugs after 3 months of treatment the body composition of middle aged subjects became normalized; 3. in elderly the beta-blocking drugs had no effects on body composition, while they normalized in most cases the blood pressure. Diurectics normalized the PV, but diminished the intracellular compartements.

DEUTERIUM AND OXYGEN-18 ISOTOPE DILUTION SPACES IN NORMAL ADULTS. William Wong, William Cochran, Lucinda Lee, William Klish, and Peter Klein. USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas

The volumes in which ^2H_2O and $H_2{}^{18}O$ tracers are diluted in the body are not identical and may vary with physiological age. In light of the limited series of published comparisons we have determined the deuterium and oxygen-18 isotope dilution spaces in 10 normal subjects, 5 males and 5 females. The male subjects ranged from 32 to 58 yr in age, 168.1 to 177.2 cm in height, and 73.0 to 82.5 kg in weight. The female subjects ranged from 28 to 41 yr in age, 160.7 to 172.2 cm in height, and 53.6 to 60.0 kg in weight. Labeled water was administered orally at doses of 40 mg deuterium oxide and 60 mg oxygen-18 per kg of body weight. One predose blood sample and six hourly postdose blood samples were collected from each subject. Aliquots of plasma water were reduced directly to hydrogen gas with zinc shot in individual quartz reaction vessels and $^2H/^1H$ isotope ratios were determined by gas-isotope-ratio mass spectrometry (GIRMS). $^{18}O/^{16}O$ isotope ratios were determined after plasma samples were equilibrated with CO_2 in an isotope exchange system. Both ^2H- and ^{18}O-labeled water attained isotopic equilibrium in plasma within 3 hr after administration. The deuterium dilution spaces in males and females were 56.4 $\pm$ 2.1% (mean $\pm$ SD) and 55.9 $\pm$ 0.9% of body weight, respectively, while the ^{18}O dilution spaces constituted 54.1 $\pm$ 1.85% and 53.30 $\pm$ 1.30%. The deuterium spaces were larger than the ^{18}O spaces by 4.55 $\pm$ 0.56% in men and 4.78 $\pm$ 1.63% in women and were significant at $P < 0.01$. These results compare with values of 3.81 $\pm$ 2.66% for males ($n = 6$) and 1.10 $\pm$ 2.67% for females ($n = 2$) previously reported by Schoeller et al (Am. J. Clin. Nutr. 33 2686-2697, 1980).

BODY WATER, EXTRACELLULAR WATER, BODY POTASSIUM, and EXCHANGEABLE SODIUM

in BODY BUILDERS USING ANABOLIC STEROIDS

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ABSTRACT

Nine competitive male body builders aged 21 to 34 who were determined to take anabolic steroids were studied before and 6 to 10 weeks after a training cycle which included steroid administration. A control group of nine subjects matched in age and duration of competitive career, but using only natural training methods were studied on a single occasion while in training. Total body potassium (TBK) by ^{40}K, total body water (TBW) by $^{3}H_2O$ dilution, extracellular water (ECW) by $^{35}SO_4$ dilution and zero time extrapolation, and exchangeable sodium by ^{24}Na dilution were measured before and after training. Intracellular water (ICW) was calculated from TBW - ECW.

Initially steroid users had greater skeletal muscle mass than control subjects, and obtained a further weight gain on steroids (+ 5%, p,.05), all in skeletal muscle, based on parallel increases in TBK and ICW. Other body composition measurements did not change significantly. A single steroid user became ill taking steroids, decreased potassium by 5%, and increased extracellular water, changes which may represent the effects of hepatic dysfunction which occurred while on anabolic steroids.

DIRECT MEASUREMENTS OF TOTAL BODY OXYGEN IN BODY COMPOSITION STUDIES

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Since Williams and Boddy first reported in 1978 the measurement of body oxygen in vivo using the $^{16}O(n,p)^{16}N$ reaction induced by 14 MeV neutron activation, the method has been routinely applied to all TBIVNAA multielement patient analyses at SURRC. A considerable bank of data has thus been accumulated which lends itself now to detailed analysis to assess aspects of the effectiveness and applicability of the measurement. We have taken a selected group of 85 patients with abnormal blood pressure and used their total body oxygen to calculate total body water by compartmental means from the known oxygen stoichiometry of protein, mineral, water and fat and intercompared this with other methods for body water namely: tritium dilution and the sum of chlorine and potassium spaces. The findings are presented and discussed. In routine use the repeatability of total body water measurement by TBIVNAA has been found to be 7.8% (2σ) and 5.1% (2σ) for compartmental and electrolyte space analyses respectively.

Anthropomorphic models for the Calibration of equipment for in-vivo neutron activation analysis

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At present each centre performing chemical analysis in vivo calibrates its equipment with home-made anthropomorphic models containing the elements of interest. These models are of varying construction, usually contain only one element at a time, and often approximate poorly to human anatomy and its variation.

To improve on this state of affairs I have constructed 3 models of the human body of different sizes.

	Height		Weight	
	m	ft.in.	kg	stone, lb.
Small	1.50	4'11"	41.4	6 st. 7 lb.
Medium	1.82	5'11"	66.8	10 st. 7 lb.
Big	1.91	6' 3"	110	17 st. 4 lb.

Miss Small and Mr. Average are made up of circular or elliptic cylinders with walls of Polythene, polypropylene or Perspex. Mr. Big is modelled on an actual person and is made of a transparent plastic (Uvex). The bony skeletons are Perspex tubes filled with various chemicals, mainly calcium phosphate. The tibias of Mr. Average contain lead. The bony anatomy is severely simplified; for example, the ribs run longitudinally and the lower legs and arms contain only a single bone in each. Each model contains thyroid, lungs, liver and kidneys. Thyroids contain only iodine. Lungs have densities of about 0.3 and Miss Small's lungs contain silicon. The other organs contain the following elements:

	Kidneys	Liver
Small	Cd, Pt, Hg	Al, Cu, Se, Cd
Average	Cd	Cu, Se, Cd
Big	Cd, Pt, Hg	Mn, Cu, Se, Cd

Soft tissues are stabilised with Agar gel and contain H, C, N, O, Na, Mg, P, S, Cl, K, Fe, Zn, Br in approximately the correct proportions. Bones contain H, C, N, O, Na, Mg, P, S, Cl, K, Ca. There is also a pocket for a neutron film badge to measure the dose-equivalent in the middle of the body.

The models can be taken to any centre wishing to calibrate its equipment. The idea is that they should be treated as though they were living subjects. Measurements can be made either of total body contents or of the quantities of trace elements in individual organs. The two larger models have been assayed at Edinburgh and Hammersmith for the total-body content of Na, Cl, P, Ca, K and N. The results of the calibrations will be published when the series of visits is complete.

Relationship between density and body weight in prematurely born infants recieving different diets. R.B. Dell, Y. Aksoy, S. Kashyap, M. Forsythe, R. Ramakrishnan, C. Zucker, W. C. Heird. Department of Pediatrics, College of Physicians and Surgeons, Columbia University.

Body density, defined as weight/volume, is a function of total body fat, protein, bone mineral and water. If bone mineral and total body water are relatively constant over time within a subject then changes in density reflect changes in the proportion of fat to protein in the body that occur with growth. We determine density by weighing the infant and by measuring volume utilizing a newly developed instrument (Volumeter).

The principle of air displacement is used in the Volumeter to measure volume. The instrument consists of two identical plexiglas cylinders enclosed in a thermostated box with a sensitive differential manometer monitoring the pressure difference between the two cylinders. At one end of each cylinder is a diaphragm and at the other end is a door with a quick release catch. The diaphragms are connected to a reciprocating mechanism which moves the diaphragms in and out producing sinusoidal changes in volume. With the chambers empty, no pressure difference between the chambers is observed when the diaphragms are cycled but when an infant is placed in one of the chambers, air is displaced and the volume of that chamber is decreased. Now, when cyclical volume changes are induced, there is a greater pressure change in the cylinder containing the infant. This pressure change is measured by the differential manometer. The magnitude of the pressure change is linearly related to volume and, so with adequate calibration, volume of the infant can be computed from the pressure differences. Sinusoidally varying volumes permit extraction, by harmonic analysis, of the pressure signal from noise created by motion and breathing artifacts. The device has been validated in piglets by comparing volume determined in the Volumeter with volume determined by underwater weighing. To date 220 volume and weight measurements have been made on 54 infants.

Infants weigning 900 to 1750 g at birth were studied at least weekly from the time they reached full volume of intake until the time of discharge. The infants were receiving one of 6 different diets. The slope of the weekly density measurements versus body weight is given in the table below.

	Formula			HM*	HM +	PM +
	1	2	3	Fresh	Suppl	Suppl
Energy (kcal/(kg.d))	121	118	144	115	113	106
Protein (g/(kg.d))	2.85	3.75	3.92	2.65	3.38	2.92
Slope(x100) (g/(cc.kg))	-1.95	-1.85	-2.07	-3.00	-0.67	-2.36
Density at 2.2 kg (g/cc)	1.016	1.009	1.017	1.016	1.007	1.036

*HM=Human Milk; HM +=protein supplemented HM; PM +=Pooled HM supplemented

The decrease in density is due to an increasing proportion of fat relative to protein in the whole body and was significant for every diet group except for the protein supplemented fresh human milk group. Larger proportions of energy to protein in the diet tend to cause the slope of total body density versus body weight to fall indicating that higher energy to protein ratio in the intake causes growth with an increased fat content.

A B S T R A C T

A Neutron Activation Analysis Technique for the Measurement of Phosphorous in Sections of the Human Body.

D.Glaros, J.Xatzikonstantinou, J.Leodiou and J.Kalef-Ezra

A partial-body neutron activation analysis technique has been developed for the in-vivo measurement of Phosphorous in skeletal sections via the ^{31}P (n a) ^{28}Al fast neutron reaction. Sections of the body's extrimities were unlaterally and bilaterally irradiated using two $1,3 \times 10^{11}$Bq ^{241}Am-Be sources in a fixed position and also with the source oscillating over a pre-selected length of a long bone,simulating an"extended" source. The induced ^{28}Al activity was measured with the body section under investigation sandwichied between two NaI detectors, 28 cm diameter X 10 cm thick. Measurements on "phantoms" and humans showed that with radiation skin doses ranging 5-20 mSv,Phosphorous can be determined with an overall reproducibility coefficient of variation of about 3%.

ABSTRACT

BODY COMPOSITION IN INFANTS BY DUAL-PHOTON ^{153}Gd ABSORPTIOMETRY.

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The body composition (lean % and total body bone mineral, TBBM) was investigated in 60 newborn infants (on their third day of life) by dual-photon ^{153}Gd absorptiometry (DPA) and anthropometric measurements (ponderal index, PI = weight/lenght^3; skinfold thickness, SK; and weight). Preliminary data on a group of the infants (n = 31) comprising mostly normal infants revealed significant relationship between the lean % versus the PI, the SK, and the weight, respectively. Furthermore, we found significant correlations between the TBBM versus the weight and the gestational age, respectively. We failed to demonstrate a significant correlation between the lean % and the gestational age. Our final presentation will include results on the normal infants as well as those being preterm, light for date, and dysmature. It will be investigated whether the DPA measurements give a better separation between normal infants and preterm/dysmature infants than the classical clinical estimates of dysmaturity.

In-vivo measurements of nitrogen using a neutron activation technique

L. Larsson, M. Alpsten, J. Tölli, N. Drugge and S. Mattsson

Knowledge of body composition is essential for understanding of many diseases such as obesitas, anorexia, cancer, kidney and heart diseases. For many years, total body potassium (TBK) has been used as an estimate of the intracellular protein. In some diseases intracellular- and extracellular protein may vary significantly. Together with TBK, total body nitrogen (TBN) should in these cases be measured to estimate the total protein content. The nitrogen content can be measured by in-vivo neutron activation (1,2,3). In this work we have used the prompt gamma technique: Thermalized neutrons from a Cf-252-source are captured in (n,γ)-reactions. Prompt 10.8 MeV photons are emitted and can be detected during irradiation.

The source is contained in a polyethylene block which forms a collimator surrounded by a Ø 1.40 m x 0.80 m water tank. The patient is irradiated from below by a 15 cm x 50 cm neutron field. It is possible to scan the whole patient or to measure a part of the body. A Ø 15 cm x 15 cm NaI(Tl)-detector is used for detection of the 10.8 MeV photons. The detector is mounted above the patient outside the neutron field.

However, in prompt gamma measurements a great number of counts add to the signals to be studied, from the nitrogen reaction 10.8 MeV photons. By a proper choice of surrounding materials, background pulses can be kept at a minimum. Still a careful analysis of the background contribution in the interesting pulse height region is necessary. This has been done by fitting a polynomial to experimental data.

Total as well as partial body determinations of nitrogen are carried out on patients undergoing cancer therapy in order to compensate changes in nitrogen content by adequate nutritional intake.

The effective dose equivalent for the patient is estimated to be less than 0.3 mSv per measurement.

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MEASUREMENTS OF BODY PROTEIN FOR CLINICAL INVESTIGATION

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Body protein (Nitrogen) is determined by bilaterally irradiating the body with neutrons using Pu-Be sources and measuring the resultant 10.8 MeV gamma rays from the reaction $^{14}N(n,8)\ ^{15}N$. In our lab the whole body can be scanned or separate segments of the body can be measured independently.

A nitrogen index has been developed based on body size and is used as a predictor of normal total body nitrogen (TBN). We have found that TBN, when normalized to body size in this way, provides a reliable index of protein status which cannot be accurately determined by body weight, anthropometry, or body potassium measurements.

Changes in body composition with age were studied by measuring the composition of 56 healthy female volunteers aged 20-80. Measurements were made for K(^{40}K), Ca (as described previously) and N. It was shown that protein and bone mineral decrease with age but that this is not reflected in K or anthropometry measurements. Results of this study will be presented.

Results of other studies to be presented include: body protein measurements pre and post TPN (total parenteral nutrition), nutritional status of patients on long term CAPD (continuous ambulatory peritoneal dialysis) and changes in body composition as a result of TPN in patients with small cell lung cancer receiving chemotherapy. Clinical results show that indirect measurements of body protein based on weight, potassium or anthropometry, do not give an accurate measure of body protein. For an accurate measurement, direct measurement of body protein is necessary.

The Design and Construction of a New Instrument for Multi-elemental IVNAA

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A new instrument for the in-vivo analysis of major and minor body elements has been designed and built for clinical studies within a General Hospital. The design objectives were to provide a system capable of measuring primarily calcium, nitrogen and cadmium in a manner, and at a cost, which would not preclude a wider utilisation of the technique. The choice of a ^{252}Cf neutron source, a pneumatic source transport system and a scanning couch geometry have fulfilled these objectives and produced a system which can operate in three modes, viz prompt, delayed and cyclic activation.

A 4.0 GBq ^{252}Cf source is stored in a heavily shielded safe 1m below ground from where it is driven pneumatically via a source-diverter mechanism to one of two irradiation ports. The neutron and gamma shielding, consisting of borated wax, lead, poly-Pb-B bricks and bismuth, provides a safe operating environment and maintains a low background in an adjacent room which houses a shadow-shield whole body counter.

The irradiation ports are designed to deliver two different dose-rates (11 and 47 $mSvh^{-1}$, assuming a QF of 10) at the level of the couch. The collimators are constructed of bismuth and in each case provide a beam of adequate width to achieve a total-body measurement when the subject is scanned from head-to-toe across the aperture. In addition, each collimator can accommodate a tapered insert which reduces the aperture to a size suitable for partial-body measurements of organs such as the liver and kidneys.

The shorter collimater (higher dose-rate) is used for total-body measurements of calcium (and nitrogen) by prompt-gamma analysis and for partial-body analysis of elements such as iron, copper, and aluminium using either delayed, prompt or cyclic analysis as appropriate. The longer collimator is used for total-body measurements of nitrogen (when this is the element of prime interest) and for partial-body analysis of cadmium, both by prompt-gamma analysis.

The pneumatic transport system and scanning couch are controlled by purpose-built electronic modules which incorporate the facilities of preset irradiation time, preset cycling periods, safety interlocks, data acquisition gating signals, couch position and speed indicators, and a fibre optic system to monitor the source position.

The spectroscopy system comprises two 20% relative efficiency HPGe and two 152 x 152mm NaI(Tl) detectors, 400MHz Wilkinson ADCs, an 8K MCA and a PDP-11 computer with peripherals.

A New Multi-Element Analysis System Using ^{252}Cf: Calibration and Performance

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A new neutron activation system has been designed and constructed within the clinical environment of a General Hospital. A 4.0 GBq ^{252}Cf neutron source may be pneumatically driven to one of two irradiation ports, each of which is wide enough to achieve a total-body measurement when the subject is scanned from head-to-toe across the aperture. Alternatively, collimator inserts can reduce the aperture to a size suitable for partial-body measurements. Further details of the design and construction of the instrument are given in an accompanying presentation.

A novel feature of this system is the ability to measure total-body calcium by the prompt-gamma technique using large volume (100 cm^3) HpGe detectors. Preliminary results using phantoms have shown that TBCa can be measured to a precision of 2.8% for a total body dose equivalent of 5mSv, assuming a QF of 10 for fast neutrons. This compares favourably with the performance of the delayed technique, particularly when it is noted that the prompt-gamma method can provide a profile of the distribution of calcium along the length of the body. In addition, the measurement of other elements such as nitrogen, hydrogen and chlorine is achieved simultaneously.

For those categories of patients where calcium is not of major interest, nitrogen (with chlorine and hydrogen) may be measured to a precision of 2.2% for a dose equivalent of less than 0.5mSv, using the lower dose-rate collimator and two NaI(Tl) detctors mounted above the patient in a geometry similar to that originally described by Vartsky. The uniformity of activation and detection response is only slightly inferior to those systems employing (α,n) neutron sources but the use of hydrogen as an internal standard diminishes the importance of such discrepancies.

Cadmium measurements in the liver and kidney are also carried out using the longer collimator, but with an insert provided to reduce the aperture to the dimensions of the kidney. A detection limit (2 SD of the background) of 1.40 mg Cd in the kidney is achieved for a skin dose equivalent of 3 mSv; results of measurements on both environmentally and occupationally exposed persons will be summarised.

The instrument is also capable of measuring other trace and toxic elements such as iron, copper, aluminium and selenium, the last two by a cyclic activation method for which particular attention has been paid to the choice of neutron source, source transport system, and control electronics. Results of phantom studies currently in progress will be given.

ABSTRACT: INTERNATIONAL SYMPOSIUM ON
IN VIVO BODY COMPOSITION STUDIES

ANALYTICAL SIGNALS FROM CANCER PATIENTS FOLLOWING RADIATION TREATMENT

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Cancer patients are treated with high energy (8 to 30 MeV) gamma radiation (1). This treatment modality provides better depth dose distribution than more conventional low-energy gamma treatments, in particular for deeply located tumors. A by-product of the high-energy treatment is gamma-induced activity in the treatment volume following photonuclear reactions. These reactions are endoergic and require that the gamma radiation energy be above threshold value in order for the reaction to take place. For most elements, the threshold value is above 8 MeV; however, for low Z elements, this threshold may reach 18 MeV as is the case for oxygen. The cross sections for the (γ,n) reactions are few millibarns for low Z elements and increases up to few hundreds of millibarns for the heavy elements. The radionuclides resulting from photonuclear reaction are typically positron emitters or decay by electron capture. Thus, it is possible to monitor either the annihilation radiation (511 KeV) or the characteristic gamma radiation.

In the past photoactivation has been used for elemental analysis of biological and environmental samples (2). The present work demonstrates that the activity induced in cancer patients following a single treatment (300 rad) enables the monitoring of nitrogen and phosphorus in the irradiated volume. The results from measurements in phantom, cadavers, and cancer patients from different regions in the body are presented. The hypothesis to be tested is whether there are local changes in these two elements during the course of radiation treatment which might correlate with the efficacy of the treatment.

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(2) J.S. Hislop, Photon-Activation Analysis of Biological and Environmental Samples: A Review, Photonuclear Reaction and Application Conf-730301 (1973) 1159-1170.

DETERMINATION OF BODY COMPOSITION IN ELDERLY SUBJECTS SUFFERING OF DIABETES MELLITUS AND ARTERIOSCLEROSIS.

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We determined the body composition of 23 diabetic (14 females: 77, 33±3, 6; 9 males: 75±7,2yrs) and 36 arteriosclerotic (12 females: 84±6, 9; 14 males: 71, 8±7,2yrs) subjects by multiple-isotope methode. Their hormonal status was also assessed (aldosteron, plasma renin activity, cortisol) at the same time. We determined the body composition of well compensated, orally treated diabetic elderly (diabetes mellitus type II) and it was found that the intracellular volumes are unchanged comparing to healthy elderly controls, the total body fat is slightly increased, while the intracellular volumes (except extracellular volume ECV, in the case of females) are diminished significantly, mainly, in the case of males.

In the case of decompensated diabetes treated originally with insulin (diabetes mellitus type II with insulin treatment), we found a general dehydration affecting mainly the intracellular compartments, but also in a less extent the extracellular ones. After one week of treatment with insulin and perfusions (normalization of blood sugar) the body composition became normalized, i.e., comparable to healthy elderly. It seems that in the case of diabetes mellitus type I the same changes of body composition are encountered in the middle aged group (data not yet completely analyzed) during the ketoacidotic decompensation and treatment. The hormonal changes were not significative. In the case of arteriosclerosis we made a distinction after the dominating signs and symptoms between central peripheral arteriosclerosis. It seems after our results that except a diminution of plasma volume (PV), more marked in central arteriosclerosis, no changes could be observed comparing to healthy age-matched controls.

In conclusion we can say that diabetes in its decompensated form cause a general perturbation of body composition in the sens of dehydration necessitating a well-managed rehydration.

BODY COMPOSITION CHANGES IN CONGESTIVE HEART FAILURE BEFORE AND TREATMENT.

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The body composition of 50 elderly (20 females: 77, 8+3,2; 30 males: 80, 8+5,9yrs) and 20 middle-aged (9 females: 52, 3+4,5; 11 males: 56, 3+7,6yrs) people presenting the symptoms and signs of congestive heart failure (N.Y.H.A.: II-III) was determined by multiple-isotope method ($^{3}H_2O$; ^{22}Na; ^{35}S; ^{131}I-HSA).

In both sexes independently of age the extracellular fluids (extracellular volume ECV; interstitial volume ISV) except plasma volume (PV) were enhanced comparing to healthy age-matched controls. The total body water (TBW) did not change. The intracellular water diminished. It seems to exist a redistribution of body fluids during cardiac decompensation. All of these patients were reassessed at least after 1 week of treatment but some of them were followed for 2 weeks. The majority received a combined treatment of diurectics and digitalis (digoxin) but a few of them (12 elderly and 5 middle-aged) received only digitalis.

In the first group we observed a significant diminution of PV, TBW and a less marked diminution of ECV and ISV. Interestingly the ICV diminished further. In the group treated by digitalis alone, the PV did not change, while the TBW, ECV and ISV enhanced further and the ICV normalized. After 2 weeks of digitalis treatment the ECV and ISV normalized also, while TBW showing a tendency to decrease without normalization.

The hormonal status was also assessed in each persons before and after treatment. A good correlation was found between the body composition changes and hormonal changes mainly in the case of aldosteron and plasma renin activity.

These investigations show that 1. congestive heart failure cause a redistribution of fluids in favour of extracellular fluids: 2. the combined treatment of diurectics and digitalis is very effective but applied too quickly could cause further imbalance in the body composition; 3: the digitalis treatment alone approach to normal body composition in its effect after 2 weeks only, which would signify that mild cases of congestive heart failure are the best candidates for this type of treatment.

AGE-RELATED VARIATIONS IN THE BODY COMPOSITION OF PATIENTS IN MAINTENANCE HEMODIALYSIS

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Total body water/TBW, tritiated water/, extracellular fluid volume /ECV, radiosulfate/, exchangeable sodium /NaE, 22-Na/, and plasma volume /PV, 131-I-HSA/ were determined in 96 patients with end-stage renal disease treated on maintenance hemodialysis. The study was aimed at getting objective informations about the patients' excess fluids and nutritional states. Intracellular and interstitial fluid volume /ICV and ISV/, red blood cell mass /RCM/, total blood volume /TBV/, lean body mass /LBM/, total body fat /TBF/, and dry body weight /DBW/ were derived from the measured values. 25 healthy young /12 males and 13 females, age 23,5 $\pm$ 4.59 yrs/ and 45 healthy elderly volunteers /22 males and 23 females, age 76.3 $\pm$ 8.67 yrs/ served as control. They were found healthy in a health screening programme.

In the whole hemodialysed population the same age-related changes could be observed as in healthy people, however some absolute values differed significantly. The decrease in TBW was caused by both decreasing ICV and increasing TBF. TBV and its components did not change. The most important differences between healthy control and dialysed patients were found as follows: ECV and ISV increased; it seemed that ICV decreased more rapidly with age in renal patients than in control.

Edema-free renal patients showed practically no difference in body composition from age-matched control and their age-related changes were also the same as those of the healthy people.

BODY FLUID COMPARTMENTS, HYPERTENSION AND THE RENIN-ANGIOTENSIN-ALDOSTERONE SYSTEM /RAAS/ IN HEMODIALYSED PATIENTS

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Total body water /TBW, tritiated water/, extracellular fluid volume /ECV, radiosulfate/, exchangeable sodium /NaE, 22-Na/, and plasma volume /PV, 131-I-HSA/ were determined by means of the modified multiple isotope dilution method of Bauer et al./1975/ in 96 hemodialysed patients. Plasma renin activity /PRA/, angiotensin I, and aldosterone in 43 cases, then solely plasma aldosterone in more 34 cases were measured simultaneously. The interrelationships between body fluid compartments, arterial hypertension /systolic, diastolic, mean/, and RAAS were investigated.

Good correlation was found between arterial blood pressure, ECV and NaE, respectively. In hypertensive patients the volume-pressure-RAAS axis has been changed comparing with normotensive patients: /1/ no correlation was found between PRA and arterial blood pressures; /2/ there was a good correlation between PRA and plasma K level; /3/ angiotensin I showed negative correlation with blood pressures and total blood volume, respectively; /4/ aldosterone did the same with arterial pressures and NaE, respectively.

The authors concluded that in end-stage renal disease the extracellular volume seemed to be the main factor in determining blood pressure. In contrast, RAAS exists and has its own autoregulatory function to preserve hypertension. Plasma K may play an important role in the regulation of PRA secretion.

Body composition studies in aging rats. S. Yasumura, G.M. Kiebzak, K.J. Ellis, A.F. LoMonte, R. Zhang, K. Yuen, and S.H. Cohn. SUNY-Health Science Center, Brooklyn, NY 11203 (SY); Brookhaven National Laboratory, Upton, NY (SY, KJE, AFL, RZ, KY, SHC); Gerontology Research Center, NIA, NIH, Baltimore, MD (GMK).

Several parameters of body composition were measured in female rats 6, 12 and 24 months of age. Total body calcium (TBCa), sodium (TBNa), and chloride (TBCl) were determined by neutron activation (BNL Medical nuclear reactor); total body potassium (TBK) was measured by ^{40}K counting; and total body water (TBW) was measured by isotope (HTO) dilution. In addition to these measured values, we present derived values for extracellular water (ECW), intracellular water (ICW), intracellular potassium concentration (ICK), and total body fat. ECW is derived from the TBCl and plasma chloride concentration, and ICW = TBW - ECW. The intracellular potassium: ICK = TBK/ICW; and body fat is derived from BW - lean body mass (LBM) where the LBM is derived from a combination of TBK, TBCa, and ECW.

Mean body weights were 327, 381 and 383 g in the 6-, 12-, and 24-month-old rats, respectively. There was a concomitant increase in TBW with age so the TBW:BW ratio remained constant and averaged .64±.04 for all rats in the study. However, the distribution of water was altered; the ECW:TBW ratio increased from .41 to .47 with age. The absolute amounts of ICW and TBK were similar for all age groups; thus, the intracellular potassium concentration remained unchanged and averaged 153.8±15.5 mEq K/liter ICW. Like the TBK, the TBCa also remained unchanged at all ages studied. Therefore, since BW increased while TBK and TBCa remained unchanged, the difference in weight was presumed to be body fat. Using the equation Fat = BW - LBM, we calculated the fat as a percent of BW: 11%, 19%, and 21% for the three age groups, respectively.

In summary, there is a modest weight gain between 6 and 12 months of age but no further increase thereafter. The rats neither gained nor lost bone or muscle mass, however, the proportion of fat and ECW were increased with age.

IN-VIVO CALCIUM DETERMINATION OF SAMLL SAMPLES USING ^{252}Cf NEUTRON ACTIVATION FACILITY

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An in-vivo neutron activation analysis (IVNAA) facility is required to measure calcium content of hands, since it is felt that, in certain diseases such as renal osteodystrophy, the bone is preferentially lost from the hand rather than the central skeleton. In addition it is also required for animal experiments such as with rats.

This paper describes the design and details of such a facility. The neutron flux in the irradiation chamber is fairly uniform and errors due to the movement of samples within it is $\pm$ 1.2% which is within counting statistics. The effect of variations in sample size is -4.85% for 100 mL increase in volume. The reproducibility of the measurement of a 3g calcium aqueous standard is $\pm$ 4% most of which is due to counting statistics.

A series of animal experiments done on this facility and compared with atomic absorption analysis of the total bone after sacrificing the animals show that the average difference in the values is 4.6%$\pm$ 3.7% (S.D.) for animals over 150g body weight. The paper also reports results of correllation studies of central skeletal calcium by IVNAA vs hand calcium in volunteers and untreated osteoporotics.

AN INSTRUMENT FOR IN VIVO DETERMINATION OF BONE MINERAL CONCENTRATION BY COHERENT-COMPTON SCATTERING.

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An instrument to measure the bone mineral concentration in the human vertebrae using the ratio of coherent to compton scattered 60 keV protons will be described.

Two 11 GBq ^{241}Am sources are used and the scattered radiation (145°) is measured by means of a Ge-spectrometer.

To convert the measured ratio of coherent/compton scattered photons to bone mineral concentration we have used vertebrae like phantoms placed in water. The phantoms contained various amounts of $CaHPO_4$ in epoxy.

The influence on the measurements of different positions of the vertebrae has been studied as well as the variation in sensitivity inside the vertebrae.

Pre-Reconstruction Dual-Energy X-Ray Computerized Tomography (CT): Theory, Implementation, Results, and Clinical Use

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For the task of bone mineral measurement, single-energy quantitative CT has demonstrated its worth in terms of precision for most longitudinal clinical studies. However, for cross-sectional clinical studies, known inaccuracy exists due to less than robust beam-hardening corrections, and negatively biased bone mineral measurement, due to the effect of unknown variable concentration of bone marrow fat within the metabolically active trabecular bone space. A dual-energy measurement technique provides a solution to these deficiencies of single-energy measurements.

The fundamental theory of dual-energy measurement techniques is based on a Compton-photoelectric approximation and the mixture rule for the total attenuation coefficient. Resolution of atomic composition and electron density components of attenuation should then be possible. To take full advantage of these principles, the raw dual-energy projection values are operated on before reconstruction (pre-reconstruction). This method provides an avenue to implement more robust corrections for beam-hardening and composition-selective imaging. Rapid kilovoltage switching between projection measurements, rather than serial measurements, assures the best measurement quality.

This measurement method has been implemented on a commercially available system (Somatom DR, Siemens AG). Measurement results of such a dual-energy implementation yield high and low kV single-energy images, calcium and water equivalent density images, synthetic monoenergetic and electron density images from a single scan measurement. Hence, efficient and comprehensive study of metabolic bone diseases can be performed through morphological analysis of high energy and monoenergetic images, quantitative longitudinal tracking with low energy images and quantitative cross-sectional study of sample populations with calcium-equivalent density images.

Though the measurement of bone mineral is of most current interest, many other quantitative and qualitative studies of body composition have been suggested, but have yet to be explored with this implementation.

In-Vitro Comparision of DE-QCT Parameters with the Compressive Strength of Cancellous Bone

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Quantitative computed tomography (QCT) is used as a method for assessing bone mineral in patients with osteoporosis. The implication being that if the mass of bone mineral is low enough than the patient is at risk for developing symptoms, ie. fracture. We performed an in-vitro test which compared dual energy-QCT (DE-QCT) parameters with compressive strength. Thirty cylindrical cancellous bone samples (20mm dia x 10mm) were precisely machined from three cleaned and de-fatted proximal tibiae. Samples were kept hydrated throughout the study. The samples were placed in a water bath and CT scanned using a Siemens DR-3. Alternating x-ray pulses of 125 and 85 kVp were used to generate the dual energy images. Four images, high kVp, low kVp, monoenergenic, and calcium equivalent, were reconstructed from each scan. A specially constructed bone mineral calibration phantom, consisting of a polyethylene rod and varying tubes of K_2HPO_4, was placed within the water bath along with the specimens. Compression testing was performed and stress-strain curves and elastic moduli developed from the load deflection data. Comparisions will be made between the various DE parameters and their relationship to the compressive strength of cancellous bone. The critical effect of trabecular bone orientation will also be discussed. Work is in progress, using fresh cancellous specimens (un-defatted), to define the relationship between DE parameters, apparent density (Archimede's principle), ash weight, compressive strength, and trabecular orientation.

ABSTRACT

CYPROTERONE ACETATE, AN ALTERNATIVE GESTAGEN IN POSTMENOPAUSAL ESTROGEN/GESTAGEN THERAPY.

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Seventy six healthy, early postmenopausal women (aged 45-54 years) were allocated to 2 years of treatment with a cyclic combination of 2 mg estradiol valerate (21 days) and 1 mg cyproterone acetate (11 days) or placebo. Sixty five women (86%) completed the study. In the hormone treated group there was a significant decrease in biochemical estimates of bone turnover (serum alkaline phosphatase, serum phosphate, fasting urinary calcium and hydroxyproline), whereas these values were unchanged placebo treated group. In the placebo group the bone mineral content in the forearms (measured by single photon absorptiometry) and the bone mineral content in the lumbar spine and in the total skeleton (measured by dual photon absorptiometry) decreased significantly and at the same magnitude ($p<0.001$), whereas all bone mass measurements remained unchanged in the hormone treated group. From the present study it can be concluded that treatment with a cyclic combination of 2 mg estradiol valerate and 1 mg cyproterone acetate is effective as prophylaxis in postmenopausal osteoporosis.

CALCIUM REQUIREMENT AND FACTORS INFLUENCING THE SKELETAL STATUS IN MAN. Herta Spencer, M.D. Metabolic Section, V.A. Hospital, Hines, IL 60141.

In view of the high incidence of bone loss with aging, particularly in females, the maintenance of the integrity of the skeletal status with age is of utmost importance. In addition to hormonal deficiency multiple factors may play a role in the development of skeletal demineralization. The effect of certain dietary factors such as calcium, phosphorus and protein, as well as the effect of several drugs was investigated on mineral metabolism. In studies of the calcium requirement, the amount of calcium needed to achieve calcium equilibrium or a positive balance was determined. During a low calcium intake of 250 mg/day, there was calcium loss, as expected. There was no adaptation to the prolonged low calcium intake in terms of the negative calcium balance or in terms of the intestinal absorption of calcium. During a normal calcium intake of 800 mg/day, the recommended calcium intake (RDA), the average calcium balance became slightly positive, +22 mg/day, but it was negative in 34% of the subjects studied. Increasing the calcium intake to 1200 mg/day resulted in a positive calcium balance. However, increasing the calcium intake further to various levels up to 2200 mg/day did not increase the retention of calcium indicating a plateau and a threshhold of calcium absorption at the 1200 mg calcium intake. Increasing the phosphorus intake by a factor of 2.5 led to a decrease in urinary calcium irrespective of the calcium intake; there was no adverse effect on the calcium balance nor on the intestinal absorption of calcium. A high protein intake, given as meat, did not affect urinary of fecal calcium nor the calcium balance in contrast to the effect of purified proteins which induce an increase in urinary calcium and calcium loss. Several drugs such as aluminum-containing antacids, certain diuretics, certain antibiotics, corticosteroids and antituberculosis drugs and thyroid medications induced a distinct increase in urinary calcium and some of these also caused fecal calcium loss. Advanced osteoporosis has been observed in our patients who have consumed excess alcohol for prolonged periods of time. In view of the widespread use of alcohol and of the drugs mentioned above their long-term use singly or combined would be expected to lead to calcium loss and would thereby increase the calcium requirement.

CARBONATED BEVERAGE CONSUMPTION AND BONE FRACTURES. G. Wyshak, R.E. Frisch, N.L. Albright, T.E. Albright, I. Schiff, and J. Witschi. Harvard Center for Population Studies, 9 Bow Street, Cambridge, MA 02138.

We present data on an association between the consumption of non-alcoholic carbonated beverages and the occurrence of bone fractures among 5,398 college alumnae, 2,622 former college athletes and 2,776 non-athletes, ranging in age from 21 to 80 yr. There has been a 300% increase in the intake of carbonated beverages in the U.S. in the last three decades, and an accompanying decline in milk consumption (FDA Consumer, Oct., 1985). The percentage of alumnae drinking carbonated beverages was 71% for the youngest alumnae (under 30 yr), declining to 28% in the oldest group, (70 yr and over). The amount consumed per day also declined with increasing age, from 22 oz per day to 15 oz per day for alumnae 70 yr and older. The annual carbonated beverage consumption of former college athletes was 6 gallons greater than that of non-athletes.

Relative risk (RR) was evaluated: a) among all alumnae up to age 50 for the association between consumption of carbonated beverages (yes/no) and for any bone fracture occurring at or after 22 yr; and b) among all alumnae at or after age 50 for any bone fracture occurring at or after age 40. Among alumnae under age 50, consumers had a significantly higher risk of fractures: RR was 1.33, 95% CL (1.06, 1.65). For alumnae age 50 yr and over, only the former college athletes had a significant association between carbonated beverage consumption and bone fractures. The RR was 1.63, 95% CL (1.05, 2.53). The RR for the association of drinking carbonated beverages and a first fracture occurring at or after age 40 among former college athletes was more than twice as high for drinkers of carbonated beverages as for non-drinkers: RR was 2.28, 95% CL (1.15, 4.53).

The deleterious effects of drinking non-alcoholic carbonated beverages on the risk of bone fractures has not been reported heretofore, as far as we know. An altered calcium-phosphorous ratio may contribute to the increased risk of fractures.

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A feasibility study for the in-vivo measurement of beryllium by photonuclear activation

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Diagnosis of the beryllium-induced disease, berylliosis, is often difficult and always requires that the presence of the metal in tissue be demonstrated. The feasibility of developing an in-vivo method of measurement, which exploits the uniquely low photonuclear reaction threshold of 1.67MeV in beryllium, has been investigated. Suitable photon sources and detector systems were assessed, both experimentally by phantom studies and theoretically by use of a Monte Carlo neutron transport code. It is concluded that by using a filtered source of ^{124}Sb for bilateral irradiation of the chest, and an array of twenty BF_3 counters, a detection limit of 0.67 ± 0.33mg of beryllium per lung could be achieved for a skin dose of 50 mGy delivered within a period of 90 seconds. Such a facility would be capable of contributing to the aetiology of the disease in a large proportion of cases, but the wider use of the method for screening exposed workers would require further improvements in detection efficiency.

IN VIVO MEASUREMENT OF ORGAN MERCURY BY PROMPT GAMMA ACTIVATION ANALYSIS USING A MOBILE NUCLEAR REACTOR

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ABSTRACT — The *in vivo* measurement of mercury in kidney is explored by detecting prompt γ-rays emission after neutron absorption. The neutrons are provided from a low-power mobile educational reactor, which was designed and constructed by National Tsing Hua University in 1976. The kidney phantom is filled with $HgCl_2$ solution, and prompt γ-rays are collected by a 59.4 cc portable HPGe detector. Figure 1 shows a portion of an *in vivo* spectrum from the left kidney study with the experimental arrangements as shown in Fig. 2. The detection limit of Hg in the left kidney for a skin dose of 23.9 mSv (2.39 rem)is 58 ± 8 ppm under 7200 s irradiation/counting. Finally the possible ways and tests of reducing detection limit and irradiation/counting time are discussed.

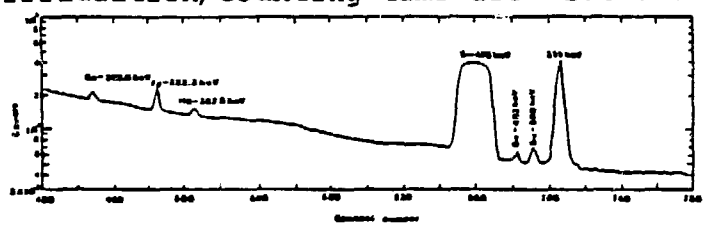

Fig. 1 Prompt γ-rays spectrum of 43.5 mg of mercury in the irradiated left kidney.

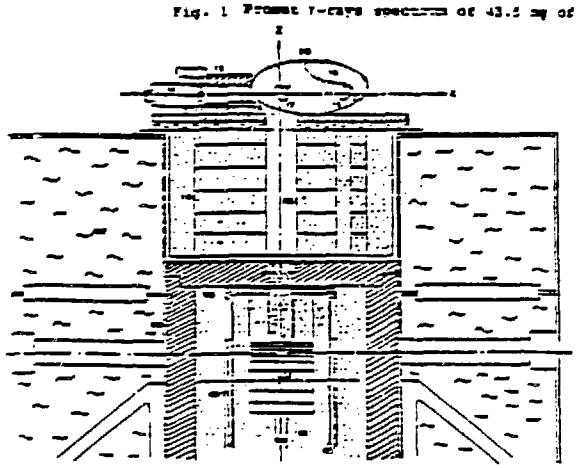

Fig. 2 The experimental arrangements of *in vivo* measurement of organ mercury by PGAA using a mobile nuclear reactor: 01- inner graphite reflector, 02- nuclear fuel, 03-control plate, 04- ^{226}Ra-Be neutron source, 05- aluminum fuel tank, 06- central vertical beam tube, 07- B_2O/WO_3, 08- lead wall, 09- outer graphite reflector, 10- thermal column, 11- PE/BO_3, 12- lead shield, 13- 59.4 cm^3 HPGe detector, 14- 24 l holding time dewar of LN_2, 15- lead shield, 16- ^6LiF neutron shield, 17- left kidney phantom, 18- liver phantom, 19- right kidney phantom, and 20- trunk phantom.

THE IN VIVO MEASUREMENT OF SILICON IN THE LUNG AND OTHER BODY ELEMENTS, USING FAST NEUTRON INELASTIC SCATTERING REACTIONS.

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Silica dust inhalation by industrially exposed personnel can lead to serious lung disease, in particular silicosis. The quantitative measurement of lung silicon would be useful in the study of the silica exposure and patient symptoms relationship.

Previous work (1) has shown that the fast neutron inelastic scattering reaction $^{28}Si(n,n'\gamma)^{28}Si$ emitting 1779keV γ-rays is most suitable for Si measurement having a higher cross-section than other neutron-silicon reactions. This technique is being developed further by the use of 5.2 MeV neutrons produced via the D-D reaction by a 2MV Van de Graaff generator accelerating deuterons on to a deuterated-Ti target. A 5MeV incident neutron energy has the advantage of (i) corresponding to the maximum cross-section of the silicon inelastic scattering reaction and (ii) avoiding the interference from identical γ-rays from the $^{31}P(n,\alpha)^{28}Al$ reaction which becomes significant above 5MeV. Pulsing the neutron flux also improves sensitivity by separating in time the prompt inelastic γ-rays from those emitted by slow neutron capture reactions, and measuring only during the neutron burst.

Much work has been dedicated to converting an existing Van de Graaff generator (H.V.E.C., GS5) from electron to positive ion operation and to the construction of a remote controlled beam pulsing system, giving a pulse width range of 15μs to 200μs at a repetition rate of 1 to 3kHz. Preliminary trials have yielded beam dose-equivalent rates of $10mSv.h^{-1}$ at 30 cm (Q.F.= 10). Optimization of neutron production is expected to yield the 60 $mSv.h^{-1}$ neutron equivalent dose-rate planned for phantom studies.

Si lung burdens of several grams are typical in silicotic individuals whilst the non-occupationally exposed population has levels of about 0.1g per lung (1). It is estimated that irradiation of a lung phantom with a neutron equivalent dose-rate of 10mSv and measurement of the prompt Si γ-rays with two large HPGe n-type detectors (Canberra, relative efficiencies 34% and 29% and 2 keV F.W.H.M.) can yield a minimum detection limit for Si of 0.21g.

Our pulsed 5MeV neutron irradiation and γ-ray measurement system has the potential advantage of measuring other elements, e.g. Fe, C and Mg by inelastic scattering and H, N, Cl, Na and Ca from capture reactions during the beam-off period between neutron bursts. Hence, the prospect of determining the major body elements (except O) in a single irradiation.

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BODY LEAD BURDEN, I: VALIDATION OF RAPID, NON-INVASIVE, IN-VIVO BONE LEAD DETERMINATION BY X-RAY FLUORESCENCE.

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Some nephrologic diseases have recently been attributed to chronic Pb absorption as determined by time-consuming,provocative,blood and urine tests(1) which are too cumbersome for large-scale studies of environmental Pb toxicity.The observstion that over 95% of body Pb is stored in bone with a biological half-life of about 10 years prompted the development of several variations of non-invasive,in-vivo detections schemes based on X-ray fluorescence(XRF)in bones(2-4). Our approach is to expose the human tibia bone for 30 mins. to the 88 KeV gamma rays from a 50 mCi ^{109}Cd source(half-life: 453 days)and record simultaneously the fluoresced Pb K X-rays and elastically scattered photons from bone Ca and P with a planar Ge(Li) detector.The ratio of Pb K to elastic events(the latter is a measure of bone mass from which the Pb signal arises)can then be converted to absolute Pb ppm values for any wet or dry bone parameter on the basis of known physical and biological characteristics of the system.Calibration was accomplished with plaster of Paris phantoms doped with known concentrations of Pb acetate,with 8 random amputation legs and 22 clinical patients.Pb values obtained by ^{109}Cd XRF,proton-induced X-ray emission(PIXE),synchrotron radiation-induced X-ray emission(SRIXE) and atomic absorption spectroscopy(AAS) on phantoms and cadaver legs are comparable with in-vivo XRF bone Pb values in patients. About 30% accuracy is achieved with XRF at the 10 ppm(wet bone)Pb detection level with minimal radiological hazard to the patient.In a population of 22 patients and 6 amputation legs the maximum number of observations cluster about 35 ppm Pb(bone ash)in agreement with observations by Sommervaille et al.(3),Wielopolski et al.(4),Aufderheide et al.(7)and our own earlier work (5,6). Pb values obtained from bone XRF and urine EDTA chelation test are compatible,although a more thorough understanding of their relationship to Pb nephrotoxicity is desirable(4).We believe that our present design parameters are satisfactory for continuing use and development of the clinical instrument for body Pb burden measurements in large human population segments.

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THE IN VIVO ASSESSMENT OF INHALED IRON-BEARING LUNG CONTAMINANTS USING (i) FAST NEUTRON INELASTIC SCATTERING AND (ii) REMANENT MAGNETIC FIELD MEASUREMENTS.

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The metal working and iron-ore mining industries are major sources of respired iron-bearing dust particles. The present study aims to use two techniques to provide an index of iron-dust burden in the lung. In vivo neutron activation analysis can provide a quantitative measure of elemental iron in the human chest. When this iron is in magnetic form (e.g. magnetite), measurement of the remanent magnetism following external field magnetization can also be related to dust deposition in the lung.

Fast neutron irradiation of iron produces 847keV γ-rays by the $^{56}Fe(n,n'\gamma)^{56}Fe$ inelastic scattering reaction. Fast neutrons are produced with a 2MeV Van de Graaff accelerator, by the $^{2}H(d,n)^{3}He$ reaction. The iron γ-rays are measured by two large HPGe detectors (34% and 29% relative efficiency respectively). Interferences due to other neutron reactions are reduced by pulsing the accelerator beam and gating the detectors to count only during the neutron pulses (1). Decreasing the incident neutron energy below the energy threshold of competing reactions also helps in reducing background.

The present detector arrangement and a neutron dose-rate equivalent (Q.F.= 10) of 10 $mSv.h^{-1}$ is estimated to yield a detection limit better than 200mg of iron. Although this limit must be improved before normal lung iron burdens can be measured, it is quite suitable for organs in which disease states cause iron overloads of several grams to occur.

The magnetic technique has been shown to be successful in detecting quantities of lung magnetite as low as 0.1mg(2). The present work uses a Superconducting Quantum Interference Device (SQUID) magnetometer for remanent field measurements. To permit measurements at high levels of ambient noise, a second-order gradiometer capable of a uniform field rejection of 1 part in 10^{6} is used. Phantom studies are in progress and will be presented at the meeting.

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A Longitudinal Study of Ex-employees of a Ni-Cd Battery Company

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A long-term study of 20 ex-employees of a Ni-Cd battery Company commenced in 1982, following the closure of the factory in 1979. The aim of the study is to measure kidney and liver cadmium levels by in-vivo neutron activation analysis and to relate these values to biochemical and physiological indices of renal function. By repeating these measurements over a period of many years it is hoped to identify the critical parameters at the point when renal dysfunction might first be observed.

The study protocol includes blood and urine analyses of urea, creatinine, protein, calcium, amino-acids and B_2-microglobulin; an isotopic test of glomerular filtration rate and effective renal plasma flow; single photon absorptiometry of the distal radius; and where possible separation and identification of urinary and plasma metallothionein. In addition, all subjects are asked to complete a questionnaire relating to employment history, diet and smoking habit.

To date, all volunteers have been measured once, four have received a follow-up measurement, and the remainder are scheduled for review in the coming months. Measured values of kidney cadmium range from 'normal' (i.e. 2-3mg) to 19.6mg, while liver cadmium concentrations are generally less than 20 ppm.

So far, there have been no significant indications of renal dysfunction, but several volunteers have complained of non-specific symptoms such as tiredness and irritability, particularly during their period of employment at the factory.

When the second phase of measurements is complete, it is expected that some estimate of biological half-life of kidney and liver Cd can be made.

In Vivo Measurement of Li

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Lithium is used therapeutically for the treatment of manic depression. Lithium does not have a radioactive isotope that would permit standard investigations of its dynamics and distribution in vivo.

This paper describes a neutron activation method for the in vivo determination of Li in humans, with a particular emphasis on its distribution in brain. The method is based on the production of tritium (T) when a neutron is captured by a ^{6}Li nucleus present in the body. A fraction of the tritium produced is exhaled from the lungs in HT form. After the separation of HT from other gases present in breath, its activity is measured in a low-background proportional counter. The amount of activity should be proportional to the Li present in the irradiated organ.

To date, the following parameters have been determined: (1,2)

1. The ratio of gaseous tritium to total tritium produced in rat brain tissue is 21.3$\pm$ 1.5% (1).

2. The sensitivity of the method is 1.93 mBq per mg Li for a dose of 10 mSv (1).

3. The limit of detection for 10 mSv of thermal neutrons is 350 µg natural Li in the brain (1).

4. The gaseous tritium was eliminated from the body of a guinea pig with a half life of 10 min (1).

5. The feasibility of the method of was demonstrated by measurement of Li in the head of a sheep (2).

Further investigations are required to determine the elimination time of tritium from the brain, the influence of recirculation of tritium in the body on the elimination of tritium and the interference from the Li present in the skull on the brain lithium measurement.

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ABSTRACT

"Particle-Induced X-ray Emission Analysis of Trace Elements in Human Brain Tumors"

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We have been using particle-induced X-ray emission (PIXE) in cancer research for some time (1) and atomic absorption spectrophotometer, fluorometer to assay trace elements in selenium treated rats (2). In this contribution we report the relative elemental weight distribution in human brain tumors measured by PIXE method. The results are compared with those of healthy brains and discussed from the point of view of metal carcinogenesis and pathology.

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Estimation of Total Body Potassium in the Presence of Interfering Radio-Isotopes. G.I. Lykken[+*], K.K. Speaker[*], and A.K. MacKichian[++]. [+]Department of Physics, University of North Dakota and [*]USDA-ARS Human Nutrition Research Center, Grand Forks, ND 58202

A whole body counter employing 32 4"x4"x16" single-crystal NaI(Tl) detectors has been assembled and used to monitor total body potassium-40 (TBK-40) emissions from subjects participating in mineral bioavailability studies. The system calibration has been performed daily by counting 4 Na-22 sources and having a computer-controlled power supply set the voltage on each photomultiplier tube so that the centroid of the 1.275 MeV photopeak, observed by each detector, occurred at a designated channel in the computer-based multichannel pulse height analyzer. The total net Na-22 counts from the 32 detectors has been recorded as a stability check, and when the ln of the daily total count was plotted as a function of time, a straight line was observed ($r = 0.998$) with a slope of $-0.00072\ d^{-1} \pm 0.000004\ d^{-1}$. This system has been designed to estimate corrected gamma ray activity, independent of radionuclide distribution and body size, and to use matrix inversion to estimate activities from a number of isotopes having overlapping gamma ray spectra. Matrix elements for the matrix inversion program were generated by using four 25-liter, rectangular, polyethylene jugs (filled with an appropriate radioactive solution) to simulate a human body; the self-and peak-overlap contributions of each of 4 isotopes (Bi-214, Fe-59, K-40 and Zn-65) to 5 photopeak windows in the energy range 0-2.2 MeV were sequentially measured and later stored on a system disk. Estimations have been obtained for detector counts due to Bi-214 (a decay product arising from inhalation of Rn-222) for all cases when detector counts due to TBK-40 were recorded. It was found that the average Bi-214 count per gram of TBK was lower for Metabolic Unit volunteers than for free-living volunteers (19 vs 15); there was also a sex difference for free-living subjects with women having approximately twice as much Bi-214/g K as men. The coefficient of variation (C.V.) of estimated TBK (TBK > 100 g) was less in studies employing trace amounts of Zn-65 (0.10 μCi ingested dose) than in studies employing trace amounts of Fe-59 (0.12 μCi ingested dose) with respective K-40 C.V.'s of 3.4% ± 2.0%, 9 subjects, 130 whole body counts (WBC) and 4.6% ± 1.3%, 11 subjects, 339 WBC. In a double-label study a subject was fed 0.16 μCi of Fe-59 and 0.08 μCi of Zn-65 in a single meal, 55 days later a second meal was fed containing 0.20 μCi Fe-59 and 0.10 μCi Zn-65, and again 51 days later a third meal was fed containing 0.13 μCi Fe-59. The C.V. in K-40 counts during the 202 days after the first double-labeled meal was 4.4% in 34 WBC's. During the period of these studies K-40 and Bi-214 counts from a bottle phantom (425 g K, 0.043 μCi Zn-65 on 6/84) were 67877 ± 1762 and 275 ± 206, respectively, for 131 WBC's. We conclude that matrix inversion, as applied to TBK determination in the presence of interfering gamma rays, allows TBK estimation with a C.V. within 5% when off-the-shelf single-crystal scintillation detectors are used, and that a significant error in TBK estimation may occur if the Bi-214 contribution to the K-40 window counts is not considered.

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TOTAL BODY WATER MEASUREMENT BY ISOTOPIC WATER IN VERY YOUNG ANIMALS. Hwai-Ping Sheng, William Wong, Cutberto Garza, and Peter Klein. USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas

An accurate estimate of total body water (TBW) using isotopically-labeled water is necessary for in vivo body composition studies. Studies of animals at various physiological ages indicate that the volume of distribution of tritiated or deuterated water may be significantly larger than the volume of TBW measured by desiccation. This overestimation may be as large as 15% of body weight in young growing animals. Although oxygen-18 (^{18}O) has been used to measure TBW in human infants and adults, the accuracy of the measurement in the growing animal has not been determined. We evaluated the volumes of distribution of ^{18}O and tritiated water (^{3}H) as measures of TBW in the infant minipig. Four minipigs, 9 to 12 days old were studied. Total body water was calculated from the volumes of distribution of ^{18}O and ^{3}H. Both tracers were administered simultaneously into the jugular vein and the plasma enrichment of ^{18}O and specific activity of ^{3}H were measured on the 2-, 3-, and 4-hr post-dose plasma samples. Total body water calculated from ^{18}O and ^{3}H was compared with TBW obtained by desiccation. Total body water measured by desiccation was 70.2 $\pm$ 1.47%. ^{3}H- and ^{18}O-labeled water overestimated TBW measured by desiccation by 2.9% and 8.3%, respectively. The overestimations were significant at $P < 0.05$. Our initial results suggest that water labeled either with ^{3}H or ^{18}O overestimates the total physical body water in the young growing animal.

COMPARISON OF TOTAL BODY WATER DETERMINATIONS IN LACTATING WOMEN BY ANTHROPOMETRY, WATER DISPLACEMENT, AND DEUTERIUM ISOTOPE DILUTION. William Wong, Nancy Butte, Lucinda Lee, Cutberto Garza, and Peter Klein. USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas

To expand the limited data on total body water in lactating women, we have determined total body water contents in eight subjects from anthropometric measurements, water displacement, and isotope dilution of deuterium oxide. The women were 27.5 ± 3.7 (mean ± SD) yr in age, 163.7 ± 3.3 cm in height, and 62.8 ± 7.5 kg in weight. On the day of the study, their skinfold thicknesses were measured over the biceps and triceps muscles and at the suprailiac and subscapular areas. Their body densities were measured by water displacement. Deuterium oxide was administered orally at 100 mg/kg of body weight. One predose milk sample was collected from each subject. Postdose milk samples were collected at 1, 2, 3, 4, 5, 6, 7, 8, 24, 120, 216, 288, and 312 hr. The milk samples were defatted by centrifugation and the milk water was reduced to hydrogen gas for hydrogen isotope ratio measurements by gas-isotope-ratio mass spectrometry. The results indicated that total body water in lactating women estimated from anthropometric measurements was 49.7 ± 3.3% of body weight, by water displacement was 54.9 ± 7.2%, and by isotope dilution was 50.8 ± 3.7%. Analysis of the variances among these values demonstrated that total body water in these lactating women determined from anthropometric measurements was not significantly different from the values determined by isotope dilution of deuterium oxide. The higher water content value determined by water displacement, however, was significantly different ($P < 0.02$) from those derived by anthropometry and deuterium isotope dilution. Furthermore, the deuterium isotope dilution spaces in these lactating women were smaller than those in normal adult females (55.8 ± 0.9% of body weight, $n = 5$), probably because of their higher fat content.

THE INFLUENCE OF PHYSICAL ACTIVITY ON THE METABOLISM AND THE TOTAL BODY CONTENT OF SODIUM AND POTASSIUM IN THE RAT

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The purpose of this study was to investigate the effect of exercise(EX) and immobilization(IMB) on the absorption, excretion and total body content of sodium(TBNa) and potassium(TBK). Female Sprague Dawley rats 5 weeks old were divided into four groups: EX; Control(CON); EX with pair feeding to the level equal to the CON (EX-P); IMB by sciatica denervation. The nutritional balance study data was taken 5 weeks into the experimental period and the animals were sacrificed after 5 additional weeks of experimentation. The carcasses were kept frozen and used for total body composition by neutron activation. The results of the total body composition show that EX resulted in an increase, IMB resulted in a decrease, of the TBNa and TBK. There was no significant difference in TBNa or TBK, between the EX and the EX-P groups eventhough,the food intake was higher in the EX group. The results of the nutritional balance study confirmed the results of the total body composition; that is, EX resulted in an increase and IMB resulted in a decrease in the net balance of both Na and K. The increase in the net balance of these minerals after EX was attributed to the decrease in the fecal excretion indicating that the net absorption of these minerals was enhanced by the EX. The higher urinary excretion of both Na and K in the EX group indicates that the excess Na and K absorbed into the body will be excreted in the urine. The decrease in the net balance of both Na and K after IMB was attributed to the increase in the urinary excretion of these minerals. In conclusion, the TBNa and TBK were positively correlated with physical activity. EX increased the net intestinal absorption of these minerals. However, IMB enhanced the renal excretion of these minerals.

	EX	EX-P	CON	IMB
BODY WEIGHT(gm)	305+6.37**	301+8.01*	274+5.76	242+10.2*
TBNa (gm)	376+14.8*	374+10.1*	338+6.78	310+12.3*
TBK (mg)	744+37.3*	753+36.9*	637+13.4	579+30.5*
FOOD INTAKE(gm)	18.8+0.68	17.3+0.30	17.1+0.32	17.2+0.63
URINARY Na (mg)	31.5+2.06**	27.1+1.88	24.1+1.58	29.6+1.78*
FECAL Na (mg)	6.1+1.37**	5.9+0.82**	11.4+0.88	9.7+1.07
Na BALANCE (mg)	27.2+1.35*	26.8+1.12*	23.5+0.76	20.1+1.18*
URINARY K (mg)	99.1+5.49**	92.1+4.13*	76.1+5.03	102.9+5.34**
FECAL K (mg)	12.8+2.14**	8.6+1.75**	29.5+2.77	25.3+3.04
K BALANCE (mg)	49.1+2.65*	48.3+2.17*	41.4+2.3	19.8+4.15**

Values are mean + S.E. of 5 to 7 rats in each group.
*;** Significantly different from the CON group($p<0.05$; $p<0.01$).

EXPERIENCE WITH BIOELECTRICAL IMPEDANCE DETERMINATIONS IN YOUNG CHILDREN: SOURCES OF VARIABILITY. C. Barillas, C. Vettorazzi, S. Molina, O. Pineda. Center for Studies of Sensory Impairment, Aging and Metabolism of the National Committee for the Blind and Deaf of Guatemala, Guatemala City, Guatemala, Central America.

The bioelectrical impedance analysis (BIA) technique for the estimation of body composition could have wide application in children, but before it can be effectively used, factors that alter the measurements have to be evaluated. Using a BIA-101 instrument (RJL Systems, Detroit, MI), we studied the effects of: a) inter-electrode distance and b) electrode placement on the measurements of resistance (R). In adults, sensor electrodes are conventionally placed over the dorsal wrist and dorsal ankle, with signal electrodes placed at the proximal end of the metacarpals and metatarsals, respectively. Given that children's hands and feet are smaller, we were concerned about interaction between the two electrodes on the same extremity. Close approximation of electrodes is known to increase the R value artifactually. On the right foot of all children studied (n = 13, ages 3 to 10 y), we found it possible to separate the electrodes to a distance at which a plateau in R values was observed (note: upper extremity electrodes remained fixed throughout the adjustment of foot electrodes). On the dorsal right hands of six children examined, aged 3 to 10 y, R values did not stabilize when the maximum inter-electrode displacement was reached (note: foot electrodes fixed in the standard position throughout). An alternative site for the upper extremity electrodes was sought on the ventral forearm. In nine children, aged 3 to 10 y, a series of measurements were taken with the foot electrodes in the standard position. The sensor electrode for the upper extremity was placed with its flat margin at the crease of the elbow flexture on the ulnar side of the ventral forearm, instead of at the wrist. The signal electrode was moved distally from the sensor pole toward the hand, with R measurement taken at 0.5 cm intervals. A mid-inter-electrode distance of 5.5 cm was the minimal displacement that eliminated the electrode:electrode interactions. Theoretically, when the electrode are placed in the elbow instead of the wrist, the volume of the conductor through which the current is flowing is diminished. The effect of this reduction in the "length of the cylinder" of body conduction of electricity on the R value, i.e. by changing electrode placement over the length of the forearm, was studied in six children, aged 3 to 9 years. Foot electrodes were in the standard position throughout. For the upper extremity, the signal electrode was placed on the dorsal wrist and the sensor on the dorsal forearm and moved centrally, away from the wrist toward the elbow, in 1 cm increments. In all subjects, the R value diminished, but proportional to the distance over which the signal pole had been displaced. Correlation between displacement in cm and R in ohms was highly significant (R^2 = 0.97 to 0.99). At a 6 cm central displacement from the wrist, the R value was between 80.7 and 86.8% (mean: 85 $\pm$ 1%; $\pm$ SD) of that estimated by extrapolating back to 0 distance at the wrist. This technique allows a prediction of impedance readings taking advantage of the maximum conduction volume. In the young child, certain specific modifications in the BIA technique are required to get the most stable, reproducible and artifact-free measurments.

SEGMENTAL BIOELECTRIC IMPEDANCE MEASURES OF BODY COMPOSITION. Wm. Cameron Chumlea, R.N. Baumgartner, A.F. Roche, Division of Human Biology, Department of Pediatrics, Wright State University School of Medicine, Yellow Springs, Ohio, 45387.

Bioelectric impedance is measured conventionally as the resistance (R) to the flow of a small alternating current in the body through the right foot to the right hand. Stature (S) squared divided by resistance (S^2/R) as measured from the foot to the hand, has been used to estimate total body water (TBW) and lean body mass (LBM) with high correlations. However, direct estimation of these components of body composition from bioelectric impedance is inherently inaccurate. S^2/R provides a partial measurement of total body volume based upon resistance for the right leg, the trunk and the right arm only, and stature is not a true measurement of the length of the conductor. This may limit the accuracy of the estimation of TBW or LBM. Moreover, the "volume resistivity" (p) of the body has been ignored in most studies.

The volume of any body segment is equal to its length squared divided by its bioelectric impedance; thus, the volumes of adjoining segments of the body, estimated from their individual lengths and bioelectric impedance, can be combined to provide a direct estimate of lean body mass. On this basis, the following equations have been developed: $V_b = 2pL_a^2/Z_a + 2pL_l^2/Z_l + pL_t^2/Z_t$, where V_b is volume of the body; "p" is volume resistivity; L_a is length of the arm, and Z_a is impedance of the arm; L_l is length of the leg, and Z_l is impedance of the leg; L_t is length of the trunk, and Z_t is impedance of the trunk. If we assume that "p" is a constant, the equation becomes $V_b = p(2V_a + 2V_l + V_t)$, or $V_b = p \times V_s$, where V_a is the volume of the arm, V_l is the volume of the leg, V_t is the volume of the trunk, and V_s is the sum of the volumes of the body segments. Lean body mass (LBM) divided by the volume of the body (V_b) equals the density of lean body mass (D_{lbm}). If $LBM/V_b = D_{lbm}$ and $V_b = pV_s$, by substitution, $LBM/pV_s = D_{lbm}$ or $LBM = pD_{lbm}V_s$. Thus, to estimate the LBM of an individual directly from bioelectric impedance segment volumes, the average value and variance of the product of "pD_{lbm}" must be determined.

The present data indicate the value of "pD_{lbm}" has a more limited range of values for men than women, and is less in children. Values of "pD_{lbm}" plotted against lean body mass indicate that the values increase with age, and there is a sex difference in adults. Also, the values of "pD_{lbm}" appear to be independent of percent body fat. These results are in agreement with accepted knowledge of the differences in the body composition of children and adults and between men and women. It is known that the density of lean body mass is more specific for adult men than women which would explain the greater variability in values of "pD_{lbm}" in the women. Also, children and women have less lean body mass than men. These results indicate the possibility that there is a limited value of "pD_{lbm}" ranging from 0.3 to 0.4 that converts bicelectric impedance measurements to estimates of LBM. This will allow bioelectric impedance to be considered a direct method of measuring body composition for individuals.

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THE USE OF TOTAL BODY ELECTRICAL CONDUCTIVITY (TOBEC) TO DETERMINE TOTAL BODY WATER. William Cochran, William Wong, Hwai-Ping Sheng, Peter Klein, and William Klish. USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas

Total body electrical conductivity (TOBEC) has been introduced as a safe and rapid method to estimate body composition (fat and fat-free mass) in infants and adults. Recently, a second generation instrument that operates in a scanning mode has been developed by D-j Medical Instruments Co., Auburn, IL. A study was undertaken to calibrate this new instrument and to assess the feasibility of its use in estimating total body water. Six healthy adults, 3 males and 3 females, ranging in age from 25 to 57 years, and in weight from 43.3 to 104.7 kg were analyzed. Simultaneously, determinations of total body water were made by standard dilutional techniques using $H_2{}^{18}O$. A baseline plasma sample was obtained and 60 mg ^{18}O/kg was given orally as $H_2{}^{18}O$. Five hr later, a postdose plasma sample was obtained. The $^{18}O/^{16}O$ ratio in the plasma samples was determined as CO_2 by gas-isotope-ratio mass spectrometry and used to calculate the $H_2{}^{18}O$ volume of distribution. The total body water values ranged from 26.35 to 58.02 and represented 51 to 58% of body weight. There was good linear correlation between the total body water measurement and its phase average (TOBEC number) with a linear correlation coefficient of 0.998. The standard error of the estimate was 0.98. In addition to estimating fat and fat-free mass, the TOBEC method also estimates total body water with excellent correlation to physical dilution methods.

AN EVALUATION OF TOTAL BODY ELECTRICAL CONDUCTIVITY (TOBEC) MEASUREMENTS FOR THE DETERMINATION OF BODY COMPOSITION IN THE HUMAN INFANT. Marta Fiorotto, William Cochran, Hwai-Ping Sheng, and William Klish. USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas

Most techniques used for routine measurement of fat and fat-free mass (FFM) of adults are not suitable for use in infants. The TOBEC instrument, with the appropriate calibration, may provide an alternative that is safe, noninvasive, and accurate. The infant miniature pig was selected as a model because it is similar in size and composition to the human infant. Twelve healthy infant mini-pigs (age 10 to 33 d; weight 2 to 6 kg) were studied. Each infant mini-pig was measured 10 times in the TOBEC (model M-60) and an average measurement obtained. The animals were analyzed for total body water (TBW), fat, and electrolyte contents by chemical analysis. Plasma was obtained, and water and electrolyte concentrations were measured. FFM, intra-and extracellular fluid volumes were calculated. TOBEC values were highly correlated with both TBW ($r = 0.995$; 1 SEE = 0.09 kg) and FFM ($r = 0.994$; 1 SEE = 0.12 kg). The predictive accuracy was improved by accounting for age-related changes in compartmental volumes and electrolyte composition. The calibration derived for the infant mini-pigs was then evaluated by estimating the FFM and fat of 20 healthy infants between (age, 2 to 12 wk) from their individual TOBEC measurements. Values for the fat content of the infants correlated well ($r = 0.73$) with their individual skinfold thickness measurements, and to a lesser extent with their weight for height ($r = 0.59$). There was a good correlation between FFM and indices of muscle size, such as mid-upper arm area ($r = 0.71$). FFM also was calculated from the estimates for TBW (from the piglet TBW-TOBEC relationship) using the values reported by Fomon et al. (Am. J. Clin. Nutr. 35:1169-1172, 1982) for the water content of FFM in infants of similar ages. The latter estimates of FFM were 1.5% lower than those derived directly from the piglet FFM-TOBEC relationship. The values derived for the fat content of these infants were within the anticipated values for infants of these ages. Thus, the infant miniature pig provides a reasonable model with which to calibrate the TOBEC for use in human infants.

VALIDATION OF THE TOTAL BODY ELECTRIC CONDUCTIVITY METHOD BY DIRECT CARCASS ANALYSIS OF SWINE. N.L.Keim, S.J.Taylor, P.L.Mayclin and D.L.Brown. Western Human Nutrition Research Center, ARS, USDA, San Francisco, CA and Department of Animal Science, Univ. of California, Davis, CA.

In vivo determination of body composition by measuring total body electric conductivity (TOBEC) is based on the principle that lean and fat tissues differ in conductive and dielectric properties. To date, only indirect measurements of human body composition have been used to validate the TOBEC instrument, Model HA-2 (Dickey-john Medical Instrument Corp., Auburn, IL). In this study, direct chemical carcass analysis of pigs was used to examine relationships between TOBEC and body water (W), lean mass (LM) and fat mass (FM). Twenty-five pigs were selected with body weights and estimated compositions comparable to human adults. For TOBEC measurement, animals were anesthetized, transferred to the HA-2 sled and scanned. On the following day, pigs were slaughtered and partitioned into carcass, viscera, blood and ingesta compartments. Proximate analysis of compartment samples was used to determine total content of W, LM and FM.

Total body composition profile of pigs by proximate analysis, n = 25.

	Body wt kg	Body W kg	Body LM kg	Body FM kg	Body FM %
Mean	87	45	62	25	28
S.D.	26	14	19	12	9
Range	48-137	26-64	37-87	7-51	14-45

The best correlations were found between TOBEC phase average (PhA) and empty body (total body - ingesta) W and LM, r=.978 and .976, respectively. The prediction equation for empty body W is W = 15.6 + 0.0285(PhA), $s_{y.x}$=2.672 kg. The prediction equation for empty body LM is LM = 21.6 + 0.0395(PhA), $s_{y.x}$=3.810 kg. Empty body FM correlated poorly with TOBEC PhA alone, r=.588. However, empty body FM could be predicted when both PhA and live body weight were included as covariates. The equation is FM = 1.12(body weight) - 0.0499(PhA) - 26.0, $s_{y.x}$=5.177 kg, R^2=.827. Another objective of this study was to determine if body fatness affected the sensitivity of TOBEC in predicting body W or LM. The pigs were classified as 'lean' (<25% fat, n=13) or 'fat' (>30% fat, n=12), and separate regression analyses were performed for both groups and compared. The TOBEC PhA was closely related to empty body W in both lean pigs, r=.981 and fat pigs, r=.987. Further, residual mean squares, slopes and intercepts for the regression of PhA on W were similar for both groups, as were regressions of PhA on empty body LM. Thus, TOBEC, as measured by HA-2, is a valid method for predicting body W, LM and FM over a wide range of body weight and composition.

A FEASIBILITY STUDY OF IN VIVO BODY COMPOSITION MEASUREMENTS USING A RESONANT A.C. CIRCUIT.

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When a sample of conducting material is introduced into a coil carrying an alternating current, a change in the complex impedance of the coil is observed. If the coil is part of a resonant circuit there are corresponding changes in the frequency and height of the resonance peak. These changes can be expressed in terms of the changes in magnetic and electric fields inside the coil, which can be found by solving Maxwell's equations for the system (1). This approach has been used for the estimation of body composition of live animals (2).

The present experimental system consists of a single layer solenoid connected in parallel with a variable tuning capacitor and driven, via a power amplifier, by a radio frequency sweep oscillator. The resonance peak is displayed on an oscilloscope which monitors the coil current and whose time-base ramp signal is used to sweep the oscillator through the resonant frequency at the circuit.

The technique is being applied to non-biological conductors and present studies involve the extension of the method to conductivity measurements on limbs and eventually the whole human body.

A whole body conductivity measurement can be used to estimate the relative volume of conductive tissue, and hence of non-conducting fat, simply and inexpensively. There are, however, questions concerning the influence of obesity and other factors on the method and since we have available to us both whole body ^{40}K or neutron activation measurements, it is intended to carry out an intercomparison of the methods.

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SOURCES OF VARIABILITY IN BIOELECTRICAL IMPEDANCE DETERMINATIONS IN ADULTS.
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Although the bioelectrical impedance analysis (BIA) technique for determining body composition is straight-forward, rapid and non-invasive, it does not follow that its application is not without limitations, pitfalls and caveats. Some inherent problems in the use of BIA have been signaled by Cohn (1). As any diagnostic test is only as sound as the care and attention put into the collection and the interpretation of results, however, we undertook studies to define the precision, reproducibility, and detection limits for changes in the BIA indices. Studies were conducted using a BIA-103 or BIA-101 instrument (RJL Systems, Detroit, MI). In a study to determine inter-observer correlation, 10 subjects were measured for resistance (R) and reactance (Xc) by two experienced operators independently: once with only the anatomical references; and again with marks on the skin indicating the agreed upon positions. The correlation coefficients of R were, with marks, $r = 0.989$, and without marks, $r = 0.998$, and for Xc, $r = 0.990$ and $r = 0.977$, respectively. Observer A had consistently lower R values, with a mean difference of $0.7 \pm 1.2\%$ from the readings of observer B without skin marks; a similar difference, $0.9 \pm 0.5\%$, was seen between A and B with the marks as well. A study in which the sensor electrodes on the wrist (phase 1) on the ankle (phase 2) and at both sites (phase 3) were displaced centrally at 2 mm increments (using skin reference marks) up to 1 cm was performed in 10 individuals. The error in the R determinations at full displacement of electrodes in the respective phases were: $2.4 \pm 0.2\%$ (phase 1); $2.1 \pm 0.3\%$ (phase 2) and $4.1 \pm 0.7\%$ (phase 3). The coefficient of variation for the four repeat measurements of R in this study at the original, standard positions was $0.4 \pm 0.2\%$ (range: 0.3 - 0.6%). The rule of thumb that the width of the wrist defines a distance at which electrode: electrode interaction between sensor and transmitter poles is non-existent was confirmed in displacement studies in 7 subjects. When electrodes were placed on the ventral surface of the wrist and hand, opposite the corresponding landmarks for dorsal placement, a difference of $1.6 \pm 0.8\%$ in R readings, and of $-3.7 \pm 2.3\%$ in Xc readings was produced in 10 individuals. The forced respiratory cycle exerts an effect, with a $0.9 \pm 0.3\%$ higher reading of R at full inspiration, as compared to full expiration ($n = 10$). To put all of these findings into perspective, the instrumental error of the apparati is 1.0%, meaning that a R reading of 500 ohms is really between 495 and 505 ohms. To determine the acute change in hydration that is detectable by the BIA technique, subjects (5 males and 5 females) were given progressive increments of 250 ml of an electrolytic solution with 110 mEq/L of cations (71% of isotonicity) up to one liter. Contrary to expectations, the salt solution produced no changes in R or Xc distinct from that with pure water in equal volumes, or from serial monitoring alone. Apparently, in the well-hydrated individual, oral electrolytes and water do not rapidly incorporate into a body-water pool recognized by the BIA technique.

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Accuracy and Precision of Bioelectrical Impedance and Anthropometry to Estimate Body Composition

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With the aim of comparing estimates of body composition obtained through under-water weighing (UWW), bioelectrical impedance (BEI), and anthropometry (ANT), we determined body composition of 26 Guatemalan adult INCAP employees using these three methodologies. The study group consisted of 8 male and 16 female apparently healthy volunteers with a mean age of 27.8 yrs. Mean (± SD) weight was 58.4 (8.2) Kg and height 161.9 (9.3) cm. Body fat (BF) and fat-free mass (FFM) estimates were derived using Siri, Durnin and Womersley, and RJL system equations for UWW, ANT and BEI respectively. Percent fat as estimated by UWW ranged from 11 to 34.9. All measurements were taken during 2 consecutive days with the subject in a fasting state, after defecating, emptying their bladder, and without having drunk alcoholic beverages for at least 24 hrs. BEI and ANT were measured immediately before the UWW procedure. The precision of the methods was judged good. It was estimated by computing the percent body fat for each measurement and comparing group means by paired t-tests of the first vs the second measurement day. t-values were for UWW = 0.32 (p=75), BEI = -0.72 (p=48) and ANT = -0.02 (p=98) with correlation coefficients of 0.93, 0.98 and 0.99 respectively. For the accuracy analysis, BF and FFM estimates obtained by UWW were used as reference for comparing BEI and ANT estimates. On the average, BEI and ANT underestimate percent fat by 5.5 and 4.3 respectively. The following table shows the results of regression analysis of BF and FFM mass (in Kg) estimated with UWW as the dependent and BEI or ANT as the independent estimators.

	BF (kg)		FFM (Kg)	
	BEI	ANT	BEI	ANT
Intercept	5.59 Kg	5.28 Kg	2.86 Kg	2.62 Kg
Slope (SE)*	0.81 Kg (0.09)	0.79 (0.11)	0.87 (0.04)	0.89 (0.06)
R^2_{adj}	75.8 %	65.9 %	93.7 %	89.7 %
SEE **	2.1 Kg	2.5 Kg	1.96 Kg	2.5 Kg

* All $p < 0.005$ ** Standard error of the model ($\sqrt{MSE}$)

The results reveal that: 1) better prediction equations are obtained for FFM than for BF as judged by the smaller SEE and intercept, and the larger R^2_{adj} for both BEI and ANT estimators; 2) BEI is moderately and consistently better than ANT to estimate body composition; 3) BEI and ANT overestimate FFM, and this overestimation increases as FFM augments. Conclusions: a) Our results show that when using impedance and anthropometric data to estimate body composition of our group through equations developed in a different population, there is not an acceptable agreement between the estimates, especially for BF; b) According to our results, we recommend caution in using either the RJL or the Durnin and Womersley algorithm to estimate FFM or BF; c) Finally, given the growing popularity of BEI, we recommend the development of more accurate equations to estimate body composition, if this method will be used in populations dissimilar from that where equations were developed.

BODY COMPOSITION DETERMINATIONS BY BIOELECTRICAL IMPEDANCE IN OLYMPIC-CLASS ATHLETES AT THE THIRD CENTRAL AMERICAN GAMES. M.J. Guzmán, R. Elsen, A. Padilla, N.W. Solomons, C. Whalen, M-L Siu, M. Mazariegos, S. Molina, L. Neufeld, A. Rosas, C. Barillas, D. Canales, C. Vettorazzi, F. Beltranena, O. Pineda. Center for Studies of Sensory Impairment, Aging and Metabolism of the National Committee for the Blind and Deaf of Guatemala, Guatemala City, Guatemala, Central America.

It is logical that body composition, specifically the balance between fat- and lean-mass should: a) be altered by physical training; and b) influence performance in a given sport. Relationships of body composition to athletic performance are poorly understood, in part due to limitations in ways of determining body-fat and body-water. Using the newest innovative approach, bioelectrical impedance (BIA), we studied 452 individuals at the III Central American Games (January, 1986), using the BIA-103 instrument (RJL Systems, Detroit, MI) and calculating with RJL software nomogram (8.51) on an Epson computer. Subjects were studied between 8 a.m. and 6 p.m., both in the fasting and the non-fasting state. The resistance (R) readings ranged from 317 to 787 ohms (median: 530 ohms), with the expected trend to greater R values in women (median: 600 ohms; range: 462-787 ohms) as compared to men (median: 500 ohms: range: 317-688 ohms). Reactance (Xc) ranged from 26 to 106 ohms for the whole group (median: 64 ohms), with a parallel shift toward higher values for women athletes. Per-cent body mass as water (%TBW) ranged from 49 to 85% in men (median: 60%) and from 42 to 73% in women (median: 54%). Per-cent total-body mass as fat (%TBF) ranged from 1 to 33% in men (median: 16%) and from 4 to 53% in women (median: 20%). If we accept 15%, as the expected average of %TBF for non-trained adult men, then 128 of 280 (46%) were at or below this level. Using 27% as the anticipated %TBF for untrained women, we found 146 of 164 (89%) with this or a lesser fat content. Thus, for the female athletes, the distribution was shifted toward leaner individuals. Data on selected sports are shown below:

Table: *Per-Cent Body-Fat in Selected Sports*

	male athletes			female athletes		
	number	median	range	number	median	range
Track & Field	28	16%	11-22%	19	21%	4-53%
Fencing	3	16%	16-25%	5	26%	22-30%
Basketball	17	16%	6-21%	46	23%	12-32%
Equestrian	11	16%	11-27%	6	20%	15-24%
Gymnastics	0	--	--	14	14.5%	8-24%
Softball	19	20%	12-29%	26	20%	10-27%
Volleyball	38	16%	3-23%	37	19%	10-39%
Ping Pong	8	19.5%	5-24%	8	20%	10-30%
Cycling	13	15%	11-22%	0	--	--

For men, wrestlers were leanest, with %TBF at 12.5%, while softball players, with a median of 20% were the fattiest. Among women, the gymnasts were the leanest (median %TBF = 14.5%), while fencers had the most adiposity at 26%. Thus, at the level of population distributions, the data from the BIA system provide results in the expected direction (toward leaness) for women. The expected displacement between men and women, based on established prinicples of anatomy, is reflected both in the basic R values and in body composition.

EVALUATION THROUGH SEQUENTIAL DETERMINATION OF THE STABILITY OF BIOELECTRICAL IMPEDANCE MEASUREMENTS FOR BODY COMPOSITION ANALYSIS. M-L Siu, R. Elsen, M. Mazariegos, N. Solomons, O. Pineda. Center for Studies of Sensory Impairment, Aging and Metablism of the National Committee for the Blind and Deaf of Guatemala, Guatemala City, Guatemala, Central America.

The bioelectrical impedance analysis (BIA) technique offers a non-invasive, in vivo approach to determining human body composition. The limits of detection for real changes in body composition, such as short-term changes in hydration or longer-term changes in fat-mass or lean-body mass, will inherently depend on the stability of the measurements of impedance (Z) over time. In the present study, we sought to determine the interval variation in the readings of the vector components of impedance -- resistance (R) and reactance (Xc) -- over time in short-term studies (20 min) and in longer-term studies (up to four weeks). Two impedance plethysmographs -- a BIA-101 junior and a BIA-103 (RJL Systems, Detroit, MI) -- were used. The subjects for the short-term study were 10 healthy volunteers ranging in age from 21 to 73 years (median: 25 years). They were studied on two occasions. The electodes were placed on the dorsal right hand and dorsal right foot in the conventional positions and remained in place for the duration of each study. Subjects reclined in the supine position on a bed for 20 min. Readings of R and Xc were taken at time zero and at 5-min intervals thereafter. On one occasion, the subjects were covered with a blanket; on the other, they were uncovered in their daytime clothing. With the blanket covers, the mean changes in R values at the 5, 10, 15 and 20 min readings were virtually zero. Without covers, however, there was a progressive drift toward higher R values with time, such that a mean 2 ± 1% increase was registered at 20 min. The coefficients of variation (c.v.'s) are presented in the Table. With a 20-min duration, c.v.'s were generally a fraction of one per-cent. In the longer-term study, individuals were studied during the 5 weekdays over 4 consecutive weeks, on each occasion at the same time of day. Subjects included 11 blind elders in a rehabilitation center (age range: 61-85 y) and 28 healthy women, ranging in age from 21 to 85 y: 12 were still menstruating and 9 were postfertile. As can be seen in the Table, c.v.'s ranged from 2.2 to 4.9% for the elders; one subject had a 119 ohm individual high-low difference in R. In the adult female population, c.v.'s ranged from 1.3 to 4.3% during the month of monitoring. Differences in day-to-day variance between the two subgroups of women were not detected. The present study, delineates the instrinsic variability within subjects for short and longer-term periods using the BIA technique for body composition.

Table: *Intrasubject Variance in Bioelectrical Impedance*

	no.	duration of study	no. of BIAs	mean c.v. (%)	range of c.v.'s (%)	range of high-low differences (ohms)
controls (with blanket)	10	20 min	5	0.4±0.6	0.1-0.7	2-10
controls (uncovered)	10	20 min	5	0.9±0.3	0.3-1.6	4-25
elderly blind	11	26 days	17-21	3.4±0.8	2.2-4.9	49-119
fertile women	12	28 days	12-22	2.3±0.8	1.3-3.9	31-84
postfertile women	9	28 days	16-22	2.8±0.9	1.8-4.3	38-110
total woman sample	21	28 days	12-22	2.5±0.8	1.3-4.3	31-110

RELATIONSHIP BETWEEN WEIGHT-FOR-HEIGHT INDEX AND BODY COMPOSITION IN CHILEAN ADULTS. Vásquez M.*, Peña J.*, Díaz E.**

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Frequently, the weight-for-height index (W/H), the ratio between observed weight and that expected according to actual height, is used as the unique tool to assess adult nutritional status in developing countries. Expected weight is obtained from USA standards that have been developed with semi-biological or statistical criteria. With the aim of studying the relationship between W/H index and body composition (BC), 81 healthy chilean men with ages ranging from 17 to 40 years, were assessed by W/H using 4 standards available from USA. These were compared to estimates of BC by densitometry. Mean W/H using Metropolitan Life Insurance (MLI) 1959, ICNND 1963, NCHS 1979 and MLI 1983 were: 106.8 $\pm$ 12.5; 101.1 $\pm$ 11.8; 104.5 $\pm$ 12.8; and 94.5 $\pm$ 10.8 respectively. W/H index was classified: as normal 90-110%, lean < 90%, overweight 111-120%, and obese > 120%. BC was normal when body fat was between 10-20% of body weight, lean < 10% and excess >20%. It was found that only a 27% of cases were classified in the same category of adequacy by both W/H and BC. By regression analysis W/H explains no more than 39% of body-fat variance, with a mean error of estimation of 3.3 kg. In conclusion, irrespective of the standard, W/H indices are not related with body composition. It is pertinent to ask: What does this index mean and what is its biological significance?