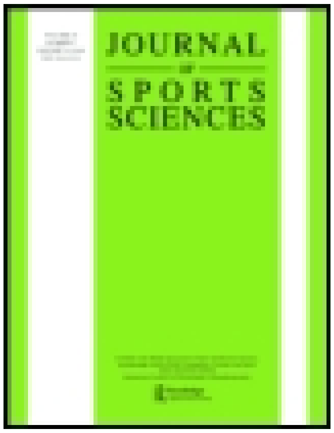

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Kinanthropometry: Roots, developments and future

Gaston Beunen [a] & Jan Borms [b]

[a] Katholieke Universiteit Leuven , Tervuursevest 101, Leuven (Heverlee), B-3030, Belgium

[b] Vrije Universiteit Brussel , Pleinlaan 2, Brussels, 1050, Belgium

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Kinanthropometry: roots, developments and future

GASTON BEUNEN[1] and JAN BORMS[2]
[1]*Katholieke Universiteit Leuven, Tervuursevest 101, B-3030 Leuven (Heverlee), Belgium*
[2]*Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium*

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Introduction

What is 'kinanthropometry'? Is it merely an attempt to market, old and established knowledge, under a new name – or does it indeed mean a new conception of the study of man in motion?

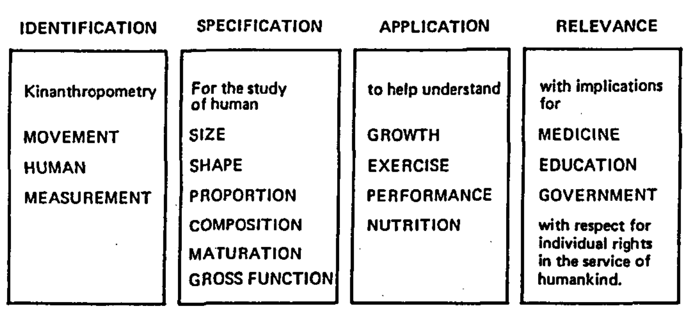
Conception is a well chosen term for two reasons. Firstly, it is not so much a separate branch of science, but rather a certain state of mind towards the 'human being as a most interesting and important animal and the movements it performs'. The 'kinanthropometrist' is involved with measurement and evaluation of different aspects of humans in motion, and with the physical characteristics of the human, with a view to studying inter-human variations. He or she is not only interested in characteristics and qualities of one individual, but also in the range, the variation which is found within one population, and in the differences occurring between populations in the course of time. Kinanthropometry can be considered as a subject of human biology or physical anthropology, both of which are concerned with the biological characteristics of this unique species.

In the second place, it is a new conception because in the past, especially also in circles of physical education, sport and recreation, the terms anthropometry and biometry were commonly used (Ledent and Wellens, 1922; Vandervael, 1943; De Nayer, 1956). It is, however, characteristic of biometry and anthropometry that the emphasis was mainly, if not exclusively, on the study of body build. This becomes apparent when fundamental works in human biology or physical anthropology are read. Weiner and Lourie (1969), for example, mentioned in their basic work on techniques in human biology, under the heading anthropometry, only a series of body measurements. Biometry and anthropometry were, however, originally introduced with a much larger content. Karl Pearson, a British mathematician, developed *biometry* as a science of measurement and quantitative comparison of the biological variation. For the study of this variation and covariation (literally, 'varying together'), he used the correlation technique. According to Boyd (1980) and Tanner (1981), the term anthropometry seems to have been used for the first time in its contemporary meaning, by the German medical doctor Sigismund Elsholtz (1623–1688), who also studied dimensions of the human body. Kinanthropometric research, therefore, has a long history, but the term is of a rather recent origin. This origin is to be found in university institutes of physical education which were searching for a specific approach of their scientific discipline.

According to Parlebas (1981), it was Roch Meynard of the Université de Laval, Québec, Canada, who introduced for the first time the term 'Kinanthropology' in 1966. Soon after, in 1969, the journal 'Kinanthropologie', in the French language, appeared. In this journal, the term 'Kinanthropometry', was first used in an article by Ross *et al.* (1972). A later article by Hebbelinck and Ross (1974), also contributed to the use of this term. In physical education circles, the terms biometry and anthropometry were slowly being replaced by kinanthropometry. Within the physical education field itself, a shift took place towards the quantitative measurements and evaluation of aspects of the human being in movement. Concerns included:

– components of body build, namely body measurements, -proportions, -form, -composition and physical maturation;
– physical qualities, neuro-motor qualities, such as strength, flexibility, speed, balance, co-ordination, and cardio-respiratory characteristics;
– measurement of their physical activity level; daily physical activity and sport skills.

Ross and Borms (1980) stated that this scientific discipline can be formally considered as the study of the relationship between human structure and movement, as shown in Fig. 1 (Ross, 1978). The central theme of kinanthropometry is the measurement of the human in a variety of morphological perspectives and its application to movement in its varied forms and to those factors which influence movement (Malina, 1984).



(from Ross, 1978)

Fig. 1. Kinanthropometry: 'An emerging scientific specialization'

Since kinanthropometry has grown from anthropometry and/or biometry, and since its purpose is also the construction and improvement of measurement techniques to study inter-human variation, these measurement techniques must be applicable in population research. The measurements must be applicable in a field situation, outside the laboratory, and must allow the study of large samples of test subjects within a short period of time.

Measuring techniques in kinanthropometry

When qualities and characteristics of human individuals are evaluated quantitatively, the problem of developing valuable measuring techniques arises. As a research tool, a measurement has to meet a number of prerequisites, which can be summarized as follows.

– A test/measurement must be *standardized*, meaning that the subjective input of the test leader when measuring or testing, must be eliminated as far as possible. For the measurement of size, the chance for an 'interpretation' of the measured length is small. It is a different story when the robustness of an individual must be estimated;

– A test or measurement must be *reliable*, meaning essentially that, when the measurement is repeated twice or more within a short interval, varying from a couple of days to 2 weeks, the results of the measurements must be the same. The reliability of a test/measurement can be impaired because of external factors influencing the result of the measurement or because of factors which are inherent to the test itself. The unreliability of a test can thus be caused by many factors among which are the changes occurring within the examiner, the test person, the external environment–circumstances and also because the quality is measured by one single measurement or test;

– A test or measurement must be *valid*, which implies that a test/measurement ought to measure what it purports to measure. This seems, at first glance, obvious; but in practice it is one of the most difficult test requirements to verify. It is clear that with the measurement of size, we acquire a picture of the length development. It can, of course, be questioned whether size is really one of the most indicated measurements for the evaluation of length development. It becomes even more difficult when, for example, one wants to assess the motor performance capacity of a growing child. Which measurements need to be done to acquire a good picture of the performance capacity? Finally, a test/measurement must be accompanied by *reference values*, which are needed to check the individual performance or measurement.

In the next paragraphs, a brief overview is given of a number of techniques which are used in kinanthropometry and which meet these requirements.

Anthropometric techniques

Body dimensions

Without doubt, the body dimensions are the most widely used measurements in kinanthropometry. It would be almost impossible to start analysing the differences in measuring techniques, described by so many authors. For a more detailed and accurate description of a series of 'classic' anthropometric techniques, reference is made to standard works such as 'Lehrbuch der Anthropologie' published by Martin in 1914 and later reworked by Martin and Saller (1957).

More recently, a standard text has been published by Weiner and Lourie (1969, 1981), in which body measurements were described, the way they were applied in studies of the International Biological Programme. In the field of physical education, pioneer work has been done by Larson (1974) in order to attain international standardization. Furthermore, it should be mentioned that the former 'International Working Group on Kinanthropometry' (now ISAK) used the measurement protocol which was, among other things, applied for the evaluation of participants of MOGAP, the Montreal Olympic Games Anthropological Games Project (Borms *et al.*, 1979; Carter, 1982). In 1985, a number of researchers from several disciplines gathered in the Arlie Consensus Committee and published an Anthropometric Standardization Reference Manual (1988). For the study of living individuals, the following components in body dimensions can be distinguished, according to Tanner (1964):

– *skeletal size*; this component comprises measurements of the size of trunk and limbs, such as body height, shoulder width, length of the limbs. These dimensions are taken with a stadiometer or an anthropometer for length dimensions and with an anthropometer or spreading caliper for width measurements;

– *trunk-limbs component*; this component points to the opposition between the size of the trunk and the size of the limbs. This component therefore indicates a component of skeletal size as well;

– *skeletal width of the extremities*; this component comprises measurements of the width of the bones. These width measurements are performed with a spreading or Vernier caliper.

– *muscle component*; when only 'classic' anthropometric techniques are being used, then perimeters of the limbs, eventually corrected for subcutaneous adipose tissue thickness, are the best indicator of this muscle component. When soft X-rays or medical imaging are used, this component can then best be evaluated by measuring the muscle width. Perimeters are, preferably, taken with a metal tape.

– *fat component*; measurements of subcutaneous adipose tissue thickness are taken with a skinfold caliper. The thickness of a skinfold is measured on specific sites on trunk and limbs.

Furthermore, it should be mentioned that the dimensions of hands, feet and head appear also as separate components.

Body proportions, -form, -type and -composition

Anthropometry found its origin not in medicine or biology, but in the plastic arts. Sculptors and painters were indeed searching for the ideal proportions between body parts, in order to give the proper 'picture' of the human body. The 'Proportionslehre' (1528) of Albrecht Dürer (1471–1528), is perhaps one of the best known works on human proportions, although Tanner (1981) doubted whether Dürer ever measured a human individual. Although Thompson (1917) published an impressive work on 'On Growth of Form', the study of proportions was mostly restricted to the study of a number of indices which were perhaps introduced by the French medical doctor Godin (1880–1935). In the course of time, tens of indices have been proposed which, among other things, aimed to quantify the relative weight, robustness or the masculinity. The great difficulty with these indices, is that one never knows what in fact decreases or what increases when the index becomes larger (smaller). Information, in fact, is lost.

Allometry is another approach where the growth of a part of the body is put in relation to the growth of another part, mostly the body height. This approach has gained recognition especially through the work of J.S. Huxley (1887–1975). Allometry is based on the principle that, when a linear dimension increases by 5 cm, all surfaces increase by '5 cm squared' and all volumes by '5 cm raised to the third power'. This implies that during growth, the proportions remain unchanged. More recent studies, such as those of Ross and Wilson (1974) and of Goldstein and Johnston (1978), have concentrated once again on the body form. Ross and Wilson (1974) used for this purpose a 'unisex phantom model' as 'yardstick', while Goldstein and Johnston (1978) departed from the transformation of Cartesian coordinates, originally worked out by Thompson (1917). Most recently Bookstein (1986) proposed another approach which merits further attention of kinanthropometrists.

A totally different approach is found in the studies of body type. Body typologies have as a main characteristic the attempt to make up, on the basis of external somatic appearance, classifications in which groups of human individuals can be placed.

According to C.H. McCloy (1886–1959), an American physical educator, most of the typologies depart from the assumption that on the one extreme end a relatively small, fragile, linear type can be situated, and on the other extreme, a rather short stocky, relatively massively built type, with in between a type which could be defined as 'normal'. McCloy (1936), however, rightly noted that the body type provides much more information than just body proportions. Those who have ever attempted to assess the body type, on the basis of standardized pictures, will confirm this. To put it in another way, the human examiner sees and perceives, while calipers and measurement instruments do neither. This has led to the view that everything concerned or related to typologies or constitution theory, was unscientific. Nevertheless, body typologies seem to be useful as a reference frame, or model, since it has been demonstrated that these classifications are related to the most diverse human characteristics and qualities, such as the physical performance capacity. This does not mean that present day kinanthropometrists still advocate the outdated opinions concerning the relations between body proportions, constitution and health. The old ideas about the humoral and physiognomy classification of diseases and deformations have indeed been abolished, since the progress of cellular pathology and bacteriology.

This overview will be restricted by stating that, at the end of the past century and at the beginning of this century, anthropological schools emerged in Italy, France and Germany, which created their own typology – Di Giovanni (1838–1916) and Viola (1870–1943) in Italy; Sigaud (1862–1921) and McAuliffe (1876–1937) in France and Kretschmer (1888–1964) in Germany. Sheldon (1899–1977) gave in 1940, with the publication of *The varieties of human physique*, a new impulse to the study of the body type. According to Sheldon, the body type is determined by the interaction of three components which he called according to three germ layers, namely *endomorphy*, *mesomorphy* and *ectomorphy*. The somatotype would be, according to him, the best estimate of the 'genotype', laid down in the genetic material. The endomorphy component is characterized by a voluminous trunk with the largest mass concentrated in the abdomen. The body type of mesomorphic individuals is dominated by squareness, massiveness and an outspoken muscular development. The ectomorphy component is characterized by a stretched out, linear and fragile body build. The somatotype is estimated through each of these components, scored on a seven-point scale (Sheldon *et al.*, 1954, 1969, 1970).

The somatotype method of Sheldon provoked a stream of criticism, which has led to modified techniques. The most important modifications were proposed by Parnell (1958) and by Heath and Carter (1967). In both techniques, the three components of body type are determined by means of anthropometric measurements, and the idea to 'estimate genotype' is abandoned. The aim of Parnell, as well as Heath and Carter, was to acquire a picture of the phenotypical body type on the basis of the present body measurements. The method of Heath and Carter (Carter, 1975) appears to be applied world-wide in the domain of the study of the body type of elite athletes, most probably because of its practical applicability.

The composition of the human body can be studied in different ways, although the most exact and direct analysis can be carried out only on cadavers. All other techniques are indirect methods and rely on data assembled with the analysis of a rather restricted number of cadavers. The indirect techniques, used so far depart mostly from a two compartment model where the total body mass is divided in a lean body mass and a fat mass. Both components can be estimated with the help of different laboratory techniques. Nevertheless, it is only the anthropometric approach that allows a large scale application. In the antropometric approach, the components of a model are estimated from body measurements, among which skinfolds are perhaps the most applied anthropometric parameters. Matiègka had proposed in 1921, the estimation of muscle, bone, and fat masses, through anthropometric measurements, but it was especially Behnke (1961) and Brozek (1960) who performed pioneer work in this area. It should be pointed out, however, that the anthropometric estimation of body composition is prone to rather large errors of estimate. For the evaluation of adiposity in the body, the use of reference scales for subcutaneous fat measurements is perhaps more recommendable and more accurate than the estimation of total body fat mass, obtained through all kinds of formulae, unless age-specific equations are used which will vary with the populations (e.g. obese, athletic, and girls vs. boys) (Lohman *et al.*, 1988; Lohman, 1989). More recently a number of researchers have used the bioelectric impedance technique to assess body composition. This technique has the advantage of being applicable in large scale surveys but needs further validation, especially in children and adolescents (Lohman, 1989).

Developmental age, physiological age or maturity

Already at the beginning of this century, the American–German anthropologist, Franz Boas (1858–1942), was aware of the fact that chronological age was not a good criterion for estimating the biological maturity of an individual. Children with the same calendar age can differ enormously in their developmental process. At about the same time, Crampton (1908) introduced the notion of physiological age. By taking the appearance of the first pubic hair as a point of reference, he was able to check how long it was since a boy or a girl had reached that milestone or, retrospectively, how many years the child was remote of this biological milestone. Acording to Tanner (1962), there are nowadays four systems being used to assess the biological maturity status.

(i) The sexual age, whereby biological maturity assessment is based on different stages of primary and secondary sex characteristics. Most commonly, the development of the penis, scrotum, pubic hair, breast and the age of menarche are being considered.

(ii) The dental age, which is usually estimated by the study of the eruption of the teeth, although Demirjian (1978) argued that the estimation is more accurate when the different developmental stages of the teeth are studied on panoramic X-rays of the teeth.

(iii) The morphological age, which can be obtained by checking the mean height of a population at a certain age. This 'height-age', as well as the 'weight-age', gives an inaccurate estimation of the biological age. For instance, a certain height (e.g. 132 cm) at a certain age (9 years) tells us how tall a child is and how tall it is in relation to his sex and age group, but it does not reveal how remote the child is from its adult height. It would be better to take the percentage of mature height as a criterion. Certain methods do allow the prediction of adult height as a result of a few measurements at one moment. The age of maximal growth velocity is a good indicator of biological maturity, as well.

(iv) The skeletal age is being determined by the study of bones during their different developmental stages. Usually an X-ray of the hand and wrist or knee is taken for this purpose.

Although Todd's (1937) atlas technique, adapted later by Greulich and Pyle (1950), had much appraisal in clinical use, the more systematic and elaborate techniques from Tanner *et al.* (1975) and Roche *et al.* (1975) have gained more and more attention in scientific research. Both techniques describe the successive alterations which occur in bone centres. On the basis of those descriptions, stadia are appointed to bone centres which serve as the starting point for the calculation of the skeletal age. Just recently, Roche *et al.* (1988) proposed a new method for the hand and wrist, similar in procedures to their method for the knee (Roche *et al.*, 1975; Roche, 1978).

Skeletal age is considered as the most appropriate biological development criterion when there is only one criterion available. Nevertheless, the relation between skeletal age, sexual age and morphological age is not perfect. So it is not possible to predict sexual age from skeletal age for one individual, though the relation is strong enough to make predictions for groups. If, for instance, a group of female gymnasts is retarded in skeletal development, then one can conclude that the sexual development of this group is also retarded (Malina, 1978).

Physical performance characteristics

Test batteries for the measurement of motor fitness

The measurement of human physical performance capacity is not such an easy matter for a scientist. Trainers and coaches too are still looking for a simple technique to identify the best athletes. Physical education teachers meet the same problem in trying to give their pupils an objective score. Standard works in physical education test evaluation describe lots of tests, although it is difficult to find out whether these measurements are valid or not (Barrow and McGee, 1972; Clarke, 1967; Cureton, 1947; Fleishman, 1964; Larson and Yocum, 1951; Matthews, 1968; Safrit, 1973).

In the 1920s, there was the notion that physical performance capacity could be measured with one single test. Therefore, Sargent (1921) developed his well known 'Sargent Jump' (a vertical high jump without dash) as 'the physical test of a man'. Later, when more sophisticated multivariate statistical techniques, and more specifically factor analysis, were developed, it became possible to see more clearly into the complex field of physical performance capacities. The major conclusion was that physical fitness could be split into different components. Within the scope of this article, the evolution in measurement techniques for the evaluation of physical performance capacity can not be reported at length. Yet, it is worth knowing that much of this research was done in the U.S.A. and that, in the same tradition, test batteries in Europe were constructed for the measurement of motor ability and cardio-respiratory endurance. The factor analytic studies of Simons *et al.* (1969, 1978), based on the research of Fleishman (1964), were the major points of reference for Kemper and Verschuur (1977) when they developed the MOPER fitness test in the Netherlands. The Eurofit-battery, which was constructed by a team of experts, representing all members of the Council of Europe, is based on the work of Simons *et al.* (1969, 1978). In this Eurofit-battery (Simons and Renson, 1982; CDS, 1988), six domains in motor fitness and cardio-respiratory endurance are measured, namely, strength, muscular endurance, flexibility, speed, balance and cardio-respiratory endurance. In each of these domains, one or two components or factors were identified, which can be evaluated by means of a test.

The strength domain contains the factor *static strength*, which measures maximum isometric muscular strength (no movement in the articulations) during a short effort against an external resistance. The 'hand grip' test measures this factor. In executing this test, a handgrip dynamometer is squeezed as forcefully as possible while holding the dynamometer away from the body. *Explosive strength* is also a maximum muscular strength test, executed against one's own body weight. In this case, movement in the articulations is obvious. 'Standing broad jump' is the most appropriate test for measuring this factor. In this test, one jumps as far as possible without a run-up, while the feet stay together.

The domain of muscular endurance is also divided into two components. Muscular endurance of the upper limbs on the one hand, is called *functional strength*. This component measures the capability to sustain a long effort against one's own body weight or a part of it, by executing as many repetitions as possible within a limited time, or by executing a maximum effort without time pressure. For this factor, the 'bent arm hang' is introduced. The subject hangs, as long as possible, with flexed arms on a horizontal bar, the eyes above the bar. On the other hand, the muscular endurance of the trunk is called *trunk strength*. The capability to sustain a lasting effort, with regard to the trunk muscles, is being measured. The test which measures this factor is called 'sit up'. The subject tries to alternate, as quickly as possible, a sitting position with a lying down position for 30 s. The legs are flexed and fixed by an assistant while the subject holds his arms behind his neck.

For *flexibility*, one factor is identified which measures articulo-muscular movement range. 'Sit and reach' is an appropriate test to measure this dimension. The subject reaches forward, as far as possible, from a seated position, the feet placed against a table and the legs extended.

Speed is divided into two components, namely, *speed of limb movement* and *running speed*. Speed of limb movement measures the capability to move the upper or lower limbs as fast as possible in simple movement gestures. In the test 'plate tapping', the subject has to tap alternately two plates, as fast as possible, with the preferred hand. The plates have a diameter of 20 cm, are 60 cm apart and are placed on a table. Running speed measures the capacity to move, as fast as possible, over a short distance. This component is measured by 'shuttle run 50 m', whereby the subject has to run five times over a distance of 5 m as fast as possible.

For the domain balance, one factor is identified which measures *total body balance*. The test that goes along with this factor is called 'flamingo balance'. The number of attempts to keep in balance for 60 s is counted. In the starting position, the subject stands on the preferred foot on the long axis of a beam of set dimensions, while holding the back of the free foot with the hand on the same side.

Tests for the measurement of cardio-respiratory endurance

For the domain of *cardio-respiratory endurance*, two test procedures were chosen for the EUROFIT test battery (Anon., 1982; CDS, 1988). One test procedure is more adapted for survey and project use, although, given the proper instruments, this test can also be performed in the field. Therefore, a submaximal effort test (the subject does not continue till exhaustion) on the bicycle ergometer is chosen. The subject cycles continuously on a bicycle ergometer, for a total of 9 min, during which time the workload is increased twice. The initial load is normally set at 1 W kg^{-1} body weight and then increased after the third and sixth minute, according to the heart rate response of the subject. In laboratory conditions, and if the proper equipment is available, the exhaled air is analysed. The oxygen consumption and CO_2 production give an idea of how well the cardio-respiratory apparatus adapts to effort.

Another type of effort test is the field test, which is proposed by the European Commission of Experts. It concerns an endurance shuttle run test, which begins at walking pace and ends running fast, whereby the subjects move from one line to another 20 m away, reversing direction, and in accordance with a pace dictated by a sound signal, which gets progressively faster.

Although it can be argued that the evaluation of fine motor skills has to be included in kinanthropometric research, this happens only rarely. This subject is not considered herein and the reader is referred to the works of Fleishman (1964), Kiphard (1972), Sloan (1954) and Wiegersma (1980) among others. Also, for the manifold tests, which were designed for the evaluation of specific sport skills, standard works, mentioned at the beginning of this paragraph should be consulted.

Measurement instruments for the evaluation of daily physical activity

The physiological problem is essentially simple, and valid methods for the measurement of oxygen consumption, and hence energy expenditure, have been in use since the introduction of the Douglas bags in the early years of the century. Nevertheless, one struggles with the problem that measurement techniques must be found which do not disturb daily physical activity. Besides, these techniques have to be applicable in large surveys, where energy consumption has not only to be followed during at least 24 h, but also over days, weeks or even a year. Weiner and Lourie (1969) mentioned a few techniques which can be used, varying from simple questionnaires to direct measurements of energy consumption. The questionnaire technique requires that the subject fill in a questionnaire or someone interviews the subject about his/her physical activities. A more precise method, requires the subject to keep a diary of his/her activities. This method calls for good cooperation from the subject and a certain level of education. Another possibility is the study of the intensity of activities by means of the registration of the heart rate. It would be more appropriate to link the registration of the heart rate to the observation of the activities that were carried out by the subjects. Also a pedometer, a counter of steps, an accelerometer, or an actometer, used at the same time as the registration of the heart rate can give useful information (Verschuur, 1980). When weight is constant, and assuming that energy expenditure is equal to energy intake, one can also record the food intake to get an estimate of the energy consumption. Finally, there is the possibility of the measurement of oxygen uptake in field situations or even in simulated situations specific for a number of activities. With this technique, the expired air is collected, for instance in a 'Douglas bag', and it is analysed after the effort. More recently, efforts are being made to use telemetric techniques to record several parameters, including oxygen consumption. Perhaps the most promising field technique, especially in children, is the use of stable isotopes. It may bridge the gap between the very accurate but very restrictive methods like the respiration chamber technique and the commonly used field techniques (Saris, 1986).

Some examples of kinanthropometric research

It should now be clear that kinanthropometric measurement techniques can be used for different purposes such as the study of the normal growth and development process, the influence of training on physical characteristics and the study of physical differences between sport participants. It is not at all the intention to give here an overview at length of the diverse studies in kinanthropometry. Only a number of research projects will be outlined to demonstrate the different directions that studies have taken.

Since the well-known growth studies of the Belgian mathematician and astronomer Adolphe Quetelet (1796–1874), many growth studies have been conducted in Belgium. In the same tradition, physical fitness studies were conducted with the aim of making up a 'status quaestiones' of the physical performance capacity of Belgian youth. Reference values were drawn up for children from 6 to 13 years by Hebbelinck and Borms (1975), for boys from 12 to 20 years by Ostyn *et al.* (1980) and for girls 6–18 by Simons *et al.* (1989). Partly under the impulse of research conducted by Kemper *et al.* (1974), Bovend'eerdt *et al.* (1980) derived reference values for the Netherlands for 12–18-year-olds and Leijten *et al.* (1982) for 9–11-year-olds. These research teams also conducted longitudinal studies to investigate individual growth and development of physical performance capacity (see Beunen *et al.*, 1988; Hebbelinck *et al.*, 1980; Kemper and Van t'Hof, 1977; Simons *et al.*, 1970–1971).

Proceedings from four symposia on kinanthropometry (Quebec, Canada 1976; Leuven, Belgium 1978; Eugene, USA 1984; Glasgow, Great Britain 1986) (Landry and Orban, 1978; Ostyn, Beunen and Simons, 1980; Day, 1986; Reilly *et al.*, 1986) show also the diversity of research subjects. Bouchard *et al.* (1980) came to the conclusion that growth in skeletal width or skeletal length, irrespective of position in the body, is being controlled by the same genes. The relation between somatic measurements of the participants of the Olympic Games in Mexico 1968 was discussed by Carter (1978). At the same time, reference values were given for the somatic measurements of the 1265 athletes who were studied.

Pauwels (1978) showed in a study on 12–19-year-old boys that the speed of a handball throw by 13–15-year-olds is explained to the extent of 64–70% by somatic and motor components, while for 16- and 17-year-old boys this is reduced to 35–50%. This difference was attributed to the better movement co-ordination in older age groups.

From a series of studies, Rarick (1980) concluded that components in motor characteristics are similar in girls and boys, whether they have normal intellect or are mentally handicapped. Further evidence indicates that motor performance obviously differs in relation to age, sex and intellectual capabilities. Rarick concluded that these findings have an important implication for physical education programmes.

Renson *et al.* (1980) reached the conclusion that a series of sociocultural factors, such as the socio-professional status of the father, the degree of urbanization of the village, family size, ethnic group and sport participation, are related to somatic dimensions as well as motor abilities, even when somatic differences are taken into account.

The search for new and better measurement techniques to study the aforementioned domains goes on. Sheffer and Herron (1978), for example, determined on the basis of stereophotograms, taken with two stereometric cameras, the body volume and the distribution of the volume over the total body. Stepnicka (1986) summarized his 20 years research findings concerning the relationships between somatotype, physical performance, sports and body posture. Relying on large samples of top athletes, university students, children, adolescents and young athletes, he came to the conclusion that somatotype is a morphological predisposition of motor and sport efficiency, as well as body posture.

Martin *et al.* (1986) demonstrated on the basis of the 25 dissections of the Brussels Cadaver Study that a standard deviation of 0.02 g ml^{-1} for the fat free density seems probable. Thus the constancy of the fat free mass can no longer be assumed.

The use of medical imaging techniques was nicely demonstrated in a review paper by Maughan (1986) about muscle structure and strength in the human. He concluded that magnetic resonance imaging techniques will result in further revisions of accepted anthropometric techniques.

Based on the findings of the existing literature and maturity characteristics in elite young athletes, Malina (1986) demonstrated that the rate of biological maturation may be of significance in youth sport, perhaps in providing early competitive advantages in some sports. Furthermore, it is difficult to implicate the stress of training and competition as an initial influence on biological maturation. Hypotheses concerning the effect of training on young female athletes need to consider other factors that are known to influence circulating gonadotrophic and gonadal hormone levels. Moreover, the stress of training and competition in young successful male athletes also needs to be considered. Both anthropometric and training factors may also influence positional roles in a team. Soares *et al.* (1986) provided evidence for an association between the physical fitness of Brazilian national basketball players and their function in the game.

These and other examples give ample evidence of the importance of appropriate and adequate measuring techniques and of the impact of these techniques in designing adequate research projects to test a variety of hypotheses. Notwithstanding its long tradition, albeit under a different name, kinanthropometry is still moving and striving for more appropriate and better measurement techniques.

Annotated bibliography

Journals

The International Society for the Advancement of Kinanthropometry, founded in Glasgow in 1986, is now officially affiliated with the *Journal of Sports Sciences*. Very often, kinanthropometric studies are published in scientific journals in the domain of sport, exercise, physical education, recreation and dance. A number of studies are also published in specialist journals of human biology or physical anthropology. For the moment, the ones of most interest are *American Journal of Physical Anthropology*, *Annals of Human Biology*, *Human Biology* and *American Journal of Human Biology*.

Monographs, readers and reviews

A few monographs, readers and introductory reviews were mentioned in the article and are consequently referred to in the reference list. For works dealing with measurement techniques and standard works we refer to:

Barrow, H.M. and McGee, R. (1972) *A Practical Approach to Measurement in Physical Education*. Philadelphia: Lea & Febiger.

Carter, J.E.L. (Ed.) (1982) *Physical Structure of Olympic Athletes. Part I. The Montreal Olympic Games Anthropological Project* (Medicine and Sport 16). Basel: Karger.

Larson, L.A. (Ed.) (1974) *Fitness, Health and Work Capacity. International standards for assessment*. New York: MacMillan.

Safrit, M.J. (1973) *Evaluation in Physical Education*. Englewood Cliffs: Prentice-Hall.

Weiner, J.S. and Lourie, J.A. (Eds) (1981) *Practical human biology*. London: Academic Press.

References

Anon. (1982) *4th European Research Seminar on Testing Physical Fitness – Cardio-respiratory Aspects*. Strasbourg, Committee for the Development of Sport of the Council of Europe.

Barrow, H.M. and McGee, R. (1972) *A Practical Approach to Measurement in Physical Education*. Philadelphia: Lea & Febiger.

Behnke, A.R. (1961) Anthropometric fractionation of body weight. *Journal of Applied Physiology* **1**, 949–54.

Beunen, G., Malina, R.M., Van t'Hof, M.A., Simons, J., Ostyn, M., Renson, R. and Van Gerven, D. (1988) Adolescent Growth and Motive Performance: a Longitudinal Study of Belgian Boys. (HKP Sport Science Monograph Series 1.) Champaign, Ill.: Human Kinetics.

Bookstein, F.L. (1986) Biological shape change as a latent variable. In *Human Growth: a Multidisciplinary Review* (edited by A. Demirjian and M. Brault Dubuc), London: Taylor & Francis.

Borms, J., Hebbelinck, M., Carter, J.E.L., Ross, W.D. and Lariviere, G. (1979) Standardization of basic anthropometry in Olympic athletes – The MOGAP procedure. In *Methods of Functional Anthropology* (edited by V.N. Novotny and S. Titlbachova), Praha: University Carolina Pragensis.

Bouchard, C., Demirjian, A. and Malina, R.M. (1980) Genetic pleiotropism in skeletal lengths and breadths. In *Kinanthropometry II* (International Series on Sport Sciences 9) (edited by M. Ostyn, G. Beunen and J. Simons), Baltimore: University Park Press.

Bovend'eerdt, J., Kemper, H. and Verschuur, R. (1980) *De MOPER fitness test. Handleiding en prestatieschalen*. Haarlem: De Vriesebosch.

Boyd, E. (1980) *Origins of the Study of Human Growth*. sl: University of Oregon Health Sciences Center Foundation.

Brozek, J. (1960) The measurement of body composition. In *A Handbook of Anthropometry* (edited by M.F.A. Montagu), Springfield: C.C. Thomas.

Carter, J.E.L. (1975) *The Heath-Carter Somatotype-Method*. San Diego: San Diego State University.

Carter, J.E.L. (1978) Anthropometric profiles of Olympic athletes at Mexico City. In *Biomechanics of Sports and Kinanthropometry* (edited by F. Landry and W.A.R. Orban), Miami: Symposia Specialists.

Carter, J.E.L. (Ed.) (1982) *Physical Structure of Olympic Athletes. Part I. The Montreal Olympic Games Anthropological Project* (Medicine and Sport 16). Basel: Karger.

Clarke, H.H. (1967) *Application of Measurement to Health and Physical Education*. Englewood Cliffs: Prentice Hall.

Crampton, C.W. (1908) Physiological age, a fundamental principle. *American Education Review* **13**, 3–6.

Cureton, T.K. (1947) *Physical Fitness Appraisal and Guidance*. St. Louis: Mosby.

Day, J.A.P. (Ed.) (1986) Perspectives in Kinanthropometry. Champaign, Ill.: Human Kinetics.

De Nayer, P.P. (1956) *Handleiding bij de Cursus in Biometrie*. Leuven: Le Moniteur.

Demirjian, A. (1978) Dentition. In *Human Growth. 2. Postnatal Growth* (edited by F. Falkner and J.M. Tanner), New York: Plenum.

Fleishman, E.A. (1964) *The Structure and Measurement of Physical Fitness*. Englewood Cliffs: Prentice Hall.

Greulich, W.W. and Pyle S.I. (1950) *Radiographic Atlas of Skeletal Development of the Hand and Wrist*. Stanford: Stanford University Press.

Goldstein, H. and Johnston, F.E. (1978) A method for studying shape change in children. *Annals of Human Biology* **5**, 33–9.

Heath, B.H. and Carter, J.E.L. (1967) A modified somatotype method. *American Journal of Physical Anthropology* **27**, 57–64.

Hebbelinck, M. and Borms, J. (1975) *Biometrische studie van een reeks lichaamsbouwkenmerken en lichamelijke prestatietests van Belgische kinderen uit het lager onderwijs*. Brussel: Centrum voor Bevolkings- en Gezinsstudiën, Ministerie van Volksgezondheid en van het Gezin.

Hebbelinck, M., Blommaert, M., Borms, J., Duquet, W., Vajda, A. and Vandermeer, J. (1980) A multidisciplinary longitudinal growth study: introduction of the project 'LLEGS'. In *Kinanthropometry II* (International Series on Sport Sciences 9) (edited by M. Ostyn, G. Beunen and J. Simons), Baltimore: University Park Press.

Hebbelinck, M. and Ross, W.D. (1974) Kinanthropometry and biomechanics. In *Biomechanics IV* (International Series on Sport Sciences 1) (edited by R. Nelson and C.A. Morehouse), Baltimore: University Park Press.

Kemper, H.C.G. and Verschuur, R. (1977) MOPER Fitness Test. *De lichamelijke Opvoeding* 65 (16).

Kemper, H.C.G., Ros, K., Snel, J., Splinter, P., Tavecchio, L. and Verschuur, R. (1974) *Invloed van extra lichamelijke oefening*. Amsterdam: Posthuma en Snabel.

Kemper, H.C.G. and Van 't Hof, M.A. (1977) Project groei en gezondheid van tieners. *Tijdschrift Sociale Geneeskunde* **55**, 445–51.

Kiphard, E.J. (1972) *Bewegungsdiagnostik bei Kindern*. Gutersloh: Flöttmann.

Landry, F. and Orban, W.A.R. (1978) *Biomechanics of Sports and Kinanthropometry*. Miami: Symposia Specialists.

Larson, L.A. (Ed.) (1974) *Fitness, Health and Work Capacity. International standards for assessment*. New York: MacMillan.

Larson, L.A. and Yocum, R.D. (1951) *Measurement and Evaluation in Physical, Health, and Recreation Education*. St. Louis: Mosby.

Ledent, R. and Wellens, L. (1922) *Précis de Biomètrie*. Liège: Vaillant-Carmanne.

Leyten, C., Kemper, H. and Verschuur, R. (1982) *De MOPER fitheidstest. Handleiding en prestatieschalen 9-t/m 11-jarigen*. Haarlem: De Vriesebosch.

Lohman, T.G. (1989) Assessment of body composition in childen. *Pediatric Exercise Science* **1**, 19–30.

Lohman, T.G., Roche, A.F. and Martorell, R. (Eds) (1988) *Anthropometric Standardization Reference Manual*. Champaign, Ill.: Human Kinetics.

McCloy, C.H. (1936) *Appraising Physical Status. The Selection of Measurements*. University of Iowa Studies in Child Welfare 12 (2).

Malina, R.M. (1978) Adolescent growth and maturation: selected aspects of current research. *Yearbook of Physical Anthropology* **21**, 63–94.

Malina, R.M. (1984) Kinanthropometric research in human auxology. In *Human Growth and Development* (edited by J. Borms, R. Hauspie, A. Sand, C. Suzanne and M. Hebbelinck), New York: Plenum Press.

Malina, R.M. (1986) Maturatural considerations in elite young athletes. In *Perspectives in Kinanthropometry* (edited by J.A.P. Day), pp. 29–43. Champaign, Ill.: Human Kinetics.

Martin, R. (1914) *Lehrbuch der Anthropology*. Jena: Fisher.

Martin, R. and Saller, K. (1957) *Lehrbuch der Anthropologie*. Stuttgart: Fisher.

Martin, A.D., Drinkwater, D.T., Clarys, J.P. and Ross, W.D. (1986) The inconstancy of the fat-free mass: a reappraisal with implications for densitometry. In *Kinanthropometry III* (edited by T. Reilly, J. Watkins and J. Borms), pp. 92–7. London: E. & F.N. Spon.

Matthews, D.K. (1968) *Measurement in Physical Education*. Philadelphia: Saunders.

Matiègka, J. (1921) The testing of physical efficiency. *American Journal of Physical Anthropology* **4**, 223–30.

Maughan, R.J. (1986) Muscle structure and strength in man. In *Kinanthropometry III* (edited by T. Reilly, J. Watkins and J. Borms), pp. 267–79. London: E. & F.N. Spon.

Ostyn, M., Beunen, G. and Simons, J. (Eds) (1980) *Kinanthropometry II* (International Series on Sport Sciences 9), Baltimore: University Park Press.

Ostyn, M., Simons, J., Beunen, G., Renson, R. and Van Gerven, D. (1980) *Somatic and Motor Development of Belgian Secondary School-boys. Norms and standards.* Leuven: Leuven University Press.

Parlebas, P. (1981) *Contribution à un Lexique Commenté en Science de l'Activité Motrice.* Paris: Publications INSEP.

Parnell, R.W. (1958) *Behaviour and Physique.* London: Arnold.

Pauwels, J. (1978) The relationship between somatic development and motor ability, and throwing velocity in handball for secondary school students. In *Biomechanics of Sport and Kinanthropometry* (edited by F. Landry and W.A.R. Orban), Miami: Symposia Specialists.

Rarick, G.L. (1980) The factor structure of the motor domain of mentally retarded children and adolescents. In *Kinanthropometry II* (International Series on Sport Sciences 9) (edited by M. Ostyn, G. Beunen and J. Simons), Baltimore: University Park Press.

Reilly, T. Watkins, J. and Borms, J. (Eds) (1986) *Kinanthropometry III.* London: E. & F.N. Spon.

Renson, R., Beunen, G., De Witte, L., Ostyn, M., Simons, J. and Van Gerven, D. (1980) The social spectrum of the physical fitness of 12–19-year-old boys. In *Kinanthropometry II* (International Series on Sport Sciences 9) (edited by M. Ostyn, G. Beunen and J. Simons), Baltimore: University Park Press.

Roche, A.F. (1978) Bone growth and maturation. In *Human Growth. 2. Postnatal Growth* (edited by F. Falkner and J.M. Tanner), New York: Plenum.

Roche, A.F., Chumlea, W.C. and Thissen, D. (1988) Assessing the skeletal maturity of the hand and wrist: Fels method. Springfield: C.C. Thomas.

Roche, A.F., Wainer, H. and Thissen, D. (1975) *Skeletal Maturity. The Knee Joint as a Biological Indicator.* New York: Plenum.

Ross, W.D. (1978) Kinanthropometry: An emerging scientific technology. In *Biomechanics of Sport and Kinanthropometry* (edited by F. Landry and W.A.R. Orban), Miami: Symposia Specialists.

Ross, W.D. and Borms, J. (1980) Kinantropometrie, wetenschappelijke interface van menselijke structuur en functie. *Geneeskunde en Sport* **13**, 34–6.

Ross, W.D., Hebbelinck, M., Van Gheluwe, B. and Lemmens, M.L. (1972) Kinanthropométrie et l'appréciation de l'erreur de mesure. *Kinanthropologie* **4**, 23–34.

Ross, W.D. and Wilson, N.C. (1974) A stratagem for proportional growth assessment. In *Children and Exercise, Acta Paediatrica Belgica* (edited by J. Borms and M. Hebbelinck), **28**, 169–82.

Safrit, M.J. (1973) *Evaluation in Physical Education.* Englewood Cliffs: Prentice Hall.

Sargent, D.A. (1921) The physical test of a man. *American Physical Education Review* **26**, 188–94.

Saris, W.H.M. (1986) Habitual physical activity in children: methodology and findings in health and disease. *Medicine and Science in Sports and Exercise* **15**, 253–63.

Sheffer, D.B. and Herron, R.E. (1978) Body volume distribution using biostereometrics. In *Biomechanics of Sports and Kinanthropometry* (edited by F. Landry and W.A.R. Orban), Miami: Symposia Specialists.

Sheldon, W.H., Dupertuis, C.W. and McDermott, E. (1954) *Atlas of Man.* New York: Harper.

Sheldon, W.H., Lewis, N.D.C. and Tenney, A.M. (1969) Psychotic patterns and physical constitution. In *Schizophrenia, Current Concepts and Research* (edited by D.V. Siva Sankar), Hicksville: PJD Publications.

Sheldon, W.H., Stevens, S.S. and Tucker, W.B. (1970) *The Varieties of Human Physique.* Darien: Hafner.

Simons, J. and Renson, R. (1982) Evalution of Motor Fitness. Leuven: Institute of P.E., K.U. Leuven.

Simons, J., Beunen, G. and Renson, R. (1970–1971) De Leuvense groeistudie over physical fitness. Werken Belgische Geneeskundige Vereniging Lichamelijke Opvoeding en Sport **22**, 45–52.

Simons, J., Beunen, G., Renson, R., Claessens, A., van Reusel, B. and Lefevre, J. (1989) Growth and Fitness of Flemish Girls. HKP Sports Science Monograph Series. Champaign, Ill.: Human Kinetics.

Simons, J., Beunen, G., Ostyn, M., Renson, R., Swalus, P., Van Gerven, D. and Willems, E. (1969) Construction d'une battérie de tests d'aptitude motrice pour garçons de 12 à 19 ans, par la méthode de l'analyse factorielle. *Kinanthropologie* **1**, 233–362.
Simons, J., Ostyn, M., Beunen, G., Renson, R. and Van Gerven, D. (1978) Factor analytic study of the motor ability of Belgian girls age 12 to 19. In *Biomechanics of Sports and Kinanthropometry* (edited by F. Landry and W.A.R. Orban), Miami: Symposia Specialists.
Sloan, W. (1954) *Manual for Lincoln Oseretsky Motor Development Scale*. Chicago: Stoelting.
Soares, J., De Castro Mendes, O., Neto, C.B. and Matsudo, V.K.R. (1986) Player fitness characteristics of Brazilian national basketball team as related to game functions. In *Perspectives in Kinanthropometry* (edited by J.A.P. Day), pp. 127–33. Champaign, Ill.: Human Kinetics.
Stepnicka, J. (1986) Somatotype in relation to physical performance, sport and body posture. In *Kinanthropometry III* (edited by T. Reilly, J. Watkins and J. Borms), pp. 39–52. London: E. & F.N. Spon.
Tanner, J.M. (1962) *Growth at Adolescence*. Oxford: Blackwell.
Tanner, J.M. (1964) Human Growth and constitution. In *Human Biology* (edited by G.A. Harrison, J.S. Weiner, J.M. Tanner and N.A. Barnicot), Oxford: Clarendon.
Tanner, J.M. (1981) *A History of the Study of Human Growth*. Cambridge: University Press.
Tanner, J.M., Whitehouse, R.H., Marshall, W.A., Healy, M.J.R. and Goldstein, H. (1975) *Assessment of Skeletal Maturity and Prediction of Adult Height*. London: Academic Press.
Thompson, D.A.W. (1917) *On Growth and Form*. Cambridge: Cambridge University Press.
Todd, T.W. (1937) *Atlas of Skeletal Maturation* (part 1). London: Kimpton.
Vandervael, F. (1943) *Biométrie Humaine*. Liège: Desoer.
Verschuur, R. (1980) Methoden ter bepaling van de dagelijkse lichamelijke activiteit. *Geneeskunde en Sport* **13**, 13–19.
Weiner, J.S. and Lourie, J.A. (1969) *Human Biology. A Guide to Field Methods*. Philadelphia: Davis.
Weiner, J.S. and Lourie, J.A. (1981) *Practical Human Biology*. New York: Academic Press.
Wiegersma, P.H. (1980) *Motorische Diagnostiek*. Lisse: Swets en Zeitlinger.