Journal of Sports Sciences
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rjsp20

Muscle mass of competitive male athletes

Linda F. Spenst [a], Alan D. Martin [b] & Donald T. Drinkwater [c]
[a] School of Kinesiology, Simon Fraser University, Burnaby, BC, VSA 1S6, Canada
[b] School of Physical Education, University of British Columbia, 6081 University Boulevard, Vancouver, BC, V6T 1Z1, Canada
[c] College of Physical Education, University of Saskatchewan, Saskatoon, Saskatchewan, S7N 0W0, Canada
Published online: 14 Nov 2007.

To cite this article: Linda F. Spenst, Alan D. Martin & Donald T. Drinkwater (1993) Muscle mass of competitive male athletes, Journal of Sports Sciences, 11:1, 3-8, DOI: 10.1080/02640419308729956

To link to this article: http://dx.doi.org/10.1080/02640419308729956

Journal of Sports Sciences, 1993, **11**, 3–8

Muscle mass of competitive male athletes

LINDA F. SPENST,[1] ALAN D. MARTIN[2]* and DONALD T. DRINKWATER[3]

[1]*School of Kinesiology, Simon Fraser University, Burnaby, BC V5A 1S6,* [2]*School of Physical Education, University of British Columbia, 6081 University Boulevard, Vancouver, BC V6T 1Z1* and [3]*College of Physical Education, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, Canada*

Accepted 15 November 1991

The recent publication of the first validated equation for the estimation of muscle mass (MM) in men has made possible a comparison of MM in athletes from different sports. Limb girths and skinfold thicknesses were measured in 62 male athletes (aged 17–38 years) and 13 non-athletic males (aged 22–36 years). The MM (g) was calculated from the equation $MM = S(0.0553\ G_t^2 + 0.0987\ G_f^2 + 0.0331\ G_c^2) - 2445$, where S is stature, G_t is the mid-thigh girth corrected for the front thigh skinfold thickness, G_c is the maximum calf girth corrected for the calf skinfold thickness and G_f is the uncorrected maximum forearm girth (all in cm). The athletes were classified as gymnasts ($n = 10$), basketball players ($n = 10$), body-builders ($n = 10$), track and field power athletes ($n = 12$), track and field long sprinters ($n = 10$) or distance runners ($n = 10$). The MM means ranged from 38.4 kg for the distance runners to 58.7 kg for the body-builders. Both body-builders and basketball players had significantly greater MM than gymnasts, long sprinters, non-athletic males and distance runners ($P < 0.01$). Also, MM was greater in track and field power athletes than in distance runners ($P < 0.05$). The MM as a percentage of body mass (%MM) ranged from 56.5% in the non-athletic group to 65.1% in the body-builders; body-builders scored higher than basketball players ($P < 0.05$), distance runners ($P < 0.01$) and the non-athletic group ($P < 0.01$). The non-athletic men had a lower %MM than basketball players ($P < 0.05$), long sprinters ($P < 0.05$) and power athletes ($P < 0.01$). Controlling for body mass by analysis of covariance altered the ranking of the group means such that the long sprinters had the greatest adjusted muscle mass, followed by the body-builders and power athletes, with the non-athletes showing the least. Statistically significant differences remained only between the adjusted means for the non-athletes and all the other groups: basketball players ($P < 0.01$), gymnasts ($P < 0.001$), distance runners ($P < 0.05$), power athletes ($P < 0.0001$), body-builders ($P < 0.0001$) and long sprinters ($P < 0.0005$). These muscularity rankings in the male athletes make biological sense given the body types and functional demands of the various sports. The equation applied here appears to provide the best estimate of skeletal muscle mass to date, in that (1) it is the only cadaver-validated equation, (2) it gives values that are consistent with all known dissection data and (3) it gives appropriate results when applied to young men with a wide range of muscularity.

Keywords: Muscle mass, sport, body composition, anthropometry, men.

Introduction

Since athletes in different sports often show greater variability in muscle mass than in fat mass, the ability to assess muscle mass (MM) using anthropometry can provide a quick, inexpensive, simple and non-invasive strategy for the selection, training and monitoring of athletes. Various approaches to the assessment of muscularity in athletes have been used. The mesomorphy component of the Heath-Carter somatotype classification system is size-independent (Carter, 1980), and therefore will not reflect absolute changes in muscularity, unless these are associated with shape changes. A further disadvantage is that skeletal measures are also included in the mesomorphy component. In the densitometric approach, the fat-free mass includes bone and organs as well as muscle. Skinfold-corrected girths may provide a purer measure of muscularity (Heymsfield *et al.*, 1982; Jelliffe and Jelliffe, 1979; Jelliffe and Jelliffe, 1969), but assumptions must be made to convert this linear measure to a mass. However, all these approaches suffer from the same

* To whom all correspondence should be addressed.

problem – lack of validation. We have recently reported the first cadaver-validated anthropometric equation for the estimation of MM in men (Martin *et al.*, 1990). Here we apply this equation to 13 male non-athletes and to 62 male athletes competing in six different sporting activities. Our aims were (1) to determine if there were significant group differences in MM both in absolute terms and when expressed as a percentage of body mass (%MM), (2) to assess whether estimated MM was consistent with subjective observations of the performance requirements of each group and (3) to compare estimated MM with cadaver data.

Methods

A total of 62 male athletes (aged 17–38 years) and 13 non-athletic males (aged 22–36 years) volunteered for the study and were categorized by sport:

- The basketball players ($n=10$) were those subjects who were members of the University of Saskatchewan basketball team.
- The body-builders ($n=10$) were members of the Saskatchewan Body-Building Association who had competed in the 6 months prior to the study.
- The track and field power athletes ($n=12$) were those subjects who competed in either jumping or sprinting events up to 200 m. Decathletes were also included in this category.
- The track and field long sprinters ($n=10$) competed in sprints ranging in distance from 300 to 800 m.
- The track and field distance runners ($n=10$) competed at distances of 1500 m or longer.
- The non-athletic men ($n=13$) participated in vigorous physical activity no more than twice a week.

The following anthropometric measurements were carried out by the same person on all subjects: stature and body mass; skinfold thicknesses at the triceps, subscapular, biceps, front thigh and medial calf; girths of the arm (midway between acromiale and radiale), forearm (at maximum girth), thigh and calf (at the maximum girth). The location and technique of these measurements are conventional (Ross and Marfell-Jones, 1991), except for the mid-thigh girth which was taken at the midpoint of a vertical line from the midpoint of the patella to the intersection with the inguinal fold. Measurements were made in triplicate and the median used.

Use of the MM estimation equation

Muscle girths were estimated by correcting limb girths for the appropriate skinfold thicknesses using a circular model of the limb cross-section and assuming that the adipose tissue thickness was half the skinfold thickness. The corrected girth was obtained by subtracting π times the skinfold thickness from the limb girth (Jelliffe and Jelliffe, 1969). The MM (g) was then calculated from the anthropometric measurements according to the equation:

$$MM = S(0.0553\ G_t^2 + 0.0987\ G_f^2 + 0.0331\ G_c^2) - 2445$$

where S is stature, G_t is the mid-thigh girth corrected for the front thigh skinfold thickness, G_f is the uncorrected maximum forearm girth and G_c is the maximum calf girth corrected for the calf skinfold thickness (Martin *et al.*, 1990), with all measurements in cm. Based on anthropometric and dissection data from 12 male cadavers (Clarys *et al.*, 1984), this equation explained 97% of the variation in dissected muscle mass with a coefficient of variation of 5.9%. Since regression equations are normally quite sample-specific, external validity of this equation was improved by (1) using more variables than would result from the optimal regression analysis and (2) forcing dimensional consistency (Yates, 1978).

Results

Reliability of the anthropometry was assessed by calculating the technical error of measurement (Mueller and Martorell, 1988). Expressed as a percentage of the median values, this was 0.11% for stature, 0.4% for the girths and 3.2% for the skinfolds. These values are well within the recommended limits of 1% for girths and 5% for skinfold thicknesses (Ross and Marfell-Jones, 1991).

For the seven groups of men, MM ranged from 38.4 kg for the distance runners to 58.7 kg for the body-builders. Muscle mass expressed as a percentage of body mass (%MM) ranged from 56.5% in the non-athletic group to 65.1% in the body-builders (Table 1). Analysis of variance (ANOVA) and Scheffé's statistic revealed significant differences between the groups. Both body-builders and basketball players had greater MM than gymnasts ($P<0.001$), long sprinters ($P<0.001$), non-athletic males ($P<0.0005$) and distance runners ($P<0.0001$). Also, MM was greater among track and field power athletes than among distance runners ($P<0.05$). The three groups with the most muscle – the body-builders, basketball players and power athletes – were not significantly different from each other; neither were the four groups with the least muscle – the gymnasts, long sprinters, non-athletes and distance runners. Comparing %MM, body-builders scored higher than gymnasts ($P<0.01$), distance runners ($P<0.001$) and the non-athletic group ($P<0.0001$).

Table 1 Mean (±S.D.) anthropometric data and estimated muscle mass for 75 young men

Group	n	Age (years)	Height (cm)	Body mass (kg)	Sum of nine skinfolds (mm)	G_a (cm)	G_f (cm)	G_t (cm)	G_c (cm)	MM (kg)	%MM
Basketball players	10	21.4 (±0.7)	192.5 (±8.7)	89.8 (±12.5)	79.1 (±28.0)	29.6 (±1.8)	29.1 (±1.6)	54.7 (±3.2)	37.3 (±1.8)	54.7 (±8.0)	60.9 (±2.5)
Body-builders	10	24.6 (±1.6)	176.7 (±8.1)	89.9 (±12.3)	62.3 (±7.7)	37.7 (±2.7)	32.4 (±1.7)	58.9 (±4.3)	38.1 (±2.7)	58.7 (±9.6)	65.1 (±2.0)
Gymnasts	10	24.1 (±2.1)	172.4 (±7.8)	68.1 (±8.6)	51.9 (±13.0)	29.9 (±1.5)	27.4 (±1.1)	49.7 (±2.8)	33.8 (±2.6)	40.7 (±6.8)	59.5 (±2.9)
Track and field power athletes	12	24.9 (±0.6)	180.9 (±6.2)	78.6 (±5.7)	65.2 (±17.6)	28.8 (±1.7)	28.0 (±1.2)	54.3 (±2.3)	37.1 (±2.2)	49.3 (±4.9)	62.7 (±3.3)
Track and field long sprinters	10	23.2 (±1.1)	176.4 (±3.1)	65.4 (±4.5)	48.2 (±7.0)	26.3 (±2.1)	25.9 (±1.1)	49.6 (±2.7)	34.7 (±2.2)	40.4 (±4.2)	61.7 (±2.7)
Track and field distance runners	10	24.1 (±1.1)	174.7 (±3.1)	65.4 (±4.5)	60.6 (±7.0)	25.2 (±2.1)	25.6 (±1.1)	48.3 (±2.7)	34.4 (±2.2)	38.4 (±4.2)	58.6 (±3.2)
Non-athletes	13	26.6 (±1.9)	179.4 (±7.4)	71.4 (±10.2)	86.5 (±35.0)	25.6 (±1.6)	26.2 (±1.8)	48.5 (±3.2)	34.4 (±1.7)	40.3 (±5.8)	56.5 (±3.4)

Abbreviations: G_a, corrected arm girth; G_f, forearm girth; G_t, corrected mid-thigh girth; G_c, corrected calf girth; MM, muscle mass.

The non-athletic men had a lower %MM than the long sprinters ($P<0.05$) and power athletes ($P<0.0005$).

Inter-group comparisons based on ratios such as %MM can be misleading (Tanner, 1949); therefore, analysis of covariance (ANCOVA) with MM as the dependent variable and body mass as a covariate was carried out. This reduced the number of inter-group differences, such that with Scheffé's statistic, significant differences were observed between the non-athletes and every other group but not between any other pairs (see Fig. 3).

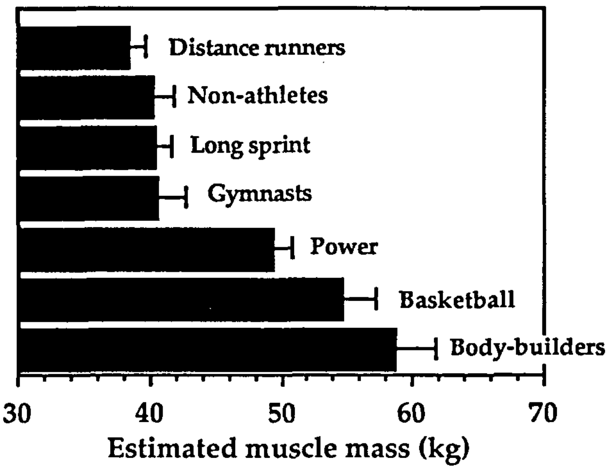

Figure 1 Mean (±S.E.) estimated muscle mass of male athletes in different sporting activities.

Discussion

There appears to be nothing unusual about the MM rankings of each activity (Fig. 1) from the perspective of visual observation of physique. In terms of a physical model, total muscle mass in the body can be viewed as a cylinder, with limb circumferences representing the circumference of the cylinder and stature its length (Matiegka, 1921). Assuming constant density of skeletal muscle, increases in MM are achieved by increasing either the circumference or the height. Body-builders would be expected to have large values of MM due to their enlarged muscle circumferences, while basketball players benefit from exaggerated stature. The track and field power athletes probably represent a combination of both situations, since this group includes jumpers who tend to be tall and sprinters who tend to have large muscle circumferences. The rankings of MM also agree with the type of movement involved in each activity. As a rule, sports that involve short bouts of intense activity against resistance are conducive to increases in muscle mass. Both body-builders and power athletes should show high MM because their training consists of dynamic, high-resistance work. Conversely, distance runners rank low in MM because they train primarily for endurance, not for lower or upper body strength; indeed, upper body musculature may hamper their performance. Although basketball involves short bursts of high-intensity movement, endurance is also necessary, as is the case in sprints of longer duration. Finally, the low muscle mass of the gymnasts (Fig. 1) is, in part, due to their having a small body mass.

The trend for %MM rankings is similar to that for MM, with the exceptions of a noticeable drop in rank for the basketball players and an increase in rank for the long sprinters (Fig. 2). These changes can probably be attributed to a larger adipose tissue weight in the basketball players and a lower relative adipose tissue weight in the long sprinters, since basketball players had

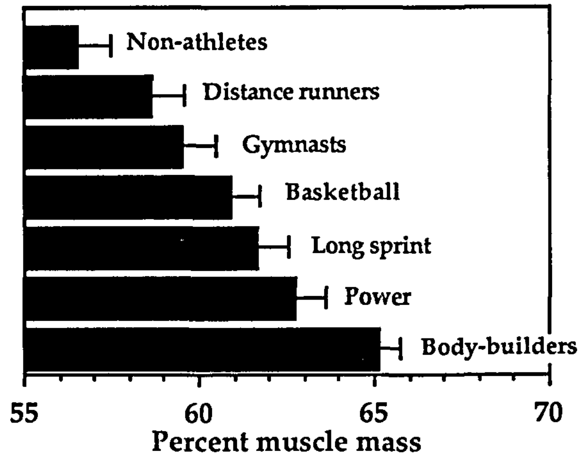

Figure 2 Mean (±S.E.) estimated muscle mass as % body mass of male athletes in different sporting activities.

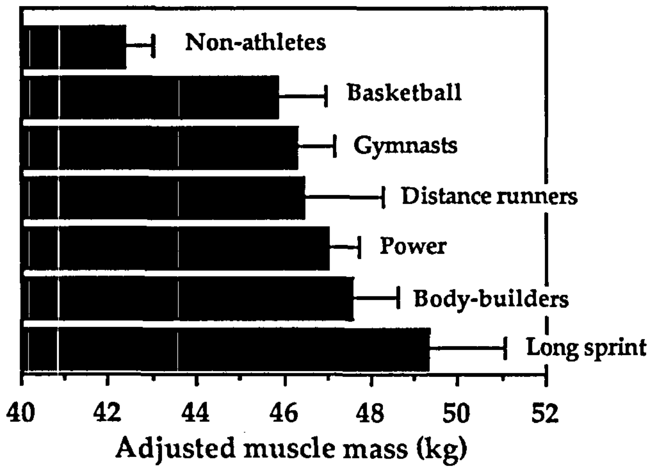

Figure 3 Mean (±S.E.) estimated muscle mass of male athletes in different sporting activities, adjusted for body mass by analysis of covariance.

the highest sum of skinfolds of all the athletes and the long sprinters had the lowest (Table 1).

The only disparate result was the low %MM ranking of the gymnasts. Both their sum of skinfolds and their muscular appearance would suggest that they should have a high percentage of muscle relative to body mass. It is possible that the absence of the corrected arm girth from the equation may have led to an underestimate in MM for this group, a situation that may also be true for the body-builders. The gymnasts in this study ranked second highest in corrected arm girth and lowest in corrected calf girth (Table 1), supporting a previous report that gymnasts ranked very high on upper extremity muscle volumes but low on the lower extremities when compared with athletes of other sports (Walt *et al.*, 1986). Although it might seem necessary for gymnasts to have a large muscle mass in the legs for the propulsive requirements of the vault and the floor routines, complete weight-bearing by the upper body in the other four events (rings, pommel, parallel bars and horizontal bar) would demand both large upper body musculature and low leg mass. Since, in the Brussels cadavers (Clarys *et al.*, 1984), about 60% of the body's skeletal muscle mass was in the lower extremities (including gluteals), any reduction in this region will have a large impact on both %MM and MM.

Interpretation of these data is clouded by the fact that the athletes in certain sports such as basketball and body-building will have greater muscle mass partly because they have greater body mass, since within any single group muscle mass increases with body mass. The effect of body mass on muscle mass was removed by ANCOVA. This altered the ranking of the group means such that the long sprinters had the greatest adjusted muscle mass (49.3 kg), followed by the body-builders (47.6 kg) and power athletes (47.0 kg) (Fig. 3). Scheffé's statistic revealed statistically significant differences only between the adjusted means for the non-athletes and all the other groups: basketball players ($P<0.01$), gymnasts ($P<0.001$), distance runners ($P<0.05$), power athletes ($P<0.0001$), body-builders ($P<0.0001$) and long sprinters ($P<0.0005$).

The foregoing has demonstrated that results obtained by the application of the MM estimation equation seem reasonable for the inter-group comparisons. While the equation gives appropriate rankings for the groups, it is impossible to know the accuracy of the MM values. For some insight into this, the estimated MM values can be compared to the known dissection data. A comprehensive search of the literature, including the European dissections of the nineteenth century, revealed muscle mass values for 25 men (Table 2). This includes the 13 male cadavers from the Brussels Cadaver Study. Dissected MM ranged from 15.8 to 40.4 kg for the 25 men. However, most of these were over 50 years of age, while the younger cadavers used for the German dissections were largely from executed prisoners whose body composition may have reflected sub-normal nutrition. The %MM values are also confounded by adiposity; in fatter subjects, such as some of the older Belgians, lower %MM may be due to a greater adipose tissue mass. It is not surprising that %MM estimated for the young athletes is greater than that of the cadavers; the athletes' low adiposity and higher muscularity will elevate these values.

Conclusion

In general, the rankings for MM and %MM in the male athletes make biological sense given the variation in the structural and functional demands of the various sports.

Table 2 Muscle mass in the adult male: Dissection data from the literature

Reference	Age (years)	Height (cm)	Body mass (kg)	Total MM (kg)	%MM
Theile (1884)	26	[a]	64.0	18.9	29.5
Bruel (cited in Welcker and Brandt, 1903)	26	184	60.3	26.6	44.1
Bruel (cited in Welcker and Brandt, 1903)	30	165	52.7	25.2	47.8
von Liebig (1874)	30	[a]	55.7	23.1	41.5
Bischoff (1863)	33	168	69.7	29.1	41.8
Mitchell *et al.* (1945)	35	183	70.6	22.3	31.6
Dursy (cited in Vierordt, 1906)	36	163	50.5	18.5	36.6
Dursy (cited in Vierordt, 1906)	42	172	62.3	30.6	49.1
von Liebig (1874)	45	[a]	76.5	32.2	42.1
Forbes *et al.* (1953)	46	168.5	53.8	21.4	39.8
Forbes *et al.* (1956)	48	169.0	62.0	26.4	42.6
Bruel (cited in Welcker and Brandt, 1903)	50	176	63.2	28.0	44.3
Clarys *et al.* (1984)	55	186.5	88.9	40.4	45.4
Clarys *et al.* (1984)	59	173.2	76.8	31.2	40.6
Forbes *et al.* (1956)	60	172.0	73.5	29.6	40.3
Clarys *et al.* (1984)	65	166.1	54.8	23.3	42.5
Clarys *et al.* (1984)	70	159.2	58.5	20.1	34.4
Clarys *et al.* (1984)	72	165.8	65.1	25.7	39.5
Clarys *et al.* (1984)	73	156.2	52.8	17.3	32.8
Clarys *et al.* (1984)	73	172.0	85.1	34.8	40.9
Clarys *et al.* (1984)	73	163.6	57.7	15.8	27.4
Clarys *et al.* (1984)	78	162.8	70.4	26.9	38.2
Clarys *et al.* (1984)	78	167.0	71.5	26.3	36.8
Clarys *et al.* (1984)	81	176.0	61.0	21.8	35.7
Clarys *et al.* (1984)	83	167.5	51.7	17.9	34.6

[a]Missing data.

The estimation equation was able to distinguish athletes in different sports. Using ANCOVA to control for body mass revealed that long sprinters, body-builders and power athletes had the greatest adjusted muscle mass, but significant differences were only observed between the non-athletes and all other groups. Despite the limitations of the cadaver sample, the cadaver-validated equation applied here appears to provide the best estimate of skeletal muscle mass to date, in that (1) it is the only cadaver-validated equation, (2) it gives values that are consistent with all known dissection data and (3) it gives appropriate results when applied to young men with a wide range of muscularity.

References

Bischoff, E. (1863). *Einige Gewichts und Trockenbestimmungen der Organe des Menschilichen Korpers*, **3**, 75–85.

Carter, J.E.L. (1980). *The Heath-Carter Somatotype Method*, 3rd edn. San Diego: San Diego State University Syllabus Service.

Clarys, J.P., Martin, A.D. and Drinkwater, D.T. (1984). Gross tissue weights in the human body by cadaver dissection. *Human Biology*, **56**, 459–473.

Forbes, R.M., Cooper, A.R. and Mitchell, H.H. (1953). The composition of the adult human body as determined by chemical analysis. *Journal of Biological Chemistry*, **203**, 359–366.

Forbes, R.M., Mitchell, H.H. and Cooper, A.R. (1956). Further studies on the gross composition and mineral elements of the adult human body. *Journal of Biological Chemistry*, **223**, 969–975.

Heymsfield, S.B., McManus, C., Smith, J., Stevens, V. and Nixon, D.W. (1982). Revised equation for calculating bone free arm muscle area. *American Journal of Clinical Nutrition*, **36**, 680–690.

Jelliffe, D.B. and Jelliffe, E.F.P. (1979). Midarm muscle volume: A suggestion. *American Journal of Clinical Nutrition*, **32**, 2170–2172.

Jelliffe, E.F.P. and Jelliffe, D.B. (1969). The arm circumference as a public health index of protein-calorie malnutrition of early childhood (Letter to the Editor). *Journal of Tropical Pediatrics*, **15**, 179.

Liebig, G. von (1874). *Gewichtsbestimmungen der Organe des minsched Korpers*, **96**, 117.

Martin, A.D., Spenst, L.F., Drinkwater, D.T. and Clarys, J.P. (1990). Anthropometric estimation of muscle mass in men. *Medicine and Science in Sports and Exercise*, **22**, 729–733.

Matiegka, J. (1921). The testing of physical efficiency. *American Journal of Physical Anthropology*, **4**, 223–230.

Mitchell, H.H., Hamilton, T.S., Steggerda, F.R. and Bean, H.W. (1945). The chemical composition of the adult human body and its bearing on the biochemistry of growth. *Journal of Biological Chemistry*, **158**, 625–637.

Mueller, W.H. and Martorell, R. (1988). Reliability and accuracy of measurement. In *Anthropometric Standardization Reference Manual* (edited by T.G. Lohman, A.F. Roche and R. Martorell), pp. 83–86. Champaign, Ill.: Human Kinetics.

Ross, W.D. and Marfell-Jones, M.J. (1991). Kinanthropometry. In *Physiological Testing of the High-Performance Athlete* (edited by J.D. McDougall, H.A. Wenger and H.J. Green), 2nd edn, pp. 223–308. Champaign, Ill.: Human Kinetics.

Tanner, J.M. (1949). Fallacy of per-weight and per-surface area standards and their relation to spurious correlation. *Journal of Applied Physiology*, **2**, 1–15.

Theile, F.W. (1884). *Gewichtsbestimmungen zur Entwickelung des Muskelsystems und des Skelettes beim Menschen*, **46**, 170.

Vierordt, H. (1906). *Anatomische, Physiologische und Physikalische Daten und Tabellen.* Jena: Fisher.

Walt, T.S.P. van der, Blaaw, J.H., Desipré, M., Daehne, H.O. and Rensburg, J.P. van (1986). Proportionality of muscle volume calculations of male and female participants in different sports. In *Perspectives in Kinanthropometry* (edited by J.A.P. Day), pp. 229–238. Champaign, Ill.: Human Kinetics.

Welcker, H. and Brandt, A. (1903). Gewichteswerthe der Korperorgane bei dem Menschen und den Thieren. *Archiven Anthropologische*, **28**, 1–89.

Yates, F.E. (1978). Good manners in good modelling: Mathematical models and computer simulations of physiological systems (Editorial). *American Journal of Physiology*, **234**, 159–160.