Heights and Body Weights of Canadian Tuberculosis Patients

- CFCS -

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I. Introduction

One part of the Canadian Fluoroscopy Study is the development of organ-specific dose factors for external radiation for the members of the study cohort, for the relevant age groups and for each sex. The development of the dose factors requires selection of appropriate heights and weights for each age group and sex (Lee et al. 2010; Geyer et al. 2014). The time period of interest for the Canadian Fluoroscopy Study is 1930-1969, the period during which tuberculosis patients treated by pneumothorax were monitored by fluoroscopy. All patients entered the cohort between 1930 and 1952, when improved treatments became available, but use of pneumothorax and monitoring by fluoroscopy, and thus exposures to some members of the cohort, continued until the end of 1969. This report describes the results of a literature review in two parts: (1) selection or estimation of average heights and weights for the Canadian white population during the time period of interest (Section II); and (2) estimation of any difference in body weight between tuberculosis patients and the general population (Section III). Table 1 summarizes the results of the review, in terms of the estimated mean heights and weights, by age and sex, for the general population and for tuberculosis patients. Detailed explanations are provided in Sections II and III of the report.

Table 1. Average height and weight of Canadians by age and sex, with estimated weights for Canadian tuberculosis patients.[a]

	Males			Females		
	General population		TB patients	General population		TB patients
Age	Height (cm)	Weight (kg)	Weight (kg)	Height (cm)	Weight (kg)	Weight (kg)
0 months (birth)	50.7	3.3	3.3	50.1	3.2	3.2
3 months	60.8	6.0	6.0	59.2	5.6	5.6
6 months	67.6	7.8	7.8	65.8	7.3	7.3
9 months	72.1	9.0	9.0	70.4	8.5	8.5
12 months	75.6	9.9	9.9	74.3	9.4	9.4
15 months	78.9	10.7	10.7	77.6	10.0	10.0
18 months	81.9	11.3	11.3	81.1	10.7	10.7
2 years	88.1	13.6	13.6	85.3	12.7	12.7
3 years	93.0	14.5	14.5	91.4	14.1	14.1
4 years	99.6	16.8	16.8	99.6	16.3	16.3
5 years	106.4	18.1	18.1	106.2	18.6	18.6
6 years	113.3	19.9	19.9	112.3	20.0	20.0
7 years	119.4	22.7	21.6	118.1	22.2	22.2
8 years	124.7	25.9	23.3	124.2	25.9	23.3
9 years	130.3	28.6	25.7	129.5	28.1	25.3
10 years	135.9	31.8	28.6	135.4	31.3	28.2
11 years	140.7	34.9	31.4	140.5	34.9	31.4
12 years	145.8	38.1	34.3	147.8	41.7	37.5
13 years	150.6	42.6	38.3	153.4	46.3	41.7
14 years	158.0	49.0	44.1	155.7	48.5	43.7
15 years	164.3	54.0	48.6	158.0	50.8	45.7
16-17 years	169.4	61.7	55.5	158.8	54.4	49.0
18-19 years	172.7	65.3	58.8	159.0	56.2	50.6
20-24 years	172.5	69.9	62.9	159.5	56.2	50.6
25-29 years	173.5	72.6	65.3	159.3	57.2	51.5
30-34 years	172.7	75.7	68.1	159.5	59.0	53.1
35-44 years	171.4	75.7	68.1	158.5	61.2	55.1
45-54 years	169.9	74.4	67.0	157.0	65.3	58.8
55-64 years	167.6	73.0	65.7	155.7	66.7	60.0
65+ years	166.4	70.3	63.3	153.9	62.6	56.3
Adults 20+ years	170.2	73.3	66.0	156.8	61.2	55.1

Table 1. (continued)

[a] Heights and weights for birth to 18 months are taken from Demirjian et al. (1983) based on a longitudinal study of French Canadian children born in Montreal in 1975-1976. Heights and weights for 2 years and older are weighted means taken from Pett and Ogilvie (1956; 1957) from a 1953 survey of the Canadian general population. Estimation of weights for tuberculosis patients is described in the main text.

II. Average body heights and weights for the Canadian population

Table 2 and Figures 1-2 provide a summary of average heights and weights for Canadians by age and sex.[1] Data for ages 2 to 65+ are weighted averages for the Canadian population in 1953, taken from Pett and Ogilvie (1956; 1957). Data for birth to 18 months are taken from Demirjian et al. (1983) and are based on French Canadians in Montreal born in 1975-1976. Table 3 summarizes these two data sets and a number of other Canadian and U.S. data sets for heights and weights of adults and children. Sections II.1 and II.2 describe the two primary Canadian data sets in more detail. Section II.3 describes other Canadian data sets, and Section II.4 describes various U.S. data sets. Section II.5 discusses several issues involved in the selection of suitable data sets for this study, such as secular changes in average body sizes within a population.

II.1. 1953 survey of the Canadian population

Body heights and weights for the Canadian general population (ages 2 to 65+) were compiled in 1953 by the Nutrition Division of the Department of National Health and Welfare (Pett 1955a; 1955b; Pett and Ogilvie 1956; 1957). As described by Pett (1952) and Pett and Ogilvie (1957), no comprehensive or properly documented statistics for the Canadian population predate this effort, although some regional information is available (see Section II.3). The 1953 sampling involved close to 22,000 Canadians, out of a population of about 14 million (1951 census; Basavarajappa and Ram 2014). Participants were selected by an area stratification plan, proportionate to population density, developed by the Dominion Bureau of Statistics using 1951 census data (Pett 1955b; Pett and Ogilvie 1956; 1957). The goal was to collect heights and weights for a representative sample of the entire Canadian population, from which tables of average weight for height, age, and sex would be developed (Pett and Ogilvie 1956; 1957). The sample was expected to be representative for such things as socioeconomic status, climate, and geographic conditions, and results were expressed as weighted means to account for the sampling procedure (Pett and Ogilvie 1957). For each measurement, a weighting factor was assigned, based on the population represented by a given individual in his or her area (the ratio of the sample to the total population in the sampling area); the areas were weighted in proportion to total population when the sample was selected (Pett and Ogilvie 1956; 1957). Thus, the results were reported as weighted means intended to represent the entire Canadian population.

The 1953 survey of the Canadian population excluded pregnant women, children less than 2 years old, military personnel in camp or barracks, native populations on reserves, disabled people, and people who were confined to bed due to illness (Pett 1955b; Pett and Ogilvie 1956). The data summarized by Pett and Ogilvie (1956) and Pett (1955a; 1955b) should thus be representative for the general healthy population of Canada at the time of the survey, apart from these exclusions. Table 4 provides a summary of the origins of the Canadian population included in the national censuses from 1931 to 1971, including the 1951 census which was the basis for the sampling plan of the 1953 survey. The vast majority (97%) of the 1951 population was of British, French, or other European ancestry (Basavarajappa and Ram 2014), and as noted earlier, native populations on reserves were specifically not included in the 1953 survey (Pett 1955b; Pett and Ogilvie 1956).

[1] Table 1 provides heights and weights in metric units (cm and kg, respectively). Figures 1-2 provide heights and weights in English units (in and lb, respectively) to permit easier comparison with other data sets in later figures.

Thus, while the 1953 survey sample may not have been composed exclusively of whites, it would have been composed almost entirely of whites and can be expected to be representative for the white population of Canada in 1953. The white population constituted nearly 98% of the population in the 1931 and 1941 censuses, essentially no different from the 1951 census. The patient population for the present study comes from the white population of Canada between 1930 and 1952. Based on the census data, the population sample included in the 1953 survey would have been approximately 97% white, and thus should be sufficiently representative of the patient population in the present study (See Section II.5).

Measurements were made in English units (inches to the nearest 1/4 inch; pounds to the nearest 1/2 pound) while participants wore usual indoor clothing but with shoes removed (Pett and Ogilvie 1956; 1957). Thus, the weights include approximately 2 pounds (0.9 kg) of clothing for women, 3 pounds (1.4 kg) of clothing for men, and 1-3 pounds (0.45-1.3 kg) for children, depending on the size of the child.

For adult Canadians aged 20 years old and over, the averages were as follows: Men: height 170.2 cm, weight in indoor clothing 73.3 kg, nude weight 71.7 kg; Women: height 156.8 cm, weight in indoor clothing 61.2 kg, nude weight 60.3 kg (Pett and Ogilvie 1957, Table 1). The summarized data of Pett and Ogilvie (1956, Table 1; 1957, Table 1) or Pett (1955b, Table 1) are weighted means (as described above) by age and sex, intended to represent the entire Canadian population.[2]

Percentiles (25th, 40th, 50th, 60th, 75th) of height and weight are also available (Tables 3 and 4 of Pett and Ogilvie 1956; Table 6 and 7 of Pett and Ogilvie 1957). Average weights for height, age, and sex are available for persons at least 15 years old (Table 2 of Pett and Ogilvie 1956; Tables 3A and 3B of Pett and Ogilvie 1957; Table 1 of Pett 1955a; Table 3 of Pett 1955b) or at least 5 years old (Tables 2A, 2B, 4A, and 4B of Pett and Ogilvie 1957).

II.2. 1975-1976 study of French Canadian children

The primary source of data for children less than 2 years old is a longitudinal study of French Canadian children born in Montreal in 1975-1976 (Demirjian et al. 1983). The French Canadian data for children from birth to 18 months are included in Table 2. Percentiles (3rd, 10th, 25th, 50th, 75th, 90th, 97th) are also available, along with comparisons of weight as a function of height (both percentiles and means). While French Canadians or residents of Quebec tended to be smaller than residents of the rest of Canada (Pett and Ogilvie 1957; Stoudt et al. 1960; 1965) for the youngest ages any differences are not likely to be significant.

II.3. Comparisons with other Canadian data sets

Besides the two data sets described above, limited data for white Canadians are available, especially for time periods prior to the 1953 survey. For adults there are some data for Ontario, and a few U.S. data sets include some Canadians (Table 3). For school-age children, there are some data for Toronto, Ottawa, and Central Vancouver Island (Table 3). For infants and children

[2] There is one small discrepancy between the two tables (65.4 vs. 65.5 inches for men aged 65 and over); the height in cm (166.4) in Pett and Ogilvie (1956; 1957) corresponds to the 65.5 inches given by Pett (1955b). The metric values for height and weight are otherwise consistent.

below school age, no additional Canadian data sets for whites were located. Several regional data sets for school-age children are available for later time periods (Table 3).

II.3.1. Data sets for adults

Figure 3 provides a comparison of the mean heights of Canadian adults by age, as measured in 1953 (Pett and Ogilvie 1956; 1957), with heights measured or estimated in Ontario in the 1940s (McHenry et al. 1947; actual time period not provided), the Eastern U.S. and Canada in 1922-1934 (women only; Dublin and Marks 1937), and the U.S. and Canada in 1885-1900 (men) or 1885-1908 (women) (ALIMD/ASA 1912, the Medico-Actuarial report). The information from McHenry et al. (1947) and Dublin and Marks (1937, as reported by Hathaway and Foard 1960) does not include the corresponding mean weights, and so cannot be used for the present study other than in general evaluation of the representativeness of the 1953 data set in terms of heights by age and sex. While both Dublin and Marks (1937) and the Medico-Actuarial report (ALIMD/ASA 1912) included some Canadians, the proportion of Canadians is not available in either case and is likely to have been small, given the relative populations of the two countries. These two data sets are discussed further in Section II.4, along with other U.S. data sets.

The Ontario sample population (McHenry et al. 1947) included several convenience samples of Ontario residents, taken from life insurance applicants, university students, employees of a public utility and a textile factory, and applicants for driver's licenses. The paper does not provide the dates of the measurements or discuss whether some participants may have been included in more than one group. No information is available on race (although they probably were predominantly white, given the composition of the national population) or socioeconomic status. Life insurance applicants and university students, in particular, may not have been representative of the general population of Ontario in terms of their economic situation. The authors indicate that their sample was neither random nor representative. Heights of the driver's license applicants (24% of the males and 38% of the females) were self-reported and probably included shoes. The paper indicates that the other groups in the sample were measured in "customary indoor clothing" but does not specifically state whether that includes shoes.

McHenry et al. (1947) included a comparison with the 1912 Medico-Actuarial report (ALIMD/ASA 1912) and found that average heights of the Ontario subjects were slightly greater than the heights reported in 1912, but not significantly so, except for the youngest men and for university men. The 1912 Medico-Actuarial report was based on accepted life insurance applicants in 1885-1900 (males) or 1885-1908 (females, with most applications being dated after 1900) and specifically indicates that height was measured (or estimated for perhaps 40% of the sample) with shoes. The heights reported by Dublin and Marks (1937) also included shoes. Thus the main difference between the 1953 Canadians and the other groups shown in Figure 3 is that the 1953 Canadians were measured without shoes, while the other groups were definitely or likely measured with shoes. Hathaway and Foard (1960), in discussion of the 1912 Medico-Actuarial report and other studies, estimate that heights with shoes should be reduced by one inch for men and two inches for women. Figure 4 shows the same comparisons as Figure 3, following adjustments for the height of shoes (1 inch for men and 2 inches for women, as suggested by Hathaway and Foard 1960). This comparison suggests that these three data sets may not be so different from the 1953 Canadian survey in terms of the general range of measured heights. (Clearly the trend of age-dependent heights is different in some cases, especially between the

1953 Canadian data and the Medico-Actuarial numbers for men past their mid-40s). Remaining differences are likely due to nonrepresentativeness of the Ontario and U.S./Canadian samples for the general Canadian population, as already described.

II.3.2. Data sets for children

For children, there are several additional Canadian sets (Table 3). All of these data sets are based on schoolchildren and are thus limited in their range of ages (generally ages 5-6 to teenage), while the 1953 data set goes from age 2 to adulthood. In addition, each of these other data sets is limited to one city or region and thus are not expected to be representative of Canadians more generally. Farkas and Wood (1982) point out that the 1953 data set contained a large fraction of rural children, while most of the other available samples are limited to urban children. Most of these studies reported measurements without shoes, the same as for the 1953 Canadian data set; in a few cases this information was not provided. Figures 5-8 provide comparisons of the 1953 data set with other Canadian data sets for children. Both heights and weights are available for all of these data sets except for Toronto in 1892 (heights only). Means are shown in most cases, but only medians or geometric means were available for a few data sets (details in Table 3). The data in Figures 5-8 for Ottawa represent averages of three time periods: 1933-1935, 1938-1940, and 1943-1945 (Hopkins 1947). Comparisons of the 1953 data set with the individual time periods for Ottawa (above-average and below-average socioeconomic status shown separately) are shown in Figures 9-10.

As shown in Figures 5-8, the 1892 and 1923 data for Toronto children (from Meredith and Meredith 1944; Pett 1955b; Helmuth 1983) are generally lower than the 1953 data, after about age 6, while the Toronto 1939 data (Meredith and Meredith 1944; Pett 1955b) are very close to the 1953 data. The data for children of higher socioeconomic status in Ottawa (Hopkins 1947) are also close to the 1953 data, while the data for children of lower socioeconomic status are lower than the 1953 data (Figs. 5-8). For most age groups, the increase in height and weight from the earliest to the latest time period is also apparent, especially for the lower income children (Figs. 9-10). However, in general, the Ottawa data are consistent with the 1953 national data.

Data for 1947-1956 (Central Vancouver Island, British Columbia; from Stennett and Cram 1969, described by Best and Doughty 1963) and 1967-69 (London, Ontario; from Stennett and Cram 1969) are greater than the national data from 1953 (Figs. 5-8). Best and Doughty (1963) used measurements of all public school children in Central Vancouver; their data represent 1-18 measurements per child (average about 5 per child). Best and Doughty (1963) stated that their means exceeded the corresponding means from the 1953 Canadian survey by an average of 0.8 (males) or 1.0 (females) inches and 2.4 (males) or 3.0 (females) pounds, for ages 6-15 years. Data for London, Ontario (1967-1969) were based on measurements of public school students (Stennett and Cram 1969) and were considered likely to be representative of urban, school-age children in Ontario.

Demirjian et al. (1972) described French Canadian children (2,722 boys ages 6-17; 2,332 girls ages 6-16) in Montreal surveyed in 1969 (a cross-sectional study). The children in Montreal were reported to be taller than the Quebec children measured in 1953, but also shorter and lighter than contemporary urban American children (Demirjian et al. 1972). On average, these children were taller than Canadian children (including Quebec) in 1953, after about age 13, although slightly

lighter in weight except for boys above about age 13 (Figs. 5-8). Demirjian et al. (1976) considered the Canadian data of 1953 to be no longer applicable for French Canadian children of the late 1960s; correspondingly, these data for French Canadian children in 1969 are probably not representative for Canadian children generally during the 1930s-1960s, the period of interest for the current study. A few additional data for ages 6, 7, 10, and 11 were reported for a small longitudinal study in Montreal (Demirjian et al. 1971).

Demirjian et al. (1976) compared the children from the cross-sectional study in Montreal with a smaller longitudinal survey (starting at age 7) in Saskatoon (English-speaking children, probably mostly white), started in 1964 (boys) and 1965 (girls). Children in Saskatoon were generally taller than those of similar age in Montreal, and of similar or slightly greater weight (Demirjian et al. 1976; Figs. 5-8). Léger and Lambert (1983;1985) described one later study of French Canadians from 11 regions in Quebec, ages 6-17, surveyed in 1981 (2,407 girls and 2,555 boys). These children were both taller and heavier than the Canadian children surveyed in 1953 (Figs. 5-8). The French Canadian children surveyed in 1969 and 1981 were thus larger than the Canadian children surveyed in in 1953, even though French Canadian children in 1953 were smaller than Canadian children in general. The children studied in Saskatoon in the 1960s-1970s were larger than the French Canadian children of 1969. Therefore, it is unlikely that these later data sets would be representative for Canadian children in general for the time period of interest for the current study, 1930s-1960s.

Farkas and Wood (1982) reported results from a 1974-1976 survey of children in Toronto schools and area recreation camps plus one school in Montreal. This study selected approximately 50 children of each sex, per age group, with a pre-decided distribution of ethnic origin. These children were generally taller and heavier than the 1953 national data (Figs. 5-8). The authors indicate the possibility for bias in the older age groups (above age 16) toward children who remained in school.

Both Farkas and Wood (1982) and Helmuth (1983) refer to a national survey of Canadian children in 1970-1972 (Demirjian 1980), and Helmuth (1983) reports some results from that survey, but so far we have been unable to obtain the 1980 report itself, so the details of that survey are not available. Helmuth (1983) also reported results of measurements of high school and university students in Peterborough, Ontario, in 1981-1982. The results of the 1970-1972 survey are generally only slightly higher than the 1953 data, while the Peterborough data, with a few exceptions, are greater than the 1953 data (Figs. 5-8).

For white Canadian infants and very young children, no further data sets are available besides the 1953 survey (ages 2 and higher) and the data for infants and young children (ages 0 to 3 years) in Montreal in the 1970s (Demirjian et al. 1983). The infant to pre-school age range is discussed further in Section II.4, in comparison with available U.S. data.

Data sets for Canadian minority populations were also examined, including data reported by Partington and Roberts (1969), Demirjian et al. (1976), Lee and Birkbeck (1977), Coodin et al. (1980), and Helmuth (1983). These data were for Canadian Native (Indian or First Nations) or Inuit (Eskimo) populations, which were not considered representative for the purposes of the present study.

In general, then, above about age 5 or 6, the 1953 Canadian data are quite close to other available Canadian data sets, accounting for known differences in time periods and populations as

described above. In addition, the 1953 data are internally consistent across a large age range, including most of the age range of interest for the current study. The 1970s data for infants and young children are also internally consistent across their age range, and consistent with the 1953 data for the range of overlap (Figs. 1-2). Section II.4 provides comparisons with available U.S. data, and Section II.5 provides further discussion of secular trends in body size and other relevant issues.

II.4. Comparisons with U.S. data sets

A variety of U.S. data sets for population heights and weights have been published since the late 1800s; many of these are listed in Table 3. Hathaway (1957) and Hathaway and Foard (1960) have provided compilations of many published and unpublished data sets and height-weight standards for a variety of age groups and populations. Some of the major data sets are described in the following sections. Data sets that contained only a few age groups (e.g., limited to university students) or were limited to single regions are generally not considered in detail in this report. In addition, we have concentrated on data sets that provided average heights and weights by age and sex; data reported only in terms of weight for a given height (by age or for age groups) are not useful for the present purpose. Note that the data sets described below were assembled for a variety of purposes (medical information, clothing manufacture, anthropological or eugenics studies) and are not necessarily consistent in the types of measurements performed, the techniques used for the measurements, or the methods of handling ages.

II.4.1. Data sets for the general population (all ages)

Figures 11-12 compare the Canadian data provided in Table 2 (Pett and Ogilvie 1956; 1957; Demirjian et al. 1983) with two large American data sets. The greater height and weight of Americans vs. Canadians is readily noticeable for adults. For children, the U.S. data (1930s-1950s; Stoudt et al. 1960) show greater height and weight than the Canadian children in the 1953 survey. For the youngest children (Figs. 13-14), the data from Montreal and the U.S. are very close up to age 2, where they are reasonably close to the 1953 Canadian data, even considering both the different time periods during which the data were collected and the known differences between Canada as a whole and either Quebec (including Montreal) or the U.S. for older ages.

Stoudt et al. (1960) provided heights and weights for the entire U.S. population. The paper states that there were "no completely satisfactory data" for the U.S. population at that time and describes plans for a later study (Stoudt et al. 1965). Existing samples were not considered sufficiently sizeable or representative or to have used standardized methods. Some of the data sets available were made up of life insurance applicants and were considered likely to have under-represented the lower socio-economic groups. Military recruits made up some of the other samples and were considered to have been above average in size with respect to the general population, due to applicable standards of height, weight, and health.

Stoudt et al. (1960) reported heights and weights for white Americans, by age and sex for all ages (birth to old age), based on studies published from the mid-1930s through the 1950s (Stoudt et al. 1960). Each entry in their table came from a subjective balancing of the available sources, one of which was the Canadian study by Pett and Ogilvie (1956; 1957), and their report is offered as a

"synthesis" of the available information (Stoudt et al. 1960). Stoudt et al. (1960) described the Canadian survey as "a model survey" and an "excellent" survey. Although they indicated that the Canadians, even excluding Quebec, were generally smaller than Americans at corresponding ages (on average), they did use the Canadian data for areas exclusive of Quebec to support their conclusions for the U.S. population. Their report is limited to the white population of the U.S., although they stated that some of the samples used for younger age groups included some blacks.

Stoudt et al. (1965) describe a national health survey carried out in the U.S. during 1960-1962 of the height and weight of adults (ages 18-79). The survey included 6,672 persons (compared with a total U.S. population of 179 million in 1960; Bureau of the Census 1964). The survey used a stratified, random sample of the adult civilian, noninstitutionalized, population of the U.S., similar to the approach used by the Canadians (Pett and Ogilvie 1956; 1957). Thus, the survey included approximately 10% nonwhites, corresponding to the U.S. population at the time. No breakdown by race was reported. Measurements of weight included approximately 2 pounds of clothing. In general, Stoudt et al. reported differences of 6 to 12 pounds for men and about 6 pounds for women, depending on age group, between their results and the Canadian results, with the Canadians being consistently smaller. The U.S. survey participants averaged about 1.1 inches taller than the Canadians for comparable age groups. Stoudt et al. (1965) discussed the differences between their results and earlier results (including the Canadians), with respect to socioeconomic differences, civilian-military differences, racial and ethnic differences, differences in measuring techniques, and changes in body size over time (secular changes in body size).

II.4.2. Data sets for adults

The 1912 Medico-Actuarial report (ALIMD/ASA 1912) has already been mentioned (Section II.3.1). This report was based on accepted life insurance applicants (standard lives or regular rates) in 1885-1900 (males) or 1885-1908 (females, with most applications being dated after 1900). The report specifically indicates that height was measured with shoes, and about 40% of the sample is thought to have been estimated rather than measured. While the data included some unstated fractions of Canadians and of non-whites, most of the people included in the sample are likely to have been white Americans. The mean heights by age and sex from the Medico-Actuarial report are compared with the 1953 national data for Canada in Figure 3 (without adjustment for shoes) and Figure 4 (with adjustment for shoes). Mean weights by age and sex (without adjustment) are compared in Figure 15.

The Medico-Actuarial report also included "graded" (smoothed) average weights for height by age and sex. As mentioned above, data in this format are not useful for the present purpose. The tables of graded average weights for height by age and sex from the Medico-Actuarial report were copied directly by Davenport (1923) and in turn by McLester (1943) and others, who have referred to them as the "tables of Davenport." It is interesting to note that the tables of Davenport have often been treated as population norms (e.g., McLester 1943; Kemsley et al. 1962), and McHenry et al. (1947), in discussing his convenience samples of adults in Ontario, used the tables of Davenport to calculate overweight or underweight for his subjects. However, Davenport himself (1923) used them only to estimate weights for individuals at ages for which he had no measurements. For example, to compare parents and offspring at similar adult ages, he could assume that his current measurements of height applied throughout each individual's adulthood,

and from the Medico-Actuarial tables he could estimate the weight for that individual at other ages.

Mean heights and weights from several additional U.S. data sets for adults (ages 15+; Table 3) are compared with the 1953 Canadian data in Figures 16-17. Several of these are unpublished data sets reported by Hathaway and Foard (1960). In general, the greater height of Americans vs. Canadians is visible in the figures, as is a general increase in height and weight over time among the Americans; these trends are less clear for weight. The 1939-1940 data set for seven states plus the District of Columbia (women only) was part of a major study that measured 10,042 women for purposes of garment and pattern construction (O'Brien and Shelton 1941). For height, the measurements approximately parallel those from the 1953 Canadian survey; for weight, the differences are less consistent (Figures 16-17).

II.4.3. Data sets for children

A variety of "standards" for the height and weight of children are available in the literature. Many of these are not in a form useful for this study. Hathaway (1957) provides summary tables and charts of weight for height for a number of historic compilations. McLester (1943) used a data set by Faber (1929) in a manner comparable to the tables of Davenport (1923) for adults. The data of Faber (1929) represent measurements of more than 60,000 San Francisco children prior to 1925 (exact time period not stated); however, he does not provide means of height or weight or ranges by age.

Figures 18-19 provide comparisons of the 1953 Canadian data for heights and weights of children with several important sets of American data that are available in useful form (Table 3, including the synthesis of 1930s-1950s data from Stoudt et al. (1960). A very extensive set of data for 147,000 children ages 4-17 was collected in 1937-1939 from 16 states plus the District of Columbia, for the purposes of garment and pattern construction (O'Brien et al. 1941).

Three additional compilations often treated as population standards (Hathaway 1957) are also included in the figures. The tables of Hastings (1902) were based on measurements of about 8000 males and 7000 females (ages 5-20), mostly from Omaha, but for some age groups including some children from Nebraska generally, Connecticut, and Massachusetts. Hastings (1902) does not provide a date for the sample collection, but Hathaway (1957) states that the measurements were made in 1899. Stuart and Meredith (1946) reported percentiles of heights and weights for several hundred white children in Iowa City. Boyd (1952, as reported by Hathaway 1957) reported measurements of about 175 children in Denver, probably taken in the 1940s.

Additional data for American children (assumed to be about 1920, but the actual dates were not given) were published by Clark et al. (1922; 1923).[3] Clark et al. (1922) reported heights and weights of 14,335 white children ages 6-16 in Maryland, Virginia, and North and South Carolina. The later paper (Clark et al. 1923) reported similar information for 9,973 white children in South Carolina, Virginia, Maryland, Delaware, and New York. Probably many children in Maryland, Virginia, and South Carolina were included in both studies.

[3] Data shown in Figures 18-19 are from Clark et al. (1922). They are listed in the legends as being from 1920, but the actual dates of the surveys were not provided.

These children surveyed by Clark et al. (1922) were very similar in height to, or slightly shorter than, the Canadian children of 1953, but lighter in weight than the Canadians after about age 7 (Figs. 18-19). These children were also smaller than the American children summarized by Stoudt et al. (1960), which may reflect both the differences in time period and differences between the surveyed populations and the national population.

The Omaha (1899) heights were consistently lower than those reported for Canadian children in 1953 until early adulthood, where they were similar, and the weights were lower throughout the age range (Figs. 18-19). The heights for other American data sets (1930s and later) were generally greater than for the Canadians, especially for the oldest ages. Weights of the American children, however, were similar to or less than those of the Canadians, except at the oldest ages (above about age 12 for girls and age 14 for boys), where the Americans exceeded the Canadians for the later data sets (Figs. 18-19).

II.4.4. Data sets for infants and very young children

As described in Section II.4.1 (Figs. 13-14), for the youngest children, the data from Montreal in the 1970s and the U.S. in the 1930s-1950s are very close up to age 2. Above age 2, they are reasonably close to the 1953 Canadian data in their region of overlap. At age 2, the 1953 data for height are very close to the Montreal data, then lower than the Montreal data at ages 3 and higher. For weight, the 1953 Canadian data are closer to the Montreal data at ages 3+ than at age 2. Fig. 20 provides a comparison between the 1970s data in Montreal (ages 0-3), the 1953 Canadian data (ages 2-3), and several U.S. data sets from the first part of the 20th century. This comparison confirms that differences in mean body size among these populations are small during infancy and early childhood. The differences between the means of the Montreal and 1953 Canadian data are within the range of variability observed among the means of the U.S. data sets.

The U.S. data sets are summarized in Table 3. Four are regional data sets for which the time periods of data collection are not specifically stated (Faber 1920; Iowa Child Welfare Research Station 1931; Bayley and Davis 1935; Vickers and Stuart 1943). For California, data were obtained over about 10 years (probably around the 1910s) in San Francisco, for about 1000 well babies of both sexes, for the first year after birth (Faber 1920). Faber (1920) provided a chart for weight by age from birth to 52 weeks; the chart indicates ranges that included 99.6% of the observations. For this study, the upper and lower bounds were read from the chart for 0, 13, 26, 39, and 52 weeks and are reproduced on the graphs for both males and females (Fig. 20). The data of Crum (1916) represent several thousand children ages 6-48 months who participated in Better Babies Contests in 1913-1915. These data came from 23 states and thus are less subject to regional variations; however, they are not limited to white children, and they are not necessarily representative socioeconomically.

Figure 21 compares average body lengths and weights at or soon after birth for the 1970s Montreal babies with several early 20th century U.S. data sets for newborns (summarized in Table 3). As in Fig. 20, the data for California represent a range for both males and females. The unpublished data by Ratner (reported by Davenport 1923) represent the mean weight of 11 children (9 males, 2 females) born in New York City in May and June of 1922. Measurements for 250 full-term infants in Minnesota were obtained between December 1914 and May 1917 (Taylor 1919). Again, differences in body size among populations are small for the earliest ages,

and no significant changes over time (i.e., with birth cohort) are observed. The Montreal data from the 1970s are thus in general agreement with the U.S. data from earlier time periods.

II.5. Representativeness of the selected Canadian data sets for this study

The present epidemiological study of Canadian fluoroscopy patients includes exposures between 1930 and 1969. Patients in this study treated by pneumothorax started treatment between 1930 and 1952; however, fluoroscopies to monitor the treatment continued to be used through 1969. Thus, the 1953 Canadian data set (Pett and Ogilvie 1956; 1957) was obtained close to the end of the entry period for the fluoroscopy study. As described earlier, this data set was designed to be geographically representative of the whole Canadian population, includes an age range from 2 years through adulthood, and benefits from consistent measurement techniques throughout the sample. The sample itself included approximately 0.16% of the Canadian population at the time and consists almost totally of whites. The survey was held up as an example of how such population surveys should be performed (Stoudt et al. 1960; 1965).

For ages below 2 years, it is necessary to use a different data set. The only available Canadian data set is for French Canadians born in the 1970s (Demirjian et al. 1983). However, available information indicates that variability among populations is small for the youngest ages. This data set is reasonably consistent with the 1953 data in the region of overlap and with various U.S. data sets during the early 20th century. For the present study, these data are used only for ages up to 18 months.

Other Canadian data sets as well as most U.S. data sets are much more limited in their age range and their geographical scope than the 1953 survey. The only other Canadian study to include adults is self-described as not representative, and no other Canadian data sets at all are available for children ages 3-5. Canadian residents are generally smaller than U.S. residents (Section II.4.1), after the first few years of life, and therefore use of Canadian rather than U.S. data is preferred.

The available data sets, both Canadian and U.S., were assembled for a variety of purposes (medical information, clothing manufacture, anthropological or eugenics studies) and are not necessarily consistent in the types of measurements performed, the techniques used for the measurements, or the methods of handling ages (e.g., age at nearest birthday, age at last birthday, average age of a group, representative midpoint for an age group, measurements made on birthdate plus or minus 1 or 2 weeks, etc.). Dates of measurements are uncertain for many of the studies. Thus, combining several data sets to cover the whole age range, geographic range, and time period is problematic at best.

In theory, the heights and weights of patients at each treatment date could be used to produce patient-specific dose factors, which would account for age and for any effects of location, race/ethnicity, urban or rural status, and socioeconomic status. Alternatively, separate heights and weights by age could be developed for different birth cohorts. However, the available information is not sufficient for either of these approaches. In addition, generation of several sets of dose factors could have its own difficulties. Therefore, use of the 1953 national survey of the Canadian population and the 1970s measurements of French Canadian infants is considered to be the best possible use of the information that does exist. The specific issues of geographical and temporal representativeness are discussed in the following sections.

II.5.1. Geographical representativeness

The 1953 survey was designed to be representative of the Canadian population, based on the 1951 census. However, the Canadian fluoroscopy patients in this study are not necessarily representative with respect to the Canadian population of their time. For example, about 70% of the patients are from Ontario, but only 33% of the Canadian population in 1951 was in Ontario (Basavarajappa and Ram 2014). The 1953 data are not available by province, so it is not possible to select average heights and weights by age for each province. Pett and Ogilvie (1957) do provide a breakdown for Quebec and for Canada less Quebec, for ages 5 through adult (Fig. 22). While Quebeckers, especially males, are noticeably smaller than other Canadians (Pett and Ogilvie 1957; Cranfield and Inwood 2007), non-Quebec Canadians are not much taller or heavier on average than all Canadians combined. Thus it would be possible to consider generating separate dose factors for Quebeckers and non-Quebeckers, if the residence information is available for all patients and if there are sufficient patients from Quebec. Given that the data for all Canadians includes the Quebeckers, use of those averages to generate one set of dose factors for all Canadians should be sufficient, especially if residence histories are not available for all patients.

II.5.2. Temporal representativeness (secular trend)

As already mentioned, the study patients entered the cohort between 1930 and 1952, while the main survey data were obtained in 1953, close to the end of the entry period for the cohort. Given that no patients entered the cohort after 1952, the suitability of the 1953 data for later years is less important. Populations do change over time, due to local economic situations, immigration patterns, and other factors. For example, changes over time can be seen in Ottawa children (Figs. 9-10) and Toronto children (Figs. 5-8). Differences among populations (e.g., Toronto 1923 and 1939 vs. Canada 1953 in Figs. 5-8) may be due to both temporal and regional differences in such things as socioeconomic circumstances, growth patterns, degree of urbanization, and immigration patterns.

In the present case, we have a nearly complete national data set for 1953; we have incomplete (with respect to age) regional data sets for earlier (and later) time periods. The single data set for height of adults in Ontario is described by its authors as not representative, and its dates are uncertain (McHenry et al. 1947). However, the mean heights reported by McHenry et al. (1947), when adjusted for height of shoes, are generally similar to the 1953 national data set, suggesting that the national data set is probably sufficiently representative for Ontario during the time period of interest. For school-age children, several earlier data sets (e.g., Toronto in 1939 and Ottawa 1933-1945) are also generally similar to the national data in 1953.

With the 1953 survey data, it is possible to compare birth cohorts (age groups) who are assumed to have reached their full adult height (ages 20+; Table 5). For the latest birth cohorts (age groups from 20 to 34), there is no clear trend in height. Between more widely separated cohorts, differences do exist, but are not necessarily large. For a 20-year difference (born in 1909-1918 vs. born in 1929-1933), the difference in height is about 0.4 inches (1.1 cm in males, 1.0 cm in females). For a 30-year difference (born in 1899-1908 vs. born in 1929-1933), the difference is about 1.0 inch (2.6 cm in males, 2.5 cm in females). For a 40-year difference (born in 1889-1898

vs. born in 1929-1933), the difference is 1.9 in (4.9 cm) for males and 1.5 in (3.8 cm) for females. All of these adults were included in the averages for adults (ages 20+) provided with the 1953 survey results (Table 5); use of average values for all adults (ages 20+) in generation of dose factors would minimize differences among these birth cohorts.

A bigger concern would be whether children of a given age in 1953 were substantially different in size from same-aged children in 1930. Farkas and Wood (1982) suggest that the secular trend is more important for children than for adults, and for the adolescent growth spurt more than for preadolescents. Some of the comparisons described earlier between the 1953 data and later data sets are consistent with this (e.g., Vancouver 1947-1956 in Figs. 5-8). While the differences between 1953 and 1892 or 1923 could be important, differences between 1953 and the 1930s or 1940s are likely to have been less important, and are within the observed ranges of regional and other differences during the overall time period (Figs. 5-10). For example, the Ottawa data described earlier (Figs. 9-10; Hopkins 1947) show trends between 1933 and 1945, but the differences over time are less than the differences between above-average and below-average socioeconomic status. Helmut (1983) suggested that the lack of increase between 1939 Toronto and 1953 Canada represented a stalling or possible reversal of the secular trend, which he attributed to wartime conditions in Canada during the 1940s.

Farkas and Wood (1982) also suggest that secular trends have progressed at different rates in different countries and may reflect migration patterns and socioeconomic changes more than ethnic origins. None of the available surveys included birthplace (an indicator of immigration; Cranfield and Inwood 2007). Meredith (1976), in reviewing studies back to the 1800s in several countries (including Canada), concluded that the increase in mean height per decade was about 1.3 cm (one-half inch) in late childhood, 1.9 cm (3/4 inch) in mid-adolescence, and 0.6 cm (1/4 inch) in early adulthood; the larger differences observed during childhood and adolescence are not maintained into adulthood. Based on Meredith's findings, an increase in height of about 1/2 to 1 1/2 inches (depending on age) could be expected for a time period of two decades or so in Canada. Examination of the 1953 survey data by birth cohort (Table 6) indicates that the actual increases in height per decade among the Canadian population between the 1890s and the early 1930s have been smaller than Meredith's predictions. Cranfield and Inwood (2007) report a decline in average stature of Canadians during the 19th century, with a substantial trend upward during the 20th century as a whole. They also describe the differences in size, and differences in rates of change of size, among regional populations.

Overall, the information indicates that height of older children and adults increases with later birth year (birth cohort) among Canadians, but the increase during the years affecting the present study was relatively small. Although larger increases can be observed during years after 1953, during the first part of the 20th century, the increases appear not to have been large, likely due to the combined effects of two world wars, the depression, and substantial immigration.

Table 2. Reported average height and weight of Canadians by age and sex.[a]

	Males		Females	
Age	Height (cm)	Weight (kg)	Height (cm)	Weight (kg)
0 months (birth)	50.7	3.3	50.1	3.2
3 months	60.8	6.0	59.2	5.6
6 months	67.6	7.8	65.8	7.3
9 months	72.1	9.0	70.4	8.5
12 months	75.6	9.9	74.3	9.4
15 months	78.9	10.7	77.6	10.0
18 months	81.9	11.3	81.1	10.7
2 years	88.1	13.6	85.3	12.7
3 years	93.0	14.5	91.4	14.1
4 years	99.6	16.8	99.6	16.3
5 years	106.4	18.1	106.2	18.6
6 years	113.3	20.9	112.3	20.0
7 years	119.4	22.7	118.1	22.2
8 years	124.7	25.9	124.2	25.9
9 years	130.3	28.6	129.5	28.1
10 years	135.9	31.8	135.4	31.3
11 years	140.7	34.9	140.5	34.9
12 years	145.8	38.1	147.8	41.7
13 years	150.6	42.6	153.4	46.3
14 years	158.0	49.0	155.7	48.5
15 years	164.3	54.0	158.0	50.8
16-17 years	169.4	61.7	158.8	54.4
18-19 years	172.7	65.3	159.0	56.2
20-24 years	172.5	69.9	159.5	56.2
25-29 years	173.5	72.6	159.3	57.2
30-34 years	172.7	75.7	159.5	59.0
35-44 years	171.4	75.7	158.5	61.2
45-54 years	169.9	74.4	157.0	65.3
55-64 years	167.6	73.0	155.7	66.7
65+ years	166.4	70.3	153.9	62.6
Adults 20+ years	170.2	73.3	156.8	61.2

Table 2. (continued)

[a] Heights and weights for birth to 18 months are taken from Demirjian et al. (1983) based on a longitudinal study of French Canadian children born in Montreal in 1975-1976. Heights and weights for 2 years and older are weighted means taken from Pett and Ogilvie (1956; 1957) from a 1953 survey of the Canadian general population. Weights were measured with indoor clothing but shoes removed.

Table 3. Summary of reported information on population average heights and weights in Canada and the U.S.

Country	Date	Population	Content	References
Canada	1953	Survey of Canadian general population based on 1951 census; excluded children < 2 years old, military personnel in camp or barracks, native populations on reservations, disabled and ill people; survey sample statistically representative of Canadian population based on 1951 census and nearly all white; measured in indoor clothing without shoes	Mean height and weight by age and sex (ages 2 to 65+); percentiles of height and weight by age and sex (ages 2 to 65+); Mean weights for height by age and sex (ages 15+)	Pett 1952; 1955a; 1955b; Pett and Ogilvie 1956; 1957
Canada	1975-1979	Longitudinal survey of French Canadian children born in Montreal in 1975-1976; followed to age 3; dress not specified (but not likely to have included shoes)	Mean height and weight by age and sex (ages 0 to 36 months); percentiles of height and weight; comparisons of weight as a function of height	Demirjian et al. 1983
Canada	1892, 1939	Surveys of Toronto schoolchildren (public schools in 1892, public and parochial schools in 1939); measured without shoes	Medians and percentiles of heights of children (ages 6-14)	Meredith and Meredith 1944; Helmuth 1983
Canada	1923, 1939	Toronto schoolchildren; dress not stated here, but reported elsewhere as without shoes	Mean heights and weights for children (ages 5-15)	Pett 1955b
Canada	1933-1945	Ottawa children, reported separately for higher and lower socioeconomic status; measured without shoes	Mean heights and weights for children (ages 6-12)	Hopkins 1947
Canada	1940s? (not stated)	Convenience samples of Ontario residents (life insurance applicants, university students, employees of a public utility and a textile factory, driver's license applicants); 8075 males and 4318 females; measured for most groups, self-reported for driver's license applicants; possibility exists for inclusion in more than one group; not considered representative for Canada; probably with shoes but not stated ("customary indoor clothing"); no information on race or socioeconomic status	Mean heights of adults by age group (ages 15 to 50+); insufficient information on weights for the current study (average weight for height for one age group of males)	McHenry et al. 1947
Canada	1947-1956	Central Vancouver Island (British Columbia); 12,116 boys and 11,453 girls; 1-18 measurements per child over the time period (average about 5 per child); measured in indoor clothing without shoes.	Median heights and weights for children (ages 6-18)	Best and Doughty 1963; Stennett and Cram 1969; Helmuth 1983
Canada	1967-1969	Public school students in London, Ontario; approximately 16,000 boys and 16,000 girls; measured in indoor clothing without shoes	Median heights and weights for children (ages 6-18)	Stennett and Cram 1969

Table 3. (continued)

Country	Date	Population	Content	References
Canada	1969	French Canadian children in Montreal; 2,722 boys and 2,332 girls; dress not stated	Mean heights and weights for children (males ages 6-17; females ages 6-16)	Demirjian et al. 1972
Canada	1964-1973	Longitudinal survey of English-speaking children in Saskatoon, started in 1964 (103 of 207 boys still in study in 1973) and 1965 (100 girls); dress not stated	Mean heights and weights for children (ages 7-15)	Demirjian et al. 1976
Canada	1970-1972	Data from a national Anthropometry Report by Demirjian (1980); Canadian children; no details available regarding locations or number of individuals; dress not stated	Heights and weights for children (ages 6-20)	Demirjian 1980, as reported by Helmuth 1983
Canada	1974-1976	Children in Toronto (schools and area recreation camps) and Montreal (one school); approximately 50 children per age group and sex; representative distribution of ethnic origin; measurements of children lightly clad and without shoes; potentially biased for upper ages (children remaining in school past age 16)	Heights (means) and weights (geometric means) for children (ages 6-18)	Farkas and Wood 1982
Canada	1981	French Canadians from 11 regions in Quebec; 2555 boys and 2407 girls; measured in sport clothes without shoes	Mean heights and weights for children (ages 6-17)	Léger and Lambert 1983; 1985
Canada	1981-1982	High school students and Trent University students, Peterborough, Ontario; no details available regarding number of individuals; dress not stated	Heights and weights for children and young adults (ages 14-23)	Helmuth 1983
Canada	various	Canadian Native (Indian) or Inuit (Eskimo) populations; various ages	Not relevant for the current study	Partington and Roberts 1969; Demirjian et al. 1976; Lee and Birkbeck 1977; Coodin et al. 1980; Helmuth 1983

Table 3. (continued)

Country	Date	Population	Content	References
U.S. and Canada	1885-1900 for men; "generally after 1900" for women (1885-1908, according to Hathaway and Foard 1960)	Medico-Actuarial tables of 1912 Information sampled from insurance applications (standard lives or regular rates) accepted in the U.S. and Canada; comparisons with two older tables for men; measured or estimated with shoes; 40% of sample thought to have been estimated rather than measured Probably mostly Americans, given the relative populations of the U.S. and Canada Persons living east of the Mississippi River and mostly from states along the eastern seaboard, primarily "American" parentage and British ancestry (Hathaway and Foard 1960)	Weights for height by age and sex; mean weight for 5-year age groups by sex; mean height for age groups by sex was calculated from the reported information for almost full samples; mean weight and height for age reported by Hathaway and Foard 1960 for full samples (for ages 20+) Graded average weights for height and age, by sex (Table IV for males; Table IX for females); these tables were directly used by Davenport 1923 and McLester 1943 (citing Davenport 1923).	ALIMD/ASA 1912; Hathaway and Foard 1960
U.S. (and Canada)	not stated here (1885-1900 for men; 1885-1908 for women)	From ALIMD and ASA 1912, Tables IV (males) and IX (females); quoted directly from the 1912 report; used by Davenport only to estimate weights (for given heights) at different ages, e.g., to permit comparison of parents and children at the same age	Graded average weights for height and age (smoothed from original data) Not useful for present study.	Davenport 1923
U.S. (and Canada for adults)	not stated here (1885-1900 for men; 1885-1908 for women; before 1925 for children)	For children, information from Faber 1929 For adults, information from Davenport 1923 (in turn from ALIMD and ASA 1912) Information quoted directly from indicated sources	Graded weights for height by age and sex (smoothed from original data) Not useful for present study.	McLester 1943
U.S.	1899?	Hastings' tables; measurements of 8241 boys and 7089 girls, mostly from Omaha, but also including Nebraska generally, Connecticut, and Massachusetts for some age groups; dates not given in report, but Hathaway (1957) states the measurements to have been made in 1899	Mean heights and weights of children (ages 5-20)	Hastings 1902

Table 3. (continued)

Country	Date	Population	Content	References
U.S.	1910s?	Measurements of about 1000 well babies in San Francisco, based on 5227 weighings over about 10 years	Chart with shaded area for weight by age, from birth to 52 weeks; shaded area includes 99.6% of observations. For this study, the upper and lower bounds were read from the chart for 0, 13, 26, 39, and 52 weeks.	Faber 1920
U.S.	1910-1918	Measurements of 114 men and 85 women in Boston; measured without clothing	Mean heights and weights of adults (men ages 20-39, women ages 20-59)	Harris 1919, as reported by Hathaway and Foard 1960
U.S.	1910-1924	"Old Americans" (individuals whose parents and grandparents were born in the US; Carter 1932); location not given; 219 men and 201 women; measured in indoor clothing without shoes	Mean heights and weights of adults (ages 24-59)	Hrdlicka 1925, as reported by Hathaway and Foard 1960
U.S.	1913-1915	5602 males and 4821 females, ages 6-48 months; from score cards of Better Babies Contests (at least 23 states); most children probably white, of American-born parents	Mean heights and weights of male and female children (6-48 months)	Crum 1916
U.S.	December 1914-May 1917	250 full-term infants (125 males, 125 females) in Minnesota, measured between 2 and 10 days old	Mean length and weight for male and female newborns	Taylor 1919
U.S.	1917-1919	1 million draft recruits 1917-1918 (males, ages 21-30); 100,000 demobilized men 1919; all states, all races	For 868,445 accepted recruits, mean height was 67.49 inches, mean weight was 141.54 pounds (pp. 67, 119, 417) For 81,558 men at demobilization, mean height was 67.7 inches, mean weight was 144.92 pounds (p. 508; see also pp. 67, 119-121)	Davenport and Love 1921
U.S.	probably before 1925	Measurements of over 60,000 San Francisco schoolchildren (indoor clothing, without shoes, coat or sweater)	Weights for height by age and sex, 10th and 90th percentiles (ages 5-15); no means for height or weight; no ranges by age Not useful for present study.	Faber 1929

Table 3. (continued)

Country	Date	Population	Content	References
U.S.	~1920? (not stated in these papers)	White children in selected states; the two papers contain overlapping but non-identical data sets (14,335 children in Maryland, Virginia, North Carolina, South Carolina; 9,973 children in South Carolina, Virginia, Maryland, Delaware, New York). Dates of measurements not provided. Measured as dressed (indoor clothing; with shoes except for children attending barefooted)	Mean heights and weights for children (ages 6-16)	Clark et al. 1922; 1923
U.S.	May-June 1922	11 infants (9 male, 2 female) at birth and each day to 10 days old, in New York City	Weights and lengths for individual infants	Ratner (not published), as reported by Davenport 1923
U.S. and Canada	1922-1934	Measurements of 268,070 women in the eastern U.S. and Canada; measured in indoor clothing including shoes	Mean heights of adult women (ages 20-59)	Dublin and Marks 1937, as reported by Hathaway and Foard 1960
U.S.	1925-30? may include some earlier data	Measurements of 829 boys and 721 girls in Iowa City, serial measurements on 93 boys and 120 girls; total of 1300 measurements of boys and 1003 measurements of girls. Ages to nearest month, 15-50 children per age.	Mean heights and weights of children (ages 0-36 months)	Iowa Child Welfare Research Station 1931
U.S.	1920s-1930s? (not stated in this paper)	Children in the vicinity of Boston, in homes of low to middle economic circumstances. Measurements taken unclothed, very close to stated age (i.e., close to birthdays). 26-136 boys per age, 24-145 girls per age, serial measurements for many children.	Mean heights, lengths, and body weights (ages 0-10 years); percentiles also provided	Vickers and Stuart 1943
U.S.	early 1930s? (not stated)	61 infants born in a 6-month period in Berkeley, California; followed monthly for 3 years (49 still enrolled at 36 months); white, English-speaking parents	Mean lengths and weights of male and female children (ages 1-36 months)	Bayley and Davis 1935
U.S.	1930-1945	3771 measurements of several hundred white children in Iowa City, mostly of northwest European ancestry, usually taken within 2 weeks of the birthday; measured in underclothes and socks	Percentiles of heights and weights for children (ages 5-18)	Stuart and Meredith 1946
U.S.	1930s-1950s	Subjective balancing or synthesis of available sources of information from U.S. and Canadian populations; estimates are for nude values	Estimated mean heights and weights for white Americans, by age and sex, for all ages (birth to old age)	Stoudt et al. 1960

Table 3. (continued)

Country	Date	Population	Content	References
U.S.	1940s?	1200 measurements of about 175 children in Denver	Percentiles of heights and weights for children (ages 2-18)	Boyd 1952, as reported by Hathaway 1957
U.S.	1937-1939	Measurements of 147,000 children for purposes of garment and pattern construction; 16 states plus the District of Columbia	Mean heights and weights for children (ages 4-17)	O'Brien et al. 1941
U.S.	1939-1940	Measurements of 10,042 women for purposes of garment and pattern construction; Arkansas, California, District of Columbia, Illinois, Maryland, New Jersey, North Carolina, and Pennsylvania; measured without clothing	Mean heights and weights for women (ages 18-75+)	O'Brien and Shelton 1941
U.S.	1948-1950	College freshmen at 87 U.S. colleges (52,661 men, 15,656 women; most of them 20-24 years old); measured without clothing	Mean heights and weights for adults (ages 20 to 40+)	ACHA (not published), as reported by Hathaway and Foard 1960
U.S.	1948	Urban survey by USDA; 1545 men and 1750 women; dress not specified	Mean heights and weights for urban adults (men ages 20 to 79; women ages 20-80+)	USDA (not published) as reported by Hathaway and Foard 1960
U.S.	1955	National survey by USDA; 4560 men and 5019 women; estimated values in indoor clothing without shoes	Mean heights and weights for adults (ages 20 to 70+)	USDA (not published) as reported by Hathaway and Foard 1960
U.S.	1960-1962	National health survey of adults; stratified random sample of adult civilian noninstitutionalized population (~90% white, ~10% nonwhite)	Mean height and weight by age and sex for American adults (ages 18-79)	Stoudt et al. 1965
U.S.	1920-1956 (plus some earlier information)	U.S. children in various locations	Summary of selected height-weight "standards" and original height-weight data for U.S. children (white boys and girls ages 2-18 years); annotated list of literature references; includes unpublished data	Hathaway 1957
U.S.	1836-1957	U.S. adults in various locations, including studies specifically of college students and military personnel	Summary of original height-weight data for U.S. adults (men and women age 16+ years); includes unpublished data	Hathaway and Foard 1960

Table 4. Summary of the origins of the Canadian population from 1931-1971 census data (data from Basavarajappa and Ram 2014, Series A125-163).

Origin	Number	Percentage
1931 Census		
British	5,381,071	51.86
French	2,927,990	28.22
Other European	1,825,252	17.59
Asiatic	84,548	0.81
Native Indian and Inuit (Eskimo)	128,890	1.24
Black	19,456	0.19
Other or not stated	9,579	0.09
Total	10,376,786	100
1941 Census		
British	5,715,904	49.67
French	3,483,038	30.27
Other European	2,043,926	17.76
Asiatic	74,064	0.64
Native Indian and Inuit (Eskimo)	125,521	1.09
Black	22,174	0.19
Other or not stated	42,028	0.37
Total	11,506,655	100
1951 Census		
British	6,709,685	47.89
French	4,319,167	30.83
Other European	2,553,722	18.23
Asiatic	72,827	0.52
Native Indian and Inuit (Eskimo)	165,607	1.18
Black	18,020	0.13
Not stated	170,401	1.22
Total	14,009,429	100
1961 Census		
British	7,996,669	43.85
French	5,540,346	30.38
Other European	4,116,849	22.57
Asiatic	121,753	0.67
Native Indian and Inuit (Eskimo)	220,121	1.21
Black	32,127	0.18
Not stated	210,382	1.15
Total	18,238,247	100

Table 4. (continued)

Origin	Number	Percentage
1971 Census		
British	9,624,115	44.62
French	6,180,120	28.65
Other European	4,959,680	23.00
Asiatic	285,540	1.32
Native Indian and Inuit (Eskimo)	312,760	1.45
Black	34,445	0.16
Not stated	171,645	0.80
Total	21,568,310	100

Table 5. Adult height in 1953 by birth cohort (based on Pett and Ogilvie 1957).

Age group in 1953	Years of birth[a]	Average height (cm)		Average height (in)	
		Male	Female	Male	Female
65+	≤1888	166.4	153.9	65.4	60.6
55-64	1889-1898	167.6	155.7	66.0	61.3
45-54	1899-1908	169.9	157.0	66.9	61.8
35-44	1909-1918	171.4	158.5	67.5	62.4
30-34	1919-1923	172.7	159.5	68.0	62.8
25-29	1924-1928	173.5	159.3	68.3	62.7
20-24	1929-1933	172.5	159.5	67.9	62.8
All adults (20+)	≤1888-1933	170.2	156.8	67.0	61.75

[a]Assumes subjects were grouped by age in 1953. Actual age at time of measuring would have depended on date of measurement and date of birth.

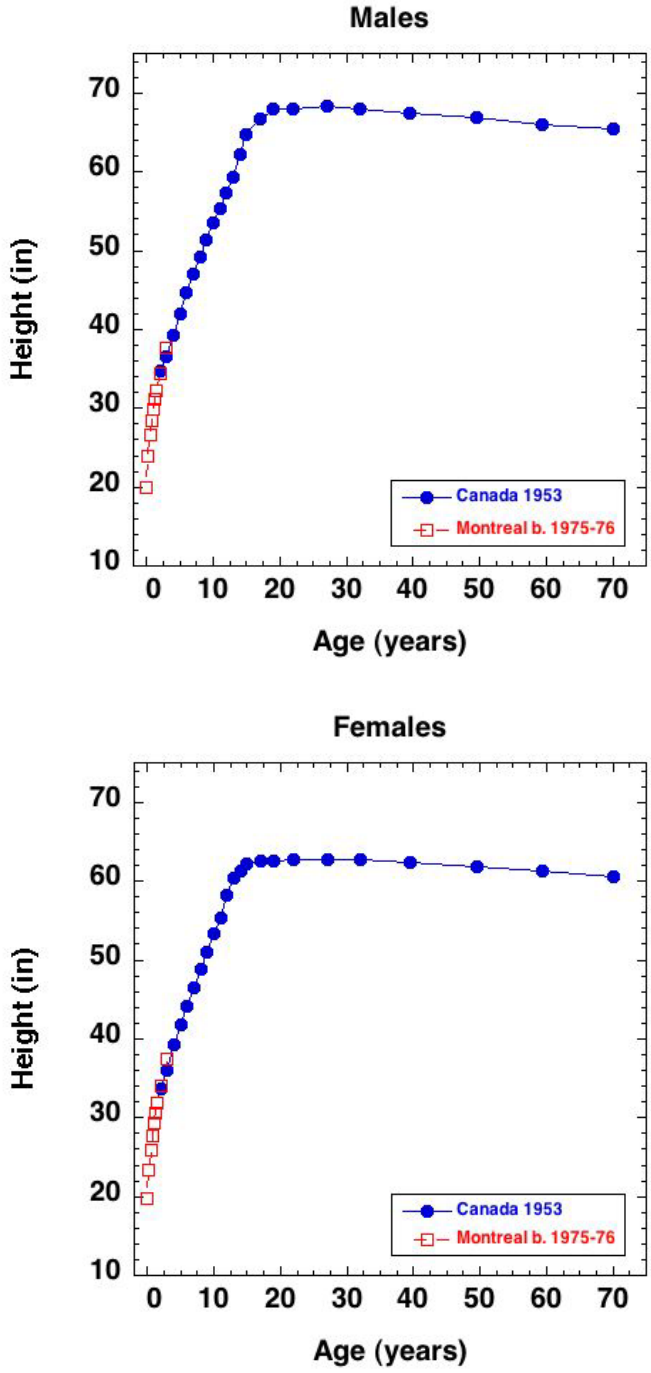

Fig. 1. Summary of mean heights (in inches) by sex and age group for the Canadian population. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957; ages 2 years and higher); Montreal children born 1975-1976 from Demirjian et al. (1983; ages 0-1.5 years).

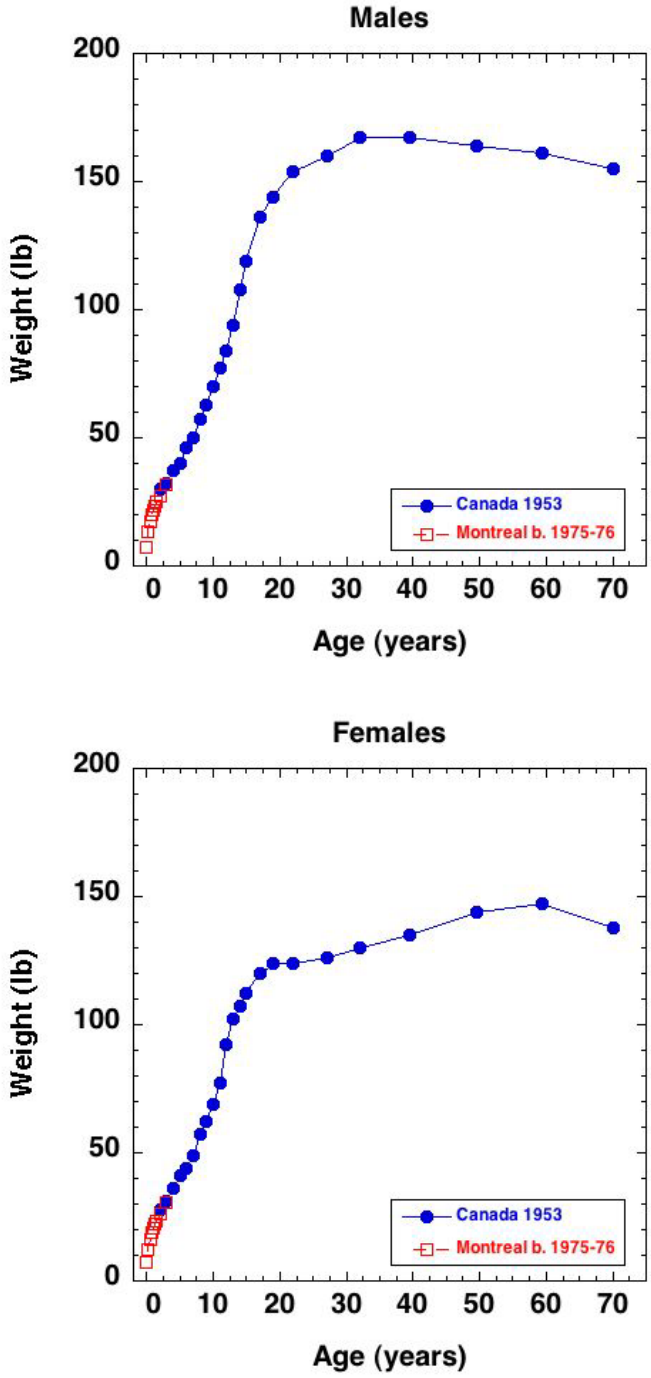

Fig. 2. Summary of mean weights (in pounds) by sex and age group for the Canadian population. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957; ages 2 years and higher); Montreal children born 1975-1976 from Demirjian et al. (1983; ages 0-1.5 years).

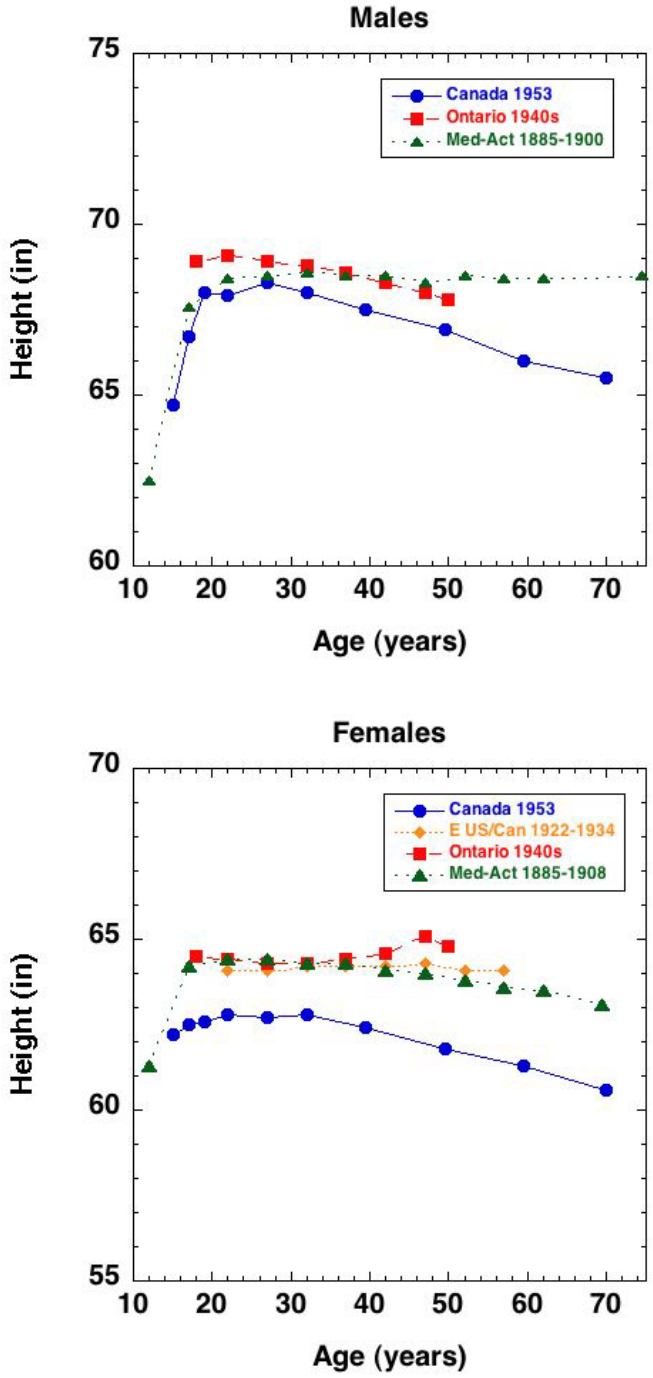

Fig. 3. Comparison of heights (in inches) for Canadian adults. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Ontario 1940s from McHenry et al. (1947); Eastern U.S. and Canada 1922-1934 from Dublin and Marks (1937); Medico-Actuarial data from ALIMD/ASA (1912). See text for details.

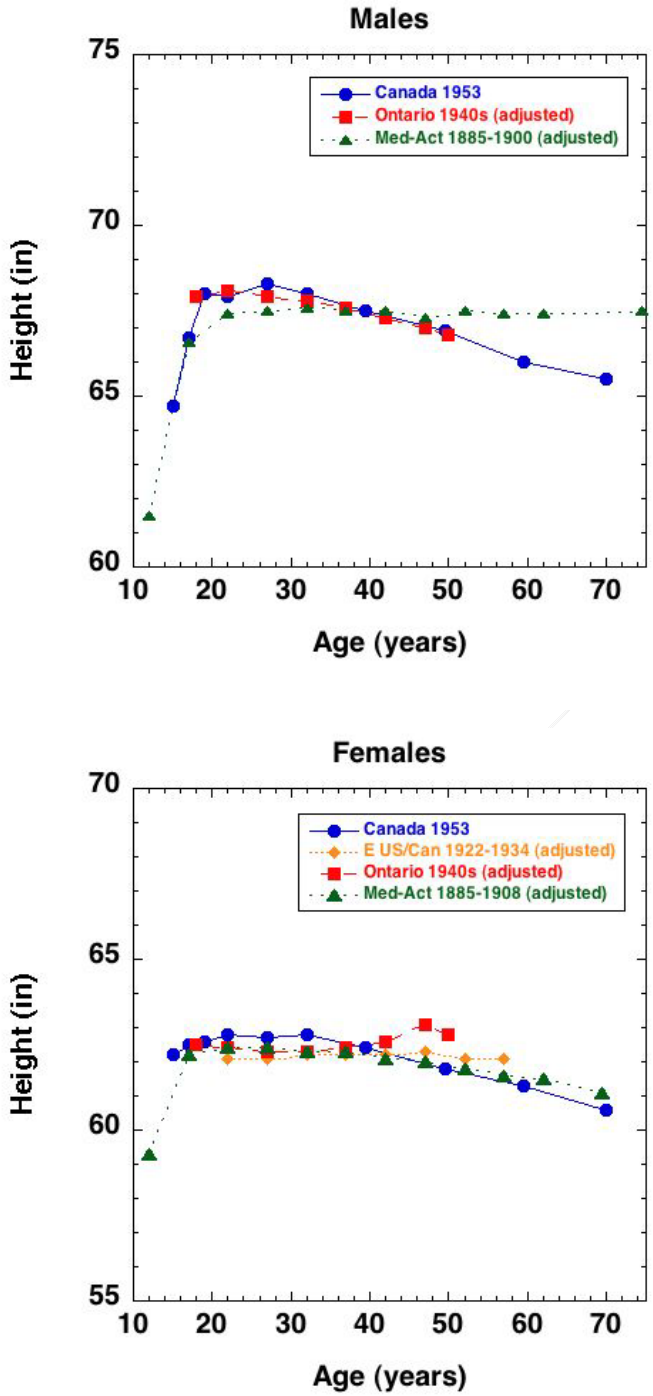

Fig. 4. Comparison of heights (in inches) for Canadian adults, with heights adjusted for shoes as indicated (heights reduced by 1 inch for men and 2 inches for women). Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957, not adjusted); Ontario 1940s from McHenry et al. (1947); Eastern U.S. and Canada 1922-1934 from Dublin and Marks (1937); Medico-Actuarial data from ALIMD/ASA (1912). See text for details.

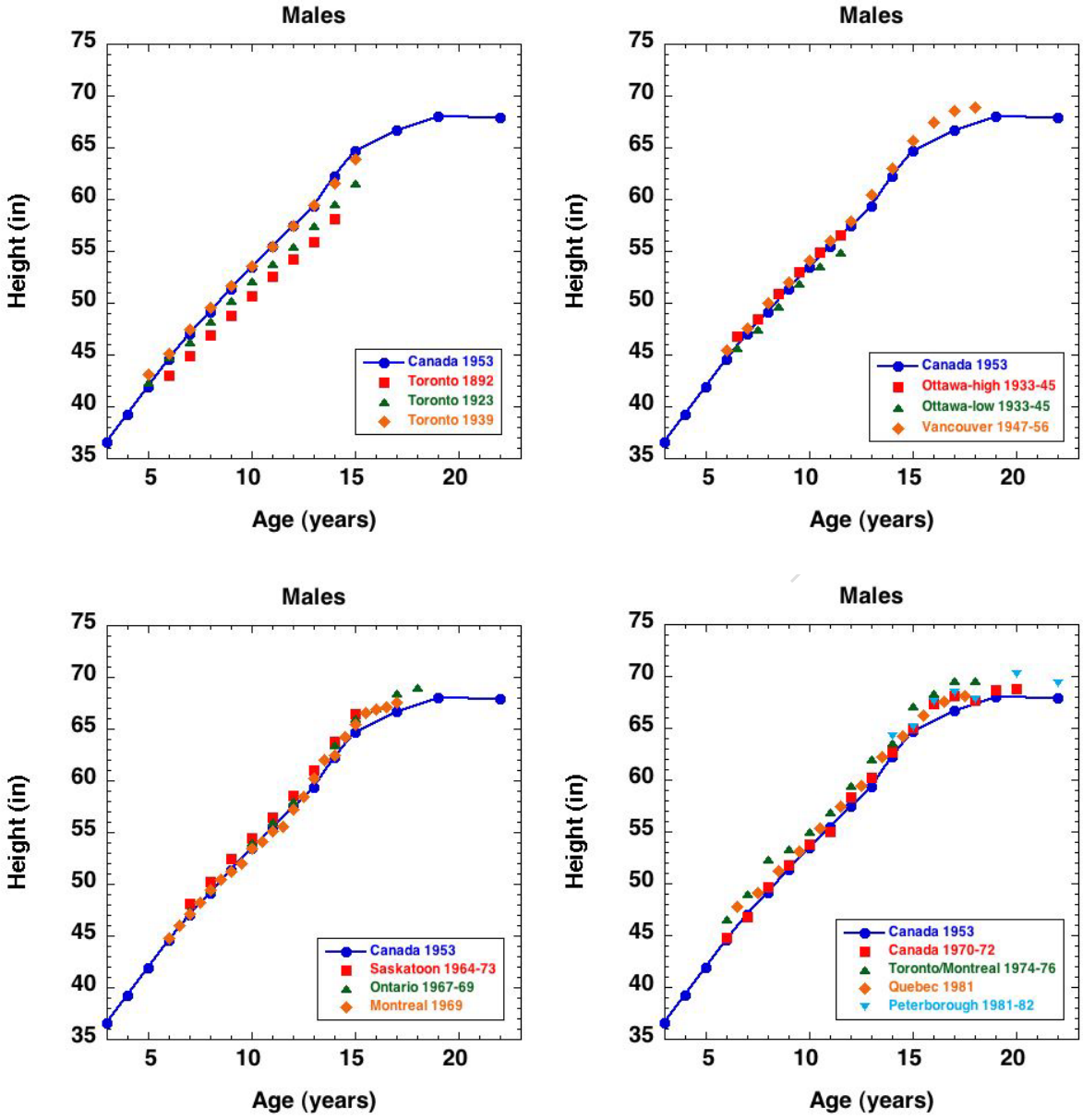

Fig. 5. Comparison of heights (in inches) by age for Canadian male children during various time periods. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Toronto 1892 from Meredith and Meredith (1944); Toronto 1923 and 1939 from Pett (1955b); Ottawa 1933-1945 from Hopkins (1947); Vancouver 1947-56 and Ontario (London) 1967-69 from Stennett and Cram (1969); Saskatoon 1964-73 from Demirjian et al. (1976); Montreal 1969 from Demirjian et al. (1972); Canada 1970-72 and Peterborough 1981-82 from Helmuth (1983); Toronto/Montreal 1974-76 from Farkas and Wood (1982); Quebec 1981 from Léger and Lambert (1983; 1985). For Ottawa, "high" and "low" represent above-average and below-average socioeconomic status, respectively. Points represent medians for Toronto 1892, Vancouver 1947-56, and Ontario 1967-69, and means for all other data sets (where known).

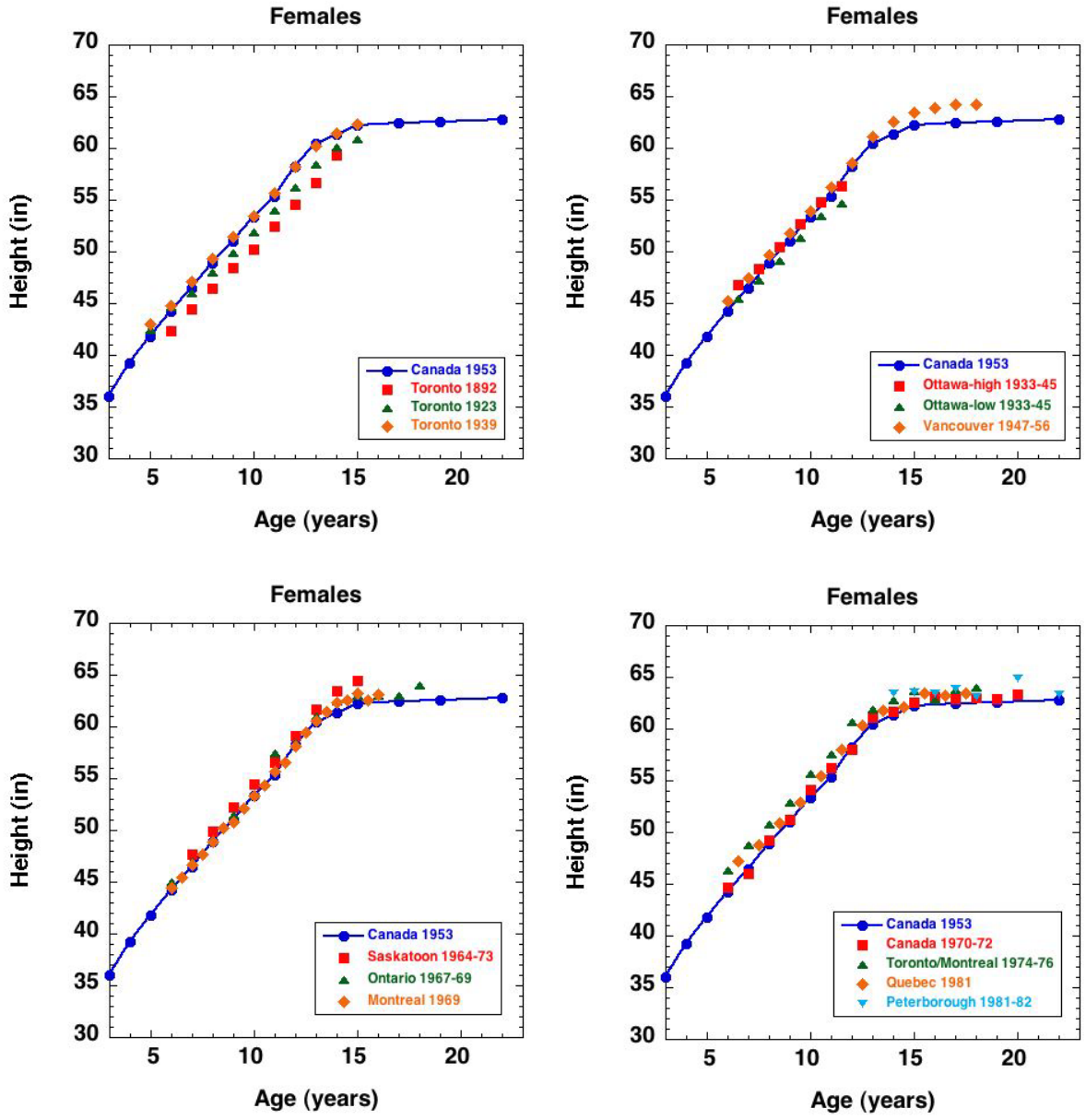

Fig. 6. Comparison of heights (in inches) by age for Canadian female children during various time periods. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Toronto 1892 from Meredith and Meredith (1944); Toronto 1923 and 1939 from Pett (1955b); Ottawa 1933-1945 from Hopkins (1947); Vancouver 1947-56 and Ontario (London) 1967-69 from Stennett and Cram (1969); Saskatoon 1964-73 from Demirjian et al. (1976); Montreal 1969 from Demirjian et al. (1972); Canada 1970-72 and Peterborough 1981-82 from Helmuth (1983); Toronto/Montreal 1974-76 from Farkas and Wood (1982); Quebec 1981 from Léger and Lambert (1985). For Ottawa, "high" and "low" represent above-average and below-average socioeconomic status, respectively. Points represent medians for Toronto 1892, Vancouver 1947-56, and Ontario 1967-69, and means for all other data sets (where known).

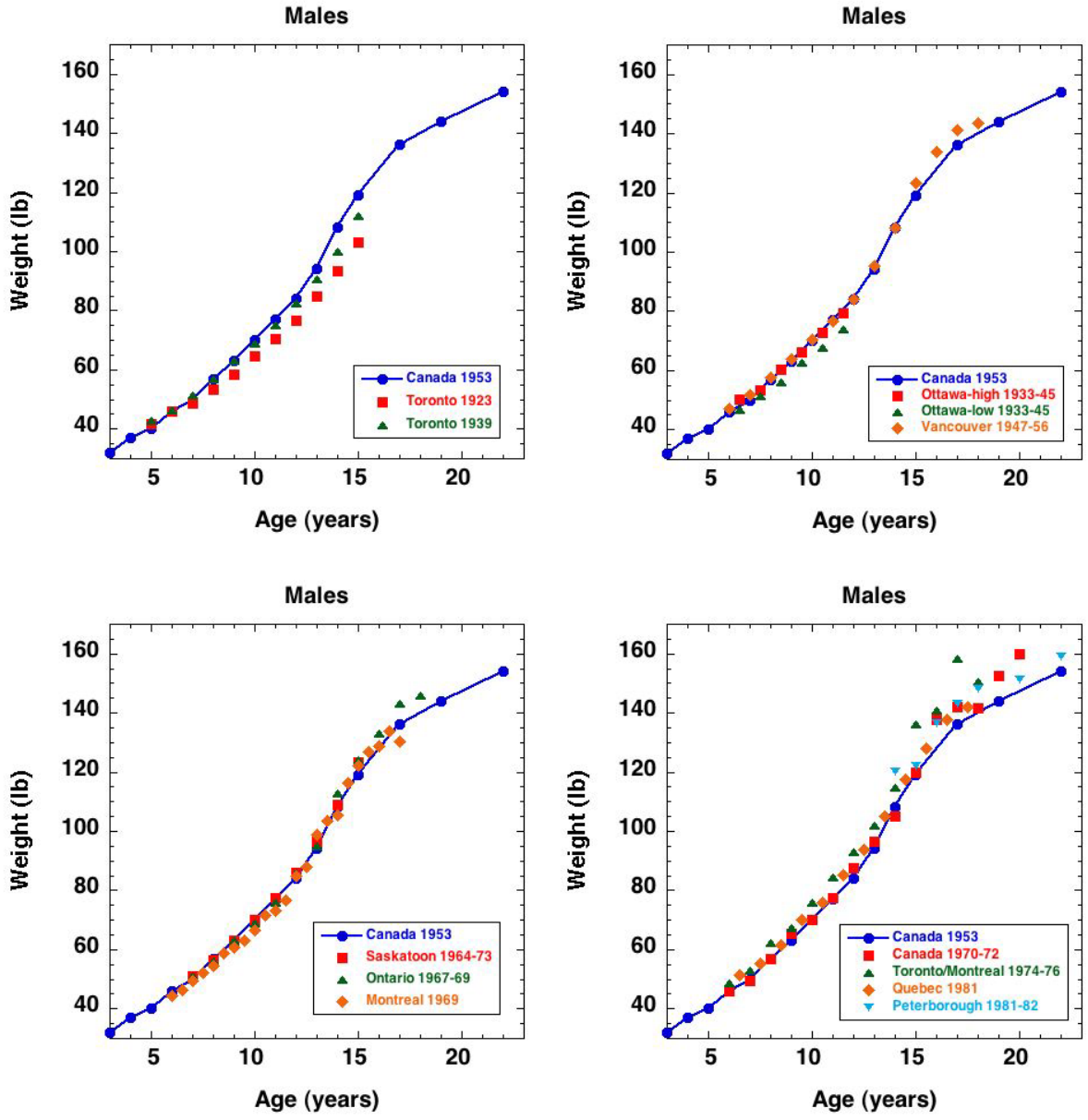

Fig. 7. Comparison of weights (in pounds) by age for Canadian male children during various time periods. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Toronto 1923 and 1939 from Pett (1955b); Ottawa 1933-1945 from Hopkins (1947); Vancouver 1947-56 and Ontario (London) 1967-69 from Stennett and Cram (1969); Saskatoon 1964-73 from Demirjian et al. (1976); Montreal 1969 from Demirjian et al. (1972); Canada 1970-72 and Peterborough 1981-82 from Helmuth (1983); Toronto/Montreal 1974-76 from Farkas and Wood (1982); Quebec 1981 from Léger and Lambert (1985). For Ottawa, "high" and "low" represent above-average and below-average socioeconomic status, respectively. Points represent medians for Toronto 1892, Vancouver 1947-56, and Ontario 1967-69, geometric means for Toronto/Montreal 1974-76, and means for all other data sets (where known).

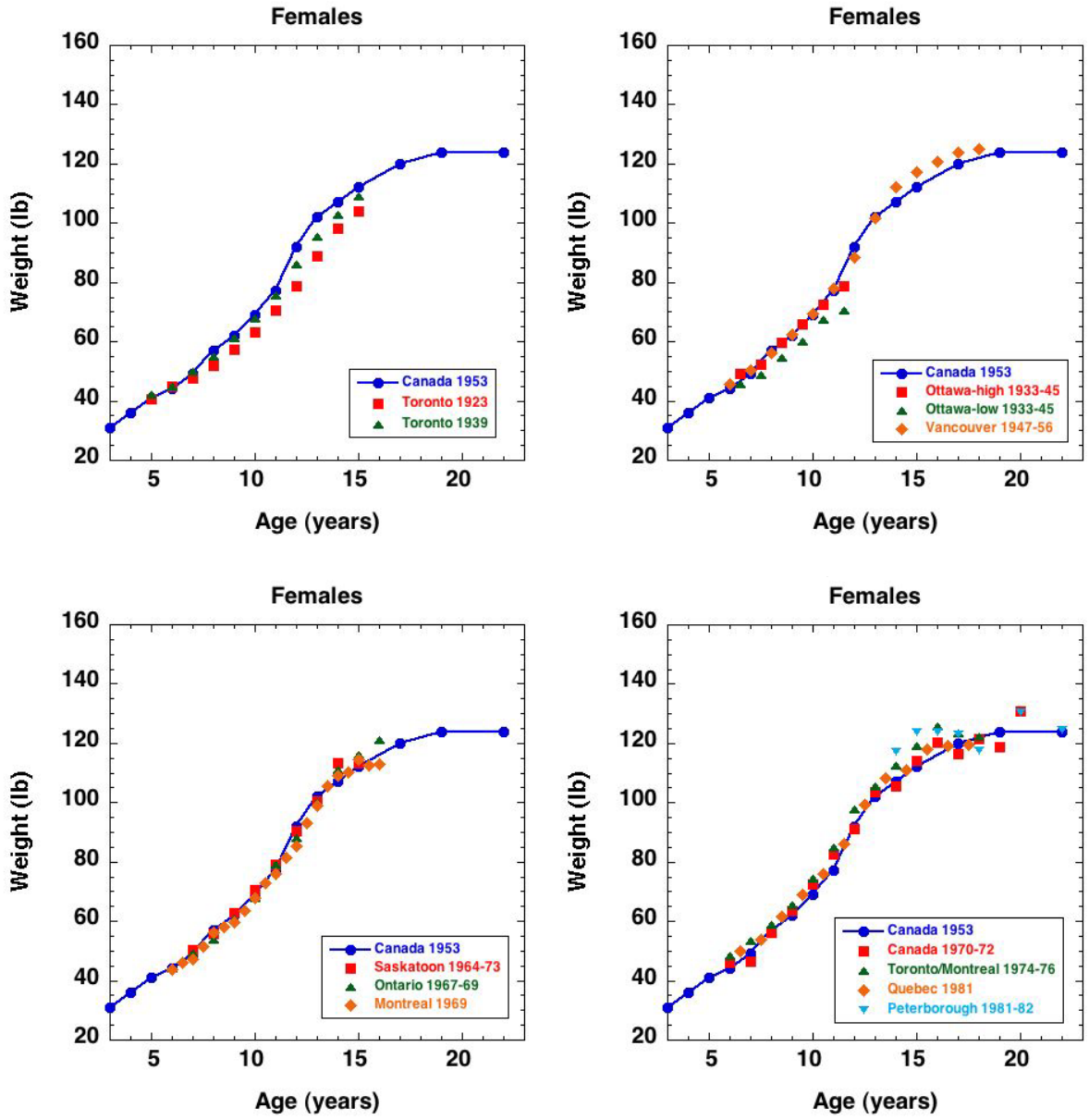

Fig. 8. Comparison of weights (in pounds) by age for Canadian female children during various time periods. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Toronto 1923 and 1939 from Pett (1955b); Ottawa 1933-1945 from Hopkins (1947); Vancouver 1947-56 and Ontario (London) 1967-69 from Stennett and Cram (1969); Saskatoon 1964-73 from Demirjian et al. (1976); Montreal 1969 from Demirjian et al. (1972); Canada 1970-72 and Peterborough 1981-82 from Helmuth (1983); Toronto/Montreal 1974-76 from Farkas and Wood (1982); Quebec 1981 from Léger and Lambert (1985). For Ottawa, "high" and "low" represent above-average and below-average socioeconomic status, respectively. Points represent medians for Toronto 1892, Vancouver 1947-56, and Ontario 1967-69, geometric means for Toronto/Montreal 1974-76, and means for all other data sets (where known).

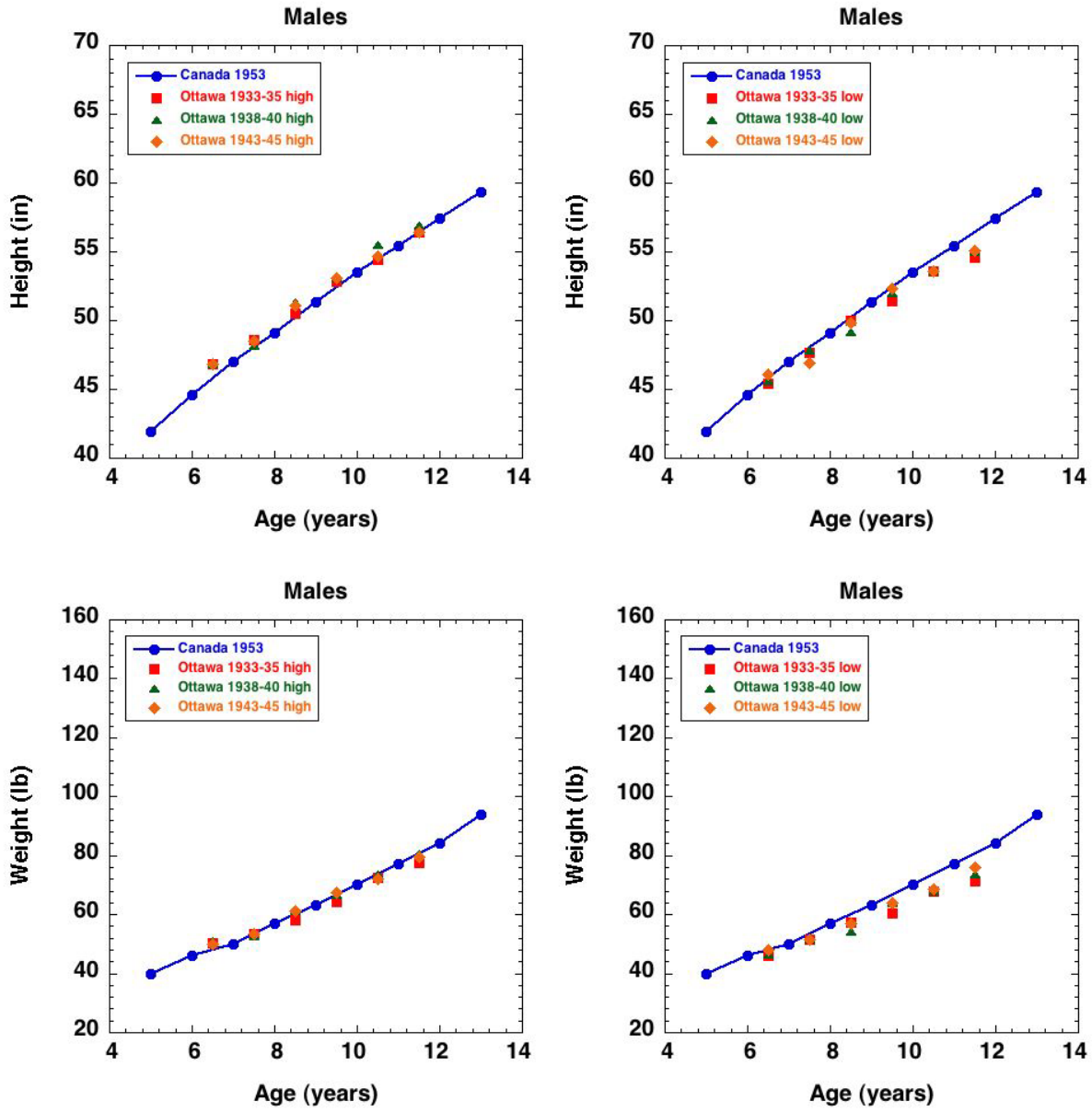

Fig. 9. Comparison of heights (in inches, top) and weights (in pounds, bottom) by age for Canadian male children in the 1953 survey and various time periods between 1933 and 1945 in Ottawa. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Ottawa 1933-1945 from Hopkins (1947). For Ottawa, "high" and "low" represent above-average and below-average socioeconomic status, respectively. Points represent means.

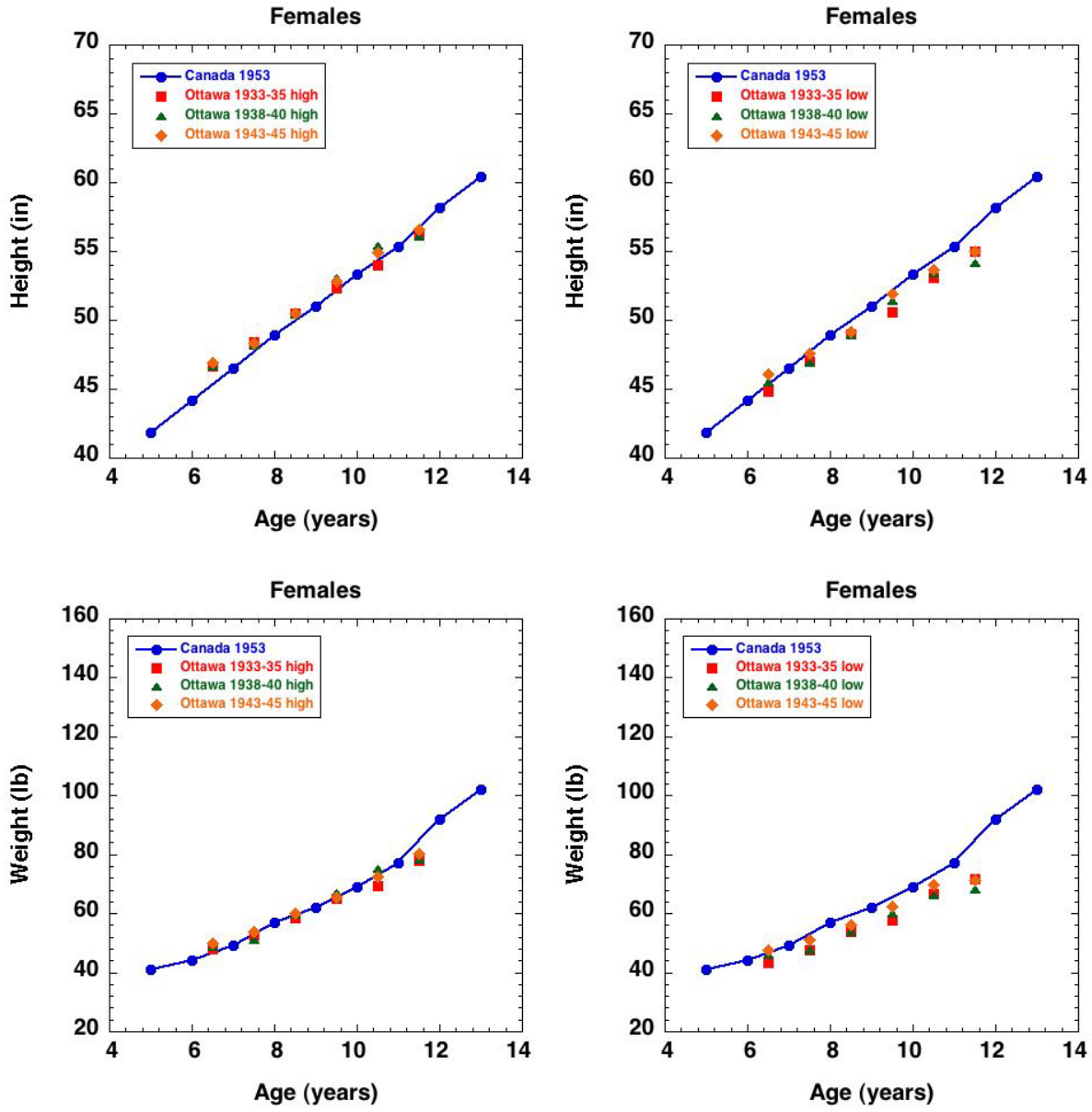

Fig. 10. Comparison of heights (in inches, top) and weights (in pounds, bottom) by age for Canadian female children in the 1953 survey and various time periods between 1933 and 1945 in Ottawa. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Ottawa 1933-1945 from Hopkins (1947). For Ottawa, "high" and "low" represent above-average and below-average socioeconomic status, respectively. Points represent means.

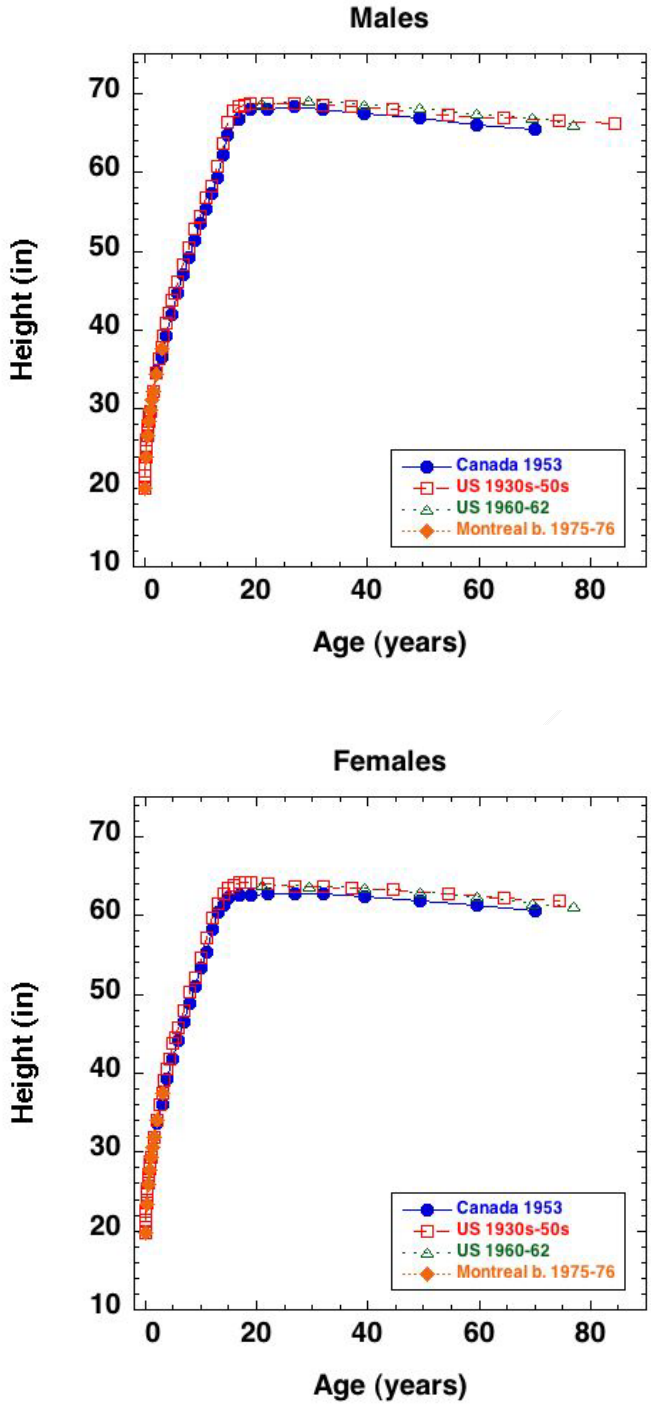

Fig. 11. Comparison of heights (in inches) for all age groups for Canadian and U.S. populations. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957; ages 2 years and higher); Montreal children born 1975-1976 from Demirjian et al. (1983; ages 0-1.5 years); U.S. 1930s-1950s from Stoudt et al. (1960; all ages); U.S. 1960-1962 from Stoudt et al. (1965; ages 18 years and higher).

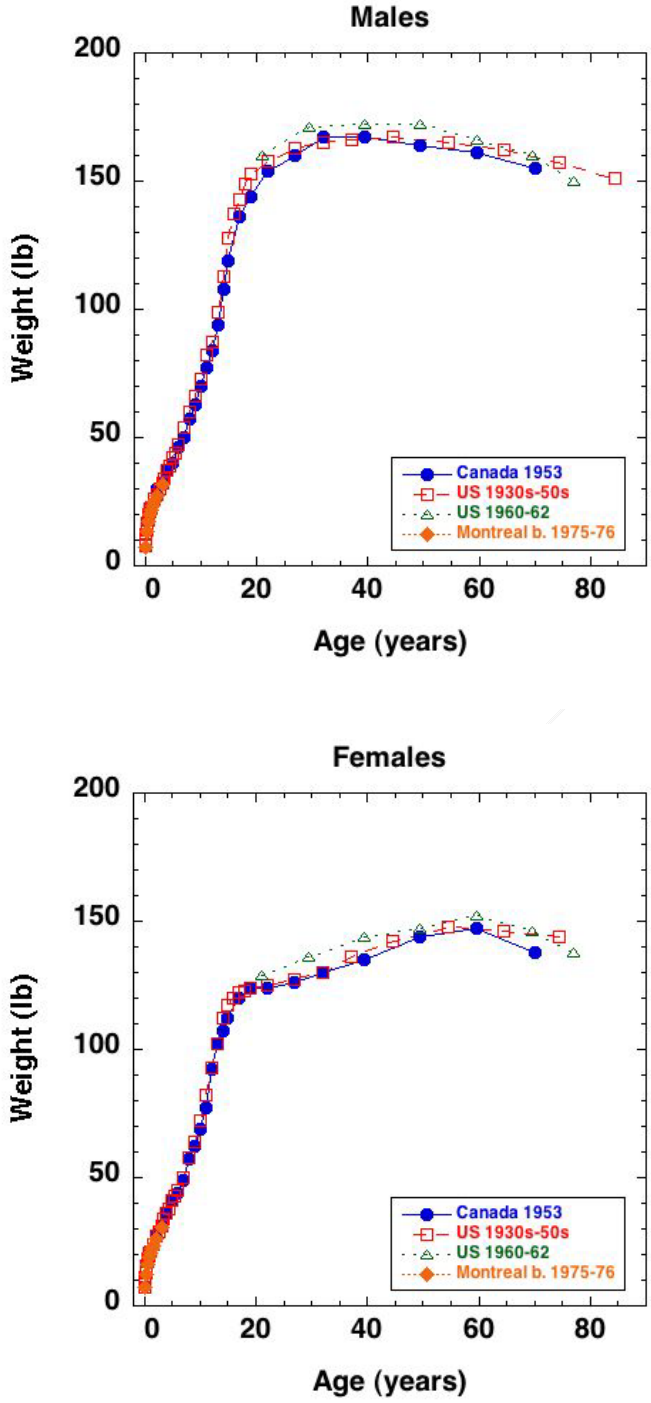

Fig. 12. Comparison of weights (in pounds) for all age groups for Canadian and U.S. populations. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957; ages 2 years and higher); Montreal children born 1975-1976 from Demirjian et al. (1983; ages 0-1.5 years); U.S. 1930s-1950s from Stoudt et al. (1960; all ages); U.S. 1960-1962 from Stoudt et al. (1965; ages 18 years and higher).

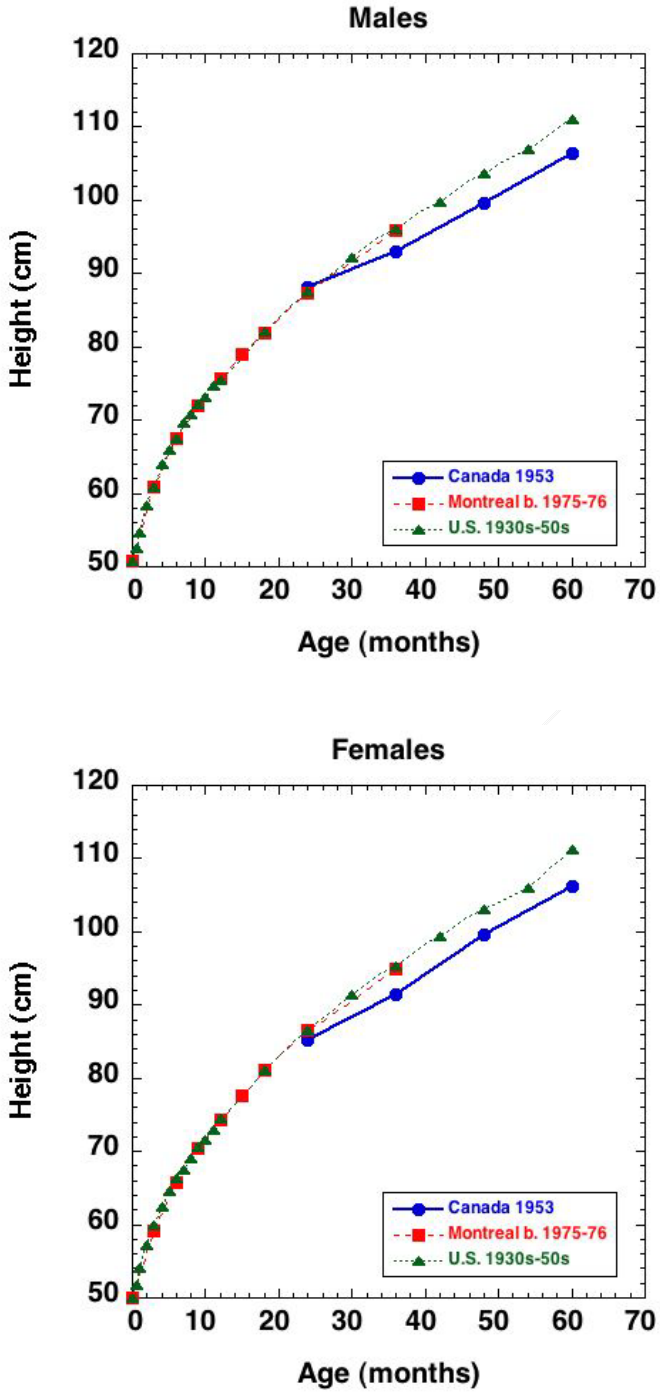

Fig. 13. Comparison of heights (in centimeters) by age for Canadian and U.S. infants and young children. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Montreal children born 1975-1976 from Demirjian et al. (1983); U.S. 1930s-1950s from Stoudt et al. (1960).

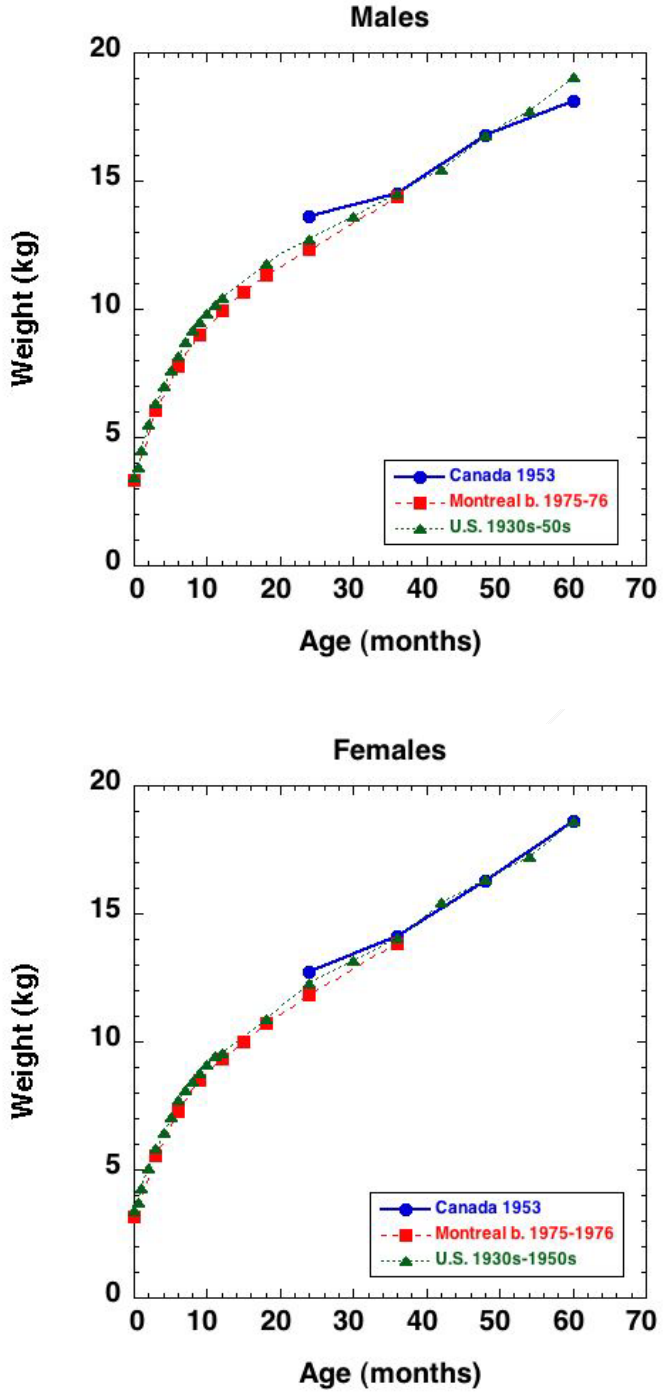

Fig. 14. Comparison of weights (in kilograms) by age for Canadian and U.S. infants and young children. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Montreal children born 1975-1976 from Demirjian et al. (1983); U.S. 1930s-1950s from Stoudt et al. (1960).

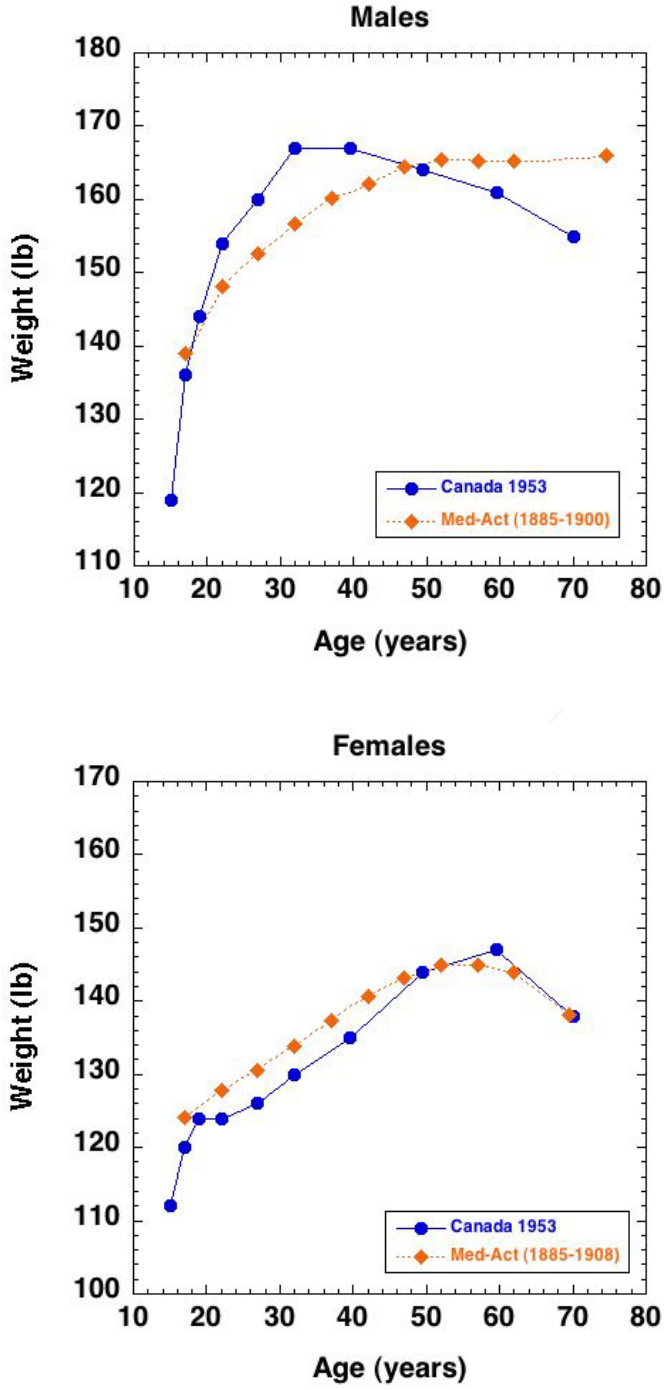

Fig. 15. Comparison of weights (in pounds) for persons 15 years and higher for Canadian and U.S. populations. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Medico-Actuarial data from ALIMD/ASA (1912).

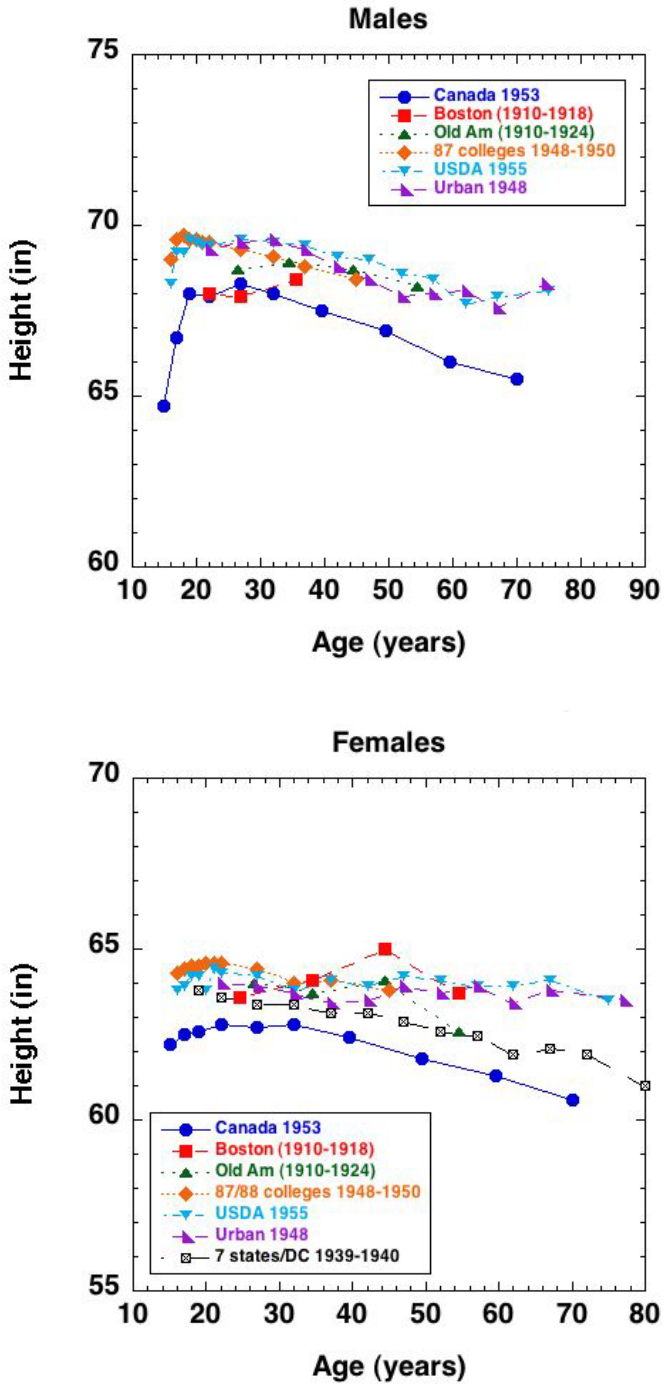

Fig. 16. Comparison of heights (in inches) for persons 15 years and higher for Canadian and several U.S. populations. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Boston 1910-1918 from Harris (1919, as reported by Hathaway and Foard 1960); Old Americans 1910-1924 from Hrdlicka (1925, as reported by Hathaway and Foard 1960); 87/88 colleges 1948-1950 from ACHA (as reported by Hathaway and Foard 1960); Urban 1948 and USDA 1955 from Hathaway and Foard 1960); 7 states plus DC from O'Brien and Shelton 1941.

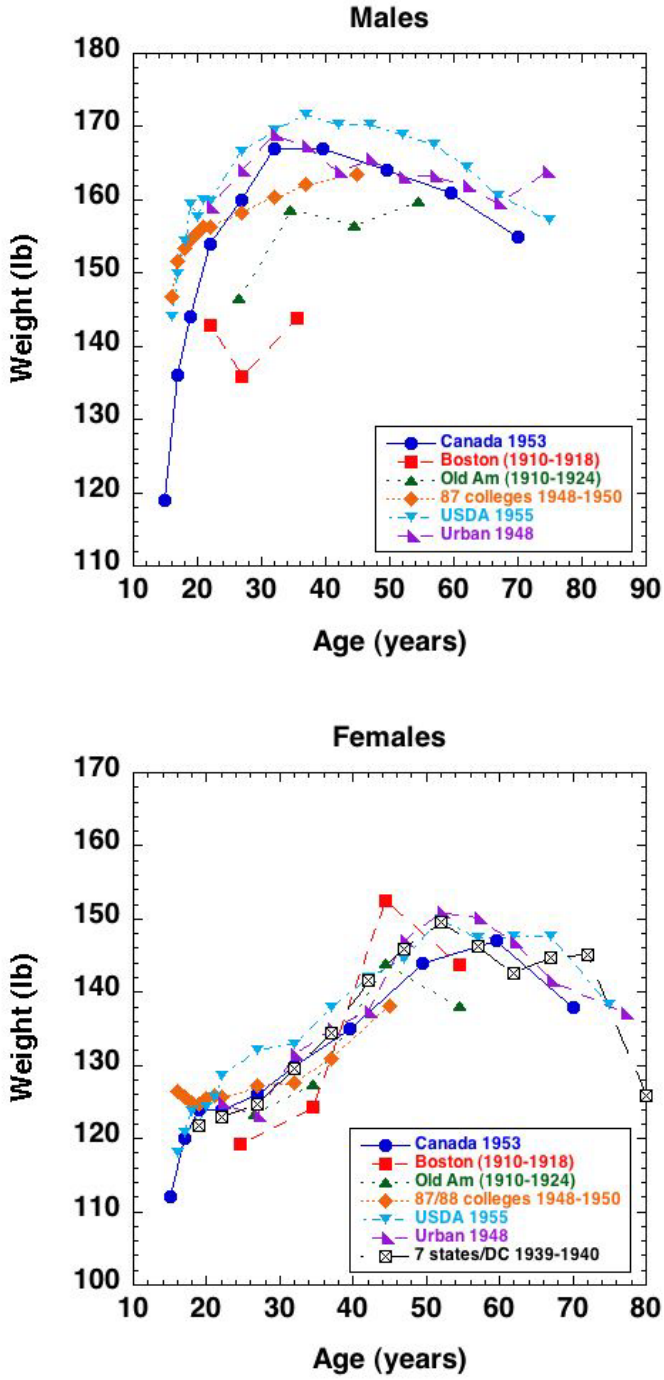

Fig. 17. Comparison of weights (in pounds) for persons 15 years and higher for Canadian and U.S. populations. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Boston 1910-1918 from Harris (1919, as reported by Hathaway and Foard 1960); Old Americans 1910-1924 from Hrdlicka (1925, as reported by Hathaway and Foard 1960); 87/88 colleges 1948-1950 from ACHA (as reported by Hathaway and Foard 1960); Urban 1948 and USDA 1955 from Hathaway and Foard 1960); 7 states plus DC from O'Brien and Shelton 1941.

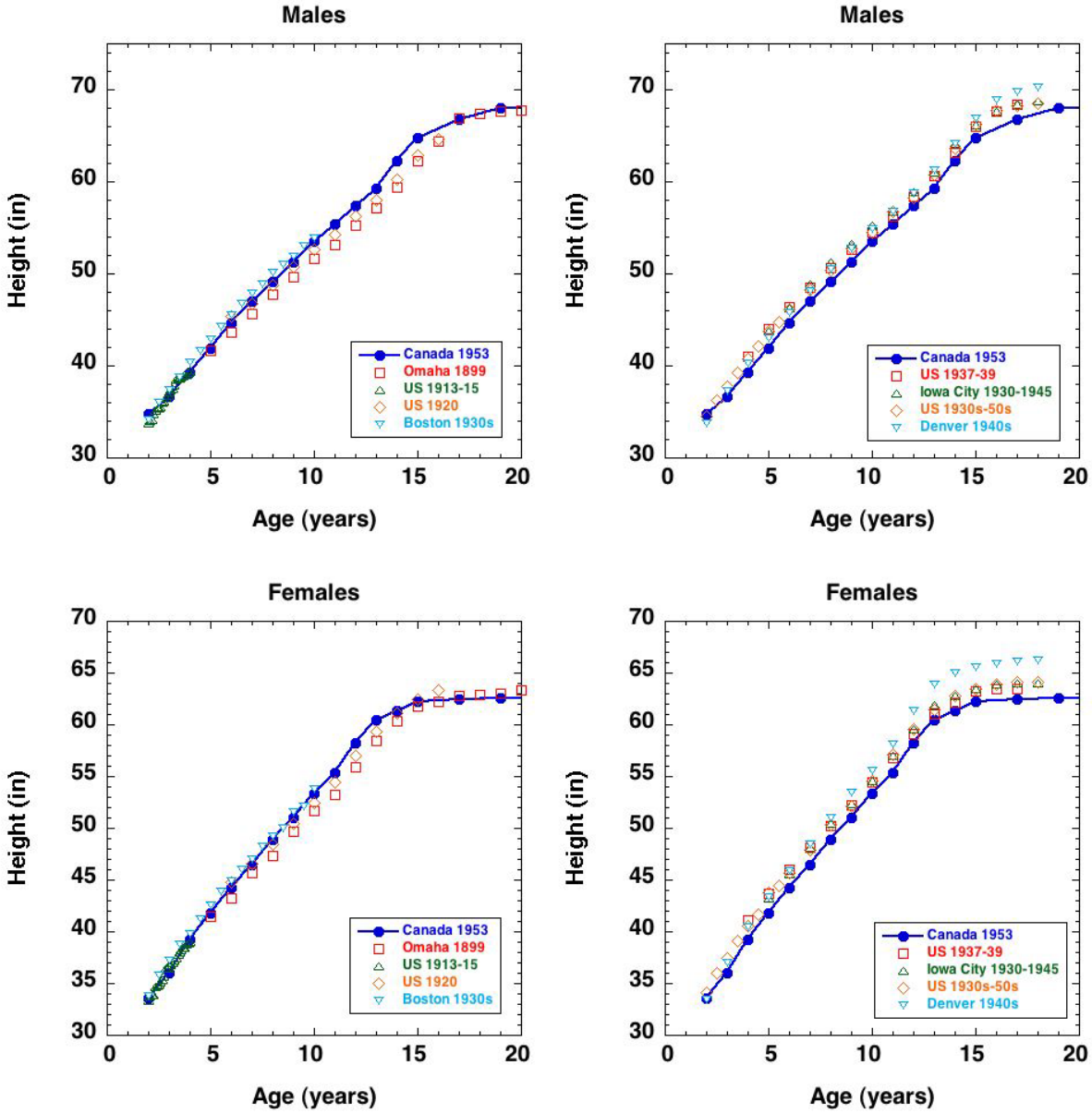

Fig. 18. Comparison of heights (in inches) by age for Canadian and U.S. children. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Omaha 1899 from Hastings (1902); U.S. 1913-1915 from Crum (1916); U.S. 1920 from Clark et al. (1922); Boston 1930s from Vickers and Stuart (1943); U.S. 1937-1939 from O'Brien et al. (1941); Iowa City 1930-1945 from Stuart and Meredith (1946); U.S. 1930s-1950s from Stoudt et al. (1960); Denver 1940s from Boyd (1952, as reported by Hathaway 1957).

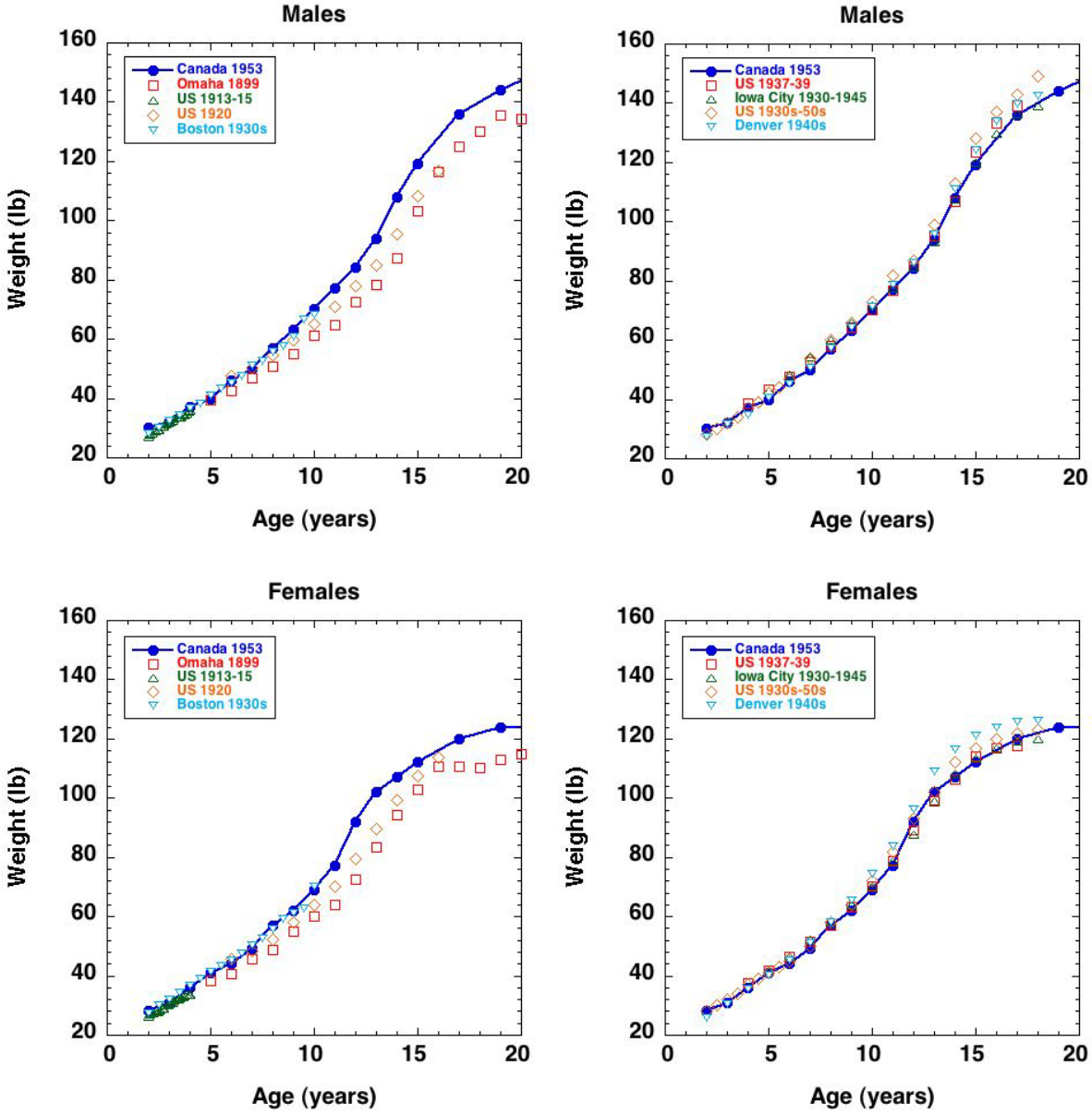

Fig. 19. Comparison of weights (in pounds) by age for Canadian and U.S. children. Data sources: Canada 1953 from Pett and Ogilvie (1956; 1957); Omaha 1899 from Hastings (1902); U.S. 1913-1915 from Crum (1916); U.S. 1920 from Clark et al. (1922); Boston 1930s from Vickers and Stuart (1943); U.S. 1937-1939 from O'Brien et al. (1941); Iowa City 1930-1945 from Stuart and Meredith (1946); U.S. 1930s-1950s from Stoudt et al. (1960); Denver 1940s from Boyd (1952, as reported by Hathaway 1957).

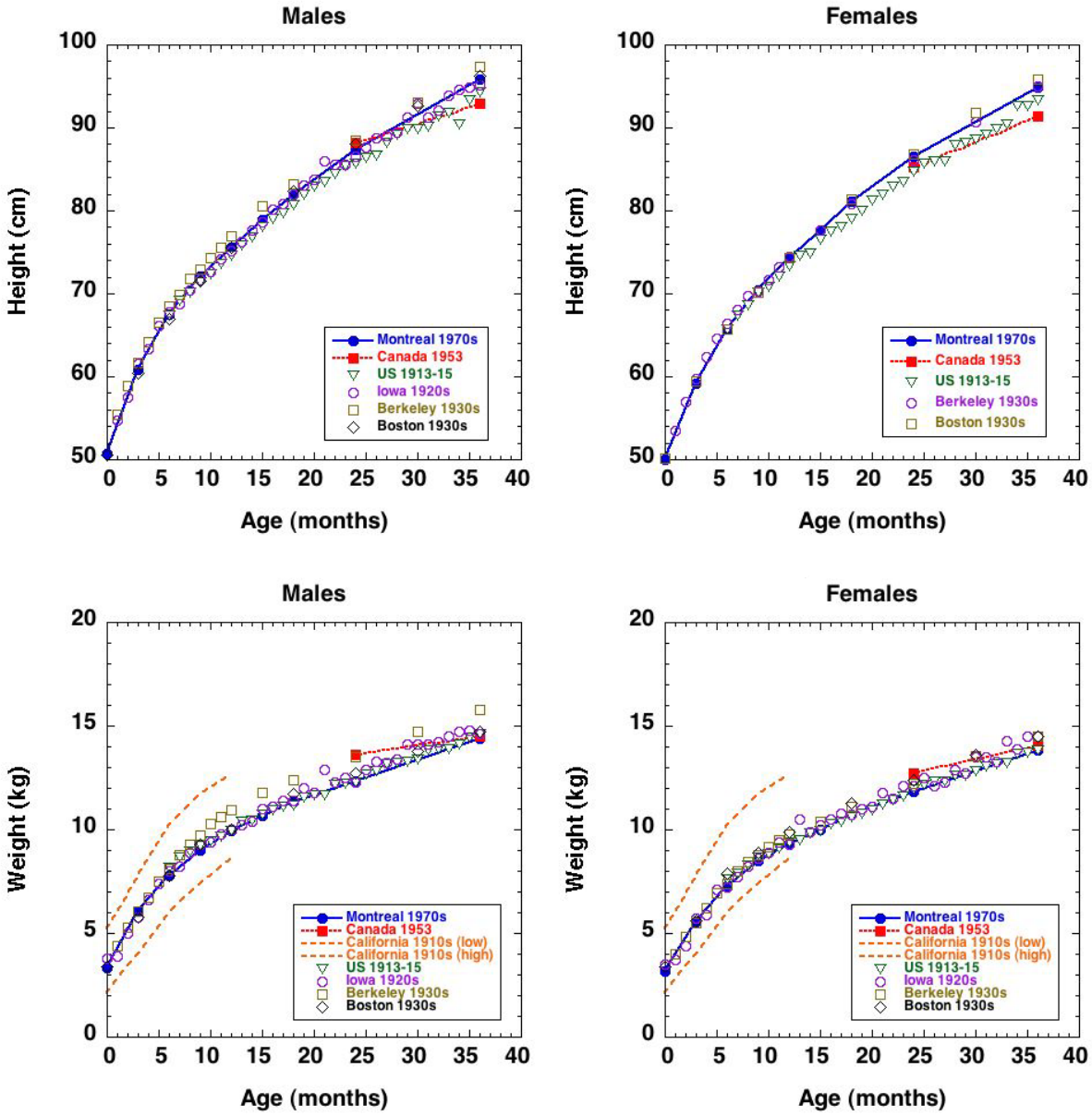

Fig. 20. Comparison of heights (top) and weights (bottom) of Canadian and U.S. infants and young children (to age 36 months). Data sources: Montreal 1970s from Demirjian et al. (1983); Canada 1953 from Pett and Ogilvie (1956; 1957); California 1910s (range) from Faber (1920); U.S. 1913-1915 from Crum (1916); Iowa 1920s from Iowa Child Welfare Research Station (1931); Berkeley 1930s from Bayley and Davis (1935); Boston 1930s from Vickers and Stuart (1943). Points represent means except for California, where the dashed lines indicate the observed range.

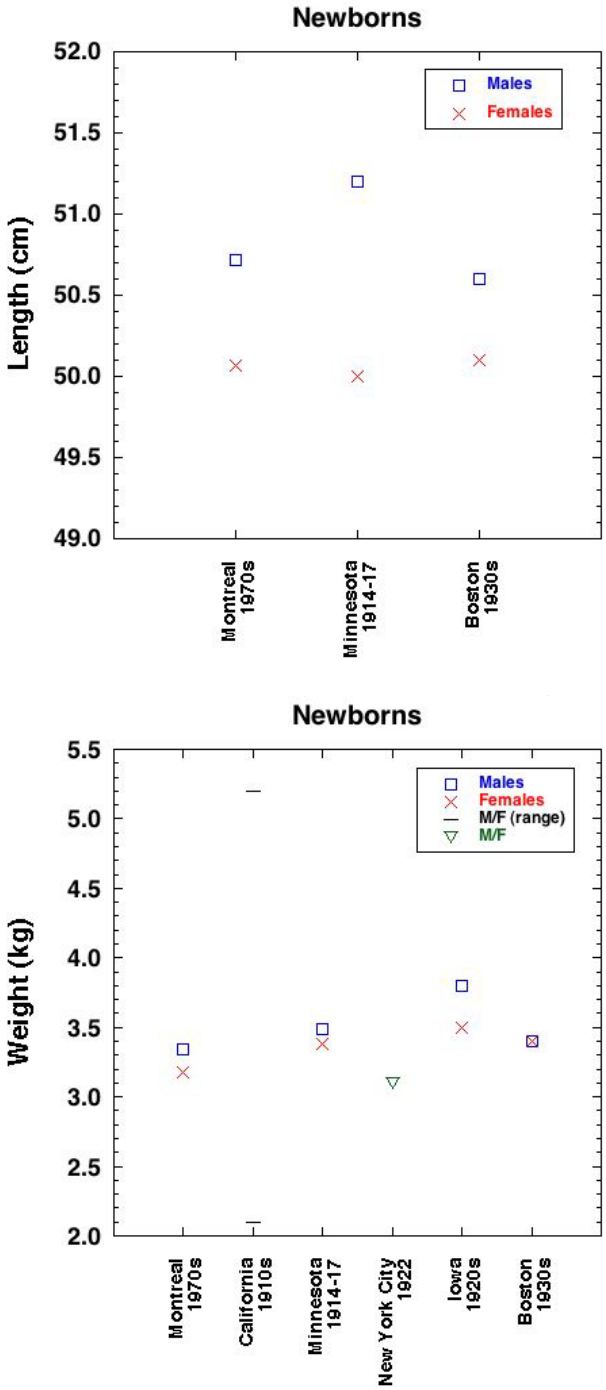

Fig. 21. Comparison of lengths (top) and weights (bottom) of Canadian and U.S. newborn infants. Data sources: Montreal 1970s from Demirjian et al. (1983); California 1910s from Faber (1920); Minnesota 1914-1917 from Taylor (1919); New York City 1922 from Ratner (as reported by Davenport 1923); Iowa 1920s from Iowa Child Welfare Research Station (1931); Boston 1930s from Vickers and Stuart (1943). Data for California and New York City include both males and females. Points represent means except for California, where they indicate the range.

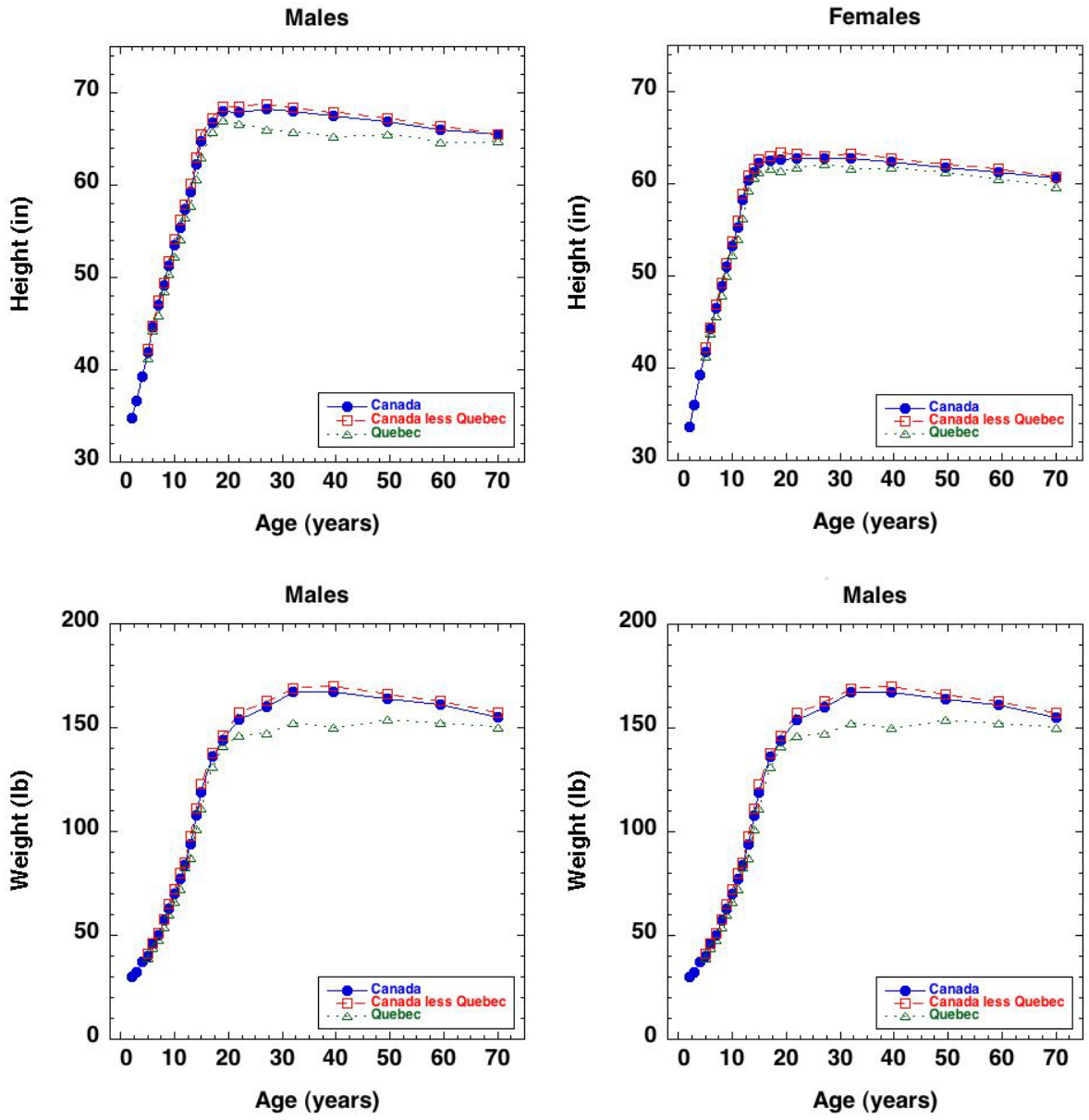

Fig. 22. Comparison of heights (top) and weights (bottom) by age of Canadians: all of Canada, Canada less Quebec, and Quebec. Data source: Pett and Ogilvie (1957). Points represent means.

III. Decreased body weight among tuberculosis patients

Considerable information exists indicating that tuberculosis (consumption) patients routinely have had lower body weights than the corresponding general population. With respect to the Canadian Fluoroscopy Study, the concern is that below-average body weights among tuberculosis patients might require a different set of dose factors than for the average population. This paper summarizes available information on reported body weights of tuberculosis patients and the percentage differences from normal or control body weights.

III.1. Adult tuberculosis patients

Table 6 summarizes several studies reporting heights and weights for groups of adult tuberculosis patients, including comparisons with relevant control or normal groups, or with former "healthy" weights for the same individuals. These studies are based on U.S. and English populations, which would have been reasonably similar to the Canadian population of the same time period (first half of the 20th century) in terms of race, ethnicity, lifestyle, and socioeconomic status. No corresponding Canadian studies were located.

- Weber and Kirkness (1909) reported average heights and weights on admission to an English hospital of 500 male and 100 female patients, at least 25 years old, with active tuberculosis (sputum positive) and 100 male patients, at least 29 years old, considered to have had "old pulmonary tuberculosis" (sputum negative). For patients with active tuberculosis, mean weights on admission were 12% (males) and 11% (females) below the corresponding mean "former ordinary weights" of the same individuals. For males with old tuberculosis (sputum negative), the mean weights on admission were 9% below the mean former ordinary weights. The former ordinary weights were reasonably close to the reference weights (147 lb for males, 119 lb for females; reported as 10 1/2 stones for males and 8 1/2 stones for females). With respect to former ordinary weights, 40-54% of patients were above the reference weights; for weights on admission, only 10-20% of patients were above the reference weights.
- Garvin et al. (1918a; 1918b), in a study of lung volumes, reported heights and weights for 31 male patients and 20 female patients in New York, ages 16-42. Reported weights included the weight at the time of the study, the lowest and highest recorded weights for the patient, the patient's idea of normal weight, and a theoretical normal weight (apparently accounting for build as well as height). The dates of the lowest and highest weights were reported (number of months or years before the present), along with the time since onset of the disease and the duration of treatment. Recorded lowest weights were usually around the time of the start of treatment, and highest weights were usually after some amount of treatment (often coinciding with the "present" weight) or well before the reported onset of the disease. For the present purpose, the lowest weight for each individual was compared with the highest weight for the same individual. For males, the mean percentage change in individual body weight was -14.8% (range, -37% to -6%; lowest weights compared with highest weights). For females, the mean percentage change in individual body weight was -16.5% (range, -23% to -6%). A third study by the same group (Lundsgaard and Van Slyke 1918) reported heights and body weights of a convenience sample of normal individuals (11 males and 7 females); these

cannot be considered matched controls. Comparing the mean "lowest" weights for the patients to the mean weights of the normal groups gave results of -13% for males and -19% for females.

- Love (1929) reported mean heights and body weights for male U.S. Army recruits (ages 21-30, mean age 24.7; men sent to military camp between September 1, 1917, and April 1, 1918) found to have tuberculosis on entry into service and for the entire cohort of recruits (4,653 cases of tuberculosis among 868,445 men sent to camp). These were considered to be early or incipient cases, the more advanced cases presumably having been rejected before being sent to camp. The mean height was 0.8% higher for the cases, while the mean weight was 7% lower for the cases. The percentage difference ranged from -6% for a height of 60 inches to -10% for a height of 78 inches.
- Karpinos (1958) reported mean heights and weights of U.S. Selective Service registrants (ages 18-37) between January 1943 and January 1944 (including both those eventually inducted and those eventually disqualified). Registrants disqualified for tuberculosis averaged 3.8 (whites) or 4.4 (blacks) pounds below the averages for all registrants, or about 2.5% (whites) or 3% (blacks) lower in body weight than the averages for all registrants. Institutionalized tuberculosis cases were not included among the registrants.

Additional studies of other populations (e.g., Indians, African blacks) are summarized in Table 7 for comparison purposes; however, these populations are less similar to the Canadian population in terms of race, ethnicity, lifestyle, and socioeconomic status and were surveyed after the period of interest for the present study (1970s or later). Some of these populations may also have had a greater degree of underweight apart from any effect of tuberculosis. Mean body weights of patient groups ranged from 4 to 40% below the corresponding control patients. It should be noted that some of the studies summarized in Table 7 measured their tuberculosis patients sometime after the start of treatment and thus the measurements might not coincide with the maximum weight loss. For example, Harries et al. (1988) reported weight gains in most patients after 4 and 8 weeks of treatment. In addition to the studies in Table 7, Van Lettow et al. (2004) reported decreased body mass index (BMI, kg/m^2) with increasing severity of tuberculosis, Villamor et al. (2006) reported lower BMI among tuberculosis patients than among the general population of the same city (based on Bovet et al. 2002), and Ladefoged et al. (2011), in Greenland, reported lower median BMI for tuberculosis patients than for matched controls.

III.2. Child tuberculosis patients

Very little information is available for weights of pediatric tuberculosis patients compared with healthy children, for any population during any time period. The primary paper we use in the present study actually states that data on the growth of tuberculous children were relatively scarce (Spaulding 1933).

Spaulding (1933) reported average heights and weights, by age and sex, for approximately 600 children (ages 5 to 16 years) admitted to two treatment facilities in Minnesota (Minneapolis) between 1922 and 1932. Measurements were made at entrance. More than 80% of the children were from an institution that appears to have been an outpatient facility. Children were largely from lower socioeconomic groups, with many having experienced broken homes or loss of a parent. Comparisons of height and weight were made with other national or local samples of

children (most of them published in the 1920s), but these comparison groups were not considered to be a satisfactory control for the study. Most of the age groups included 15-40+ children, but the youngest and oldest groups (ages 5 and 15) each included fewer than 10 children. In general, the children with tuberculosis appeared to be taller and lighter for age than the comparison groups.

These data are probably the best available, although they are not entirely satisfactory, primarily due to the absence of adequate controls and the lack of information as to how the population from which the patients came compared with the general population of the U.S. at that time. Figures 23-25 provide comparisons of height, weight, and body mass index (BMI[4]) for the Minnesota patients, the estimated U.S. population, and the measured Canadian population. Note that the Canadian population is consistently lower than the U.S. population in height, generally lower in weight (for most age groups), but fairly similar in BMI (for most age groups, especially for boys). In contrast, the average heights for age among the patients (especially boys) are close to the estimated heights for age for the general U.S. population (Stoudt et al. 1960) and generally above the heights for the Canadians, while the average weights for age among the patients are substantially lower than those estimated for either the general U.S. population or the Canadian population after about age 6 (boys) or 7 (girls). BMI for the patients is substantially lower than for either general population, except at the youngest ages.

Figure 26 shows the weight for height (kg/cm), by age, for the U.S. general population (estimates from Stoudt et al. 1960) and the Minnesota tuberculosis patients (Spaulding 1933). Except for the youngest ages, weight for height in the general U.S. population is clearly greater than among the patients. Table 8 shows the weight for height, by age, obtained for the Minnesota patients, the U.S. general population, and the Canadian general population. The calculated percentage difference in weight for height between the Minnesota patients and the U.S. general population averaged -9.4% for boys (ages 7-14) and -10.1 for girls (ages 8-14). Below ages 7 (boys) or 8 (girls) the percentage difference was small. The weight for age data from Spaulding (1933) show small standard deviations (3-5 lb) at these ages, but much larger standard deviations for older ages (10-13 lb for boys and 12-15 lb for girls). This observation is consistent with a smaller variability in size at younger ages. For ages 5 and 15, the sample sizes were small (less than 10 individuals each).

Topper and Rosenberg (1936) also reported heights and weights of children with pulmonary tuberculosis (about 250 children, ages 5-16 years, at a hospital in Staten Island, New York); this information was reported incidentally to a study of basal metabolic rates, with information obtained approximately 1933-1935. These measurements probably were not necessarily made at entrance, and time since start of treatment is not provided. No controls or comparisons were provided (the main interest of the study was increased metabolism compared with "normal"). Many of the age groups included very small samples (fewer than 10 individuals). Related papers (Topper and Shore 1939; Topper 1939; Topper and Rubin 1939; 1940) have similar limitations for the present purpose.

Whereas the data from Spaulding (1933) are quite close to the estimates for the U.S. population (Stoudt et al. 1960) in terms of height for age, the data from Topper and Rosenberg (1936) seem to reflect a generally shorter population (Fig. 27), although the weights of patients are actually

[4] Body mass index = the body weight (kg) divided by the square of the height (m), or kg/m^2.

greater than for the general population for a few age groups (Fig. 28). Thus, the estimates from Stoudt et al. do not appear to provide an adequate normal population for the Staten Island tuberculosis patients, and no other normal or control population is available. In addition, while the data from Spaulding (1933) are relatively self-consistent, with increases in height, weight, BMI, and weight for height with increased age, the data from Topper and Rosenberg (1936) show inconsistent changes in weight and weight for height with increased age (Figs. 28-29), probably due at least partly to small sample sizes for many age groups. Thus, the data of Topper and Rosenberg (1936) are not considered suitable for the present purpose. Similar calculations to those described above, of weight for height and differences between the patient and general populations (assuming use of Stoudt et al. 1960 for the general population), would lead to estimates of increased weight for height among patients for the youngest ages for boys and most ages for girls (Fig. 29), in contradiction to other available information.

In a more recent study, Chavalittamrong et al. (1987) measured weight for age among tuberculosis patients in Thailand 0-12 years old, in comparison with normal values for Thai children, but very few details are provided in the paper. Among children with pulmonary tuberculosis, 69% were below the 50th percentile for the general population, and 29% were below the 10th percentile for the general population. Actual weights or reductions in weight were not provided. While this study lends support to a reduction in body weight for children with tuberculosis, the paper does not provide useful information for the present purpose, and the population (children in Thailand, 1980-1983) is not relevant to the Canadian population of the 1930s-1960s.

Several relatively recent studies list weight loss or failure to thrive among symptoms that should lead to a consideration of pediatric tuberculosis (e.g., Qazi et al. 1998a; 1998b; Marais et al. 2005a; 2005b; 2006; Schaaf et al. 2007; Cruz et al. 2013; Dizdar et al. 2014). Marais et al. (2005a) distinguished between subjective weight loss (reported by the patient or the patient's parents) and objective weight loss (based on measurements); objective weight loss is defined as loss of at least 10% of body weight (minimum of 1 kg) over any time period, or decline by at least 1 percentile line in the previous 3 months. This value (weight loss of 10%) is consistent with the findings described above. Some of these studies also indicate that weight loss does not occur in all patients, with the reported fraction showing loss of weight ranging from 30% to 70%.

III.3. Association of body weight and susceptibility to tuberculosis

Several studies in adults indicate that lower body weight (and often slightly greater height) is evident years before the development of tuberculosis (Reed and Love 1933; Britten (1933); Berry and Nash 1955; Long and Jablon 1955; Palmer et al. 1957; Edwards et al. 1971; Tverdal 1986; 1988), presumably indicating some sort of relationship between lower body weight for height and susceptibility to tuberculosis.

- Reed and Love (1933) followed 5021 U.S. Army officers (men, most commissioned at or after age 21) who were in service on January 1, 1901, or commissioned between that date and the end of 1916. By the middle of 1929, 106 cases of pulmonary tuberculosis had been reported. Average body weights of men who later developed tuberculosis were 7-10% lower (depending on age at measurement) than for the cohort as a whole. Body

weights of tuberculosis patients were below average for many years before the disease became evident, and heights were often above average.

- Britten (1933) reported higher mortality from tuberculosis among underweight persons than persons of normal weight or overweight persons. He considered this to be evidence of a higher susceptibility to tuberculosis among underweight persons.
- Berry and Nash (1955) reported that English males who later developed tuberculosis were thinner than those who did not, with longer, narrower chests.
- Long and Jablon (1955), describing U.S. Army recruits during World War II, reported significantly higher rates of tuberculosis for underweight men and for the tallest men, i.e., for low weight with respect to height.
- Palmer et al. (1957) followed U.S. Navy recruits (white men entering service 1949-1951; ages 17-21 at entry) for up to 5 years and reported much higher rates of tuberculosis among the most underweight men. Body build was not related to chance of infection, but strongly related to chance of developing active disease.
- Edwards et al. (1971) followed a later cohort of U.S. Navy recruits (white men entering service 1958-1967, ages 17-21 at entry) for up to 12 years and reported similar findings. The median body weight of recruits who later developed tuberculosis was about 4 lb (1.8 kg) less than for those who did not, or about -2.6% lower. For each height group, the median weight at entry into service for men who later developed tuberculosis (383 men, 95% of whom had pulmonary or pleural disease) was "appreciably less" than for the whole group of recruits (823,199 men), especially for the tallest men.
- Tverdal (1986; 1988) reported on a large Norwegian cohort (1.7 million men and women, ages 15+ at time of screening) who were measured and screened for tuberculosis between 1963 and 1975 and followed up through 1982. Among those who later developed pulmonary tuberculosis (1070 men and 672 women), average body weights were about 7% below the average body weights of the whole cohort (calculated separately for men and women).

A relationship between low body weight for age and height and the development of tuberculosis (active disease) was also found in infected children in an outbreak in Missouri in 1990 (Hoge et al. 1994).

III.4. Estimated reduction in weight for Canadian tuberculosis patients

Based on the findings described above, we suggest a downward adjustment of 10% (range, 5 to 15%) on average adult body weights to account for the decreased body weight of tuberculosis patients. While average reductions in body weight appear to be more than 10% for patients entering treatment, average reductions for patients in treatment or less severe cases (e.g., the Army recruits) appear to be less than 10%. Use of a 10% reduction in average adult body weight for all adult tuberculosis patients thus seems to be a reasonable estimate, based on the available information. A multiplier of 0.9 was used to adjust the reported body weight of Canadian adults (general population) to estimate the body weight of Canadian tuberculosis patients.

For children, assuming sufficient similarity of the U.S. general population and the Minnesota tuberculosis patients, the difference in average weight between the Minnesota patients and the U.S. general population, above about age 8, approximates that seen between adult patients and controls, around -10%. Therefore, we suggest a downward adjustment of 10% (range, 5 to 15%) on average body weights for children at least 8 years old, to account for the decreased body weight of tuberculosis patients. A multiplier of 0.9 was used to adjust the reported body weight of Canadian children ages 8 years and older (general population) to estimate the body weight of Canadian tuberculosis patients.

For younger children (ages 5 for males, 5-7 for females), we suggest no adjustment on the body weights for the general population in estimating the body weight of tuberculosis patients (range, 0 to 5%). For 6- and 7-year-old males, we suggest a downward adjustment of 5% (range, 0 to 10%).

Based on the smaller variability in size at the youngest ages for which any information is available, and in the absence of specific information for patients younger than 5, we assume that the weight for height of patients less than 5 years will be the same as that for the general population of the same age (no adjustment, range 0 to 5%).

The calculated percentage differences were used to select multipliers to adjust weight for height for a general population to a corresponding population of tuberculosis patients. Selected values are 1.0 (ages 5 for males, 5-7 for females), 0.95 (ages 6-7 for males), and 0.9 (males and females ages 8-15 and adults). The adjusted values of weight for height (values for the Canadian general population times the multiplier) for children ages 5-15 are included in Table 8. The resulting estimated average weights for age (all ages) for Canadian tuberculosis patients, relative to the general population in 1953, are shown in Figure 30 and Table 9.

Table 6. Body weight for adult tuberculosis patients as a percentage change from normal or control weights (U.S. and England).

Country/description	Age (range)	Number	% change	Notes	Reference
Males					
England				weights at admission, % change from reported former weights (which were close to "reference" weights)	Weber and Kirkness (1909)
Sputum positive	(25+)	500	-12.2%		
Sputum negative (old TB)	(29+)	100	-9.1%		
U.S. (New York)	26.6 (16-42)	31	-14.8%	range -36.6 to -5.6; % change of recorded lowest weights (usually around time of start of treatment) from recorded highest weights (usually after treatment) for individuals	Garvin et al. (1918a)
U.S. (Army recruits; September 1, 1917 to April 1, 1918)	(21-30)	4653	-6.95%	-5.8% for height of 60 inches to -9.9% for height of 78 inches; early or incipient TB cases from 868,445 men sent to camp (more advanced cases were probably rejected before being sent to camp)	Love (1929); Davenport and Love (1921)
U.S. (Selective Service registrants; January 1943-January 1944)	(18-37)	not given	-2.5% (whites) -3.0% (blacks)	Includes essentially all registrants, both those inducted and those disqualified (385,937 whites, 78,638 blacks); number of tuberculosis cases not provided; excludes institutionalized tuberculosis cases	Karpinos (1958)

Table 6. (continued)

Country/description	Age (range)	Number	% change	Notes	Reference
Females					
England (Sputum positive)	(25+)	100	-10.8%	weights at admission, % change from reported former weights (which were close to "reference" weights)	Weber and Kirkness (1909)
U.S. (New York)	22.3 (16-39)	20	-16.5%	range -23.0 to -6.2; % change of recorded lowest weights (usually around time of start of treatment) from recorded highest weights (usually after treatment) for individuals	Garvin et al. (1918b)

Table 7. Body weight for adult tuberculosis patients as a percentage change from normal or control weights (other countries).

Country/description	Age (range)	Number	% change	Notes	Reference
Males					
India	(18-55)	150	-19.2	sex not given, but height suggests mostly males; comparison with similar normal sample	Sidhu and Sodhi (1975)
South Africa (blacks, pulmonary TB patients)	44 (16-68)	64	-15.3	measured after 1-4 months of treatment; comparison with "normals," not matched controls	Cameron and Scheepers (1986)
Malawi (pulmonary TB patients)	(16-68)	73		ambulatory patients (not the sickest); controls were age- and sex-matched	Harries et al. (1988)
at admission			-20.0		
after 4 weeks of treatment			-14.9		
after 8 weeks of treatment			-12.2		
India	35.2 (16-70)	86	-37.9	comparison with controls	Sharma et al. (2008)
Sputum positive		45	-40.5		
Sputum negative		41	-35.2		
Uganda (TB^+/HIV^-)	29.3	145	-13.0	comparison with TB^-/HIV^- (n = 160; age = 29.4)	Mupere et al. (2010)
Tanzania (pulmonary TB patients)	35.5 (15+)	193	-14.4	matched controls	PrayGod et al. (2011)
Females					
South Africa (blacks, pulmonary TB patients)	36.3 (16-68)	34	-3.6	measured after 1-4 months of treatment; comparison with "normals," not matched controls	Cameron and Scheepers (1986)
Malawi (pulmonary TB patients)	(16-68)	49		ambulatory patients (not the sickest); controls were age- and sex-matched	Harries et al. (1988)
at admission			-22.1		
after 4 weeks of treatment			-16.3		
after 8 weeks of treatment			-12.5		

Table 7. (continued)

Country/description	Age (range)	Number	% change	Notes	Reference
Females (continued)					
Uganda (TB^+/HIV^-)	27.2	104	-15.0	comparison with TB^-/HIV^- (n = 256; age = 30.2)	Mupere et al. (2010)
Tanzania (pulmonary TB patients)	32.7 (15+)	162	-18.1	matched controls	PrayGod et al. (2011)

Table 8. Weight for height (kg/cm) for pediatric tuberculosis patients compared with the general population.

Age (y)	Minnesota tuberculosis patients[a]	U.S. general population[b]	% difference, patients to general population[c]	Weight for height adjustment factor (patients to general population)[d]	Canadian general population[e]	Canadian tuberculosis patients (estimated)[f]
Males						
5	0.169	0.172	-1.8	1.0	0.171	0.171
5.5		0.176				
6	0.175	0.182	-3.9	0.95	0.184	0.184
7	0.183	0.200	-8.8	0.95	0.190	0.181
8	0.192	0.213	-9.7	0.9	0.207	0.197
9	0.208	0.223	-6.9	0.9	0.220	0.198
10	0.221	0.239	-7.9	0.9	0.234	0.210
11	0.226	0.258	-12.6	0.9	0.248	0.224
12	0.248	0.267	-7.0	0.9	0.262	0.235
13	0.257	0.292	-11.8	0.9	0.283	0.255
14	0.285	0.318	-10.3	0.9	0.310	0.279
15	0.274	0.345	-20.7	0.9	0.329	0.296
16		0.362				
Females						
5	0.158	0.167	-5.6	1.0	0.175	0.175
5.5		0.173				
6	0.175	0.176	-0.8	1.0	0.178	0.178
7	0.183	0.187	-2.2	1.0	0.188	0.188
8	0.190	0.206	-7.8	0.9	0.208	0.188
9	0.202	0.220	-7.9	0.9	0.217	0.196
10	0.216	0.236	-8.4	0.9	0.231	0.208
11	0.227	0.257	-11.7	0.9	0.249	0.224
12	0.252	0.279	-9.6	0.9	0.283	0.254
13	0.264	0.297	-11.1	0.9	0.302	0.272
14	0.273	0.319	-14.4	0.9	0.312	0.281
15	0.308	0.330	-6.6	0.9	0.322	0.290
16		0.336				

Table 8. (continued)

[a]Calculated from average weights and heights, by age and sex, reported by Spaulding (1933).
[b]Calculated from average weights and heights, by age and sex, estimated for the U.S. population (1930s-1950s) by Stoudt et al. (1960).
[c]Calculated percentage difference between the weight for height for the Minnesota patients and the weight for height for the general U.S. population.
[d]Multiplier to adjust the weight for height, by age and sex, of a general population to a population of tuberculosis patients. Selected values are 1.0 (ages 5-6 for males, 5-7 for females), 0.95 (age 7 for males), and 0.9 (males and females ages 8-15).
[e]Calculated from average weights and heights, by age and sex, measured for the general Canadian population (1953) by Pett and Ogilvie (1956; 1957).
[f]Estimated weight for height for Canadian tuberculosis patients, obtained by multiplying the weight for height for the general Canadian population (by age and sex) by the multiplier estimated from the U.S. data (column 5).

Table 9. Average height and weight of Canadians by age and sex, with estimated weights for Canadian tuberculosis patients.[a]

	Males			Females		
	General population		TB patients	General population		TB patients
Age	Height (cm)	Weight (kg)	Weight (kg)	Height (cm)	Weight (kg)	Weight (kg)
0 months (birth)	50.7	3.3	3.3	50.1	3.2	3.2
3 months	60.8	6.0	6.0	59.2	5.6	5.6
6 months	67.6	7.8	7.8	65.8	7.3	7.3
9 months	72.1	9.0	9.0	70.4	8.5	8.5
12 months	75.6	9.9	9.9	74.3	9.4	9.4
15 months	78.9	10.7	10.7	77.6	10.0	10.0
18 months	81.9	11.3	11.3	81.1	10.7	10.7
2 years	88.1	13.6	13.6	85.3	12.7	12.7
3 years	93.0	14.5	14.5	91.4	14.1	14.1
4 years	99.6	16.8	16.8	99.6	16.3	16.3
5 years	106.4	18.1	18.1	106.2	18.6	18.6
6 years	113.3	20.9	19.9	112.3	20.0	20.0
7 years	119.4	22.7	21.6	118.1	22.2	22.2
8 years	124.7	25.9	23.3	124.2	25.9	23.3
9 years	130.3	28.6	25.7	129.5	28.1	25.3
10 years	135.9	31.8	28.6	135.4	31.3	28.2
11 years	140.7	34.9	31.4	140.5	34.9	31.4
12 years	145.8	38.1	34.3	147.8	41.7	37.5
13 years	150.6	42.6	38.3	153.4	46.3	41.7
14 years	158.0	49.0	44.1	155.7	48.5	43.7
15 years	164.3	54.0	48.6	158.0	50.8	45.7
16-17 years	169.4	61.7	55.5	158.8	54.4	49.0
18-19 years	172.7	65.3	58.8	159.0	56.2	50.6
20-24 years	172.5	69.9	62.9	159.5	56.2	50.6
25-29 years	173.5	72.6	65.3	159.3	57.2	51.5
30-34 years	172.7	75.7	68.1	159.5	59.0	53.1
35-44 years	171.4	75.7	68.1	158.5	61.2	55.1
45-54 years	169.9	74.4	67.0	157.0	65.3	58.8
55-64 years	167.6	73.0	65.7	155.7	66.7	60.0
65+ years	166.4	70.3	63.3	153.9	62.6	56.3
Adults 20+ years	170.2	73.3	66.0	156.8	61.2	55.1

Table 9. (continued)

[a] Heights and weights for birth to 18 months are taken from Demirjian et al. (1983) based on a longitudinal study of French Canadian children born in Montreal in 1975-1976. Heights and weights for 2 years and older are weighted means taken from Pett and Ogilvie (1956; 1957) from a 1953 survey of the Canadian general population. Estimation of weights for tuberculosis patients is described in the main text.

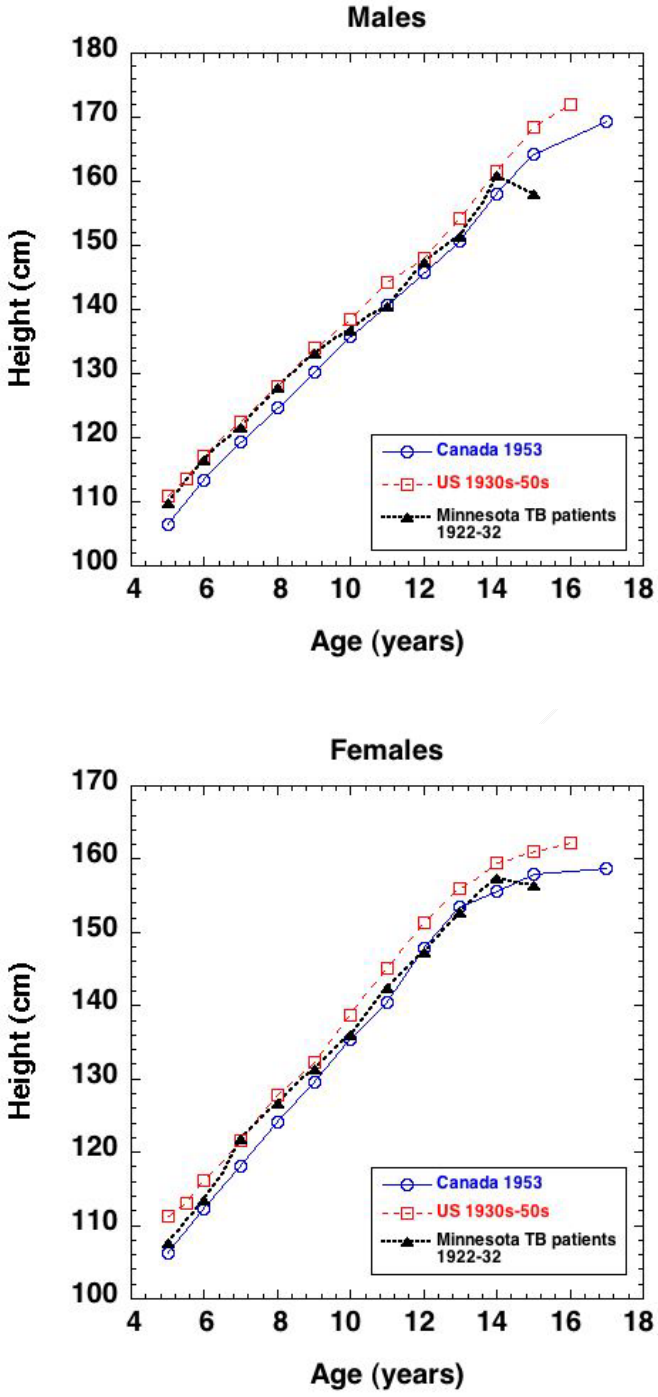

Fig. 23. Comparison of height (cm) for age for the Minnesota tuberculosis patients (Spaulding 1933), the estimated U.S. population (Stoudt et al. 1960), and the measured Canadian population (Pett and Ogilvie 1956; 1957).

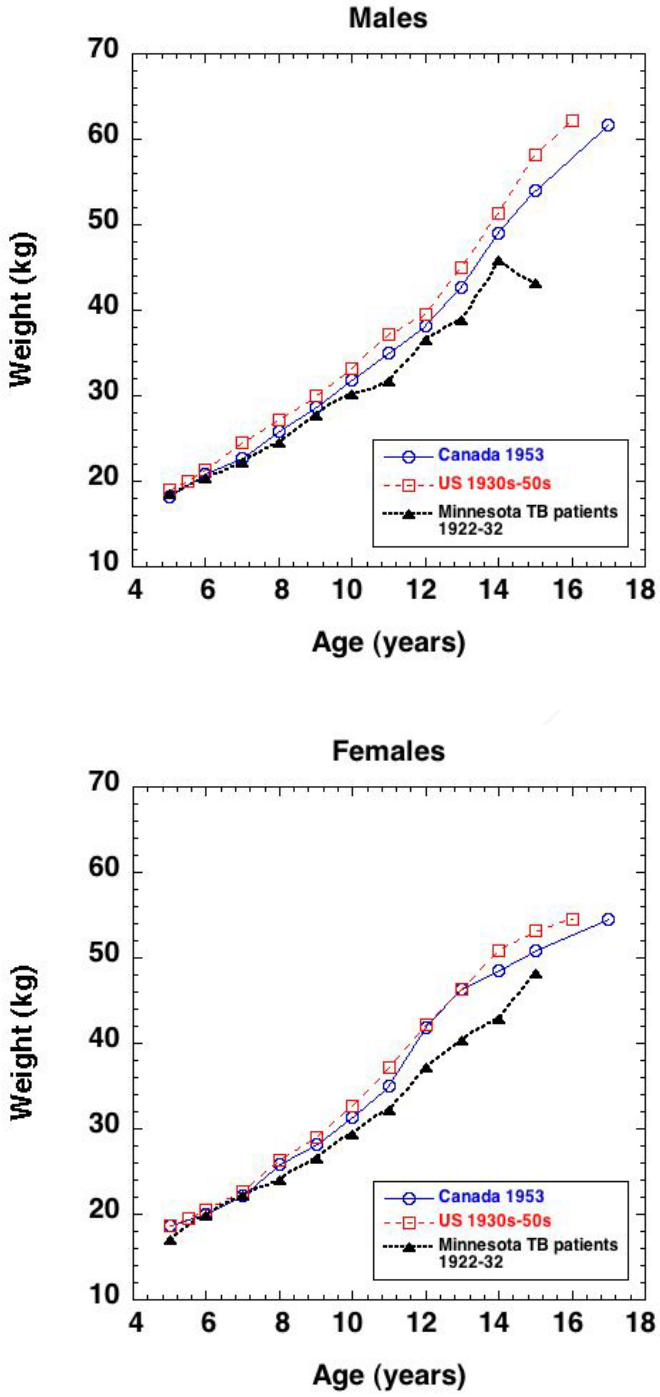

Fig. 24. Comparison of weight (kg) for age for the Minnesota tuberculosis patients (Spaulding 1933), the estimated U.S. population (Stoudt et al. 1960), and the measured Canadian population (Pett and Ogilvie 1956; 1957).

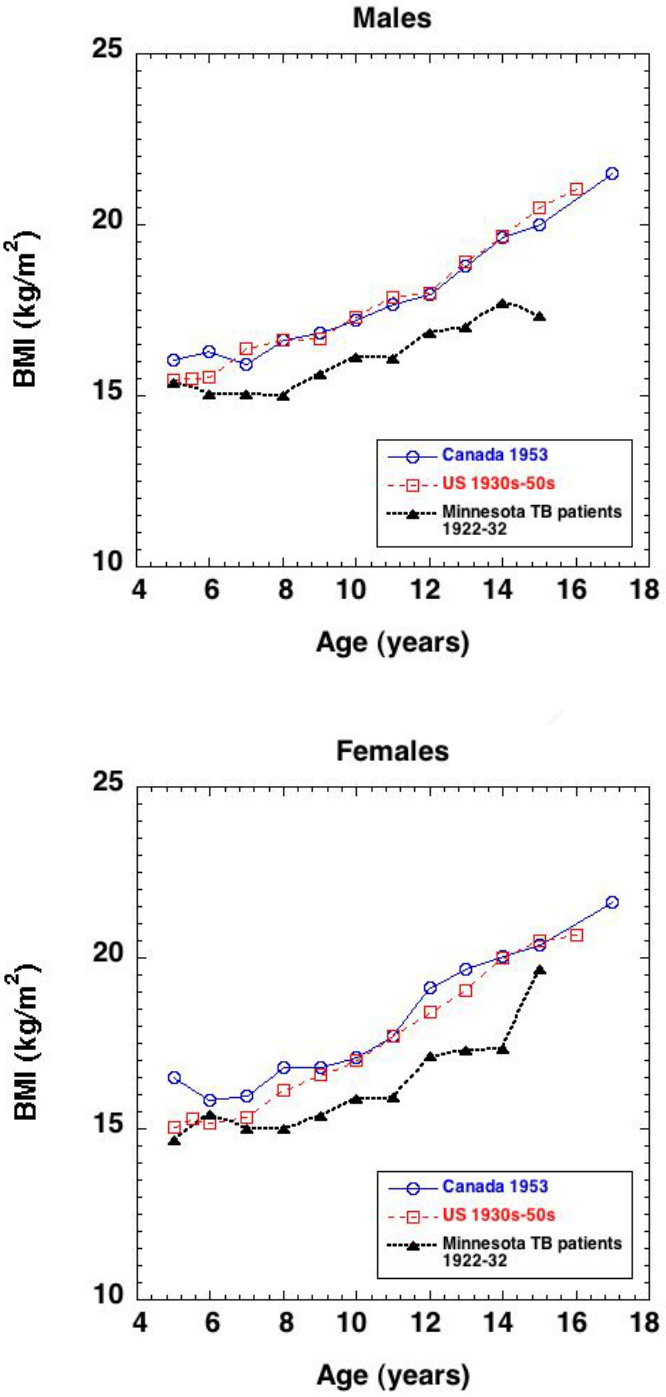

Fig. 25. Comparison of Body Mass Index (BMI; kg/m^2) for age for the Minnesota tuberculosis patients (Spaulding 1933), the estimated U.S. population (Stoudt et al. 1960), and the measured Canadian population (Pett and Ogilvie 1956; 1957).

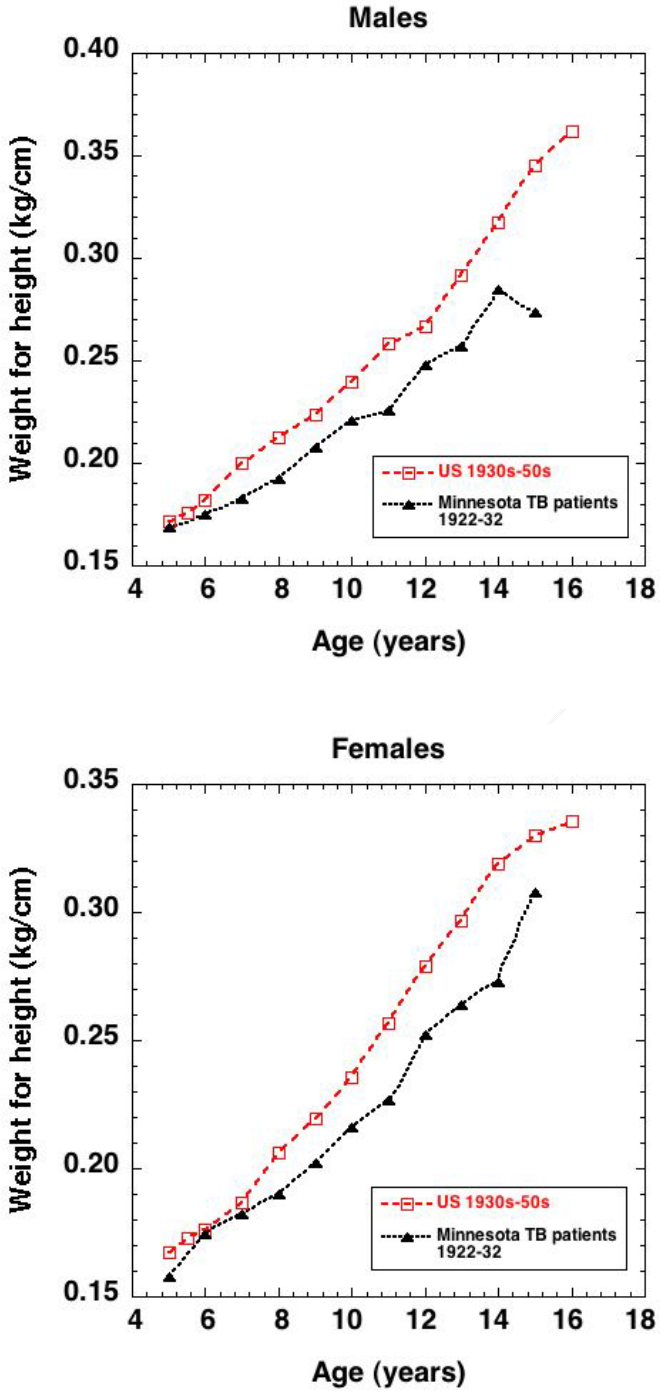

Fig. 26. Comparison of weight for height (kg/cm) for age for the Minnesota tuberculosis patients (Spaulding 1933) and the estimated U.S. population (Stoudt et al. 1960).

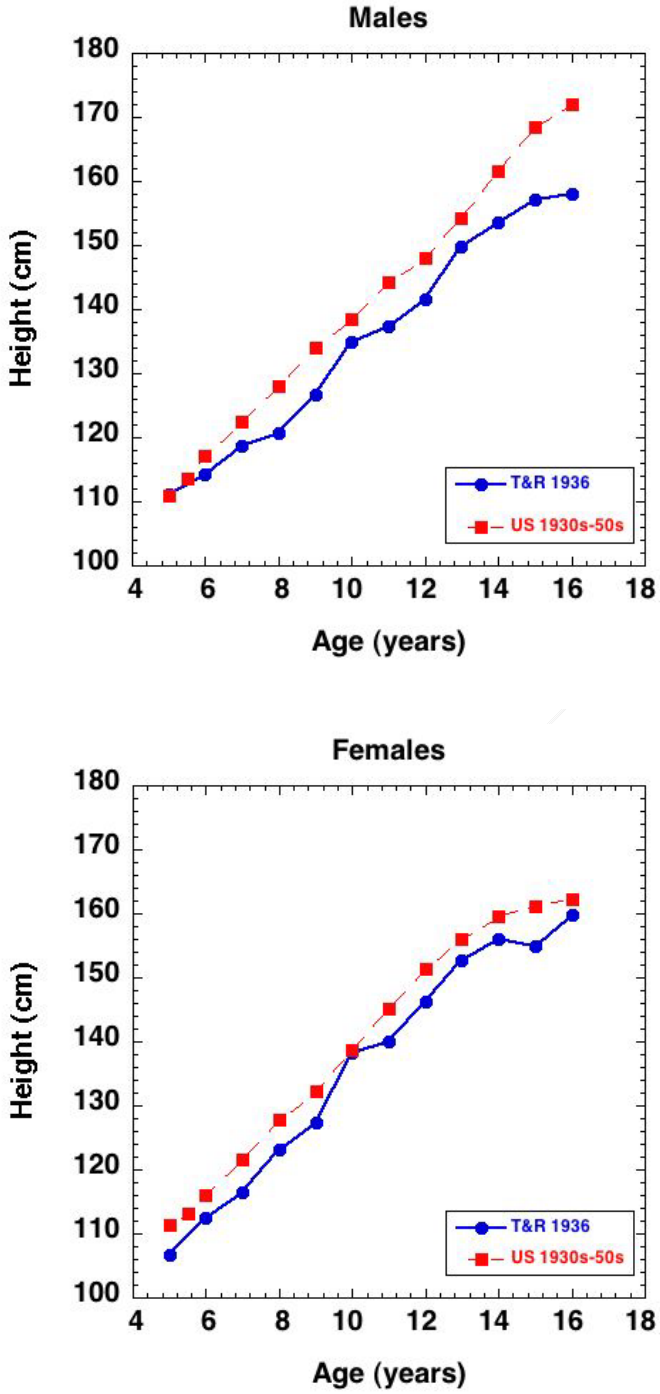

Fig. 27. Comparison of height (cm) for age for the Staten Island tuberculosis patients (Topper and Rosenberg 1936) and the estimated U.S. population (Stoudt et al. 1960).

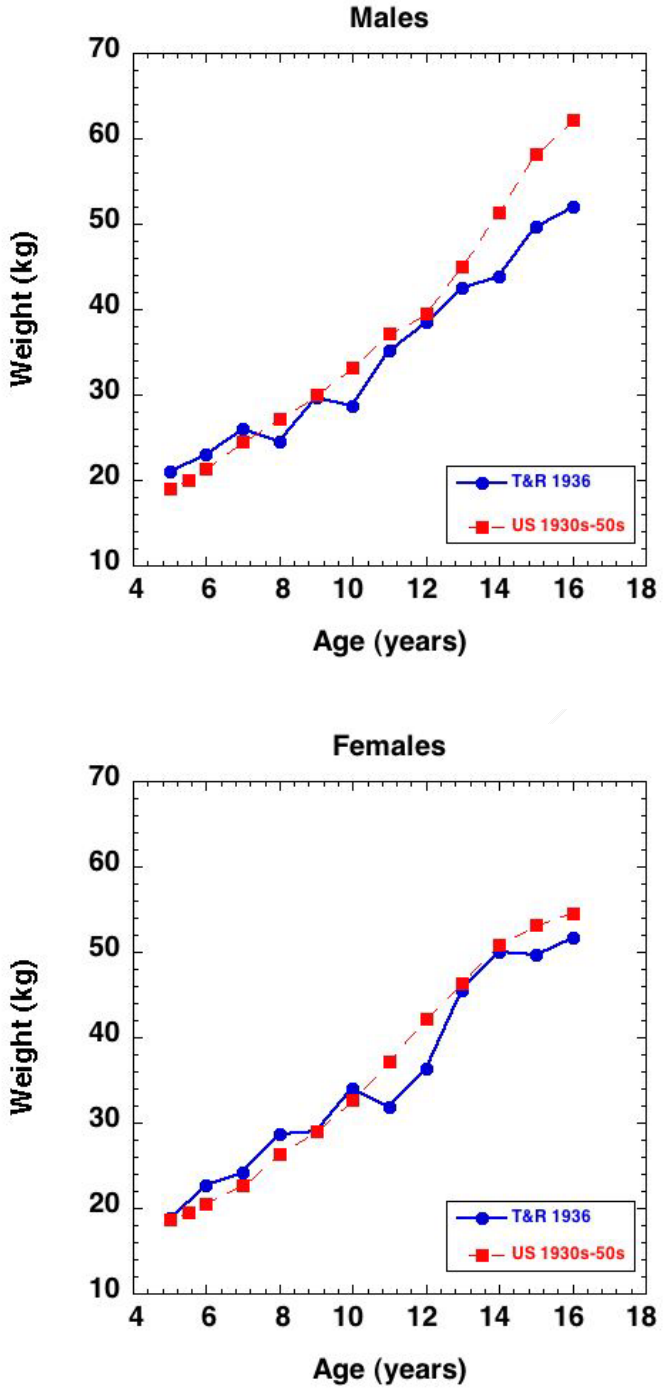

Fig. 28. Comparison of weight (kg) for age for the Staten Island tuberculosis patients (Topper and Rosenberg 1936) and the estimated U.S. population (Stoudt et al. 1960).

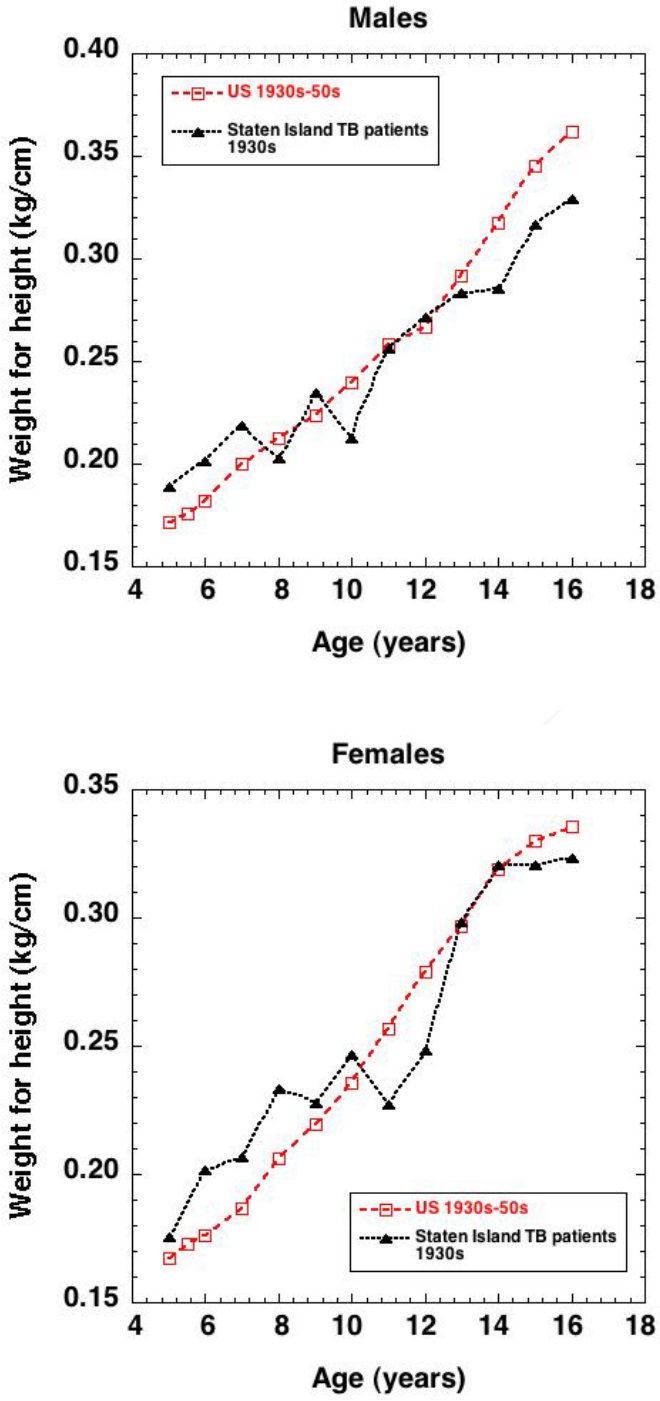

Fig. 29. Comparison of weight for height (kg/cm) for age for the Staten Island tuberculosis patients (Topper and Rosenberg 1936) and the estimated U.S. population (Stoudt et al. 1960).

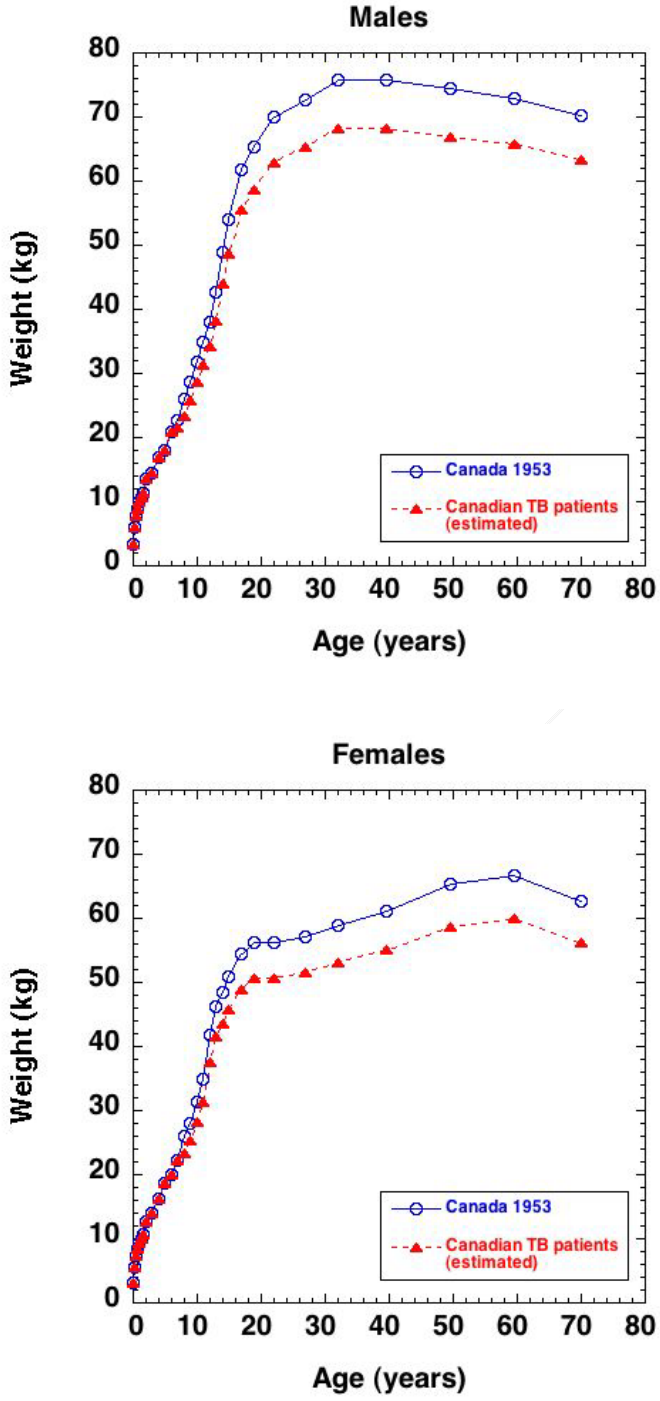

Fig. 30. Estimated average weights for age for Canadian tuberculosis patients (see main text), compared with the general population of Canada in 1953 (Pett and Ogilvie 1956;1957; Demirjian et al. 1983).

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