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Abstract

Background: This study developed age- and sex-specific normative-referenced percentile values for five physical fitness tests across a wide age range of Canadians, using a nationally representative sample.

Data and methods: The data are from 5,188 Canadians (50.1% female) and were collected as part of cycle 5 of the Canadian Health Measures Survey (2016 to 2017).

Results: Males had slightly better cardiorespiratory fitness and substantially better grip strength, jumping height and jumping power scores than females, whereas females had better sit-and-reach flexibility. Among females, there were pronounced increases in jumping height (P_{50}: 25%) and jumping power (P_{50}: 58%) between ages 8 and 13, and in grip strength (P_{50}: 193%) between ages 6 and 19. Performance gradually declined with age, beginning in adolescence for jumping ability and at approximately age 35 for grip strength. Among males, there were pronounced increases in jumping height (P_{50}: 69%) and jumping power (P_{50}: 233%) between ages 8 and 20, and in grip strength (P_{50}: 365%) between ages 6 and 20. Performance gradually declined with age, beginning immediately after adolescence for jumping ability and at approximately age 30 for grip strength. Sit-and-reach flexibility remained relatively stable with age in both sexes. Cardiorespiratory fitness scores in both sexes declined steadily with age beginning (generally) at age 8, with a larger decline evident in females until age 18.

Interpretation: These normative-referenced values for physical fitness could be useful for screening in public health and clinical practice.

Keywords: norms, cardiorespiratory fitness, muscular fitness, flexibility, jumping mechanography, health

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Physical fitness consists of multiple components (i.e., cardiorespiratory fitness [CRF], musculoskeletal strength, endurance, flexibility, agility, balance) that, together, describe an individual's ability to perform physical activity. Recent research has identified meaningful associations between physical fitness and health across the lifespan of Canadians,[1,2] and aspects of physical fitness in childhood are predictive of health outcomes later in life.[3]

Normative-referenced percentile values have been used as a way to help interpret an individual's performance in comparison with a reference population. Norms can be used to identify individuals with low performance who are in need of intervention, and to identify high-performing individuals as part of a sports talent identification program.[4]

Although norms are not linked to a health outcome like a cut point or threshold (i.e., high performance relative to a norm does not necessarily imply healthy levels of physical fitness), some studies have suggested that individuals who perform in the lowest quintile (≤ 20th percentile) are at potential risk of poor health.[5-6] More recent research on CRF cut points among children and adolescents in the United Kingdom suggests that females in the 55th percentile and lower and males in the 60th percentile and lower may be at risk for poor health outcomes.[7] Canadian-specific normative percentile values for fitness could help develop a better understanding of Canadians' progression of physical fitness with age, and could help inform cut points for low physical fitness levels across age and sex groups.

Several countries, including Canada,[8,9] have produced normative-referenced percentile values for single fitness measures across a wide age range.[10-12] Other countries have produced comprehensive norms for several physical fitness tests, but typically only for children and youth,[13-16] or older adults.[17,18] No recent study has produced norms for a comprehensive set of physical fitness tests across a wide age range of Canadians. This study aims to produce normative-referenced percentile values for five physical fitness measures (modified Canadian Aerobic Fitness Test [mCAFT], handgrip strength, sit-and-reach flexibility, jumping height and jumping power) across a wide age range of Canadians, using a nationally representative sample.

Data and methods

Participants

Data were used from a subsample of participants across a wide age range from cycle 5 (2016 to 2017) of the Canadian Health Measures Survey (CHMS). The CHMS is an ongoing direct health measures survey used to collect cross-sectional, nationally representative health and wellness data on Canadians aged 3 to 79 living in the 10 provinces.[19] Individuals not represented in the CHMS include those living in the three territories, those living on reserves and Aboriginal settlements, members of the

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Canadian Forces, institutionalized individuals, and those from certain remote areas. Those excluded from the CHMS represent approximately 3% of the target population.[19] Data collection procedures for the CHMS consist of a household interview (demographic information and health questionnaire), followed by an in-person visit to a mobile examination centre where physical measure tests are administered. All physical measure tests were conducted by specialists certified by the Canadian Society for Exercise Physiology. A more detailed overview of the sampling methodology and survey operations for the CHMS is provided elsewhere.[19,20] For cycle 5 of the CHMS, there was a combined response rate of 48.5%.[19] Survey weights were incorporated to account for non-response bias and the complex sampling design.

In total, 5,786 individuals (50.2% female) aged 3 to 79 participated in cycle 5 of the CHMS. Participants aged 8 to 69 were eligible for the mCAFT, while those aged 6 to 79 were eligible for the handgrip strength, jumping height and jumping power tests. Those aged 6 to 69 were eligible for the sit-and-reach flexibility test. After the cycle 5 respondents who did not participate in these fitness tests (i.e., those younger than 6 years old) were removed, the remaining subsample included 5,188 participants (50.1% female). Because of the small sample size among younger and older individuals who participated in the tests, the sample was further reduced to those aged 8 to 69 for the jumping height and power tests. Further information regarding the sample size retained for each fitness measure is provided in Figure 1.

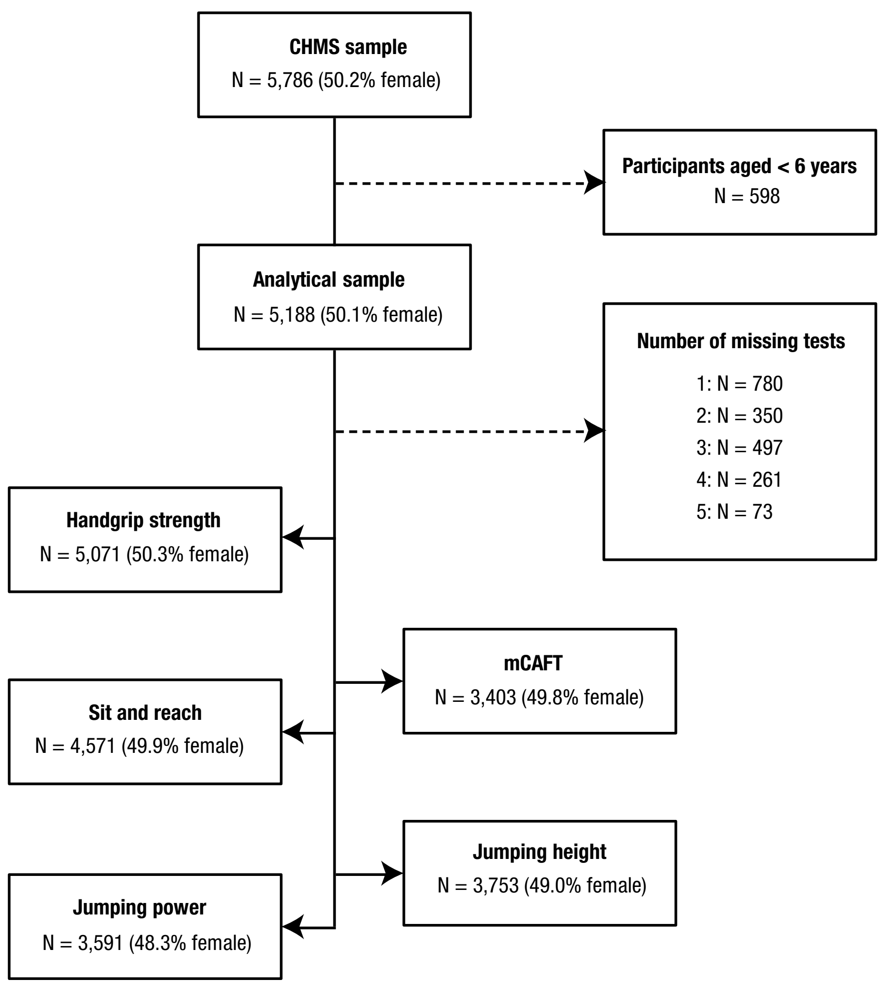
Statistics Canada obtained ethics clearance for the CHMS from the Health Canada and Public Health Agency of Canada Research Ethics Board.[21] Participation in the CHMS was voluntary, and all participants provided written informed consent. Participants aged 6 to 13 provided written informed assent, along with written informed consent from their parent or guardian.

Fitness measures

Muscular strength: Handgrip strength is an assessment of maximal isometric upper body muscular strength. Grip strength was measured using a Smedley III analogue dynamometer (Takei Scientific Instruments, Japan). The test involved participants standing with their testing arm away from their body at approximately a 45-degree angle. Grip strength was measured twice per hand, with participants alternating hands between trials. The top scores from each hand were recorded in kilograms (kg) and subsequently combined to generate a total grip strength score.[22]

mCAFT: The mCAFT is a submaximal step test used to estimate an individual's CRF, operationalized as $\dot{V}O_{2max}$ in mL•kg^{-1}•min^{-1}.[23] The test was originally developed by Jetté et al.,[24] but was later modified by Weller et al.[23] to accommodate older and fitter adults who had a tendency to obtain underestimated CRF values under Jetté's method.[23,25] A detailed overview of the mCAFT protocol is available elsewhere.[23,25] To summarize, participants completed one or more standardized three-minute stages, stepping up and down on two 20.3-centimetre (cm) steps following age- and sex-specific cadences. Fitter males performed the last two stages

Figure 1
Flowchart of participants included and excluded for each physical fitness test in cycle 5 of the Canadian Health Measures Survey



Note: CHMS: Canadian Health Measures Survey
mCAFT: Modified Canadian Aerobic Fitness Test

What is already known on this subject?

- Normative values can be used to help interpret an individual's fitness test results by identifying how their results compare with the general population.
- Several countries have produced normative values for single fitness measures, but no recent study has produced norms for a comprehensive set of physical fitness tests across a wide age range of Canadians.

What does this study add?

- Data from 5,188 individuals across a wide age range were used to calculate nationally representative age-group-specific and sex-specific Canadian normative-referenced percentile values for five physical fitness tests.
- Males had slightly better cardiorespiratory fitness and substantially better grip strength, jumping height and jumping power scores than females, whereas females had better sit-and-reach flexibility.
- Flexibility remained relatively stable with age for both sexes, whereas all other fitness measures generally declined with age.
- The normative values produced in this study can help inform public health and clinical practice.

and fitter females performed the last stage on one 40.6 cm step. Following a full stepping stage, participants who did not exceed 85% of their age-predicted maximal heart rate (220 minus age in years) were able to advance to the next stepping stage. Heart rate was measured using a heart-rate monitor (Polar Electro Canada Inc., Lachine, Quebec, Canada). Before testing, participants followed a brief stepping protocol to familiarize themselves with the stepping pattern. Although the mCAFT was only validated with those aged 15 to 69,[23] it has been implemented in previous cycles of the CHMS with individuals aged 6 in cycle 1, and aged 8 in cycles 2 and 5. The CSEP-PATH equation was applied to predict $\dot{V}O_{2max}$,[22] which was originally published in 1989:[26]

Estimated $\dot{V}O_{2max}$ ($mL•kg^{-1}•min^{-1}$) = [17.2 + (1.29 x O_2 cost*) – (0.09 x wt. in kg) – (0.18 x age in years)],

where * represents the oxygen cost in $mL•kg^{-1}•min^{-1}$ during the final stage of stepping.

Sit-and-reach: The sit-and-reach test assesses lower back and hamstring flexibility. Flexibility was measured using a flexometer (FitSystems Inc., Calgary, Canada). Participants were required to sit on the floor with their legs fully extended in front of them, with feet placed flat against the flexometer. Participants were asked to reach forward as far as possible toward their toes, while keeping their legs fully extended. A toe touch was equal to a score of 26 cm. The top score from two valid trials was recorded to the nearest 0.1 cm.[22] Before testing, participants sat in a modified hurdle stretch position, stretching each leg twice (alternating legs) for 20 seconds.

Jumping height and power: The jumping mechanography technique was used to assess leg muscle performance in terms of jumping height (cm) and power (kW). Jumping force plate tests were used to generate vertical ground reaction forces using the Leonardo Mechanograph Ground Reaction Force Plate (Novotec Medical GmbH, Pforzheim, Germany). The signal from the force sensors was sampled at a frequency of either 400 or 800 Hz. Participants performed three valid trials (maximum of five trials) of a single two-leg vertical countermovement jump, and were instructed to jump as high as possible on each trial. To complete a valid trial, participants performed a single jump with their feet leaving and landing on the plate together. Participants were permitted to swing their arms during their jumps. The trial in which participants jumped the highest was selected for the jumping height and power analyses. Prior to the jump trials (testing), participants performed one or two practice jumps to ensure proper execution and balance.

Leonardo Mechanography GRFP Research Edition® software (v.4.2.b06.10f) was used to calculate jumping height and power. A more detailed summary of the jumping mechanography protocol and calculations used to produce jumping height and power scores was published elsewhere.[27] The jumping force plate test always preceded the mCAFT, which always preceded the sit-and-reach test. The order in which the muscular (handgrip) strength test was performed varied, but this did not alter the general order in which the jumping test, mCAFT and sit-and-reach test were completed.

Statistical analysis

All statistical analyses were conducted in R (version 3.4.3) and SAS EG 5.1 (SAS Institute Inc., Cary, NC, USA). Percentile curves for each physical fitness test were calculated using the General Additive Model for Location Scale and Shape (GAMLSS) package (version 5.1-3) with age as a covariate stratified by sex. GAMLSS is an extension of the Lambda Mu Sigma (LMS) method that models the kurtosis through set distributions, in addition to data skewness (L expressed as a Box-Cox power), median (M) and coefficient of variation (S).[28,29] Box-Cox power exponential, inverse Gaussian, Delaporte, and Box-Cox Cole and Green distributions were fitted to each fitness outcome variable, stratified by sex. P-splines were used to smooth the age trend for each fitness outcome using the generalized Akaike information criterion with three, five or seven knots. CHMS survey weights were applied to all models. The Bayesian information criterion was used to assess goodness of fit to compare models. Worm plots and Q–Q plots were used for visual inspection. The model that provided the best balance between model fit and model smoothness was selected. For the selected models, the 5th, 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th and 95th percentiles were calculated for each physical fitness test. Age groups were collapsed by calculating the mean score across percentiles

Table 1
Grip strength percentile values by age group and sex

Age (years)	P_5	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{95}
	kg										
Males											
6 to 7	11.3	12.9	15.1	16.7	18.1	19.5	20.9	22.4	24.1	26.4	28.3
8 to 9	16.0	18.2	21.0	23.0	24.8	26.5	28.2	30.1	32.2	35.2	37.7
10 to 11	23.6	26.8	30.7	33.5	35.9	38.1	40.3	42.7	45.7	49.9	53.4
12 to 13	33.2	37.6	42.8	46.5	49.5	52.3	55.2	58.3	62.1	67.7	72.6
14 to 15	42.4	47.8	54.2	58.6	62.2	65.5	68.8	72.5	77.1	83.9	89.9
16 to 17	50.0	56.2	63.4	68.3	72.3	75.9	79.6	83.7	88.8	96.5	103.3
18 to 19	55.7	62.3	70.0	75.3	79.5	83.3	87.2	91.5	97.0	105.1	112.4
20 to 24	61.8	68.8	76.9	82.3	86.8	90.7	94.7	99.2	104.9	113.4	121.1
25 to 29	66.2	73.2	81.3	86.8	91.3	95.3	99.3	103.9	109.6	118.1	125.8
30 to 34	67.5	74.3	82.2	87.6	92.0	96.0	100.0	104.5	110.1	118.4	125.8
35 to 39	67.1	73.6	81.2	86.5	90.8	94.8	98.8	103.2	108.7	116.7	123.8
40 to 44	65.7	71.9	79.3	84.4	88.7	92.6	96.5	100.9	106.2	114.0	120.7
45 to 49	63.8	69.8	76.9	81.9	86.1	89.9	93.8	98.1	103.3	110.8	117.3
50 to 54	61.6	67.4	74.3	79.1	83.2	87.0	90.8	95.0	100.1	107.4	113.6
55 to 59	59.2	64.8	71.5	76.3	80.3	84.0	87.7	91.8	96.7	103.8	109.9
60 to 64	56.7	62.1	68.7	73.3	77.2	80.8	84.4	88.4	93.2	100.1	106.0
65 to 69	54.0	59.4	65.7	70.2	74.0	77.5	81.0	84.8	89.5	96.2	102.0
70 to 74	51.3	56.5	62.7	67.1	70.7	74.1	77.4	81.1	85.7	92.2	98.0
75 to 79	48.5	53.6	59.7	63.9	67.4	70.6	73.8	77.3	81.7	88.1	93.8
Females											
6 to 7	10.5	12.0	13.9	15.4	16.7	17.9	19.2	20.6	22.3	24.5	26.4
8 to 9	16.3	18.3	20.8	22.7	24.3	25.8	27.3	29.0	31.0	33.9	36.3
10 to 11	22.4	25.0	28.0	30.3	32.1	33.9	35.7	37.7	40.1	43.6	46.6
12 to 13	27.8	30.7	34.3	36.8	39.0	41.0	43.0	45.2	48.0	52.0	55.5
14 to 15	32.0	35.2	39.1	41.8	44.2	46.4	48.6	51.1	54.1	58.4	62.2
16 to 17	34.9	38.3	42.4	45.3	47.8	50.2	52.5	55.1	58.3	62.9	66.8
18 to 19	36.8	40.2	44.4	47.4	50.0	52.5	54.9	57.6	60.9	65.6	69.7
20 to 24	38.2	41.7	46.0	49.1	51.8	54.3	56.9	59.7	63.0	67.8	71.9
25 to 29	39.0	42.5	46.8	50.0	52.7	55.3	57.9	60.8	64.2	69.0	73.1
30 to 34	39.3	42.9	47.2	50.4	53.2	55.8	58.4	61.3	64.7	69.6	73.8
35 to 39	39.4	43.0	47.4	50.6	53.4	56.0	58.6	61.5	64.9	69.9	74.1
40 to 44	39.1	42.8	47.2	50.4	53.1	55.7	58.2	61.1	64.5	69.5	73.8
45 to 49	38.4	42.1	46.6	49.7	52.4	54.8	57.3	60.0	63.4	68.4	72.7
50 to 54	37.4	41.1	45.5	48.5	51.1	53.4	55.7	58.4	61.7	66.6	70.9
55 to 59	36.0	39.7	44.0	47.0	49.4	51.6	53.8	56.4	59.6	64.4	68.7
60 to 64	34.5	38.2	42.4	45.2	47.5	49.6	51.7	54.1	57.2	61.9	66.1
65 to 69	33.0	36.5	40.6	43.3	45.5	47.5	49.4	51.7	54.7	59.2	63.4
70 to 74	31.3	34.8	38.7	41.4	43.5	45.3	47.1	49.3	52.1	56.5	60.6
75 to 79	29.7	33.1	36.9	39.4	41.4	43.1	44.8	46.9	49.5	53.8	57.8

Source: Canadian Health Measures Survey cycle 5 (2016 to 2017).

by two-year age groups between ages 8 and 19 for the mCAFT, jumping height test and jumping power test, and between ages 6 and 19 for handgrip strength and sit-and-reach flexibility. Similarly, age groups were collapsed by calculating the mean score across percentiles by five-year age groups between ages 20 and 69 for the mCAFT, sit-and-reach flexibility test, jumping height test and jumping power test, and between ages 20 and 79 for handgrip strength.

Results

Tables 1 to 5 show the sex- and age-specific percentile values (P_5, P_{10}, P_{20}, P_{30}, P_{40}, P_{50}, P_{60}, P_{70}, P_{80}, P_{90} and P_{95}) for the five fitness measures. Figure 2 shows the percentile curves for the 10th, 50th and 90th percentiles for each of the five fitness measures across different age and sex groups.

Females had considerably better sit-and-reach flexibility scores than males (table 3). Among females, there were pronounced increases in jumping height between the ages of 8 and 13 (P_{10}: 24%, P_{50}: 25%, P_{90}: 27%; table 4), and then performance declined with age. Females similarly exhibited pronounced increases in jumping power between the ages of 8 and 13 (P_{10}: 67%, P_{50}: 58%, P_{90}: 67%; table 5). This was followed by incremental increases until roughly age 18, and then performance declined with age. For grip strength, females displayed pronounced increases between ages 6 and 19 (P_{10}: 235%, P_{50}: 193%, P_{90}: 168%), followed by incremental increases until approximately age 35, and then a gradual decline with age (table 1).

Fitness scores for grip strength (table 1), jumping height (table 4) and jumping power (table 5) (all measures of muscular strength and power) were noticeably greater among males. Males also had greater CRF scores (table 2), although the differences were modest. Among males, there were pronounced increases in jumping height (P_{10}: 60%, P_{50}: 69%, P_{90}: 63%; table 4) and jumping power (P_{10}: 233%, P_{50}: 233%, P_{90}: 231%; table 5) between the ages of 8 and 20, followed by a gradual decline in performance with age. For grip strength, males displayed pronounced increases between the ages of 6 and 20 (P_{10}: 433%, P_{50}: 365%, P_{90}: 330%; table 1), followed by incremental increases until approximately age 30, and then a gradual decline with age. Sit-and-reach flexibility remained relatively stable with age for both males and females (table 3). The CRF scores for both males and females declined steadily with age beginning (generally) at age 8, with a more pronounced decline visible among females until age 18 (table 2).

Discussion

In this study, data from 5,188 individuals across a wide age range were used to calculate nationally representative age- and sex-specific Canadian normative-referenced percentile values for five physical fitness tests (grip strength, mCAFT [CRF], sit-and-reach [flexibility], jumping height and jumping power). These norms can help interpret physical fitness test scores among Canadians by identifying people with

Table 2
Modified Canadian Aerobic Fitness Test ($\dot{V}O_{2max}$) percentile values by age group and sex

Age (years)	P_5	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{95}
	mL•kg^{-1}•min^{-1}										
Males											
8 to 9	45.2	46.2	47.6	48.8	49.9	51.0	52.1	53.2	54.5	56.0	57.1
10 to 11	44.1	45.3	46.9	48.2	49.4	50.6	51.8	53.1	54.4	56.1	57.4
12 to 13	43.0	44.3	46.0	47.4	48.8	50.1	51.4	52.8	54.3	56.2	57.6
14 to 15	41.8	43.1	45.0	46.6	48.1	49.5	51.0	52.5	54.1	56.2	57.7
16 to 17	40.5	42.0	44.0	45.7	47.3	48.8	50.4	52.0	53.8	56.0	57.7
18 to 19	39.1	40.7	42.9	44.7	46.4	48.0	49.7	51.5	53.4	55.8	57.6
20 to 24	36.8	38.5	40.9	42.9	44.7	46.4	48.3	50.1	52.2	54.9	56.9
25 to 29	33.7	35.6	38.1	40.1	42.0	43.8	45.7	47.6	49.8	52.7	54.9
30 to 34	31.2	33.1	35.6	37.6	39.4	41.1	42.9	44.8	47.0	49.8	52.0
35 to 39	29.5	31.3	33.7	35.6	37.3	38.9	40.6	42.4	44.4	47.1	49.3
40 to 44	28.2	30.0	32.3	34.1	35.7	37.3	38.9	40.6	42.5	45.2	47.3
45 to 49	26.6	28.5	30.8	32.5	34.1	35.6	37.1	38.8	40.7	43.3	45.5
50 to 54	24.1	26.0	28.4	30.2	31.7	33.2	34.7	36.4	38.3	41.0	43.3
55 to 59	21.2	23.1	25.5	27.3	28.8	30.3	31.7	33.3	35.3	38.1	40.4
60 to 64	18.9	20.7	23.0	24.6	26.0	27.3	28.6	30.1	31.9	34.5	36.8
65 to 69	17.4	19.0	20.9	22.3	23.4	24.5	25.6	26.8	28.3	30.5	32.5
Females											
8 to 9	45.6	46.5	47.7	48.7	49.6	50.6	51.6	52.7	53.9	55.5	56.7
10 to 11	42.3	43.4	44.8	45.9	47.0	48.0	49.1	50.3	51.7	53.6	55.2
12 to 13	39.8	41.0	42.5	43.7	44.8	45.9	47.0	48.2	49.7	51.9	53.7
14 to 15	38.0	39.3	40.9	42.1	43.1	44.2	45.2	46.5	47.9	50.1	52.1
16 to 17	36.8	38.1	39.6	40.8	41.8	42.8	43.8	44.9	46.4	48.5	50.4
18 to 19	35.9	37.2	38.7	39.8	40.8	41.7	42.7	43.7	45.1	47.1	48.9
20 to 24	34.5	35.8	37.3	38.4	39.3	40.2	41.1	42.1	43.4	45.3	47.1
25 to 29	32.3	33.6	35.2	36.3	37.3	38.3	39.2	40.3	41.7	43.7	45.5
30 to 34	29.7	31.1	32.8	34.1	35.3	36.3	37.5	38.7	40.2	42.5	44.5
35 to 39	27.0	28.6	30.4	31.9	33.1	34.3	35.6	37.0	38.7	41.2	43.3
40 to 44	24.7	26.2	28.1	29.6	31.0	32.3	33.6	35.1	36.9	39.5	41.7
45 to 49	22.6	24.1	26.0	27.5	28.9	30.3	31.7	33.2	35.0	37.5	39.6
50 to 54	20.8	22.2	24.1	25.6	26.9	28.3	29.7	31.2	33.0	35.4	37.4
55 to 59	19.3	20.6	22.4	23.8	25.1	26.4	27.8	29.3	30.9	33.2	35.0
60 to 64	17.9	19.1	20.8	22.1	23.4	24.7	26.0	27.4	28.9	31.0	32.7
65 to 69	16.7	17.8	19.4	20.6	21.8	23.0	24.3	25.6	27.0	28.9	30.4

Note: modified Canadian Aerobic Fitness Test is used as a measure of cardiorespiratory fitness.
Source: Canadian Health Measures Survey cycle 5 (2016 to 2017).

Table 3
Sit-and-reach percentile values by age group and sex

Age (years)	P_5	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{95}
	cm										
Males											
6 to 7	9.5	13.2	17.5	20.4	22.8	24.9	27.0	29.4	32.4	36.8	40.7
8 to 9	9.0	12.3	16.5	19.5	22.0	24.4	26.8	29.3	32.3	36.4	39.9
10 to 11	8.8	12.0	16.0	19.0	21.7	24.3	26.8	29.5	32.5	36.4	39.6
12 to 13	8.8	11.8	15.7	18.8	21.6	24.3	27.0	29.7	32.7	36.6	39.5
14 to 15	8.8	11.7	15.6	18.7	21.6	24.4	27.1	29.9	33.0	36.8	39.6
16 to 17	8.8	11.7	15.6	18.7	21.6	24.4	27.3	30.1	33.2	37.0	39.7
18 to 19	8.8	11.7	15.6	18.7	21.6	24.5	27.4	30.3	33.4	37.1	39.8
20 to 24	8.9	11.7	15.5	18.7	21.7	24.6	27.5	30.4	33.5	37.2	39.9
25 to 29	8.8	11.6	15.4	18.6	21.6	24.5	27.4	30.3	33.4	37.1	39.7
30 to 34	8.7	11.5	15.3	18.4	21.3	24.2	27.0	29.9	32.9	36.6	39.3
35 to 39	8.6	11.3	15.1	18.2	21.0	23.8	26.5	29.3	32.3	36.0	38.6
40 to 44	8.4	11.1	14.9	17.8	20.6	23.3	25.9	28.6	31.6	35.2	37.8
45 to 49	8.2	10.9	14.6	17.5	20.1	22.7	25.3	27.9	30.7	34.3	36.9
50 to 54	8.0	10.7	14.3	17.1	19.7	22.1	24.6	27.1	29.8	33.4	36.0
55 to 59	7.8	10.5	14.0	16.7	19.2	21.5	23.9	26.3	28.9	32.4	35.1
60 to 64	7.6	10.3	13.7	16.4	18.7	20.9	23.1	25.5	28.0	31.4	34.1
65 to 69	7.4	10.1	13.4	16.0	18.2	20.3	22.4	24.6	27.1	30.5	33.1
Females											
6 to 7	15.1	19.3	23.8	26.7	29.0	30.9	32.8	35.0	37.6	41.6	45.1
8 to 9	15.0	19.2	23.7	26.6	28.9	30.9	32.9	35.1	37.8	41.7	45.2
10 to 11	14.9	19.1	23.6	26.6	28.9	31.0	33.0	35.2	37.9	41.9	45.3
12 to 13	14.9	18.9	23.5	26.5	28.9	31.0	33.1	35.3	38.1	42.0	45.3
14 to 15	14.8	18.8	23.4	26.4	28.9	31.0	33.1	35.5	38.2	42.1	45.4
16 to 17	14.7	18.7	23.3	26.4	28.8	31.1	33.2	35.6	38.4	42.3	45.5
18 to 19	14.6	18.6	23.1	26.3	28.8	31.1	33.3	35.7	38.5	42.4	45.6
20 to 24	14.4	18.3	22.9	26.1	28.7	31.1	33.5	36.0	38.8	42.6	45.7
25 to 29	14.1	17.9	22.5	25.8	28.5	31.1	33.7	36.2	39.1	42.9	45.8
30 to 34	13.8	17.5	22.0	25.4	28.3	31.0	33.7	36.4	39.3	43.0	45.7
35 to 39	13.5	17.0	21.4	24.8	27.8	30.7	33.5	36.2	39.2	42.8	45.4
40 to 44	13.0	16.4	20.8	24.2	27.3	30.2	33.1	35.9	38.8	42.3	44.8
45 to 49	12.5	15.8	20.1	23.5	26.6	29.6	32.5	35.4	38.3	41.7	44.1
50 to 54	12.0	15.3	19.6	23.0	26.1	29.1	32.0	34.9	37.8	41.1	43.5
55 to 59	11.6	14.9	19.2	22.6	25.8	28.8	31.7	34.6	37.5	40.9	43.2
60 to 64	11.3	14.7	19.1	22.5	25.7	28.8	31.7	34.6	37.6	41.0	43.4
65 to 69	11.1	14.5	19.0	22.6	25.8	28.9	31.8	34.7	37.7	41.3	43.8

Source: Canadian Health Measures Survey cycle 5 (2016 to 2017).

higher and lower scores relative to the general Canadian population. It is important to identify low levels of physical fitness, given that fitness is a strong indicator of current health status, and, for children and adolescents, it is potentially predictive of future health outcomes in young adulthood. This study also builds on a growing body of norms literature that has been published for a variety of physical fitness measures, both nationally and internationally.[e.g., 8,30]

The results from this study generally align with findings from previous research. Consistent with this study's findings, pronounced increases in grip strength from childhood through adolescence were observed in cycles 1 to 3 (2007 to 2013) of the CHMS,[8] and in data from 2,779,165 individuals aged 9 to 17 representing 30 European countries.[30] Increases in grip strength until ages 40 to 44 were reported in a subsample of "healthy" individuals (i.e., individuals with no acute or chronic health conditions) who participated in previous cycles of the CHMS.[8] This differs from this study's findings, where males in cycle 5 of the CHMS had grip strength scores that generally began to plateau or decline when men reached their early 30s. These differences may represent declining trends in grip strength, as reported previously,[31] or may be due to differences in health between those included in Wong's[8] study of cycles 1 to 3 of the CHMS (i.e., a "healthy" subsample) and those who were included in this analysis (i.e., the general population).

Given that CRF ($\dot{V}O_{2max}$) can be measured using different techniques and protocols (e.g., laboratory vs. field tests), this study's CRF results were compared with other studies that used the mCAFT. A comparison of children's and adolescents' CRF scores at P_{50} from cycle 5 of the CHMS with CRF scores of children and adolescents at P_{50} from cycle 1 (2007 to 2009)[32] showed that boys in both cycles had better CRF scores than girls (though the difference was more modest in cycle 5) and that CRF scores declined with age for both sexes. Girls had comparable CRF scores across cycles 1 and 5, whereas boys' CRF scores dropped in cycle 5. Similar

Table 4
Jumping height percentile values by age group and sex

Age (years)	P_{5}	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{95}
	cm										
Males											
8 to 9	21.4	22.9	24.9	26.5	27.9	29.2	30.7	32.3	34.3	37.2	39.8
10 to 11	24.9	26.9	29.5	31.5	33.2	34.8	36.5	38.4	40.6	43.8	45.0
12 to 13	27.9	30.5	33.6	35.9	38.0	39.9	41.8	43.9	46.3	49.8	52.7
14 to 15	30.2	33.3	37.0	39.6	41.9	44.0	46.1	48.3	51.0	54.6	57.6
16 to 17	31.8	35.2	39.3	42.2	44.7	46.9	49.2	51.5	54.3	58.1	61.1
18 to 19	32.6	36.3	40.7	43.8	46.3	48.7	51.0	53.5	56.3	60.1	63.2
20 to 24	32.6	36.6	41.2	44.3	47.0	49.4	51.7	54.1	56.9	60.7	63.8
25 to 29	31.5	35.5	40.0	43.1	45.7	48.0	50.3	52.6	55.3	59.0	61.9
30 to 34	30.1	33.9	38.2	41.1	43.6	45.8	47.9	50.2	52.8	56.3	59.1
35 to 39	28.8	32.3	36.3	39.1	41.4	43.5	45.5	47.7	50.2	53.5	56.2
40 to 44	27.5	30.7	34.4	37.0	39.1	41.1	43.1	45.1	47.5	50.7	53.3
45 to 49	26.2	29.1	32.5	34.9	36.9	38.8	40.6	42.6	44.9	48.0	50.5
50 to 54	24.8	27.4	30.6	32.8	34.7	36.4	38.2	40.0	42.2	45.1	47.6
55 to 59	23.4	25.7	28.5	30.6	32.3	33.9	35.6	37.3	39.3	42.2	44.5
60 to 64	21.7	23.8	26.4	28.2	29.8	31.3	32.8	34.4	36.3	39.0	41.2
65 to 69	19.9	21.7	24.0	25.7	27.1	28.5	29.8	31.3	33.1	35.5	37.6
Females											
8 to 9	20.6	22.2	24.2	25.6	26.8	27.9	29.0	30.2	31.5	33.4	35.0
10 to 11	24.1	26.0	28.3	30.0	31.4	32.8	34.1	35.5	37.2	39.5	41.4
12 to 13	25.5	27.6	30.0	31.9	33.4	34.9	36.3	37.9	39.7	42.3	44.4
14 to 15	25.3	27.3	29.9	31.7	33.3	34.7	36.2	37.8	39.7	42.3	44.5
16 to 17	24.5	26.5	28.9	30.7	32.3	33.7	35.2	36.8	38.7	41.3	43.5
18 to 19	23.6	25.6	28.0	29.8	31.3	32.8	34.2	35.8	37.6	40.2	42.4
20 to 24	22.8	24.7	27.1	28.9	30.4	31.8	33.3	34.8	36.7	39.3	41.4
25 to 29	22.2	24.1	26.5	28.3	29.9	31.3	32.8	34.3	36.2	38.8	41.0
30 to 34	21.7	23.6	26.1	27.9	29.4	30.9	32.3	33.9	35.8	38.5	40.7
35 to 39	21.0	22.9	25.4	27.2	28.7	30.2	31.6	33.2	35.1	37.8	40.0
40 to 44	20.1	22.0	24.4	26.1	27.7	29.1	30.5	32.1	34.0	36.6	38.7
45 to 49	19.0	20.8	23.1	24.8	26.3	27.7	29.1	30.6	32.4	34.9	37.0
50 to 54	17.7	19.5	21.7	23.3	24.7	26.1	27.4	28.8	30.5	32.9	34.9
55 to 59	16.4	18.1	20.2	21.8	23.1	24.4	25.6	27.0	28.6	30.9	32.7
60 to 64	15.2	16.8	18.8	20.2	21.5	22.7	23.9	25.2	26.7	28.8	30.6
65 to 69	14.1	15.6	17.4	18.8	20.0	21.1	22.2	23.4	24.9	26.9	28.5

Source: Canadian Health Measures Survey cycle 5 (2016 to 2017).

Table 5
Jumping power percentile values by age group and sex

Age (years)	P_{5}	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{95}
	kW										
Males											
8 to 9	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.3	1.5	1.6	1.8
10 to 11	1.1	1.2	1.4	1.5	1.6	1.6	1.7	1.9	2.0	2.2	2.4
12 to 13	1.5	1.7	1.9	2.0	2.1	2.2	2.4	2.5	2.7	3.0	3.3
14 to 15	2.0	2.1	2.4	2.6	2.7	2.9	3.0	3.2	3.5	3.8	4.1
16 to 17	2.3	2.5	2.8	3.0	3.2	3.4	3.6	3.8	4.1	4.5	4.8
18 to 19	2.6	2.8	3.1	3.4	3.6	3.8	4.0	4.2	4.5	5.0	5.3
20 to 24	2.8	3.0	3.3	3.6	3.8	4.0	4.2	4.5	4.8	5.3	5.7
25 to 29	2.8	3.0	3.3	3.6	3.8	4.0	4.3	4.5	4.8	5.2	5.6
30 to 34	2.7	2.9	3.3	3.5	3.7	3.9	4.1	4.4	4.7	5.1	5.4
35 to 39	2.6	2.9	3.2	3.4	3.6	3.8	4.0	4.2	4.5	4.9	5.2
40 to 44	2.5	2.8	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.7	5.0
45 to 49	2.4	2.6	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.5	4.8
50 to 54	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.6	3.9	4.2	4.5
55 to 59	2.1	2.3	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.9	4.1
60 to 64	1.9	2.1	2.3	2.5	2.7	2.8	2.9	3.1	3.3	3.6	3.8
65 to 69	1.7	1.9	2.1	2.3	2.4	2.5	2.7	2.8	3.0	3.2	3.4
Females											
8 to 9	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.5	1.6
10 to 11	1.2	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	2.1	2.2
12 to 13	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.3	2.5	2.8
14 to 15	1.5	1.6	1.8	1.9	2.0	2.1	2.3	2.4	2.6	2.8	3.1
16 to 17	1.5	1.7	1.8	2.0	2.1	2.2	2.4	2.5	2.7	3.0	3.2
18 to 19	1.5	1.7	1.9	2.0	2.2	2.3	2.4	2.6	2.8	3.0	3.3
20 to 24	1.5	1.7	1.9	2.0	2.2	2.3	2.4	2.6	2.8	3.0	3.2
25 to 29	1.5	1.6	1.8	2.0	2.1	2.3	2.4	2.6	2.7	3.0	3.2
30 to 34	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.5	2.7	3.0	3.2
35 to 39	1.6	1.7	1.9	2.0	2.1	2.2	2.4	2.5	2.7	2.9	3.2
40 to 44	1.6	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.6	2.9	3.1
45 to 49	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.5	2.7	3.0
50 to 54	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.4	2.6	2.7
55 to 59	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.4	2.5
60 to 64	1.3	1.4	1.5	1.6	1.7	1.8	1.8	1.9	2.0	2.2	2.3
65 to 69	1.2	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.1

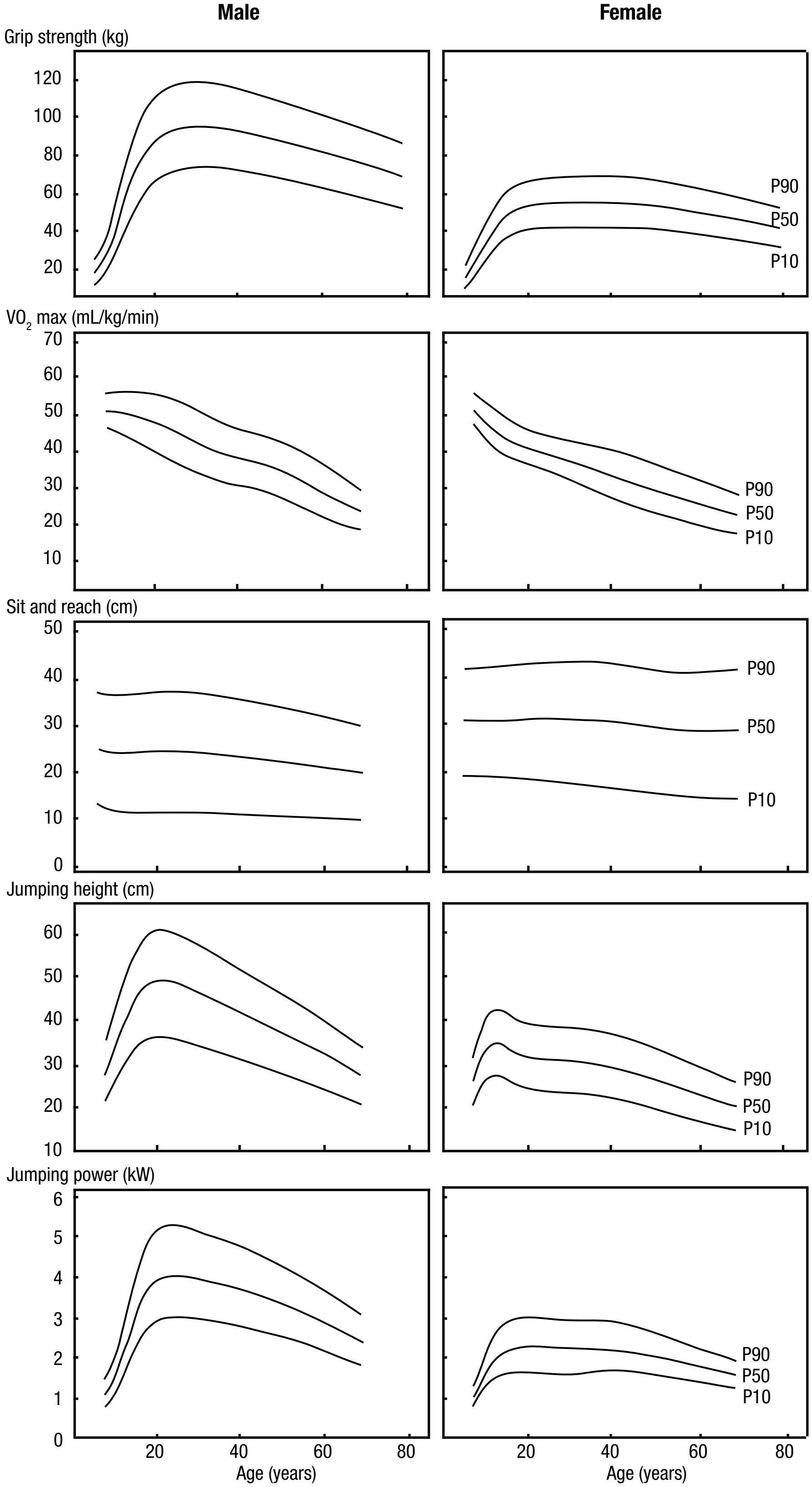
Source: Canadian Health Measures Survey cycle 5 (2016 to 2017).

to the findings for boys' and girls' CRF in cycle 5, adult males in cycle 5 had modestly higher CRF levels than adult females, and CRF levels for both sexes declined with age. Adult females' CRF levels at P_{50} from cycle 5 remained consistent with those of adult females at P_{50} from cycle 1, whereas adult males' CRF levels at P_{50} from cycle 5 appeared to be lower than those of adult males at P_{50} from cycle 1.[31] It should be noted that there is some difficulty in contrasting adult CRF scores from the current study (cycle 5) with those from cycle 1,[31] given the large age range of the groups reported in cycle 1 (i.e., 20 to 39 years, 40 to 59 years and 60 to 69 years).

This study's findings for the sit-and-reach test support previous Canadian and international studies that show that females generally have better flexibility than males at all ages.[(e.g., 16,30-32)] Further comparisons of children's and adolescents' sit-and-reach scores at P_{50} from cycle 5 of the CHMS with those of children and adolescents at P_{50} from cycle 1 (2007 to 2009)[32] reveal consistent differences in flexibility between males and females across the two cycles. Moreover, as previously documented with adults who participated in cycle 1 of the CHMS,[31] this study also showed that sex differences in flexibility persisted with age. While recent studies suggest that flexibility is not as strong an indicator of health as CRF and muscular strength,[1,2] the sit-and-reach test is nonetheless included in several fitness test batteries across the world (e.g., Eurofit, FitnessGram).

This study's findings also add to the growing body of Leonardo jumping mechanography data from Canada,[9] the United States,[33] Europe[34,35] and Japan.[11] Jumping power and height scores from this study were similar to those reported by Gabel et al.[9] for Canadian males and females aged 9 to 21, even though a different jumping protocol was used. Consistent with previous research,[9,35] this study found that males had jumping height and power scores that continually increased until late adolescence, whereas females had jumping height scores that plateaued at approximately age 13, but jumping power scores that did not plateau until mid to late adolescence. Males also had greater jumping power and height scores than females, and jumping scores for both sexes gradually declined into late adulthood. This aligns with trends from previous jumping studies conducted with adults.[33,34] Although this study reports the

Figure 2
Age-specific percentile curves for each physical fitness test, by sex



Note: Lines represent the 10th, 50th and 90th centiles.
Source: Canadian Health Measures Survey Cycle 5, 2016 to 2017.

first nationally representative age- and sex-specific Canadian normative-referenced percentile values for jumping power and height, these jumping norms should be compared only with data generated from the Leonardo Mechanograph Force Plate, given known systematic biases in jumping height data compared with other (field-based) protocols (e.g., Vertec apparatus).[e.g., 36,37] Even when compared with other studies that used the same force plate, jumping protocol differences should be noted.

Strengths and limitations

This study has several strengths, including the use of a large nationally representative sample of Canadians, the use of objective measures of physical fitness that were conducted by trained staff, results that are presented across a wide age range, and the use of robust analytical techniques that expand on the LMS technique. Survey weights were also applied to all analyses to account for non-response bias and the complex survey design.[19,20]

Despite these strengths, this study is not without limitations. The CHMS has strict inclusion and exclusion criteria for fitness testing that may have biased this study's results by screening out unfit individuals, resulting in reference values that are higher than those of the general population. The nature of the CHMS, being a health-related study, may also have resulted in a higher response rate for healthy individuals. However, this potential limitation was previously tested by comparing the obesity levels of Canadians collected in the CHMS with a different national health survey (i.e., the 2008 Canadian Community Health Survey). The authors concluded that there was no evidence to suggest that the nature of the CHMS had an impact on survey estimates among adults, at least from an obesity perspective.[31] However, the health-related nature of the survey may have had a larger impact on recruiting fitter children and adolescents.[32] As previously mentioned, the mCAFT was not validated in children younger than age 15, which represents an important area for future research. Lastly, because of a problem with the jumping mechanography software, the signal from the force sensors was sampled at times at a frequency of 400 Hz, and at other times at a frequency of 800 Hz. While this limitation should be noted, the difference in sampling frequency should not have had a significant effect on the results.

Conclusion

This study produced nationally representative normative-referenced percentile values for five physical fitness tests across a wide age range of Canadians. This can help inform public health and clinical practice by supplementing patient screening criteria. Exercise professionals who train clients can also use the results to track progress against the percentile bands annually or biannually. Future research should further investigate the health-related percentile cut points for these physical fitness measures through the development of criterion-referenced standards. ■

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