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Trends in physical fitness among Canadian children and youth

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Abstract

Background: Physical fitness during childhood is an important indicator of current and future health. This paper provides an overview of the fitness of Canadian children and youth aged 6 to 19 years.

Data and methods: Data are from three cycles of the Canadian Health Measures Survey (CHMS) spanning a 10-year period: 2007 to 2009 (n = 2,081), 2009 to 2011 (n = 2,133) and 2016 to 2017 (n = 2,070). The CHMS is a comprehensive direct health measures survey conducted on a nationally representative sample of Canadians. Descriptive statistics for measures of cardiorespiratory fitness, muscular strength and power, flexibility, and body composition are provided by age group and sex. Physical fitness measures are presented for participants who met and did not meet the physical activity and screen time recommendations.

Results: Few changes in the fitness measures occurred over the past decade. Cardiorespiratory fitness decreased between 2007-2009 and 2016-2017 in 8 to 10 (52.1 to. 51.0 $mL•kg^{-1}•min^{-1}$) and 11 to 14 (50.8 to 49.8 $mL•kg^{-1}•min^{-1}$) year old boys. Girls generally had lower levels of fitness compared to boys, except for flexibility which was higher in girls. Cardiorespiratory fitness was higher in children and youth who met the current Canadian recommendations for physical activity and screen time. Grip strength was higher in boys who met the current Canadian screen time recommendation.

Interpretation: Ongoing and periodic surveillance of fitness through the CHMS is important to monitor trends, assess future interventions designed to improve fitness levels at the population level and to increase our understanding of the relationships between fitness and health.

Keywords: cardiorespiratory fitness, muscular strength, muscular power, flexibility, obesity
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Physical fitness is a set of attributes that reflect one's ability to perform physical activity and typically includes measures of cardiorespiratory fitness, muscular strength and power, flexibility and body composition.[1] Cardiorespiratory fitness is positively associated with improved health in children and youth[2-4] and large cohort studies have reported a link between low cardiorespiratory fitness in late adolescence and early mortality.[5,6] Further, fitness in childhood is considered an important indicator of current[7] and future[8] health, independent of physical activity.[9] Evidence indicates that childhood cardiorespiratory fitness levels are declining both worldwide[10] and in Canada.[11] While cardiorespiratory fitness tends to be more strongly associated with health outcomes when compared to measures of muscular strength and flexibility,[3,12] the other components of physical fitness provide unique information related to physical performance and potentially healthy growth and development. Low grip strength is a risk factor for hypertension and type 2 diabetes[13] and predictor of all-cause and cardiovascular disease mortality.[14] Flexibility during childhood is a predictor of adult health-related fitness[15] while jumping height and power are indicators of anaerobic fitness[16] and important for many activities of daily living. Active children and youth tend to be fitter than less active children;[17,18] however the relationships among physical activity, sedentary behaviour and fitness remain unclear and have not been examined using population-level data in Canada.

Surveillance of fitness indicators at the population level is important but logistically challenging due to the breadth and complexity of the measurements. The 2007-2009 Canadian Health Measures Survey (CHMS) was the first time in more than two decades that fitness was measured at the national level in Canada. Fitness was measured in the first two cycles of the CHMS (2007-2009 and 2009-2011) and then again in cycle 5 (2016-2017). The CHMS is a comprehensive, ongoing direct health measures survey that is conducted by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada. The primary objective of the CHMS is to collect new and important data on Canadians' health status with a focus on obtaining information that can only be ascertained using direct measurement techniques (blood markers, fitness, physical activity). A comparison of the CHMS data to the 1981 Canadian Fitness Survey[19] indicated that muscular strength and flexibility had decreased, and adiposity had increased in Canadian children and youth.[11]

Using data spanning a decade (2007 to 2017) from cycles 1, 2 and 5 of the CHMS, this paper provides a comprehensive update of current fitness levels and a description of recent trends in the fitness levels of Canadian children and youth aged 6 to 19 years. The purpose of this paper is three-fold: 1) to describe age and sex differences in fitness indicators using the most recent cycle of data (2016 to 2017), 2) to examine the temporal trend in fitness across the three cycles of the CHMS (2007 to 2017), and 3) to examine how fitness measures vary

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according to meeting and not meeting current Canadian physical activity and screen time recommendations.[20]

Methods

Data source

The CHMS is an ongoing cross-sectional survey conducted by Statistics Canada that collects measured and reported health information from a representative sample of the Canadian household-dwelling population aged 3 to 79 years using mobile examination centres that travel to multiple sites across the country, except the territories. Ethics approval to conduct the survey was obtained from Health Canada's Research Ethics Board.[21] Respondents aged 14 years and older provided written consent to participate and younger children provided written assent and parental consent. A full description of the design and procedures used in the CHMS is available in previous publications.[21,22]

Following a household interview, CHMS respondents were invited to visit the mobile examination centre where they underwent biological and physical measures and participated in fitness tests. The fitness tests were conducted by specialists certified by the Canadian Society for Exercise Physiology. Before undergoing any fitness tests, respondents were asked about their physical and health conditions and their use of prescription medications. A Physical Activity Readiness Questionnaire (PAR-Q) was completed and signed by all respondents (and by the guardian if the respondent was younger than 14 years). Respondents were screened out of certain tests according to their answers to the screening questions. Respondents were requested to adhere to pre-testing guidelines regarding food, alcohol, caffeine, nicotine, exercise and blood donations. Detailed information about the screening questions and pre-testing guidelines are available elsewhere.[1,23-25]

This analysis is limited to participants aged 6 to 19 years who participated in cycles 1, 2 or 5 of the CHMS and provided valid measured fitness data (n=6,284). The analyses were divided into age groups: 6 to 10 years (mean age: 8.1 years), 11 to 14 years (mean age: 12.5 years) and 15 to 19 years (mean age: 17.0 years). The sample size of the youngest age group was smaller for cardiorespiratory fitness because the test was only completed by children aged 8 and older (mean age: 9.1 years). A further 578 children did not complete the modified Canadian Aerobic Fitness Test (mCAFT) for the following reasons: PAR-Q answer (n = 378), forgot breathing aid (n = 76), elevated heart rate (n = 44), acute or chronic condition (n = 38), contraindication with medication (n = 20), other (n = 22). A sub-sample analysis was completed on participants aged 8 to 19 years with both valid fitness and accelerometer-measured physical activity data (n = 3,071).

Fitness Measures

The fitness measures used in the CHMS are described briefly herein. A more detailed description of the testing protocols can be found it the CSEP-PATH Manual.[1] Cardiorespiratory fitness ($\dot{V}O_{2peak}$) was predicted in children aged 8 years and older using the mCAFT, a step test where respondents complete one or more three-minute stages at speeds that are predetermined based on their age and sex.[1] Each respondents' heart rate was recorded after each stage, and their test was completed when their heart rate at the end of the stepping stage reached 85% of their age-predicted maximum heart rate (220-age). Predicted maximal aerobic power ($\dot{V}O_{2peak}$ in $mL{\bullet}kg^{-1}{\bullet}min^{-1}$) was calculated for all respondents using an equation that was developed for people aged 15 to 69 years.[26] The equation was also applied to 8 to 14 year-olds in this analysis as mCAFT equations have not been developed for this age group. After cycle 1, the mCAFT was discontinued for children less than 8 years of age due to safety concerns (standard step height being too high) and a low test completion rate in that age group (which can be attributed to difficulties maintaining the cadence and stepping pattern).

Muscular strength was assessed by measuring grip strength in kilograms with a Smedley III analog hand-grip dynamometer (Takei Scientific Instruments, Tokyo, Japan). Two attempts were performed on each hand and the maximum scores from each hand were combined. Flexibility was assessed with the sit-and-reach test, where respondents sat on the floor with their legs extended against a flexometer (Fit Systems Inc., Calgary, Canada) and stretched as far forward as possible without bending the knees. Two attempts were performed and the better of two attempts was used in the analyses. A toe touch was equivalent to 26 cm.

Although not part of the CSEP-PATH testing protocol,[1] jumping mechanography testing using the Leonardo Mechanograph Ground Reaction Force Plate (Novotec Medical GmbH, Pforzheim, Germany) was introduced in cycle 5 to derive key descriptors of muscle performance and was used in the present analysis to derive predicted maximum vertical jump height (metres), peak power (kW) and relative peak power (W per kg body weight).[27] The movement pattern used for the Single Two-Leg Jump (S2LJ) differed from the CSEP-PATH vertical jump test and consisted of a single countermovement jump with arm swing performed in a fluid sequence with both feet leaving and landing on the plate simultaneously. The respondent repeated the test until three valid trials had been completed or a maximum of five trials had been attempted. The best performance was used in the analyses. After each trial, the validity of the results was confirmed by the collection application or manually by a health measures specialist and subsequently reviewed by two external reviewers. The signal from the force sensors was sampled at a frequency of either 400 or 800 Hz. The Leonardo Mechanography GRFP Research Edition® software (v.4.2.b06.10f) uses force and time data to estimate body mass, jump height, maximum (peak) power, both absolute and relative (/ body mass) during the upward phase of the jump. When the respondent's centre of gravity reaches the maximum vertical height, the body's maximal kinetic

What is already known on this subject?

- Physical fitness is associated with health among children and youth.
- Low physical fitness in late adolescence has been linked to early mortality.
- The 2007-2009 Canadian Health Measures Survey (CHMS) was the first time in more than two decades that fitness had been measured at the national level in Canada.
- A comparison of the 2007-2009 CHMS data to the 1981 Canadian Fitness Survey indicated that muscular strength and flexibility had decreased, and adiposity had increased in Canadian children and youth.

What does this study add?

- Data from the most recent cycle of the CHMS were used to describe age and sex differences in fitness indicators among children and youth aged 6 to 19 years. Girls generally had lower levels of fitness compared to boys.
- Data from three cycles of the CHMS (2007 to 2017) were used to assess temporal changes. Few changes were observed in the fitness measures over the past decade using data from three cycles of the CHMS.
- Cardiorespiratory fitness was higher in children and youth who met the current Canadian recommendations for physical activity and screen time. Grip strength was higher in boys who met the current Canadian screen time recommendation.

energy (Max E_{kin}) turns into maximal potential energy (Max E_{pot}) (i.e., the maximal height the value of Max E_{kin} equals Max E_{pot}). Maximum jump height for the S2LJ can be estimated by dividing the body's maximal kinetic energy (Max E_{kin}) by the body mass: *jump height (metres) = (Max E_{kin}) / body mass in kg.*[27]

Height was measured to the nearest 0.1 centimetre using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA), and weight to the nearest 0.1 kilogram with a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada). Waist circumference was measured to the nearest 0.1 cm using a flexible and non-stretch anthropometric tape. Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared ($kg \cdot m^2$). BMI *z*-scores were determined using the World Health Organization BMI-for-age Child Growth Standards and respondents were classified as having overweight or obesity if their BMI *z*-score was >1 standard deviation above the mean.[28]

Measurement of physical activity and screen time

Upon completion of the mobile examination centre visit, ambulatory respondents were asked to wear an Actical accelerometer (Phillips – Respironics, Oregon, USA) over their right hip on an elasticized belt during waking hours for seven consecutive days. All respondents were blind to the data while they wore the device. The Actical measures and records time-stamped acceleration in all directions, providing an index of movement intensity via a count value for each minute. A valid day was defined as having 10 or more hours of wear time and a valid respondent was defined as having a minimum of four valid days.[29] Wear time was determined by subtracting nonwear time from 24 hours. Nonwear time was defined as at least 60 consecutive minutes of zero counts, with allowance for one to two minutes of counts between zero and 100. Published movement intensity thresholds were applied to the data to derive time spent in sedentary, light (LPA) and moderate-to vigorous-intensity physical activity (MVPA).[30,31] A complete description of the accelerometer data reduction procedures is available elsewhere.[29]

Screen time and sleep duration were reported by parents for children aged 6 to 11 years and self-reported in youth aged 12 to 19 years. While the questions remained relatively consistent over time, important changes in questionnaire design occurred between cycles that affected screen time responses. For parent-reported screen time (6 to 11 year olds), there was a shift from categorical to continuous responses between cycles 2 and 5. For self-reported screen time (12 to 19 year olds), there was a shift from categorical to continuous responses between cycles 1 and 2.[23-25]

Analytical techniques

To describe age and sex differences in physical fitness indicators using the most recent cycle of data, data were analyzed separately by sex for three age groups: 6 to 10 (8 to 10 for cardiorespiratory fitness), 11 to 14, 15 to 19 years. Means and 95% confidence intervals were produced for all fitness measures. To account for the survey design effects, 95% confidence intervals were estimated using the bootstrap technique.[23-25] Between cycle differences in fitness, physical activity and screen time were assessed using pairwise contrasts at a *p*-value of <0.01 to account for multiple comparisons. To examine how fitness measures vary according to meeting and not meeting current Canadian physical activity and screen time recommendations, data from cycles 1, 2 and 5 were combined. Differences between meeting and not meeting recommendations were assessed using pairwise contrasts at a *p*-value of <0.05. Predicted maximum vertical jump height, peak power and relative peak power were not included in the analyses of temporal trends because they were only measured in cycle 5. All analyses were weighted using cycle survey weights generated by Statistics Canada. The sub-sample analysis using all three cycles used the combined cycle weights. To account for survey design effects, 95% confidence intervals were estimated using the bootstrap technique. The data were analyzed using SAS 9.3 (SAS Institute, Cary, North Carolina) and SUDAAN 11.0.

Results

Age and sex differences in physical fitness indicators using the most recent cycle of data (2016-2017)

Descriptive statistics of physical fitness indicators using data from the most recent CHMS cycle are presented in Table 1. Cardiorespiratory fitness was higher in boys compared to girls for age 11+ years only. Cardiorespiratory fitness was lower in 11 to 14 year old boys compared to 8-10 year old boys while cardiorespiratory fitness decreased steadily across age groups in girls. Grip strength increased with age and was higher in boys compared to girls in all age groups. Flexibility measures were higher in girls compared to boys in all age groups. Predicted vertical jump height and peak power (absolute and relative) were higher in boys compared to girls aged 11 to 19 years, but not 6 to 10 years. Predicted vertical jump height and peak power (absolute and relative) increased with age in boys. Absolute peak power increased with age in girls while predicted vertical jump height and relative peak power (W per kg body weight) were higher in 11 to 14 compared to 6 to 10 year old girls but not different between 11 to 14 and 15 to 19 year old girls. No differences between

Table 1
Age and sex differences for physical fitness measures, household population aged 6 to 19 years, Canada, 2016 to 2017

	6 to 10 years (8 to 10 years for cardiorespiratory fitness)			11 to 14 years			15 to 19 years		
		95% confidence interval			95% confidence interval			95% confidence interval	
Physical fitness measures and sex	Mean	from	to	Mean	from	to	Mean	from	to
	ml/kg/min								
Cardiorespiratory fitness									
Boys	51.0	49.9	52.1	49.8†	49.0	50.6	50.1	48.1	52.0
Girls	50.0	48.9	51.2	47.9*†	46.9	48.9	42.0**†‡	41.2	42.7
	kg per kg body weight								
Grip strength									
Boys	0.9	0.8	0.9	0.9†	0.9	1.0	1.2†‡	1.1	1.2
Girls	0.8*	0.8	0.8	0.9*†	0.8	0.9	0.8**†	0.8	0.9
	cm								
Flexibility: sit-and-reach									
Boys	26.1	24.6	27.7	21.5†	19.3	23.7	24.4†	22.4	26.4
Girls	30.7**	29.7	31.8	30.8**	28.8	32.7	31.8**	30.0	33.6
	m								
Predicted vertical jumping height									
Boys	0.28	0.27	0.29	0.39†	0.35	0.43	0.49†‡	0.46	0.51
Girls	0.28	0.27	0.28	0.35*†	0.34	0.36	0.36**†	0.34	0.37
	kW								
Peak power									
Boys	1.02	0.95	1.08	2.21†	2.03	2.39	3.76†‡	3.58	3.94
Girls	1.00	0.93	1.08	1.98*†	1.86	2.09	2.41**†‡	2.34	2.47
	W per kg body weight								
Relative peak power									
Boys	33.5	32.2	34.8	42.3†	39.7	44.8	51.7†‡	50.0	53.3
Girls	33.5	32.8	34.3	39.2*†	38.0	40.4	38.9**†	37.7	40.1
	kg/m^2								
Body mass index									
Boys	17.0	16.4	17.6	20.5†	20.0	21.0	23.3†‡	22.4	24.2
Girls	17.1	16.6	17.5	20.6†	19.9	21.4	23.4†‡	22.5	24.3
	z-score								
Body mass index z-score									
Boys	0.33	0.04	0.61	0.67	0.51	0.83	0.39	0.11	0.68
Girls	0.32	0.13	0.51	0.42	0.19	0.66	0.43	0.18	0.67
	cm								
Waist circumference									
Boys	58.8	57.3	60.4	71.9†	70.8	72.9	80.3†‡	78.2	82.3
Girls	58.8	57.3	60.3	70.8†	69.5	72.1	77.4*†‡	75.0	79.9

* significantly different to estimate for boys ($p < 0.05$)
** significantly different to estimate for boys ($p < 0.001$)
† significantly different to estimate for 6 to 10 year olds ($p < 0.05$)
‡ significantly differnet to estimate for 11 to 14 year olds ($p < 0.05$)

Note: cardiorespiratory fitness not measured in 6 and 7 year olds
Source: Canadian Health Measures Survey: 2016 to 2017

Table 2
Trends in physical fitness measures from 2007 to 2017, by age group and sex, household population aged 6 to 19 years, Canada

			Cycle 1 (2007 to 2009)				Cycle 2 (2009 to 2011)				Cycle 5 (2016 to 2017)			
					95% confidence interval				95% confidence interval				95% confidence interval	
Physical fitness measures			n	Mean	from	to	n	Mean	from	to	n	Mean	from	to
			(ml/kg/min)											
Cardiorespiratory fitness	8 to 10 years	Boys	215	**52.1**	51.5	52.8	210	**50.7**†	50.0	51.5	183	**51.0**†	49.9	52.1
		Girls	209	**50.7**	50.1	51.4	227	**50.2**	49.7	50.6	212	**50.0**	48.9	51.2
	11 to 14 years	Boys	283	**50.8**	50.3	51.4	267	**50.7**	49.5	51.8	265	**49.8**†	49.0	50.6
		Girls	272	**48.9**	48.2	49.6	273	**48.7**	47.9	49.4	263	**47.9**	46.9	48.9
	15 to 19 years	Boys	242	**50.7**	49.3	52.1	274	**50.7**	49.6	51.7	217	**50.1**	48.1	52.0
		Girls	241	**42.2**	41.5	42.9	238	**42.7**	42.0	43.4	222	**42.0**	41.2	42.7
			kg per kg body weight											
Grip strength	6 to 10 years	Boys	446	**0.8**	0.8	0.8	426	**0.8**	0.7	0.8	413	**0.9**†‡	0.8	0.9
		Girls	418	**0.8**	0.7	0.8	428	**0.8**	0.7	0.8	419	**0.8**†	0.8	0.8
	11 to 14 years	Boys	316	**1.0**	0.9	1.0	328	**0.9**†	0.9	1.0	320	**0.9**	0.9	1.0
		Girls	301	**0.8**	0.8	0.9	323	**0.8**	0.8	0.8	320	**0.9**	0.8	0.9
	15 to 19 years	Boys	286	**1.2**	1.1	1.2	322	**1.1**†	1.1	1.2	293	**1.2**	1.1	1.2
		Girls	307	**0.9**	0.8	0.9	294	**0.8**	0.8	0.9	282	**0.8**	0.8	0.9
			cm											
Flexibility: sit-and-reach	6 to 10 years	Boys	438	**24.4**	23.1	25.8	418	**24.3**	23.3	25.3	399	**26.1**	24.6	27.7
		Girls	414	**29.3**	28.4	30.3	419	**27.7**	26.8	28.7	415	**30.7**‡	29.7	31.8
	11 to 14 years	Boys	315	**21.4**	19.4	23.4	326	**20.1**	18.6	21.5	320	**21.5**	19.3	23.7
		Girls	300	**28.1**	27.0	29.3	315	**28.5**	26.4	30.6	317	**30.8**	28.8	32.7
	15 to 19 years	Boys	288	**23.1**	22.2	24.1	321	**22.7**	19.4	26.0	290	**24.4**	22.4	26.4
		Girls	302	**30.0**	27.7	32.3	290	**30.9**	29.0	32.8	283	**31.8**	30.0	33.6
			kg/m^2											
Body mass index	6 to 10 years	Boys	448	**17.7**	17.3	18.2	430	**18.1**	17.7	18.6	418	**17.0**‡	16.4	17.6
		Girls	420	**17.1**	16.8	17.5	429	**17.2**	17.0	17.5	421	**17.1**	16.6	17.5
	11 to 14 years	Boys	318	**20.6**	19.7	21.4	332	**20.3**	19.2	21.3	322	**20.5**	20.0	21.0
		Girls	302	**20.4**	19.8	21.1	322	**20.4**	19.7	21.1	323	**20.6**	19.9	21.4
	15 to 19 years	Boys	287	**23.8**	22.5	25.2	322	**23.5**	22.3	24.7	294	**23.3**	22.4	24.2
		Girls	306	**23.1**	22.4	23.8	298	**23.4**	22.4	24.4	284	**23.4**	22.5	24.3
			z-score											
Body mass index z-score	6 to 10 years	Boys	448	**0.72**	0.54	0.89	430	**0.84**	0.61	1.07	418	**0.33**‡	0.04	0.61
		Girls	420	**0.32**	0.17	0.46	429	**0.37**	0.28	0.47	421	**0.32**	0.13	0.51
	11 to 14 years	Boys	318	**0.54**	0.30	0.78	332	**0.37**	0.03	0.72	322	**0.67**	0.51	0.83
		Girls	302	**0.41**	0.20	0.61	322	**0.38**	0.15	0.61	323	**0.42**	0.19	0.66
	15 to 19 years	Boys	287	**0.53**	0.20	0.85	322	**0.52**	0.18	0.86	294	**0.39**	0.11	0.68
		Girls	306	**0.44**	0.22	0.66	298	**0.49**	0.26	0.72	284	**0.43**	0.18	0.67
			cm											
Waist circumference	6 to 10 years	Boys	449	**61.2**	59.6	62.8	430	**61.7**	60.5	62.9	417	**58.8**‡	57.3	60.4
		Girls	420	**59.6**	58.7	60.6	429	**59.4**	58.6	60.3	423	**58.8**	57.3	60.3
	11 to 14 years	Boys	317	**72.4**	69.9	74.9	332	**71.5**	68.6	74.4	325	**71.9**	70.8	72.9
		Girls	301	**72.3**	70.1	74.4	321	**70.5**	68.7	72.3	325	**70.8**	69.5	72.1
	15 to 19 years	Boys	288	**82.4**	78.9	86.0	322	**80.8**	77.8	83.9	295	**80.3**	78.2	82.3
		Girls	306	**79.3**	77.4	81.2	296	**77.8**	75.2	80.4	285	**77.4**	75.0	79.9

† significantly different to cycle 1, $p < 0.01$
‡ significantly different to cycle 2, $p < 0.01$
Source: Canadian Health Measures Survey: 2007 to 2009, 2009 to 2011, 2016 to 2017

boys and girls were evident in BMI or BMI z-score. As expected with normal growth and development, BMI and waist circumference both increased with age.

Temporal trend in fitness across the three cycles of the CHMS (2007 to 2017)

Table 2 depicts how the fitness measures have changed across the three cycles of the CHMS, by age group and sex. Statistically significant differences between cycles are noted ($p < 0.01$). Decreases in cardiorespiratory fitness were observed for 8 to 14 year old boys. Grip strength increased in 6 to 10 year old boys and girls but decreased in 11 to 19 year old boys. Flexibility was stable across time with a slight improvement observed in 6 to 10 year old girls. BMI and waist circumference were lower in cycle 5 compared to cycle 2 in 6 to 10 year old boys.

Temporal trend in MVPA and screen time across the three cycles of the CHMS (2007 to 2017)

Changes between cycles in MVPA and screen time are noted in Figures 2 and 3, respectively. MVPA decreased in 8 to 10

Table 3
Physical fitness measures according to meeting and not meeting current Canadian physical activity and screen time recommendations, household population aged 8 to 19 years, 2007 to 2017

	8 to 10 year olds						11 to 14 year olds						15 to 19 year olds					
	Boys			Girls			Boys			Girls			Boys			Girls		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to	Mean	from	to
	ml/kg/min																	
Cardiorespiratory fitness																		
Meets PAR	52.0	51.4	52.6	51.5	50.7	52.4	51.7	51.1	52.4	50.1	49.1	51.1	53.2	51.8	54.5	43.6	41.8	45.3
Does not meet PAR	49.9	49.0	50.7**	49.8	49.3	50.4**	49.7	48.9	50.4**	48.1	47.7	48.6*	51.0	49.8	52.1*	42.6	42.0	43.1
	kg per kg body weight																	
Grip Strength																		
Meets PAR	0.9	0.9	0.9	0.8	0.8	0.8	1.0	0.9	1.0	0.9	0.8	0.9	1.2	1.1	1.2	0.9	0.8	1.0
Does not meet PAR	0.8	0.8	0.9*	0.8	0.8	0.8	0.9	0.9	1.0	0.8	0.8	0.9	1.2	1.1	1.2	0.9	0.9	0.9
	cm																	
Flexibility: sit-and-reach																		
Meets PAR	23.9	22.4	25.3	30.4	29.0	31.7	21.4	19.5	23.3	29.1	26.8	31.3	24.4	22.1	26.6	30.4	26.1	34.7
Does not meet PAR	23.7	21.7	25.6	28.3	27.2	29.5*	20.8	19.3	22.4	29.2	27.9	30.5	24.8	21.6	27.9	32.4	30.6	34.2
	z-score																	
Body mass index																		
Meets PAR	0.49	0.24	0.74	0.32	0.08	0.57	0.13	-0.17	0.44	0.22	-0.06	0.51	0.35	0.14	0.57	0.70	0.25	1.16
Does not meet PAR	0.79	0.38	1.20	0.29	0.12	0.46	0.68	0.50	0.87*	0.38	0.21	0.56	0.44	0.20	0.69	0.30	0.08	0.52
	ml/kg/min																	
Cardiorespiratory fitness																		
Meets SBR	51.4	50.8	52.0	50.7	50.1	51.2	51.5	50.7	52.2	49.1	48.7	49.5	52.5	51.3	53.6	42.8	41.7	43.8
Does not meet SBR	50.4	49.5	51.4	49.3	48.5	50.1*	50.1	49.4	50.8*	48.2	47.6	48.8*	51.6	50.3	52.8	42.7	42.0	43.3
	kg per kg body weight																	
Grip Strength																		
Meets SBR	0.9	0.9	0.9	0.8	0.8	0.8	1.0	1.0	1.0	0.9	0.8	0.9	1.2	1.2	1.3	0.9	0.8	0.9
Does not meet SBR	0.8	0.8	0.9*	0.8	0.7	0.8	0.9	0.9	1.0**	0.8	0.8	0.9	1.1	1.1	1.2*	0.9	0.9	0.9
	cm																	
Flexibility: sit-and-reach																		
Meets SBR	24.3	22.8	25.9	29.1	28.1	30.1	22.3	19.8	24.7	29.7	27.6	31.8	26.7	21.0	32.4	32.0	28.7	35.3
Does not meet SBR	22.6	21.2	24.1	28.4	26.5	30.4	20.5	19.1	21.9	28.8	27.4	30.1	24.0	22.2	25.7	32.2	30.3	34.2
	z-score																	
Body mass index																		
Meets SBR	0.58	0.27	0.89	0.13	-0.02	0.28	0.14	-0.17	0.44	0.24	0.02	0.46	0.23	-0.07	0.53	0.28	-0.13	0.68
Does not meet SBR	0.68	0.40	0.97	0.78	0.42	1.14*	0.60	0.37	0.84*	0.42	0.21	0.64	0.46	0.27	0.66	0.40	0.18	0.61

PAR = physical activity recommendation
SBR = screen time recommendation
* significantly different to reference value (meeting recommendation), $p < 0.05$
** significantly different to reference value (meeting recommendation), $p < 0.001$
Source: Canadian Health Measures Survey: 2007 to 2009, 2009 to 2011, 2016 to 2017

year old girls but increased in 11-14 year old boys. Screen time decreased from 2007 to 2017 in 8 to 10 year old girls but increased in 15 to 19 year old girls.

Fitness measures according to meeting and not meeting current Canadian physical activity and screen time recommendations

Table 3 describes fitness measures according to meeting or not meeting the current Canadian physical activity and sedentary behaviour recommendations. Cardiorespiratory fitness was higher in those who met the physical activity recommendation compared to those who did not, with the exception of 15 to 19 year old girls. Grip strength was higher in 8 to 10 year old boys who met the physical activity recommendation compared to those who did not. BMI z-score was lower in 11 to 14 year old boys who met the physical activity recommendation compared to those who did not. Cardiorespiratory fitness was higher in those who met the screen time recommendation compared to those who did not in 8 to 10 year old girls and 11 to 14 year old boys and girls. Grip strength was higher in boys aged 8 to 19 years who met the screen time recommendation compared to those who did not. BMI z-score was lower in 8 to 10 year old girls and 11 to 14 year old boys who met the screen time recommendation compared to those who did not.

Discussion

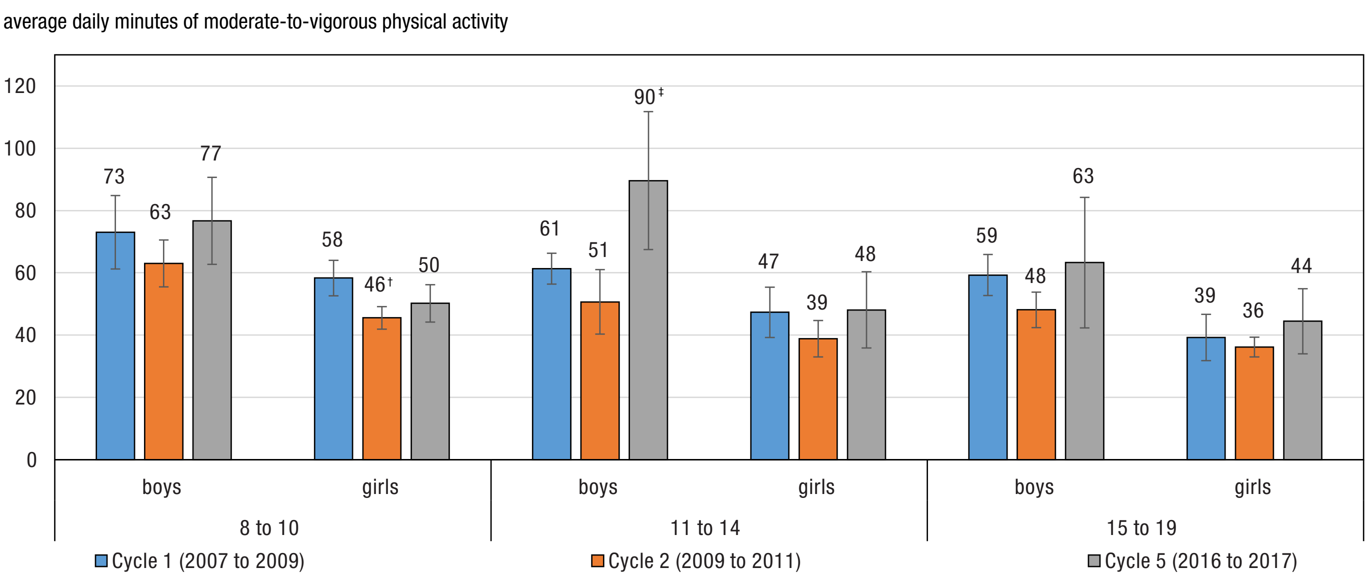
This study provides an update on the physical fitness of Canadian children and youth aged 6 to 19 years using data collected between 2007 and 2017 from the CHMS. Few changes were observed in the fitness measures over the past decade. Differences observed according to sex and age were consistent with those observed previously. Despite the challenge of collecting direct measures of fitness at the national level, ongoing surveillance of this key health indicator is important. Many methodological and measurement issues specific to children and youth remain unresolved and are discussed in greater detail below.

The age and sex differences observed are consistent with previous Canadian[3,11] and European studies.[32] In the present study, fitness measures tended to be higher in boys compared to girls of the same age, and this gap widened with increasing age. As reported previously,[3,11,32] flexibility is an exception with girls performing better than boys at all ages. Grip strength was higher in boys compared to girls at all ages while the sex difference only appeared in the older age groups for the other fitness measures. For example, cardiorespiratory fitness did not differ between boys and girls aged 8 to 10 years but did in those aged 11 to 19 years. Similarly, predicted vertical jump height did not differ between boys and girls aged 6 to 10 years but was higher in boys compared to girls aged 11 to 19 years. Differences by age were also evident and generally reflect expected changes through normal growth and maturation (discussed in greater detail below).

A comparison to the 1981 Canada Fitness Survey (CFS)[19] indicated that fitness scores for children and youth had declined between 1981 and cycle 1 of the CHMS (2007-2009).[11] Important differences in survey design, sampling and fitness measurement protocols made the CFS-CHMS comparison challenging.[11,33] An advantage of having fitness measures from three cycles of the CHMS is the consistency in measurement protocols. A modest decline in cardiorespiratory fitness was observed in the CHMS between 2007 and 2017 for 8 to 10 and 11 to 14 year olds boys (about -1.0 mL•kg^{-1}•min^{-1}or a 2 to 3% decline). Tomkinson and colleagues observed a decline of 7% or 3.3 mL•kg^{-1}•min^{-1} (3.5 to 3.1) in cardiorespiratory fitness (predicted from the 20 metre shuttle run test) in high- and upper middle-income countries between 1981 and 2014, with the majority of the decline occurring before year 2000, and a greater decline observed in boys compared to girls.[34] The more dramatic decline pre-2000 is somewhat aligned with the decreases observed in the comparison between the 1981 CFS and the 2007-2009 CHMS.[33] The decline observed post year 2000 by Tomkinson and colleagues was, on average, -0.2 mL•kg^{-1}•min^{-1} per decade which is more consistent with the stability or slight decline in boys observed in the present study. While the fitness measures from the CHMS have remained relatively stable across a 10-year period, some changes were observed in accelerometer-measured MVPA and reported screen time. MVPA decreased in 8 to 10 year old girls but increased in 11-14 year old boys. Screen time decreased from 2007 to 2017 in 8 to 10 year old girls but increased in 15 to 19 year old girls.

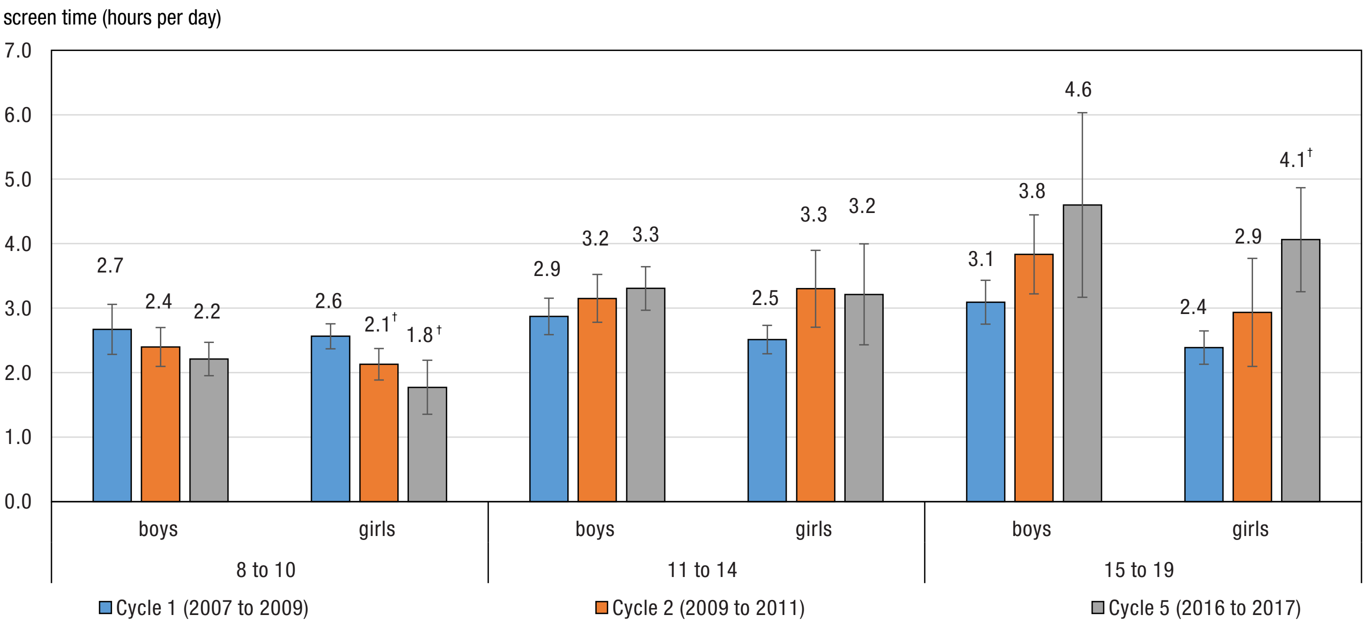
Previous CHMS analyses have reported that the overall population levels of MVPA have remained

Figure 1
Trend in accelerometer-measured moderate-to-vigorous physical activity, 2007 to 2017, household population aged 8 to 19 years, Canada



† significantly different to cycle 1, $p < 0.01$
‡ significantly different to cycle 2, $p < 0.01$
Source: Canadian Health Measures Survey: 2007 to 2009, 2009 to 2011, 2016 to 2017

Figure 2
Trend in screen time, 2007 to 2017, household population aged 8 to 19 years, Canada



† significantly different to cycle 1, $p < 0.01$
Source: Canadian Health Measures Survey: 2007 to 2009, 2009 to 2011, 2016 to 2017

unchanged between 2007 and 2013 in Canada.[35] The observation of changes in lifestyle behaviours and not fitness measures may simply be a reflection of the more variable nature of behaviours compared to fitness which is more of a summative state of one's lifestyle habits over a longer period of time.[36]

Cardiorespiratory fitness and physical activity share a bi-directional relationship.[2,37] Although positive associations have been reported between physical activity and physical fitness,[17,18] this relationship has not been precisely clarified[38,39] and this may be due, in part, to inconsistencies between studies in the measurement of both physical activity and fitness.[40,41] One of the objectives of this study was to determine whether measures of fitness differed between children and youth meeting and not meeting the current physical activity and sedentary recommendations of the Canadian 24-hour movement guidelines.[20] Cardiorespiratory fitness was higher in boys of all age groups and girls aged 8 to 14 years who met the physical activity recommendation and in some age-sex groupings who met the screen time recommendation: 8-10 year old girls and 11-14 year old boys and girls. These findings are consistent with a body of literature that has tried to disentangle the interactions among various intensities of movement and their association with cardiorespiratory fitness. Despite systematic reviews reporting that higher screen time is associated with lower cardiorespiratory fitness,[42,43] physical activity has been more consistently associated with increased cardiorespiratory fitness when compared to sedentary time,[44-46] particularly when the physical activity is of vigorous intensity.[47-49] Achieving both the physical activity and screen time recommendations still remains the desired message given that reducing sedentary time will inevitably increase opportunities to be active;[20,50,51] however, the activity may not have a significant impact on fitness if it is not of a high enough intensity.[44,47,52]

Grip strength was higher in 8 to 19 year old boys meeting the screen time recommendation when compared to those who did not. A similar finding was observed in boys from Edmonton, Canada; however the age range of that study was 6 to 10 years.[53] Potter and colleagues (2016) noted that the association between sedentary behaviour and fitness likely evolves as children move into adolescence and called for longitudinal research to examine how this relationship changes with age. Another study using data from the National Health and Nutrition Examination Survey's (NHANES) National Youth Fitness Survey reported an inverse association between TV time and all strength measures, including grip strength, in 6 to 15 year olds.[54] In the latter study, the authors noted differences between television and video game playing and suggested that collapsing everything into a variable called 'screen time' may miss important nuances in the relationship between screen-based pursuits and strength. This was not explored herein but represents an area of future study.

For the first time in the CHMS, predicted maximum vertical jump height and power data are available (Table 1). Jumping height and power were similar between boys and girls at age 6-10 years but values were higher in boys compared to girls aged 11 to 19 years.

Jumping height and power increased steadily with age in boys whereas jumping height and power increased in girls between the 6-10 and 11-14 year old age groups but then plateaued. A more thorough examination of these age and sex differences was completed using normative-references centile values.[55] The values observed by Hoffman and colleagues (2019) and herein are consistent with previous research using the Leonardo Mechanograph Force Plate;[56,57] however, it is important to note that measurement protocols often vary between studies measuring vertical height. Readers are encouraged to consult the detailed methods section to ensure any comparisons made are done so using data that were collected using the same methodology. More work is needed to understand differences in vertical jump height between various methods and protocols, particularly in children and youth.

Important strengths and limitations of this study should be noted. The CHMS fitness data are unique in Canada and are currently the only directly-measured fitness data available on a nationally-representative sample of Canadians. The CHMS is an ongoing cross-sectional survey therefore future trends in fitness will continue to be monitored. Several studies using CHMS fitness data over the past decade have demonstrated the analytical utility of fitness data beyond its relationship with movement behaviours (e.g., physical activity and sedentary behaviour)[2,3] and support the ongoing periodic measurement of fitness in the CHMS. Non-response bias is a reality of the CHMS that is mitigated using survey weighting techniques; however, it is possible that some bias still exists. This is especially true with fitness measures given the large number of respondents who are excluded from fitness testing due to their responses on the health screening questionnaire. The prediction of peak oxygen consumption (cardiorespiratory fitness) is consistent with previous research;[11] however the mCAFT prediction equation has not been validated in children and these results should therefore be interpreted with caution. An important research recommendation that has been previously noted[11,33] is to develop validated laboratory-based prediction equations specific to children and youth for the mCAFT test. Our study reported cardiorespiratory fitness findings using traditional ratio-scaled ($\dot{V}O_{2peak}$) values which are often confounded by body mass, especially during maturation through childhood and adolescence. Allometric scaling can help better describe cardiorespiratory fitness levels independent of body mass, but this technique is generally for directly measured oxygen consumption using lab-based protocols. Future research should explore the possibility of predicting allometric scaled cardiorespiratory fitness values from field-based measures. This study examined differences in fitness measures for children and youth meeting and not meeting current physical activity and screen time recommendations. The sleep recommendation was not examined because it was not measured in cycle 5 of the CHMS. An area of future research would be to examine whether fitness measures vary by meeting none, 1, 2 or all of the components of the Canadian 24-Hour Movement Guidelines.[20]

This study provides an update on the fitness of Canadian children and youth. The results demonstrate that fitness levels have remained relatively stable across the past decade. Ongoing surveillance of fitness through the CHMS will be important to monitor trends and assess future interventions designed to improve fitness levels at the population level. Increasing physical activity, reducing sedentary living and ultimately improving the fitness of the nation are key tenets of the *Common Vision for Increasing Physical Activity and Reducing Sedentary Living in Canada*.[58] The importance of reporting on the progress of the Common Vision is further highlighted in the recently published *Report of the Standing Committee on Health: Get Canada's Youth Moving!*.[50] The lack of progress in physical fitness combined with the evidence that most Canadian children and youth are not active enough and engaging too much with screens suggests that efforts to improve fitness and healthy active living behaviours of Canadian children and youth have been insufficient and continued and enhanced efforts are required. ■

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