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Original quantitative research

The association between physical fitness and health in a nationally representative sample of Canadian children and youth aged 6 to 17 years

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Abstract

Introduction: This study explored the relationship between physical fitness and indicators of physical and psychosocial health in a nationally representative sample of Canadian children and youth aged 6–17 years.

Methods: We conducted a secondary data analysis of Canadian Health Measures Survey (Cycles 1 and 2; 2007-2011) data. The physical fitness measures included cardiorespiratory fitness (CRF; modified Canadian Aerobic Fitness Test), strength (handgrip strength), flexibility (sit-and-reach), and muscular endurance (partial curl-ups). The physical health indicators included directly measured biomarkers (total and HDL [high-density lipoprotein] cholesterol, C-reactive protein, glucose, and HbA1c [glycohaemoglobin]) and measures of adiposity, resting heart rate, and blood pressure. Psychosocial health was assessed using the Strengths and Difficulties Questionnaire. Multiple linear regressions were used to determine the association between variables, stratified by age groups and sex.

Results: 3,800 (48.9% female) children and youth were retained for this analysis. CRF displayed significant favourable associations with most physical health indicators in male and female participants. There were less significant favourable associations with flexibility and muscular endurance compared with CRF across age and sex groups. Strength was associated with higher adiposity in males and females, and lower heart rate in male children ($\beta = -1.9$; 95% CI: -2.9, -1.0) and female youth ($\beta = -2.0$; 95% CI: -2.7, -1.2). There were few significant favourable associations between measures of physical fitness and psychosocial health in this sample of children and youth.

Conclusion: These findings suggest that physical fitness, and especially CRF, is a significant indicator of physical health among Canadian children and youth aged 6–17 years.

Keywords: *cardiorespiratory, psychosocial, strength, biomarkers, youth*

Highlights

- Physical fitness, especially cardiorespiratory fitness, is associated with favourable indicators of physical health among Canadian children aged 6 to 11 and youth aged 12 to 17 years.
- Associations between physical fitness and psychosocial health, as measured by the Strengths and Difficulties Questionnaire, are generally null and may require further research.
- Physical fitness assessments are feasible measures that could help improve the monitoring of paediatric health status.

Introduction

Physical fitness is a construct that includes cardiorespiratory fitness (CRF), muscular endurance and strength, flexibility, agility, and in some circumstances, body composition.[1] Physical fitness may reflect an individual's capability to perform daily physical activity or physical exercise, providing a potential indication of physical health status.[1–4] Studies indicate that some components of physical fitness, such as CRF, in late adolescence may predict future comorbidity, cardiovascular diseases, and all-cause mortality in adulthood.[5–7] Combined, these studies demonstrate the utility of physical fitness as an indicator to help better understand health among school-aged children and youth. However, in recent years, the national surveillance and regular monitoring of physical fitness among children and youth has not been prioritized in Canada.

In 2012, the Institute of Medicine (IOM) produced a comprehensive report on the role of physical fitness in describing youth health, with a focus on recommending health-related fitness measures that could be implemented in national youth fitness surveys conducted in the educational environment.[1] One area of future development identified by the IOM report was for national surveys to include measures of physical fitness along with other health measures to further confirm whether relationships between specific fitness test items and health outcomes exist (recommendation

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10-4, p. 237).[1] However, this continues to be a gap in the literature with very few studies reporting these associations in large, representative samples of children and youth. Specifically, we were unable to identify Canadian studies that investigated associations between physical fitness and health outcomes in population representative samples of children and youth.

Similarly, the relationships between components of physical fitness and psychosocial health indicators among children and youth remain poorly understood. This is an important issue given that, in Ontario, emergency department visits and hospitalizations related to mental health increased by 32.5% and 53.7% respectively between 2006 and 2011.[8] If relationships are demonstrated between physical fitness and psychosocial health, this could provide new intervention targets to help improve psychosocial health in Canadian children and youth. Thus, the purpose of this study was to assess the associations between components of physical fitness and indicators of physical and psychosocial health in a nationally representative sample of Canadian children aged 6–11 years and youth aged 12–17 years.

Methods

Participants

The present analyses used data from 6- to 17-year-olds who took part in cycle 1 (2007–09) and 8- to 17-year-olds who participated in cycle 2 (2009–11) of the Canadian Health Measures Survey (CHMS).[9] For children younger than 12 years old the majority of questionnaires were completed through proxy interviews with the child's parent/guardian.[10,11] The CHMS is a repeated cross-sectional survey that collects data from nationally representative samples of 3–79 year-olds living in private households. The survey represents approximately 96% of Canadians, with those from the three territories, Aboriginal settlements, members of the Canadian Forces, institutionalized individuals, and those from certain remote areas not represented in the survey. The overall response rate for both cycles was 53.5% of selected households, with survey weights adjusted for non-response bias.[12]

A total of 3,800 (48.9% female) children and youth aged 6–17 years, across both CHMS cycles, were included in the present analyses. The CHMS includes an interviewer-administered questionnaire at the respondent's home followed by a visit to a mobile examination centre (within the subsequent six weeks) for a series of physical measurements. Further details about the CHMS data collection procedures, screening guidelines, and eligibility criteria are available elsewhere.[10,11]

Ethics approval for the CHMS was obtained by Statistics Canada from Health Canada's Research Ethics Board.[13] Children aged 6–13 years provided written informed assent, and their parent/guardian provided written informed consent. Youth aged 14–17 years provided written informed consent.

Physical fitness measures

Physical fitness was measured by health measures specialists following the Canadian Physical Activity, Fitness, and Lifestyle Approach (CPAFLA) protocols.[14] CRF was assessed using the modified Canadian Aerobic Fitness Test (mCAFT).[14] The mCAFT is a progressive submaximal step test where participants follow an age- and sex-dependent starting cadence, with the pace increasing at every 3-minute interval. Participants were asked to follow the cadence of an audio recording, and the test was completed once participants reached 85% of their age-predicted maximal heart rate (220 – age). CRF ($\dot{V}O_{2peak}$) was calculated using the Weller et al equation:[15,16]

$\dot{V}O_{2peak} = 17.2 + 1.29 \times \dot{V}O_{2peak}{}^{*} - 0.09 \times$ body mass in kg $- 0.18 \times$ age in years, where * represents the oxygen cost of stepping at the final stage.

Grip strength was measured (in kilograms [kg]) using a Smedley III dynamometer (Takei Scientific Instruments, Japan), with each hand being measured, alternately, twice. The grip strength score combined the best score from each hand. *Muscular endurance* was assessed using the number of partial curl-up repetitions performed in one minute following the pace of a metronome set to 50 beats per minute, with 25 repetitions being the maximum score. *Flexibility* was assessed with the sit-and-reach test using a flexometer (Fit Systems Inc, Calgary, Canada) where participants were asked to sit on the floor with their legs extended in front of them, and to stretch as far forward towards their toes without bending the knees. The best score from two attempts was recorded to the nearest 0.1 cm.[14] All physical fitness measures were conducted in the mobile examination centre.

Physical health indicators

A total of 12 physical health indicators were included in this analysis. Body composition assessments were measured following the CPAFLA protocol.[14] Height was measured using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA), and weight was measured using a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada). Body mass index (BMI) was calculated from the measured height and weight values. Waist circumference was measured at the midpoint between the lowest floating rib and the top of the iliac crest, following the World Health Organization protocol.[17] The sum of skinfolds was calculated from subcutaneous fat measurements taken from five sites using Harpenden skinfold calipers (Baty International, UK): triceps, biceps, subscapular, iliac crest, and medial calf.[14]

Resting heart rate and systolic and diastolic blood pressure were measured following the CHMS protocol.[18,19] The protocol included six measurements at 1-minute intervals following 5-minutes of quiet rest using an automated oscillometer (BpTRU™ BPM-300, BpTRU™ Medical Devices Ltd., Coquitlam, British Columbia). Final measurements were calculated from the mean score of the last five measurements.

Non-fasted blood samples were collected by certified phlebotomists and analyzed at the Health Canada laboratory following standardized procedures.[20] Lipid profiles (total cholesterol and high-density lipoprotein (HDL)/total cholesterol ratio) and C-reactive protein were measured in serum; glycohaemoglobin (HbA1c) in whole blood; and glucose in plasma samples. All measures were taken in a mobile examination centre. Further details about bio-specimen sampling, storage and analysis can be found elsewhere.[20]

Psychosocial health indicators

Psychosocial health was assessed with the parent reported Strength and Difficulties Questionnaire (SDQ).[21,22] The SDQ consists of 25 items that make up five subscales including emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and

pro-social behaviour. The total difficulties score combines four subscales, excluding pro-social behaviour, the only positive subscale. For low-risk population-based studies, it is recommended to combine the emotional symptoms and peer-relationship problems into one internalizing subscale, and the conduct problems and hyperactivity/inattention subscales into one externalizing subscale. This converts the questionnaire from five subscales to three. [23]

Maturity offset

Maturity offset was estimated using sex-specific multiple regression equations that were originally calculated using prospective data from 152 Canadian children and youth aged 8–16 years, followed from 1991 to 1997.[24]

Statistical analysis

Analyses were conducted using SAS Enterprise Guide 5.1 (SAS Institute Inc., Cary, NC, USA) using survey weights. To account for the complex survey design the bootstrap technique was used to calculate 95% confidence intervals, with the degrees of freedom set to 24.[25,26] Statistical significance was set at $p < 0.01$.

The physical fitness variables (CRF, grip strength, partial curl-ups, sit-and-reach) were converted to age- and sex-standardized *z*-scores to help with interpretation and to normalize the variables. Multiple linear regression analyses were adjusted for parent self-reported household income and highest level of parental education (both measured during the home visit using a standard questionnaire) for all ages. We also adjusted the analysis for maturity offset only in youth aged 12 to 17 years. Throughout, we use the term "favourable" to help describe values that represent better health. For instance, negative beta values indicate better health for all variables, except for HDL cholesterol and prosocial behaviours where positive beta values indicate better health. We use "unfavourable" to describe beta values that indicate worse health.

Results

Descriptive characteristics of the sample stratified by age groups and sex are displayed in Table 1. Compared with females, males had higher CRF, strength, and muscular endurance scores (youth only); females had higher flexibility scores. For males and females, children (aged 6–11 years) had significantly higher CRF scores than their youth (aged 12–17 years) counterparts. Female children had significantly higher resting blood pressure when compared with male children. There were also significant differences between male and female children across some of the psychosocial health scores (externalizing, prosocial behaviours, and the total difficulties score). In youth, these sex differences were no longer significant.

Among males (Table 2), CRF was significantly associated with 9 out of 12 physical health indicators among youth, and 6 out of 12 physical health associations were significant among children. Specifically, in male children each standard deviation increase in male CRF was associated with a reduction of 2.8 cm in waist circumference, 12.1 mm in sum of skinfold thickness, 1.1 kg/m^2 in BMI, 1.4 mmHg in systolic blood pressure, 1.1 mmHg in diastolic blood pressure, and 2.7 bpm in resting heart rate. In male youth, each standard deviation increase in CRF was associated with a reduction of 5.8 cm in waist circumference, 14.1 mm in sum of skinfold thickness, 2.1 kg/m^2 in BMI, 1.1 mmHg in systolic blood pressure, 1.0 mmHg in diastolic blood pressure, 3.1 bpm in resting heart rate, 0.2 mmol/L in total cholesterol, 0.2 in total cholesterol/HDL ratio, and 0.4 nmol/L in C-reactive protein. Grip strength among males was unfavourably associated with waist circumference in children and BMI in children and youth, but favourably associated with resting heart rate only in children. Muscular endurance was significantly associated with 4 out of 12 physical health indicators for youth, and 6 out of 12 for children, although the effect sizes were not as large when compared with CRF. Flexibility was only favourably associated with 4 out of 12 health indicators in male children, and 2 out of 12 in male youth.

Among females (Table 3), CRF was the physical fitness measure that had the most significant favourable associations with physical health. In female children, CRF was favourably associated with 8 out of 12 health indicators, and 9 out of 12 health indicators for youth. In female children, one standard deviation increase in CRF was associated with a reduction of 4.3 cm in waist circumference, 12.6 mm in sum of skinfold thickness, 1.4 kg/m^2 in BMI, 1.3 mmHg in systolic blood pressure, 3.6 bpm in resting heart rate, 0.1 in total cholesterol/HDL ratio, 0.4 nmol/L in C-reactive protein, and a 0.0 mmol/L increase in HDL cholesterol. In female youth, each standard deviation increase in CRF was associated with a reduction of 4.5 cm in waist circumference, 13.6 mm in sum of skinfold thickness, 1.9 kg/m^2 in BMI, 1.6 mmHg in systolic blood pressure, 1.1 mmHg in diastolic blood pressure, 3.4 bpm in resting heart rate, 0.2 in total cholesterol/HDL ratio, and 0.1 mmol/L increase in HDL cholesterol. Grip strength was unfavourably associated with adiposity measures in female children (waist circumference, sum of five skinfolds, and BMI). Among female youth, grip strength was unfavourably associated with BMI, but there were significant favourable associations with resting heart rate. Muscular endurance was favourably associated with adiposity measures in female children, while in female youth, muscular endurance was significantly associated with 2 out of 12 health indicators. Flexibility among females was only favourably associated with 1 out of 12 indicators of health. Among female youth, muscular endurance was favourably associated with internalizing, externalizing, and total difficulties score, and CRF was also favourably associated with internalizing. No other associations were found between physical fitness measures and psychosocial health indicators.

Discussion

To our knowledge, this study is the first to explore the associations between physical fitness and indicators of physical and psychosocial health in a large representative sample of Canadian children and youth aged 6–17 years. We identified strong favourable associations between physical health and CRF among males and females. We also identified some strong favourable associations between physical health and muscular endurance and flexibility, and mixed favourable and unfavourable associations with grip strength. Most measures of fitness were not significantly associated with measures of psychosocial health, except for significant favourable associations with muscular endurance and CRF in female youth. These results highlight the importance of physical fitness, especially CRF, as an indicator that is significantly and favourably associated with several physical health indicators in paediatric populations.

TABLE 1
Participant descriptive statistics by sex for Canadian children (aged 6-11 years) and youth (aged 12-17 years)

	Total (n = 3800)		Males (n = 1943)		Females (n = 1857)	
	Children (n = 2157) Mean or % (95% CI)	Youth (n = 1643) Mean or % (95% CI)	Children (n = 1086) Mean or % (95% CI)	Youth (n = 857) Mean or % (95% CI)	Children (n =1071) Mean or % (95% CI)	Youth (n = 786) Mean or % (95% CI)
Mean age (years)	8.6 (8.5–8.7)	14.5 (14.4–14.6)	8.5 (8.3–8.7)	14.4 (14.2–14.7)	8.7 (8.5–8.8)	14.6 (14.4–14.8)
Parental education (%)						
Less than college	17.7 (14.6–20.8)	21.5 (17.6–25.4)	17.7 (13.8–21.7)	21.3 (16.6–26.0)	17.7 (14.2–21.2)	21.7 (16.3–27.0)
College	39.5 (33.9–45.1)	38.6 (32.5–44.8)	41.0 (33.1–48.8)	37.2 (30.8–43.6)	38.0 (32.9–43.1)	40.2 (33.1–47.3)
University	42.8 (35.8–49.7)	39.9 (32.6–47.2)	41.3 (32.6–50.0)	41.5 (33.6–49.4)	44.3 (38.0–50.6)	38.1 (29.4–46.9)
Household income (%)						
Less than $40 000	19.2 (15.5–23.0)	16.5 (13.3–19.6)	18.9 (13.3–24.6)	17.4 (13.3–21.6)	19.6 (16.1–23.0)	15.4 (11.7–19.2)
$40 000 to $79 999	33.7 (30.1–37.2)	32.4 (28.0–36.9)	32.0 (27.9–36.2)	33.5 (27.1–39.8)	35.4 (30.4–40.3)	31.3 (25.7–36.9)
$80 000 or more	47.1 (42.4–51.8)	51.1 (45.6–56.5)	49.1 (42.8–55.3)	49.1 (42.1–56.1)	45.1 (39.7–50.5)	53.3 (46.4–60.1)
Maturation						
Maturity offset (years)	n/a	1.5 (1.4–1.6)	n/a	1.1 (0.9–1.3)	n/a	2.1 (2.0–2.2)
Physical fitness measures						
$\dot{V}O_{2peak}$ score (mL/kg/min)	51.9 (51.6–52.2)	49.0 (48.6–49.5)	53.8 (53.2–54.3)	52.1 (51.5–52.8)	50.2 (49.9–50.6)	45.7 (45.0–46.3)
Grip strength (kg)	26.2 (25.3–27.0)	57.0 (55.2–58.8)	27.0 (25.9–28.2)	65.2 (62.7–67.7)	25.2 (24.3–26.2)	47.9 (46.5–49.2)
Muscular endurance (reps)	10.2 (9.3–11.0)	19.4 (18.7–20.2)	9.8 (8.7–10.9)	21.0 (20.3–21.8)	10.5 (9.4–11.7)	17.6 (16.6–18.6)
Flexibility (cm)	26.2 (25.6–26.7)	25.3 (24.4–26.3)	24.0 (23.3–24.6)	21.9 (20.4–23.4)	28.4 (27.7–29.1)	29.2 (27.9–30.5)
Physical health indicators						
Waist circumference (cm)	60.9 (60.3–61.5)	74.1 (72.8–75.5)	61.8 (61.0–62.6)	75.2 (73.5–76.8)	59.9 (59.2–60.6)	73.0 (71.4–74.5)
Sum of 5 skinfolds (mm)	51.6 (49.7–53.4)	59.9 (57.7–62.1)	50.2 (47.8–52.7)	49.1 (46.8–51.5)	53.0 (51.0–55.0)	71.9 (68.6–75.1)
BMI (kg/m^2)	17.9 (17.7–18.1)	22.0 (21.4–22.5)	18.2 (17.9–18.4)	21.9 (21.3–22.6)	17.7 (17.5–17.9)	22.1 (21.4–22.7)
Systolic blood pressure (mmHg)	93.9 (93.4–94.4)	98.1 (97.2–99.1)	93.5 (92.8–94.3)	99.5 (98.3–100.8)	94.3 (93.6–94.9)	96.7 (95.6–97.5)
Diastolic blood pressure (mmHg)	61.0 (60.4–61.5)	62.0 (61.0–62.9)	60.7 (59.9–61.6)	61.8 (60.6–63.0)	61.2 (60.7–61.8)	62.2 (61.2–63.1)
Resting heart rate (bpm)	80.2 (79.1–81.3)	74.8 (73.7–75.9)	78.1 (76.5–79.8)	73.5 (71.9–75.1)	82.4 (81.4–83.5)	76.3 (75.0–77.5)
Total cholesterol (mmol/L)	4.2 (4.2–4.3)	4.1 (4.0–4.1)	4.2 (4.1–4.3)	4.0 (3.9–4.1)	4.2 (4.2–4.3)	4.2 (4.1–4.2)
HDL cholesterol (mmol/L)	1.4 (1.4–1.4)	1.3 (1.3–1.3)	1.4 (1.4–1.5)	1.3 (1.2–1.3)	1.4 (1.4–1.4)	1.4 (1.3–1.4)
Total cholesterol/HDL ratio	3.1 (3.0–3.2)	3.2 (3.2–3.3)	3.1 (3.0–3.1)	3.3 (3.2–3.4)	3.2 (3.1–3.2)	3.1 (3.1–3.2)
C-reactive protein (nmol/L)	1.3 (1.1–1.6)	1.3 (1.1–1.5)	1.5 (1.1–1.9)	1.1 (0.9–1.3)	1.2 (1.0–1.3)	1.7 (1.3–2.0)
Glucose (mmol/L)	4.6 (4.6–4.7)	4.7 (4.6–4.7)	4.6 (4.6–4.7)	4.7 (4.7–4.8)	4.6 (4.5–4.7)	4.6 (4.6–4.7)
HbA1c (%)	5.5 (5.4–5.5)	5.4 (5.4–5.5)	5.5 (5.4–5.6)	5.4 (5.4–5.5)	5.4 (5.3–5.5)	5.4 (5.3–5.5)
Psychosocial health indicators						
Internalizing	2.8 (2.6–3.0)	2.7 (2.5–3.0)	2.9 (2.6–3.3)	2.6 (2.4–2.8)	2.7 (2.5–2.9)	2.9 (2.5–3.3)
Externalizing	4.2 (4.0–4.4)	3.3 (3.0–3.6)	4.9 (4.5–5.3)	3.6 (3.2–4.0)	3.4 (3.1–3.7)	2.9 (2.5–3.4)
Prosocial behaviour	9.1 (9.0–9.2)	9.0 (8.9–9.2)	8.8 (8.6–9.0)	8.9 (8.6–9.1)	9.5 (9.4–9.5)	9.3 (9.1–9.4)
Total difficulties score	7.0 (6.6–7.4)	6.0 (5.6–6.5)	7.8 (7.1–8.6)	6.2 (5.7–6.7)	6.1 (5.8–6.5)	5.8 (5.1–6.6)

Source: 2007-to-2009 and 2009-to-2011 (Cycles 1 and 2) Canadian Health Measures Survey, combined.
Abbreviations: BMI, body mass index; CI, confidence interval; CRF, cardiorespiratory fitness; HbA1c, glycohaemoglobin; HDL, high-density lipoprotein.

Although CRF, muscular endurance, and flexibility demonstrated consistent and favourable associations with indicators of physical health, this was not the case for grip strength. Rather, grip strength was associated with a greater waist circumference, sum of skinfold thickness, and body mass index, consistent with other studies.[27,28] Indeed, musculoskeletal fitness measures other than grip strength, such as those where participants are asked to propel their body through space (e.g., vertical jump, standing broad jump), might be better indicators of health in paediatric populations.[4] Previous studies have identified favourable associations between measures of muscular endurance and health,[29,30] which corresponds with our partial curl-up results. Flexibility in our study displayed favourable associations with indicators of physical health in males but not females. However, Mikkelsson et al. determined that sit-and-reach flexibility in youth was a significant predictor of future health-related

TABLE 2
Associations between physical fitness *z*-scores and physical health and psychosocial health indicators among male children aged 6-11 years (n = 1086) and youth aged 12-17 years (n = 857)

	CRF *z*-score		Grip strength *z*-score		Muscular endurance *z*-score		Flexibility *z*-score	
	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)
Physical health indicators								
Waist circumference (cm)	−2.8 (−3.7, −1.9)*	−5.8 (−6.8, −4.9)*	3.0 (1.8, 4.1)*	1.8 (0.2, 3.4)	−1.4 (−2.4, −0.5)*	−2.1 (−3.2, −1.0)*	−1.4 (−2.2, −0.7)*	−1.6 (−2.9, −0.3)
Sum of 5 skinfolds (mm)	−12.1 (−15.8, −8.4)*	−14.1 (−17.2, −11.0)*	2.9 (−0.8, 6.6)	0.6 (−2.5, 3.8)	−5.8 (−8.3, −3.4)*	−4.4 (−7.2, −1.7)*	−4.4 (−6.4, −2.3)*	−3.1 (−5.3, −0.8)*
BMI (kg/m^2)	−1.1 (−1.4, −0.8)*	−2.1 (−2.5, −1.7)*	1.0 (0.5, 1.4)*	0.9 (0.4, 1.4)*	−0.6 (−1.0, −0.3)*	−0.9 (−1.3, −0.4)*	−0.3 (−0.6, −0.1)	−0.4 (−0.8, 0.1)
SBP (mmHg)	−1.4 (−2.3, −0.6)*	−1.1 (−2.0, −0.3)*	1.2 (0.3, 2.1)	1.4 (0.2, 2.6)	−0.1 (−0.9, 0.7)	0.1 (−0.7, 0.9)	−0.9 (−1.4, −0.3)*	0.0 (−0.7, 0.7)
DBP (mmHg)	−1.1 (−1.7, −0.5)*	−1.0 (−1.6, −0.4)*	0.8 (−0.1, 1.6)	−0.1 (−1.0, 0.7)	0.1 (−0.7, 0.8)	−0.2 (−0.9, 0.6)	−0.6 (−1.2, 0.0)	−0.0 (−0.6, 0.6)
Resting heart rate (bpm)	−2.7 (−4.7, −0.7)*	−3.1 (−4.4, −1.9)*	−1.9 (−2.9, −1.0)*	−0.6 (−2.1, 1.0)	−2.0 (−3.3, −0.6)*	−0.4 (−1.5, 0.6)	−1.3 (−2.5, −0.1)	−2.0 (−3.2, −0.7)*
Total cholesterol (mmol/L)	−0.1 (−0.2, −0.0)	−0.2 (−0.2, −0.1)*	−0.0 (−0.1, 0.1)	−0.1 (−0.1, −0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.0)
HDL cholesterol (mmol/L)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.1)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, −0.0)	0.0 (0.0, 0.1)*	0.0 (0.0, 0.1)	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.1)
Total cholesterol/HDL ratio	−0.1 (−0.2, 0.0)	−0.2 (−0.3, −0.1)*	0.0 (−0.0, 0.1)	0.1 (−0.1, 0.2)	−0.1 (−0.2, −0.0)*	−0.1 (−0.2, −0.0)*	−0.1 (−0.1, 0.0)	−0.1 (−0.2, −0.0)
C-reactive protein (nmol/L)	−0.4 (−0.9, 0.0)	−0.4 (−0.6, −0.1)*	0.1 (−0.2, 0.5)	−0.1 (−0.2, 0.0)	−0.4 (−0.8, −0.0)	−0.2 (−0.4, −0.0)	−0.5 (−0.8, −0.2)*	−0.2 (−0.4, 0.0)
Glucose (mmol/L)	−0.0 (−0.1, 0.1)	−0.0 (−0.1, −0.0)	−0.0 (−0.1, 0.0)	0.0 (−0.0, 0.1)	0.0 (−0.1, 0.1)	0.0 (−0.0, 0.1)	−0.0 (−0.1, 0.0)	0.0 (−0.0, 0.1)
HbA1c (%)	−0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)
Psychosocial health indicators								
Internalizing	−0.3 (−0.6, −0.0)	−0.3 (−0.6, −0.0)	−0.1 (−0.3, 0.2)	−0.2 (−0.5, 0.1)	−0.5 (−0.9, −0.1)	−0.4 (−0.6, −0.2)*	−0.3 (−0.6, −0.1)	−0.1 (−0.5, 0.3)
Externalizing	−0.1 (−0.5, 0.4)	0.0 (−0.3, 0.3)	−0.1 (−0.5, 0.2)	0.2 (−0.2, 0.5)	−0.4 (−0.8, −0.0)	0.1 (−0.2, 0.4)	−0.3 (−0.7, 0.1)	0.2 (−0.4, 0.7)
Prosocial behaviours	−0.0 (−0.2, 0.1)	0.1 (−0.1, 0.2)	0.0 (−0.1, 0.2)	−0.1 (−0.2, 0.1)	0.2 (−0.0, 0.3)	0.0 (−0.1, 0.2)	−0.0 (−0.2, 0.1)	−0.0 (−0.1, 0.1)
Total difficulties score	−0.4 (−1.1, 0.3)	−0.3 (−0.8, 0.2)	−0.2 (−0.8, 0.4)	−0.0 (−0.6, 0.6)	−1.0 (−1.7, −0.2)	−0.3 (−0.7, 0.1)	−0.7 (−1.2, −0.2)	0.0 (−0.9, 1.0)

Source: 2007-to-2009 and 2009-to-2011 (Cycles 1 and 2) Canadian Health Measures Survey, combined.
Abbreviations: β, unstandardized beta coefficient; BMI, body mass index; CI, confidence interval; CRF, cardiorespiratory fitness; DBP, diastolic blood pressure; HbA1c, glycohaemoglobin; HDL, high-density lipoprotein; SBP, systolic blood pressure.
Note: All data are adjusted for highest parental education, household income and, in youth only, maturity offset.
* $p < 0.01$.

fitness in adulthood among males, providing some indication that flexibility could be a potentially important health-related fitness trait in pediatric male populations.[31]

Results from this study suggest that CRF is the health-related fitness component most strongly associated with physical health among children and youth, as this measure demonstrated the greatest number of significant favourable associations with physical health when compared with other physical fitness measures, and the effect sizes were considerably larger. This is consistent with other studies. For instance, among middle aged adults, a 2-mmHg reduction in systolic blood pressure was associated with a 10% lower risk of stroke mortality and a 7% lower risk of mortality from ischemic heart disease.[32] In the present cross-sectional study, we showed that one standard deviation increase in CRF was associated with a 1.1–1.4 mmHg and a 1.3–1.6 mmHg reduction in systolic blood pressure in males and females, respectively. Although these associations do not meet the 2-mmHg standard for clinical meaningfulness among adults, it is likely that these associations are meaningful in paediatric populations.

The present study also shows significant favourable associations between CRF and adiposity (waist circumference, sum of 5 skinfolds, and BMI) where better CRF scores are strongly associated with lower adiposity levels. This finding is consistent with results from a large systematic review.[3] Due to the feasibility of conducting fitness measures in the field, these findings support a growing body of evidence that highlights the possibility of monitoring physical fitness levels to help better understand the health status of paediatric populations.[1,31,33]

In addition to physical health, the present study highlights null associations between physical fitness and psychosocial health, as measured by the SDQ, except for muscular endurance in female and male youth, and CRF in female youth. Although a study reported significant associations between physical activity levels and psychosocial health,[34] the findings reported in this study are original and call for further research in the area. It is likely that a more complex analysis, such as structural equation modelling, could help better describe the association between components of physical fitness, physical activity, and

TABLE 3
Associations between physical fitness z-scores and physical health and psychosocial health indicators among female children aged 6-11 years (n = 1071) and youth aged 12-17 years (n = 786)

	CRF z-score		Grip strength z-score		Muscular endurance z-score		Flexibility z-score	
	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)
Physical health indicators								
Waist circumference (cm)	−4.3 (−5.5, −3.2)*	−4.5 (−5.5, −3.6)*	2.9 (2.0, 3.8)*	2.1 (0.2, 3.9)	−1.8 (−2.8, −0.8)*	−1.8 (−2.8, −0.8)*	−0.6 (−1.4, 0.1)	−1.2 (−2.2, −0.1)
Sum of 5 skinfolds (mm)	−12.6 (−15.9, −9.2)*	−13.6 (−16.3, −10.8)*	4.4 (2.3, 6.5)*	2.6 (−2.6, 7.8)	−5.6 (−8.1, −3.1)*	−4.1 (−7.2, −0.9)	−3.9 (−6.4, −1.3)*	−0.5 (−3.9, 3.0)
BMI (kg/m^2)	−1.4 (−1.8, −1.1)*	−1.9 (−2.2, −1.6)*	1.1 (0.8, 1.4)*	1.0 (0.3, 1.7)*	−0.7 (−1.0, −0.3)*	−0.6 (−1.1, −0.1)	0.0 (−0.3, 0.3)	−0.0 (−0.5, 0.5)
SBP (mmHg)	−1.3 (−1.9, −0.6)*	−1.6 (−2.4, −0.9)*	1.0 (0.2, 1.7)	0.1 (−0.8, 1.0)	−0.5 (−1.0, 0.1)	−1.0 (−1.9, −0.1)	0.0 (−0.7, 0.7)	0.1 (−0.9, 1.0)
DBP (mmHg)	−0.5 (−0.9, 0.0)	−1.1 (−1.8, −0.3)*	0.5 (−0.1, 1.2)	−0.2 (−1.1, 0.6)	0.0 (−0.5, 0.6)	−0.9 (−1.6, −0.3)*	0.1 (−0.6, 0.8)	−0.1 (−0.9, 0.8)
Resting heart rate (bpm)	−3.6 (−4.5, −2.7)*	−3.4 (−4.5, −2.3)*	−1.6 (−2.6, −0.6)	−2.0 (−2.7, −1.2)*	−1.0 (−1.9, −0.0)	−0.8 (−2.1, 0.6)	−0.4 (−1.7, 0.9)	−2.0 (−3.2, −0.8)*
Total cholesterol (mmol/L)	−0.0 (−0.1, 0.0)	−0.1 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.1)	−0.0 (−0.1, 0.0)	0.0 (−0.1, 0.1)	0.0 (−0.1, 0.1)	0.1 (−0.0, 0.2)
HDL cholesterol (mmol/L)	0.0 (0.0, 0.1)*	0.1 (0.0, 0.1)*	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.1)
Total cholesterol/HDL ratio	−0.1 (−0.2, −0.0)*	−0.2 (−0.2, −0.1)*	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.1)	−0.1 (−0.1, 0.0)	−0.1 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.1)
C-reactive protein (nmol/L)	−0.4 (−0.5, −0.2)*	−0.6 (−1.2, −0.1)	−0.1 (−0.3, 0.1)	−0.0 (−0.3, 0.3)	−0.2 (−0.3, 0.0)	−0.3 (−0.7, 0.1)	−0.1 (−0.3, 0.1)	0.1 (−0.2, 0.4)
Glucose (mmol/L)	−0.1 (−0.2, −0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.1)	−0.0 (−0.1, 0.0)	0.0 (−0.1, 0.1)	0.0 (−0.0, 0.1)
HbA1c (%)	−0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)
Psychosocial health indicators								
Internalizing	−0.1 (−0.4, 0.1)	−0.5 (−0.9, −0.2)*	−0.1 (−0.3, 0.1)	−0.3 (−0.8, 0.1)	−0.2 (−0.5, 0.0)	−0.5 (−0.8, −0.2)*	−0.1 (−0.3, 0.0)	−0.4 (−0.8, 0.0)
Externalizing	−0.0 (−0.5, 0.5)	−0.1 (−0.5, 0.2)	0.1 (−0.1, 0.3)	0.3 (−0.1, 0.7)	−0.0 (−0.3, 0.3)	−0.7 (−1.2, −0.3)*	−0.1 (−0.4, 0.2)	−0.3 (−0.7, 0.2)
Prosocial behaviours	−0.0 (−0.1, 0.1)	0.1 (−0.1, 0.3)	0.0 (−0.1, 0.1)	0.0 (−0.1, 0.2)	−0.1 (−0.1, 0.0)	0.2 (0.0, 0.3)	0.0 (−0.1, 0.1)	−0.0 (−0.1, 0.1)
Total difficulties score	−0.1 (−0.8, 0.5)	−0.7 (−1.3, −0.1)	−0.0 (−0.4, 0.3)	−0.0 (−0.9, 0.8)	−0.3 (−0.7, 0.2)	−1.2 (−1.9, −0.5)*	−0.2 (−0.5, 0.1)	−0.7 (−1.4, 0.1)

Source: 2007-to-2009 and 2009-to-2011 (Cycles 1 and 2) Canadian Health Measures Survey, combined.
Abbreviations: β, unstandardized beta coefficient; BMI, body mass index; CI, confidence interval; CRF, cardiorespiratory fitness; DBP, diastolic blood pressure; HbA1c, glycohaemoglobin; HDL, high-density lipoprotein; SBP, systolic blood pressure.
Note: All data are adjusted for highest parental education, household income and, in youth only, maturity offset.
* $p < 0.01$.

psychosocial health among children and youth.

Strengths and limitations

This study represents a robust assessment of the associations between physical fitness and indicators of physical and psychosocial health in a nationally representative sample of Canadian children and youth aged 6–17 years. Strengths include the large sample size, many diverse and direct measures of physical health indicators and physical fitness, and the use of the validated SDQ to measure psychosocial health. We also used survey weights and the bootstrap technique to account for non-response bias and the complex study design. Nevertheless, this study is not without limitations. For example, the cross-sectional design does not allow for causal inferences. The partial curl-up assessment suffered from a ceiling effect as a result of the maximum amount of repetitions being attained in one minute (25 repetitions). There was also a floor effect for the partial curl-up assessment where some participants were unable to perform one repetition. The results may have also been influenced by residual confounding, although we stratified by sex and age groups and controlled for potential confounders including maturity offset, highest parental education, and household income.

Conclusion

Physical fitness, and especially CRF, is a significant indicator of physical health and could help complement other measures to improve the understanding of pediatric population health in Canadians. Our findings suggest that physical fitness measures do not generally provide a good indication of psychosocial health, as measured by the SDQ, among school-aged children and youth. More research is needed in this area, especially research that examines the associations between physical fitness and psychosocial health.

Conflicts of interest

The authors have no conflicts of interest to disclose.

Authors' contributions and statement

JJL, RL, and MST conceived the study design and research objectives. JJL and

RL ran the statistical analysis. JJL drafted the manuscript. All authors reviewed and approved the final manuscript.

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