



**B**ackground  
Physical literacy (PL) has emerged as a core construct in the physical education paradigm, designed to support children's engagement in physical activity throughout the life course [1, 2]. To better understand the state of PL among Canadian children, an 11-site cross-sectional surveillance study called the Royal Bank of Canada–Canadian Assessment of Physical Literacy Learn to Play project (RBC–

#### Data collection procedures

All data collection staff had a background in fitness or physical activity assessment, and each site's coordinators were subsequently trained by research staff from the coordinating centre (Ottawa, Ontario). Data collection procedures followed the published CAPL protocol [3, 4], which provides standardized procedures to collect data across the four PL domain.

#### Independent variable

CRF was assessed using the 15 m or 20mSRT protocols [5, 6]. The 15 m protocol was used only if there was not enough space to carry out the full 20 m protocol. All children were asked to run back and forth between two parallel lines, 15 m or 20 m apart, following the pace of an audio signal that began at a speed of 8.5 km/h and increased by 0.5 km/h at every 1-min interval. Participants were encouraged at all times to run a maximal effort test. The total number of laps (shuttles) completed was recorded for each participant, and all data from the 15 m protocol were converted to the 20 m protocol using a conversion chart, which was shown to have good classification agreement [18]. Researchers used indoor gymnasiums as the primary testing location, with outdoor locations used as a back-up location when necessary. Following the Tomkinson recommendations [19], 20mSRT performance for this study was reported as the running speed at the last completed stage and number of laps completed.

#### Dependent variables

##### *Physical literacy*

PL was assessed using the CAPL instrument, which provides methods to assess the four domains of PL, as described below. The total CAPL score is an aggregate that combines all domains (Physical Competence [maximum of 32 points], Daily Behaviour [maximum of 32 points], Motivation and Confidence [maximum of 18 points], and Knowledge and Understanding [maximum of 18 points]), and ranges from 0 points (poor PL) to 100 points (excellent PL) [3]. The total CAPL score and each of the four domain scores were used to summarize the associations between CRF and PL.

##### *Physical competence*

The Physical Competence domain was modified from the original CAPL methods to provide an aggregate score that excluded the 20mSRT. Thus, the Physical Competence domain included three health-related fitness assessments, three anthropometric assessments, and one gross motor movement skill assessment.

Grip strength was assessed using a handgrip dynamometer following established procedures [20]. The

better score from two trials from each of the left and right hands, measured to the nearest 0.5 kg, were combined. The prone plank test was used to assess torso muscular endurance [21]. Participants were asked to hold a static prone position on their elbows and toes with a straight body position from the ankles to the head for as long as possible, with the time to exhaustion (nearest 0.1 s) recorded as the final score. Flexibility was assessed using the sit-and-reach protocol with a flexometer [20]. Participants were asked to remove their shoes and then sit with their legs stretched out in front of them and their knees flat on the floor. They were asked to extend their arms with their hands stacked while bending forward at the hips and keeping legs straight. The furthest distance attained while reaching forward toward their toes was recorded to the nearest 0.5 cm.

Waist circumference was measured to the nearest 0.5 cm at the top of the iliac crest, using standardized procedures [20]. Standing height was assessed to the nearest 0.1 cm using a stadiometer, and body weight was recorded to the nearest 0.1 kg using a digital weighing scale. Body mass index was calculated from the measured height and weight values ( $\text{kg}/\text{m}^2$ ).

Gross motor movement skills were assessed using the Canadian Agility and Movement Skill Assessment (CAMSA) protocol [22]. The CAMSA is a standardized agility course that provides a method to rapidly assess fundamental and complex movement skills (jumping, sliding, catching, throwing, skipping, hopping, and kicking) in a way that incorporates various 'real-world' movement capacities (coordination, balance, precision, acceleration, and deceleration). The overall CAMSA score combines movement quality scores with the obstacle course completion time to provide an overall score between 1.5 (low performer) and 42 (high performer) [22].

##### *Daily behaviour*

The Daily Behaviour domain assessed participants' engagement in physical activity and sedentary behaviours as three separate components: object-73[real p(t)-8ysicalactivating,

were accumulated per day; and at least three valid days were recorded [23, 24].

1 D	B (n=4710)	G (n=4683)	T a (n=9393)
A ( a )	10.1 (1.2)	10.1 (1.2)	10.1 (1.2)
Ma. ( a )	-2.7 (0.9)	-1.5 (1.1)	-2.1 (1.2)
S ( ,%)			
V a, B C . a	258 (5.5)	220 (4.7)	478 (5.1)
L , A a	532 (11.3)	531 (11.3)	1063 (11.3)
Ca a , A a	620 (13.2)	619 (13.2)	1239 (13.2)
W , Ma a	607 (12.9)	610 (13.0)	1217 (13.0)
N Ba , O a	529 (11.2)	578 (12.3)	1107 (11.8)
W , O a	637 (13.5)	569 (12.2)	1206 (12.8)
O a a, O a	350 (7.4)	359 (7.7)	709 (7.5)
T -R . , Q .	56 (1.2)	34 (0.7)	90 (1.0)
Ha a , N a S a	390 (8.3)	407 (8.7)	797 (8.5)
A , N a S a	482 (10.2)	506 (10.8)	988 (10.5)
C a , P.E.I.	249 (5.3)	250 (5.3)	499 (5.3)
I a a			



by the sit and reach score for boys (Cohen's  $d$  range: 0.29–0.40), and the handgrip score for girls (Cohen's  $d$  range: 0.24–0.41).

This study represents the largest effort to date to assess the associations between CRF and components of PL among school-aged children. Our findings suggest that there are clear favourable associations between

PL and CRF levels. For instance, participants in the high CRF tertile consistently demonstrated better scores across all domains of PL in comparison with their peers in lower CRF tertile groups, regardless of age and gender. Of the PL components, the strongest





20 SRT (# a )	B (n=1510)				G (n=1550)			
	CRF	CRF	CRF	C	CRF	CRF	CRF	C
	11.5 (3.3)	24.0 (4.6)	47.6 (12.2)		11.6 (2.8)	19.6 (2.6)	35.6 (9.2)	
P a L a								
T a CAPL	56.4 (11.4)	65.1 (11.0) <sup>a</sup>	72.2 (10.3) · *	1.45	58.0 (10.3)	63.5 (9.7) <sup>a</sup>	70.3 (9.9) · *	1.22
P a C								
T a a	18.1 (3.8)	21.6 (3.5) <sup>a</sup>	24.4 (3.3) · *	1.77	19.0 (3.6)	21.6 (3.3) <sup>a</sup>	24.0 (3.4) · *	1.43
Ha ( )	36.0 (9.8)	37.0 (9.1)	39.7 (8.5) · *	0.40	34.6 (9.2)	35.5 (9.0)	37.2 (8.6) · *	0.29
P a ( )	42.2 (31.9)	63.0 (39.1) <sup>a</sup>	93.2 (53.1) · *	1.16	43.3 (27.9)	60.0 (37.5) <sup>a</sup>	85.5 (48.5) · *	1.07
S-a - a ( )	23.0 (7.6)	25.2 (7.6) <sup>a</sup>	25.8 (7.3) · *	0.38	28.6 (8.6)	30.4 (8.7) <sup>a</sup>	33.1 (8.6) · *	0.52
Wa ( )	76.7 (14.1)	69.1 (9.4) <sup>a</sup>	65.3 (6.7) · *	1.31	74.1 (12.3)	68.5 (9.3) <sup>a</sup>	64.8 (7.1) · *	0.93
BMI ( / ²)	21.8 (5.0)	19.2 (3.3) <sup>a</sup>	17.8 (2.4) · *	1.01	21.1 (4.5)	19.3 (3.3) <sup>a</sup>	18.0 (2.7) · *	0.84
CAMSA	29.7 (5.4)	33.5 (4.5) <sup>a</sup>	36.1 (3.6) · *	1.40	29.5 (5.1)	32.0 (4.4) <sup>a</sup>	34.7 (4.1) · *	1.12
Da B a . a								
T a a	15.2 (7.8)	18.2 (7.5) <sup>a</sup>	20.5 (7.6) · *	0.69	15.6 (7.7)	17.2 (7.0) <sup>a</sup>	19.6 (7.1) · *	0.54
A a a	10,984 (3740)	11,825 (3865) <sup>a</sup>	13,209 (4118) · *	0.57	9679 (3282)	10,176 (3266)	11,587 (3777) · *	0.54
S - ( / a)	3.4 (2.3)	2.8 (1.9) <sup>a</sup>	2.4 (1.7) · *	0.50	2.7 (2.0)	2.4 (1.7) <sup>a</sup>	2.0 (1.5) · *	0.40
A a a /	4.4 (2.1)	5.1 (1.8) <sup>a</sup>	5.7 (1.6) · *	0.70	4.4 (1.9)	4.9 (1.7) <sup>a</sup>	5.3 (1.6) · *	0.51
M a a C a								
T a a	11.3 (3.1)	12.7 (2.8) <sup>a</sup>	14.1 (2.1) · *	1.06	11.1 (2.6)	11.9 (2.4) <sup>a</sup>	13.3 (2.4) · *	0.88
B a a	1.3 (1.2)	1.7 (1.2) <sup>a</sup>	2.0 (1.1) · *	0.61	1.3 (1.1)	1.5 (1.0) <sup>a</sup>	1.8 (1.0) · *	0.48
A a	0.6 (0.2)	0.7 (0.2) <sup>a</sup>	0.8 (0.2) · *	1.00	0.6 (0.2)	0.7 (0.2) <sup>a</sup>	0.8 (0.2) · *	1.00
S a	0.6 (0.2)	0.7 (0.2) <sup>a</sup>	0.8 (0.2) · *	1.00	0.6 (0.2)	0.6 (0.2) <sup>a</sup>	0.7 (0.2) · *	0.50
CSAPPA a a	4.4 (1.0)	4.8 (0.9) <sup>a</sup>	5.2 (0.7) · *	0.93	4.2 (0.9)	4.5 (0.8) <sup>a</sup>	4.9 (0.8) · *	0.82
CSAPPA	4.4 (1.1)	4.8 (1.0) <sup>a</sup>	5.3 (0.8) · *	0.94	4.4 (1.0)	4.6 (0.9) <sup>a</sup>	5.1 (0.8) · *	0.77
K a U a a								
T a a	11.8 (2.8)	12.7 (2.6) <sup>a</sup>	13.1 (2.5) · *	0.49	12.2 (2.6)	12.8 (2.4) <sup>a</sup>	13.4 (2.4) · *	0.48
CAPL . a	11.8 (2.8)	12.7 (2.6) <sup>a</sup>	13.1 (2.5) · *	0.49	12.2 (2.6)	12.8 (2.4) <sup>a</sup>	13.4 (2.4) · *	0.48

N : A ( SD). S ANCO A B (D...) - C CRF 20- A C A B I CA AC A M S A CA LC A. P. L CF, C A C S -P A P. A D <0.05 CRF CRF <0.05 CRF CRF <0.05 CRF CRF \* <0.001

CAPL and this study is the first to identify these strong associations; however, other studies using different tests support our findings. For instance, a previous study identified strong positive associations between the Test of Gross Motor Development–2nd Edition and achieving the FITNESSGRAM® Healthy Fitness Zone for the 20mSRT [33, 34]. This further suggests that CRF is strongly related to gross motor skills. In addition, another study reported marginal but significant correlations between CRF and the ability to perform repeated

push-ups and curl-ups [35], measures of muscular endurance that are similar to the prone plank test. These associations suggest that future interventions designed to improve CRF could incorporate skill development aimed at teaching fundamental motor skills (i.e., jumping, sliding, catching, throwing, skipping, hopping, and kicking), movement capacities (i.e., coordination, balance, precision, acceleration, and deceleration), and muscular endurance. These types of interventions may have an indirect or mediated effect by providing children

20m SRT (#)	B (n = 531)				G (n = 526)			
	CRF	CRF	CRF	C	CRF	CRF	CRF	C
	12.5 (3.9)	26.6 (4.9)	51.9 (13.1)		12.5 (3.0)	21.0 (2.9)	39.0 (10.9)	
Physical Literacy				1.60				1.26
Physical Capacity				1.94				1.45
Physical Confidence				1.36				1.11
Physical Activity				0.37				0.24
Waist Circumference				0.95				0.72
Handgrip Strength				0.57				0.39
BMI				0.93				0.78
CAMSA				1.52				1.07
Distance				0.75				0.60
Age				0.94				0.70
Sex				0.47				0.52
Age / Sex				0.63				0.62
Motivation				1.18				0.88
Confidence				0.66				0.54
Physical Activity				1.27				1.00
Physical Literacy				0.79				0.50
CSAPPA				1.13				0.94
CSAPPA				1.12				0.73
Knowledge				0.70				0.49
Physical Literacy				0.70				0.49

with the abilities needed to participate in a broader range of physical activities, and thus potentially further improve CRF. Indeed, many physical education programs incorporate these aspects of skill development in their respective curricula.

In our study, the association between CRF and adiposity (body mass index and waist circumference) ranged from moderate to large. While the relationship between CRF and adiposity is certainly important, it may not be the most vital aspect associated with 20mSRT

performance. Previous research has showed that adiposity explained between 40 and 60% of declines in distance running seen in children (aged 10–12 years) between 1985 and 1997 [36]. Indeed, 20mSRT performance in children likely results from a combination of several physiological and psychological aspects, including motivation [37].

The importance of motivation is further supported by our study, which identified the Motivation and Confidence domain as having moderate to large effect sizes



Authors' contributions

MST a PEL RBC-CAPL . JLL a MST  
JDB, a JPC a a a a a . JLL, MST,  
a . PEL, KDA, BB, JLC, MJG, NH, AMK, KNL, BL, DJM, LJM, TJS, DS,  
MRS, SJW, a MST . a a . JLL, JPC, PEL, JDB, KB, GRT,  
KDA, BB, JLC, MJG, NH, AMK, KNL, BL, DJM, LJM, TJS, DS, MRS, SJW, MST  
. A a . a a a . a a . .

Ethics approval and consent to participate

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N U R a E B a ,N a N D S B a ,  
N Pa S. Ca D S B a ,a C S S a  
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