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by Shirley Bryan, Mathieu Saint-Pierre Larose, Norm Campbell, Janine Clarke and Mark S. Tremblay

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Abstract

Background
Directly measured blood pressure (BP) data have not been collected in Canada since the Canadian Heart Health Surveys, conducted between 1985 and 1992. Because hypertension is often asymptomatic, a large proportion of those with the condition are unaware of it.

Data and methods
These analyses use BP and heart rate (HR) data from cycle 1 of the 2007-2009 Canadian Health Measures Survey (CHMS) for respondents aged 6 to 79 years. Methods and quality assurance and control procedures are explained. Logistical and feasibility issues that arose during data collection are discussed. The reasons for repeating a series of measures are given. Between- and within- series variations and inter-tester variability are assessed.

Results
The BP and HR of almost all respondents who attended the examination centre were measured. Only one series of measurements was taken for 88% of respondents. The series was repeated for around 5% with variability in their BP or HR measurements. About 3% had HR or BP values above the screening cut-offs for the fitness tests. Almost 35% of respondents with HR or BP values above the screening cut-offs after their first series had values below the cut-points after the second series; a further 3% had values below after the third series. Within a series of six measurements, BP decreased until about the fourth measure, after which it remained stable. Mean BP and HR values indicated no inter-tester variability.

Interpretation
The protocol for measuring BP and HR by oscillometry in the CHMS appears to have produced reliable estimates. No benefit to repeating the series of six measurements a third time for screening purposes is evident. Four measurements may be sufficient to provide reliable BP and HR data. Oscillometry appears to eliminate inter-tester variability.

Keywords
direct measurement, health survey, oscillometric measurement

Authors
Shirley Bryan (613-951-4968; Shirley.Bryan@statcan.gc.ca), Mathieu St-Pierre Larose and Janine Clarke (613-951-7598; Janine.Clarke@statcan.gc.ca) are with the Physical Health Measures Division, Statistics Canada, Ottawa, Ontario K1A 0T6. Norm Campbell is with the University of Calgary and Libin Cardiovascular Institute. Mark S. Tremblay is with the Healthy Active Living and Obesity Research Group at the Children's Hospital of Eastern Ontario Research Institute.

Elevated blood pressure (BP) is a leading risk factor for mortality, cardiovascular disease and kidney disease.[1,2] The World Health Organization estimates that elevated BP is responsible for approximately 7.1 million premature deaths annually and 4.4% of the global disease burden,[3] with two-thirds of stroke and half of ischemic heart disease attributable to suboptimal BP levels.[4] Worldwide, in 2000, an estimated 26.4% of adults had hypertension (high BP), a figure projected to increase to 29.2% by 2025.[5]

Population surveys in Canada (for example, the Canadian Community Health Survey) have long relied on self-reported questionnaires to determine the prevalence of chronic conditions. Hypertension, however, tends to be asymptomatic, and a large proportion of people who are affected are unaware of it. The potential for underreporting, and thereby underestimating, the prevalence of a condition with such a high public health burden necessitates the collection of directly measured BP.[6]

In Canada, the last comprehensive directly measured BP data were gathered between 1985 and 1992 as part of the Canadian Heart Health Surveys.[7] The surveys used standard mercury sphygmomanometers. Information was collected from adults during home interviews and clinic visits in the 10 provinces.[7] From these data, the prevalence of hypertension (average systolic BP ≥140 mmHg or average diastolic BP ≥90 mmHg, or current treatment with prescription medicine or non-pharmacological treatment) among adults was estimated at 22%; 42% of these hypertensive adults were unaware of their condition.[8]

In March 2007, Statistics Canada launched the first cycle of the Canadian Health Measures Survey (CHMS). The CHMS is a nationally representative, cross-sectional direct measures survey that includes the concurrent direct measurement of resting BP and heart rate (HR) using oscillometry.

The threefold objectives of this paper are to provide:

- an overview of the BP and HR collection method used for cycle 1 of the CHMS;
- information about methodological and analytical issues faced during the collection and analysis of the BP and HR data; and
- information about protocol changes implemented in cycle 2 in response to the experience gained in cycle 1.

Data source

Cycle 1 of the CHMS involved a nationally representative sample of approximately 5,600 Canadians aged 6 to 79 years. Data were collected from March 2007 through February 2009. The survey comprised an in-home interview about general health followed by a visit to a mobile examination centre where direct physical measures were conducted.[9]

The cycle 1 sample represented 96.3% of the Canadian population; full-time members of the Canadian Forces, and residents of Crown lands or Indian reserves, institutions and certain remote regions were excluded.[10] Measurement of resting HR and BP was completed on almost all respondents who participated in the physical measures portion of the survey (N=5,610; 2,709 males and 2,901 females). Test exclusion criteria for HR and BP included double-arm amputation, rashes, gauze dressings, casts, oedema, paralysis, tubes, open sores or wounds, and withered arms or v-shunts on both arms. No respondents were screened out of this component.

Equipment

BP and HR were measured electronically with an automated oscillometric device: the BpTRU™ BPM-300 at the mobile examination centre and with the BpTRU™ BPM-100 during home visits (BpTRU™ Medical Devices Ltd., Coquitlam, British Columbia). The BPM-300 allows electronic transfer of data; the BPM-100 does not.

The decision to use an automated oscillometric device was based on recommendations from a committee of hypertension and survey experts.[11] The BpTRU™ meets the Association for the Advancement of Medical Instrumentation standard and the British Hypertension Society protocol.[12] The committee recommended oscillometry rather than auscultation because oscillometric devices require less training to operate, improve the reproducibility and standardization of readings, and eliminate common problems associated auscultation such as ausculatory gaps, hearing acuity, interpretation of Korotkoff sounds, changes in technique over time, differences in technique between staff, and terminal digit bias. Oscillometry has been used in large surveys in several other countries.[11,13,14] As well, oscillometric devices allow HR and BP to be taken in the absence of survey personnel, which minimizes observer-subject interactions that can influence results (for example, white-coat effect).[11]

The oscillometric measurement protocol was assessed during a comprehensive pre-test of the CHMS and was found to meet the needs of the survey.[15] A review of the CHMS data revealed no terminal end-digit bias when using the BpTRU™. Oscillometric BP measurement was taken on more than 99% of respondents . If a respondent refused to have BP measured with the BpTRU™, or to confirm multiple series of results with excessive variability (see *Measurement procedures*), BP was taken manually using a Littman Classic II SE stethoscope and an ALMEDIC 490 mercury sphygmomanometer.

The accuracy of each BpTRU™ was verified by staff three times during the six-week period at each CHMS collection site or when a problem was suspected (for example, questionable readings, suspected damage) following standardized procedures recommended by the manufacturer (Table 1).[6] A reference gauge calibration check, including a static and dynamic accuracy test, was also performed by the manufacturer (BpTRU™ Medical

Table 1
Verification procedures, purpose and repeat criteria for verifying BpTRU™,[16] Canadian Health Measures Survey, cycle 1, 2007 to 2009

Verification procedure	Purpose	Repeat criteria
Zero calibration check	Verifies that BpTRU™ accurately measures zero pressure when no pressure is being applied	If value in PULSE display not equal to 0 or if value in READING display >10.
Reference gauge calibration check	Compares accuracy of BpTRU™'s pressure transducer against reference pressure gauge (for example, mercury sphygmomanometer) of known accuracy when pressure applied to device	Repeat based on difference between expected and actual readings at each pressure tested as follows: 275 > ± 5.5 mmHg 200 > ± 4 mmHg 50, 100 and 150 > ± 3 mmHg
Over pressure test	Verifies BpTRU™'s safety mechanism that automatically releases air in cuff and displays error code should pressure surpass 330 mmHg	Error code E2 should be displayed in SYSTOLIC display window; if not, repeat test.
Over inflation time test	Verifies BpTRU™'s safety mechanism that automatically releases air in cuff if it stays pressurized over 10 mmHg for more than 180 seconds	Error code E11 should be displayed in SYSTOLIC display window; if not, repeat test.

Services) once per year. The mercury sphygmomanometer was verified three times at each collection site using a zero calibration check. Results of all verifications were recorded in a database, and staff followed a set of repeat criteria (Table 1) to determine if a second verification was necessary. The results were reviewed by the on-site manager and sent to Statistics Canada's head office in Ottawa for review and documentation. During collection, three devices did not pass verification and were sent to the manufacturer for repair and calibration.

In addition to regular verification, the staff maintained the BpTRU™ devices. This included cleaning the cuffs after each use, cleaning and disinfecting the unit weekly, and performing a visual inspection and battery check at the beginning and end of the period spent at each collection site (approximately six weeks).

The BpTRU™ BPM-300 was chosen because it allows automated downloading of data through a USB connection. A customized data transfer program was developed to download data from the BpTRU™ to the data capture application. Occasional random communication problems prevented automatic data transmission. In 182 instances, staff had to manually enter values into the data capture application.

Training

All staff conducting the physical measures were accredited members of the Canadian Society for Exercise Physiology (CSEP). These health measures specialists completed a one-day calibration/training session for HR and BP measurement with registered nurses from the Ottawa Hospital (Ottawa, Canada) who specialize in this measure. Training included basic theory; review and practice of both the oscillometric and auscultatory protocols; in-class demonstrations on how to use the equipment, prepare a respondent for measurement, select the appropriately sized cuff and fasten it on various arm sizes and shapes (for instance, large or conical-shaped arms); and the effect of arm and body position on the measurement. Staff watched a video that described proper technique for calculating maximal inflation rate when performing measurements by auscultation. Staff were evaluated using a double-headed stethoscope. Time was also dedicated to reviewing equipment maintenance and verification procedures. During a dress rehearsal before the start of cycle 1 data collection, staff practised measurement techniques, became familiar with protocols, and addressed equipment and protocol problems. A retraining session took place nine months after collection started. During collection, time was allocated for weekly practice performing auscultation so that staff were prepared to use this technique if needed.

Staff were periodically observed by external experts (for example, with expertise in BP measurement in a clinical setting), head office staff and mobile examination centre managers. Observation guidelines and an observation checklist were developed in consultation with measurement experts to aid in the assessment and documentation of staff performance. In total, 16 observation reports were completed for each staff member conducting the BP component, and based on these reports, feedback and retraining were provided. Two protocol items that required retraining were ensuring the BpTRU™ screen could not be viewed by respondents during the measurement and ensuring that the arm was at the correct height.

Measurement procedures

During the household interview, respondents were asked: "Do you have high blood pressure?" (diagnosed by a health professional) and "In the past month have you taken any medicine for high blood pressure?"[17] These questions are consistent with those in other Statistics Canada surveys (for example, Canadian Community Health Survey).[18] Respondents were also asked about their use of prescription and over-the-counter medications, including dosage and the last time they took the medication.

At the beginning of respondents' mobile examination centre visit, the health measures specialist asked them screening questions, during which the list of medications (including BP medications) provided during the home interview was reviewed and updated. Questions were also asked about acute and chronic conditions that could result in a respondent being screened out of other physical measures.[19]

HR and BP measurement was the fourth component in the mobile examination centre visit, after screening, anthropometry, and urine collection.[20] It was administered in quiet, temperature-controlled rooms (21ºC ± 2ºC) with the lights on at all times. Respondents were asked if they needed to use the washroom before the test. They were seated in a comfortable chair with the back and arms supported and with both feet on a flat surface. The antecubital fossa (elbow crease) of the right arm was positioned at the apex of the heart (the junction of the fourth intercostal space and the lower left sternal border) with the palm facing down for oscillometric measurement or up for auscultation. Staff could use use arm pads of two different thicknesses, and chairs with adjustable height were provided to assist with arm height positioning. The left arm was used only when it was impossible to use the right arm. An appropriately sized cuff was chosen using the marked ranges on the inner side as a guideline. The cuff was fastened tightly around the bare upper part of the arm such that only two fingers could be slid under the cuff, with the center of the bladder over the brachial artery and the lower margin of the cuff 2 to 3 cm above the antecubital fossa. Because respondents had been asked to wear clothing appropriate for exercise for their mobile examination centre visit, most wore a short-sleeved shirt. On some occasions (more often among older adults), respondents were given a short-sleeved shirt to wear during the

measurement to ensure that clothing did not impede blood flow in the arm. Respondents were left alone to rest for five minutes before the measurement. The health measures specialist asked them to sit quietly, relax and refrain from moving or talking during this rest period. After the rest period, the health measures specialist re-entered the room to start the BpTRU™.

The test consisted of six oscillometric measurements taken at one-minute intervals. The health measures specialist remained in the room for the first measurement to ensure proper functioning of the BpTRU™ and that the respondent was following test instructions. The BpTRU™ digital display was positioned so that the respondent could not see the results during the test. In the case of young children who had difficulty complying with the testing procedures (for example, sitting quietly), the health measures specialist remained in the room throughout the measurement series. This practice was implemented based on experience at the first collection site where some children were anxious and tended to move during the measurement, and as a result, errors were recorded on the BpTRU™. Having health measures specialists in the room improved data quality, as they could ensure that children followed proper test protocol.

Of the six measurements taken in a series, only the last five were used to calculate average BP and HR. The health measures specialist reviewed the first series of measurements. The series was repeated a second time, after five more minutes of rest, if:

1. average BP was >144/94 mmHg; or
2. average heart rate was ≥100 bpm; or
3. fewer than three valid measurements were recorded because of BpTRU™ error codes; or
4. variability between two systolic measurements in the series was >30 mmHg; or
5. variability between two diastolic measurements in a series was >20 mmHg; or
6. variability between two heart rate measurements in a series was >30 bpm.

If the series was repeated because of BP >144/94 mmHg or HR ≥100 bpm, the results of subsequent series were used only as a screening tool to assess eligibility to participate in the aerobic fitness (modified Canadian Aerobic Fitness Test) and muscular endurance (partial curl-ups) components of the survey. These cut-points were set according to the guidelines in the Canadian Physical Activity, Fitness and Lifestyle Approach.[21]

A third series of measurements was taken if the second series indicated any of the six problems listed above. If the problem was related to variability or to too many errors, the health measures specialist would take the BP by auscultation (fewer than 1% of cases) to ensure the problem was not a malfunctioning BpTRU™. The health measures specialists could also re-do a series of measurements if, after review, they considered the validity of the measurements to be in question. In such instances, average systolic and diastolic BP and average HR were not calculated, and the values were set to "not stated" (996) in the data set for that series. More information about the survey design and data layout is available in the *CHMS Data User's Guide*.[22]

At the end of their examination centre visit, respondents received a printed report of the results of their physical measures tests. Average BP and HR were based on the last series of valid BP measurements recorded, and a comment about the result was included on the report. For adults aged 18 years or older, the classification of hypertensive status was taken from the guidelines developed by the Canadian Coalition for High Blood Pressure Prevention and Control.[23] For respondents aged 6 to 17 years, the classification was taken from the guidelines developed by the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents.[24] Respondents with a BP above the normal range received a letter to give to their health care provider, which included the test result and information about how the data had been collected.

Evaluation of cycle 1 data

An evaluation of some aspects of the BP collection protocol was undertaken to determine if adjustments were required, specifically, the number of times the series was repeated, the reason for the repeat, and the effect of the third series of measurements on the overall screen-out rate for the fitness tests. In addition, the data were reviewed to detect inter-tester variability in the measurements and to determine the difference between measures within a series and thereby assess if six repeated measurements were necessary to produce reliable average values.

Series repeats

All repeated series of measurements were assessed to determine how many times and why a series had been repeated based on the six repeat criteria. Particular attention was paid to the variability check. This was an automated procedure performed on the first and second series to assess whether a subsequent series should be performed because of too much variability between measurements that might indicate invalid data. The variability limits (30 mmHg for systolic BP, 20 mmHg for diastolic BP, 30 bpm for HR) were based on an evaluation of the CHMS pre-test data. In the pre-test, fewer than 3% of the overall sample had a range greater than these cut-points in their measurements within a single series. The 97th percentile for the maximum range in the first series was determined by age group and sex.

Between-series evaluation

The measurement of BP and HR served two distinct purposes: 1) to assess the respondent's BP and HR status, and 2) as a screening tool to exclude respondents aged 15 to 69 years from certain fitness tests (those with BP >144/94 mmHg or HR≥100 bpm were excluded from the

aerobic fitness test and partial curl-up test). Respondents whose BP or HR was above the screening cut-off on their first series of measurements were assessed to determine if repeating the series a second or a third time yielded results below the cut-points, and thus, allowed them to participate in the fitness tests.

Within-series evaluation

Six BP and HR measurements were recorded at one-minute intervals within each series of measurements. To assess whether six measurements were needed for a reliable estimate of resting values, the mean of each measurement in the series and the difference between measurements within the series was determined by age group using the series that was included as part of the derived variable calculation of the averages.[25]

Inter-tester variability

To detect inter-tester variability, the means and 95% confidence intervals of all first series measures taken by each health measures specialist were calculated.

Results

Reasons for repeating series

For a large majority of respondents (88.8%), only one series of six measurements was taken; for approximately 11% , a second series was taken; and 13.7% of those who had a second series also had a third. The most common reason for repeating a series was too much variability for both the second and third repeat (Table 2).

An assessment of the maximum range between measures in the first series showed that the 97th percentile varied widely between age groups and tended to be highest and over the variability cut-points among 12- to 19-years-olds for HR and systolic BP (Table 3).

Between-series evaluation

A total of 95 respondents aged 15 to 69 years had BP or HR above the screening cut-points (BP >144/94 mmHg; HR ≥100 bpm) during the first series of six measurements. Of these, 33 (34.7%) had average values below these limits during the second series, but only 3 (3.2%) had values below the limits during the third series. Thus, 59 (62.1%) remained screened out of the fitness components of the survey as a result of BP or HR that exceeded the screening cut-points.

Within-series evaluation

Table 4 displays the mean of each measurement within a series, the

Table 2
Reason for performing second and third series of blood pressure (BP) and heart rate (HR) measurements, Canadian Health Measures Survey, cycle 1, 2007 to 2009

First set			Second set		
Reason for second set	Number	Percent	Reason for third set	Number	Percent
First set accepted	4,980	88.8	Second set accepted	544	9.7
Elevated BP and HR	4	0.1	Elevated BP and HR	0	0.0
Elevated BP only	164	2.9	Elevated BP only	1	0.0
Elevated HR only	52	0.9	Elevated HR only	2	0.0
More than 3 errors	24	0.4	More than 3 errors	2	0.0
Variability	270	4.8	Variability	64	1.1
Option to re-do	116	2.1	Option to re-do	17	0.3

Table 3
97th percentiles of range (maximum-minimum) within first series for resting systolic and diastolic blood pressure (BP) and for resting heart rate, by age group, household population aged 6 to 79 years, Canadian Health Measures Survey, cycle 1, 2007 to 2009

Age group	Systolic BP	Diastolic BP	Heart rate
	(mmHg)	(mmHg)	(bpm)
6 to 11 years	25	26	22
12 to 29 years	30	20	33
20 to 39 years	24	17	16
40 to 59 years	24	14	11
60 to 79 years	28	20	17

What is already known on this subject?

- In Canada, the last comprehensive directly measured blood pressure (BP) data were gathered between 1985 and 1992 as part of the Canadian Heart Health Surveys using standard mercury sphygmomanometers.
- The 2007-2009 Canadian Health Measures Survey (CHMS) included direct measurement of resting BP and HR using oscillometry.
- Compared with auscultation, oscillometric devices require less training to operate, improve the reproducibility and standardization of readings, and eliminate problems associated auscultation such as changes in technique over time, differences in technique between staff, terminal digit bias, and observer-subject interactions.

What does this study add?

- The protocol used for measuring BP and HR by oscillometry in the CHMS produces reliable estimates for the Canadian population.
- Measurement of BP and HR using oscillometry eliminates inter-tester variability.
- Ocsillometry is suitable for population surveys, provided that rigorous quality assurance, quality control and calibration procedures are in place.

Table 4
Mean and 95% confidence intervals of each measurement in a series and mean difference between measurements within the series (in relation to last measurement used in creation of derived variable), by age group, household population aged 6 to 79 years, Canadian Health Measures Survey, cycle 1, 2007 to 2009

Measurements and age group	Number	Mean	95% confidence interval		Mean	95% confidence interval		Mean difference	95% confidence interval		Minimum	Maximum
			from	to		from	to	Estimate	from	to		
Second/Sixth		**Second measurement**			**Sixth measurement**							
6 to 11 years												
Systolic BP (mmHg)	952	94	81	108	92	80	106	2	-8	12	-22	25
Diastolic BP (mmHg)	951	63	51	76	60	48	74	3	-6	12	-18	20
Heart rate (bpm)	954	77	61	96	81	65	100	-3	-12	5	-30	22
12 to 19 years												
Systolic BP (mmHg)	968	100	84	11	98	83	115	2	-5	10	-26	46
Diastolic BP (mmHg)	968	64	52	77	61	49	75	3	-6	10	-19	25
Heart rate (bpm)	968	72	54	94	76	57	99	-3	-14	8	-32	28
20 to 39 years												
Systolic BP (mmHg)	1,166	106	89	126	104	87	123	2	-7	13	-22	29
Diastolic BP (mmHg)	1,166	70	57	86	68	54	84	2	-5	9	-17	18
Heart rate (bpm)	1,165	68	52	87	70	54	88	-2	-9	4	-28	24
40 to 59 years												
Systolic BP (mmHg)	1,224	115	94	143	112	92	138	3	-9	15	-22	30
Diastolic BP (mmHg)	1,224	75	60	92	74	59	90	1	-5	8	-17	21
Heart rate (bpm)	1,224	67	51	84	68	52	86	-1	-6	3	-19	12
60 to 79 years												
Systolic BP (mmHg)	1,090	127	100	160	123	98	152	4	-8	18	-27	30
Diastolic BP (mmHg)	1,090	73	57	90	72	55	88	1	-5	8	-16	22
Heart rate (bpm)	1,090	65	49	84	66	50	84	-1	-5	4	-32	21
Third/Sixth		**Third measurement**			**Sixth measurement**							
6 to 11 years												
Systolic BP (mmHg)	946	93	81	108	92	80	106	1	-9	12	-22	21
Diastolic BP (mmHg)	945	62	49	75	60	48	74	1	-8	10	-20	18
Heart rate (bpm)	949	79	62	97	81	65	100	-2	-12	6	-27	24
12 to 19 years												
Systolic BP (mmHg)	973	99	84	116	98	83	115	2	-11	14	-28	27
Diastolic BP (mmHg)	973	63	50	76	61	49	75	1	-7	9	-37	19
Heart rate (bpm)	974	74	55	98	76	57	99	-2	-12	7	-30	29
20 to 39 years												
Systolic BP (mmHg)	1,165	105	89	125	104	87	123	1	-9	12	-22	28
Diastolic BP (mmHg)	1,165	69	56	85	68	54	84	1	-5	8	-17	20
Heart rate (bpm)	1,165	69	54	88	70	54	88	-1	-8	5	-29	22
40 to 59 years												
Systolic BP (mmHg)	1,222	114	93	141	112	92	138	2	-8	13	-24	30
Diastolic BP (mmHg)	1,222	75	60	91	74	59	90	1	-5	7	-19	19
Heart rate (bpm)	1,222	67	51	85	68	52	86	-1	-5	4	-17	16
60 to 79 years												
Systolic BP (mmHg)	1,083	126	99	158	123	98	152	3	-10	15	-28	30
Diastolic BP (mmHg)	1,083	73	56	90	72	55	88	1	-5	7	-16	20
Heart rate (bpm)	1,083	66	50	85	66	50	84	0	-4	4	-20	25
Fourth/Sixth		**Fourth measurement**			**Sixth measurement**							
6 to 11 years												
Systolic BP (mmHg)	956	93	80	107	92	80	106	1	-9	11	-23	30
Diastolic BP (mmHg)	955	61	48	75	60	48	74	1	-8	10	-18	19
Heart rate (bpm)	959	80	63	100	81	65	100	-1	-10	7	-29	19
12 to 19 years												
Systolic BP (mmHg)	976	99	84	115	98	83	115	1	-10	12	-26	29
Diastolic BP (mmHg)	976	62	50	76	61	49	75	1	-7	9	-32	19
Heart rate (bpm)	975	75	56	96	76	57	99	-1	-10	8	-25	28
20 to 39 years												
Systolic BP (mmHg)	1,174	105	88	124	104	87	123	1	-9	11	-26	24
Diastolic BP (mmHg)	1,174	69	55	84	68	54	84	1	-5	7	-18	18
Heart rate (bpm)	1,174	70	54	88	70	54	88	0	-7	6	-26	20
40 to 59 years												
Systolic BP (mmHg)	1,227	113	93	140	112	92	138	1	-9	12	-20	22
Diastolic BP (mmHg)	1,227	74	60	90	74	59	90	1	-5	6	-17	15
Heart rate (bpm)	1,227	68	51	86	68	52	86	0	-5	4	-15	17
60 to 79 years												
Systolic BP (mmHg)	1,091	125	100	157	123	98	152	2	-9	14	-27	29
Diastolic BP (mmHg)	1,091	73	56	89	72	55	88	1	-6	6	-15	18
Heart rate (bpm)	1,091	66	50	85	66	50	84	0	-4	3	-15	18
Fifth/Sixth		**Fifth measurement**			**Sixth measurement**							
6 to 11 years												
Systolic BP (mmHg)	941	93	80	106	92	80	106	0	-10	10	-19	21
Diastolic BP (mmHg)	940	61	48	74	60	48	74	0	-8	9	-18	33
Heart rate (bpm)	943	80	64	100	81	65	100	-1	-9	7	-24	20
12 to 19 years												
Systolic BP (mmHg)	972	98	83	115	98	83	115	1	-11	12	-28	24
Diastolic BP (mmHg)	972	62	48	76	61	49	75	0	-7	8	-35	19
Heart rate (bpm)	972	75	56	98	76	57	99	-1	-10	8	-33	24
20 to 39 years												
Systolic BP (mmHg)	1,168	104	88	123	104	87	123	0	-9	10	-29	27
Diastolic BP (mmHg)	1,168	68	55	84	68	54	84	0	-7	7	-19	20
Heart rate (bpm)	1,168	70	54	88	70	54	88	0	-6	6	-28	28
40 to 59 years												
Systolic BP (mmHg)	1,221	113	92	138	112	92	138	0	-10	11	-23	23
Diastolic BP (mmHg)	1,221	74	59	91	74	59	90	0	-5	6	-21	18
Heart rate (bpm)	1,221	68	52	86	68	52	86	0	-5	4	-19	14
60 to 79 years												
Systolic BP (mmHg)	1,088	124	99	155	123	98	152	1	-10	12	-30	28
Diastolic BP (mmHg)	1,088	73	57	89	72	55	88	0	-6	6	-19	19
Heart rate (bpm)	1,088	66	50	84	66	50	84	0	-3	3	-16	15

difference between the means for each measurement relative to the sixth, and the maximum and minimum difference for each age group. Among all age groups, both systolic and diastolic BP tended to decrease over the six measurements, while HR tended to increase. The greatest differences were between the second and sixth measurements and the third and the sixth, after which the difference was minimal. The highest maximum and minimum differences for blood pressure were in the youngest age group; these differences narrowed with subsequent measures.

An analysis of the values in the first series of six measurements revealed instances of large differences (potential outliers) between two measurements. However, assessment of the means produced using the derived variable did not show large differences (data not shown). Consequently, no process for removing outliers is needed when calculating mean BP. More details on the determination of the derived variables can be found in the *CHMS Derived Variable Document*.[25]

Inter-tester variability

The means and 95% confidence intervals for staff performing HR and BP measurements on more than 100 respondents indicate consistent results between testers (Table 5). The results for testers who performed more than 500 tests were equally consistent, with means ranging from 107 to 109 mmHg (systolic BP), from 67 to 69 mmHg (diastolic BP), and from 70 to 71 bpm (HR).

Discussion

Analysis of the measurement procedures described in this study led to some modifications to the measurement protocol for cycle 2 of the CHMS. The most common reason for repeating a series of BP measurements was related to variability in HR or BP values between measures within a series. Because this variability was age-dependent and there was no way to determine how much of it

Table 5
Mean and 95% confidence interval for resting systolic and diastolic blood pressure (BP) and for resting heart rate, by tester, Canadian Health Measures Survey, 2007 to 2009

		Systolic BP			Diastolic BP			Heart rate		
			95% confidence interval			95% confidence interval			95% confidence interval	
Tester	Number	Mean	from	to	Mean	from	to	Mean	from	to
		(mmHg)			(mmHg)			(bpm)		
1	538	108	87	137	69	53	87	71	53	93
2	705	108	88	138	69	54	86	70	53	90
3	864	107	86	138	68	53	85	71	54	91
4	579	107	86	138	69	53	84	71	53	90
5	556	107	86	138	68	53	85	71	53	91
6	583	108	88	139	68	53	85	71	53	93
7	536	107	86	140	67	52	83	70	54	88
8	186	109	85	146	68	54	88	72	53	91
9	194	107	84	140	66	49	85	72	54	90
10	212	104	83	132	66	52	81	73	56	96
11	195	108	87	148	68	53	88	71	56	93
12	228	106	86	133	67	52	83	71	55	89

was biologically plausible, the variability check was eliminated for cycle 2.

The BP and HR measurement protocol allowed for up to three series of measurements for each respondent in order to obtain values below the fitness test screening cut-offs. Evaluation of the means between the first and subsequent series of measurements showed only minimal advantage in the third series for screening respondents into the fitness tests, and therefore, the third series of measurements was removed from the procedures for cycle 2.

Unquestionably, it is important to include BP in a comprehensive direct measures health survey, since many people with hypertension are unaware of it.[8] However, the current protocol of performing six measurements up to three times in order to collect this information takes considerable time and places an additional burden on respondents. Analysis of the data in a set of six measurements revealed that by the fourth measure within a set, there appears to be no further change, suggesting that this may be the point of diminishing returns, and that the cost and inconvenience of the fifth and sixth measurements may not merit the effort. Even so, the BpTRU™ was designed and validated when six repeated measures are performed, so no changes have been made to this protocol for cycle 2 of the CHMS. Nonetheless, the potential for improved efficiency should be explored for subsequent cycles.

No inter-tester variability was evident when the staff used the BpTRU™. This is to be expected, since oscillometric devices are designed to be used in the absence of test personnel. However, because of procedural changes during the collection of cycle 1 data, it is not possible to determine the effect of a tester being present in the room with younger children. Since measurement staff stayed in the room only when a child had difficulty following the testing procedures, research on the effect of tester-respondent interaction in the younger age group is warranted to determine if a systematic difference exists between measurements taken in the presence versus the absence of a staff member. Continued monitoring of staff is important to ensure that factors that could affect BP and HR (for example, incorrect arm position) are avoided.

Conclusions

The protocol used to measure BP and HR in cycle 1 of the CHMS was found to be suitable for cycle 2, with only minor modifications based on the findings in this study. These findings indicate no apparent advantage to performing a third series of six BP measurements, since very few respondents with initial values above the screening cut-points were subsequently screened into the fitness testing. Further methodological work is needed to determine the optimal rest period and the number of blood pressure measurements required to obtain valid and reliable estimates, while minimizing respondent burden. The BP equipment and protocol resulted in no detectable inter-tester variability, indicating that the procedures effectively eliminate this variability. The ocsillometric BP procedure appears to be suitable for population surveys, provided that rigorous quality assurance, quality control and calibration procedures are in place. ■

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