Development of the Canadian Home Fitness Test

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The Canadian Home Fitness Test is a self-administered procedure in which the participant steps at an age- and sex-specific rhythm controlled by recorded music, then palpates the pulse immediately following activity. Validation of the test has shown a correlation of 0.72 with the results of a standard submaximum bicycle ergometer test, while the directly measured maximum oxygen intake is correlated even more closely (r = 0.88) with the attained stepping rate, body weight and recovery heart rate. Given modest training, subjects could measure their immediate postexercise heart rate (correlation with electrocardiographic data, r = 0.94), although 10-second counts underestimated the true rate by an average of 7 beats/min. The safety of the test will be established ultimately by experience in its use in a large population; nevertheless, both theoretical considerations and results of trials in over 14 000 adults suggest the procedure can be self-administered without serious consequences. It is also well accepted by the general public and arouses considerable interest in most homes. The test can thus be recommended as providing an approximate measure of an individual's physical fitness in order to stimulate an increase in personal physical activity. It also has potential as a simple screening procedure that would allow paramedical personnel to record fitness levels and standardized exercise electrocardiograms in large segments of the population.

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Le Physitest Canadien est un test que l'on peut s'administrer soi-même et dans lequel chaque participant s'engage à un rythme propre à son âge et son sexe contrôlé par une musique enregistrée, et à la suite duquel il mesure son pouls. La validation du test a montré une corrélation de 0.72 avec les résultats d'un test d'effort sousmaximal sur ergomètre, alors que l'apport maximum d'oxygène mesuré directement a présenté une corrélation encore plus grande (r = 0.88) avec le rythme de marche atteint, le poids corporel et le rythme cardiaque de récupération. A la suite d'un modeste entraînement, les sujets ont pu mesurer leur rythme cardiaque immédiatement après la période d'exercice (avec un taux de corrélation avec les données électrocardiographiques de 0.94), bien que le compte pendant 10 secondes sousestime le rythme réel de 7 battements/min en moyenne. La sécurité du test sera éventuellement établie par l'expérience acquise à la suite de son emploi dans une large population; néanmoins, aussi bien des considérations théoriques que les essais réalisés chez plus de 14 000 adultes indiquent que les gens peuvent eux-mêmes s'imposer le test sans conséquences sérieuses. Il est bien accueilli du public et soulève dans la plupart des foyers beaucoup d'intérêt. Le test peut donc être recommandé pour obtenir une mesure approximative du conditionnement physique de chacun et comme un stimulant à augmenter son activité physique personnelle. On peut également envisager son emploi éventuel comme mesure de dépistage simple permettant à du personnel paramédical d'enregistrer les niveaux de conditionnement physique et les électrocardiogrammes à l'effort sur de larges échantillons de la population.

Government bookstores and other agencies are now selling the Canadian Home Fitness Test (CHFT), a motivational device designed to increase personal physical activity. The complete kit comprises a long-playing record that sets the tempo for a self-administered exercise test that can be performed on a convenient staircase, along with instructions for assessing fitness from the immediate postexercise pulse rate, and suggestions for the translation of this assessment into a program of graded activity suited to the needs of the individual.

This paper describes the development of the test, the stages in its validation and the practical experience with the procedure in some 14 000 adult subjects.

Rationale

The need for a home test of physical fitness was identified at a seminar sponsored by Sport Participation Canada in November 1971 to which we were invited to discuss the possibility of devising a simple "fitness indicator". No immediate action resulted, however, but the idea was given further impetus by a recommendation from the December 1972 National Conference on Health and Fitness.[1] This federal conference recommended that the relevant department of the Canadian government (Recreation Canada) sponsor the development of a self-administered home test of physical fitness. It was suggested that many Canadians would be motivated to increase their habitual activity if there were a simple exercise test that indicated their current physical condition. It was also hoped that maintenance of an increased level of physical activity would be encouraged if test repetition showed that the new lifestyle was improving the individual's cardiorespiratory fitness.

The logistics of mass testing were carefully reviewed at the conference, and it was regretfully concluded that the repeated testing of all Canadian adults, whether by physicians or by paramedical personnel, was impractical in terms of both staffing and the size of the national treasury. Accordingly, a three-tiered test structure was proposed: a self-administered test suitable for all Canadians between 15 and 69 years of age with no contraindication to exercise; a simple laboratory screening procedure for those dissatisfied with their response to the self-administered test; and a detailed appraisal by an exercise cardiologist in those failing the simple laboratory test.

Principles

The best single measure of an individual's cardiorespiratory fitness is his directly measured maximum oxygen intake, or $\dot{V}O_2$ max.[2] Two previous self-administered tests, the Balke 15-minute endurance run[3] and the Cooper 12-minute run,[4] have assessed the subject's capacity to sustain exhausting effort. In the general population, problems of motivation and pacing limit the correlation between maximum oxygen intake and the distance covered in 12 to 15 minutes of running; maximum tests are also likely to be a little more dangerous than those of submaximum effort.[5]

One simple mode of submaximum exercise available to almost every Canadian is stair-climbing. Accordingly, the CHFT is based on the repeated ascent and descent of the lowest two steps of a domestic staircase at a rhythm set by a long-playing record. The procedure is, in fact, a simple variant of a familiar laboratory and office double-step test,[6] calculation of the imposed workload being adjusted to allow for the lesser average height of domestic steps (20 as opposed to 22.5 cm). After answering a simple, self-administered health questionnaire the subject commences a 3-minute "warm-up" exercise at a rate equivalent to 65 to 70% of the average aerobic power anticipated in a person in the next oldest 10-year age group. The record gives time signals for the counting of an immediate recovery pulse rate; if a predetermined ceiling is not exceeded (Table I) the subject carries out a further 3 minutes of exercise at 65 to 70% of the average aerobic power for a sedentary person of his own age. In the current commercial format the test is halted after the 6-minute recovery pulse rate has been taken, although data and music allow extension of the procedure for a further 3 minutes at an exercise rate equivalent to 65 to 70% of the average aerobic power for a subject 10 years younger than the individual taking the test.

Theoretical basis

Our figures for the average fitness of the sedentary Canadian (Table II) were based on rounded data from a sample drawn from the Toronto area;[2] comparable statistics have since been obtained from a random sample of 1544 adults living in Saskatoon.[7,10]

The maximum stress demanded in laboratory submaximum exercise tests is commonly 75 or 85% of the gross aerobic power. We thus calculated rates of climbing that would yield 75% of aerobic power with exercise on the double 22.5-cm laboratory steps, and a less demanding 65 to 70% of aerobic power when the lowest two 20-cm steps of a domestic staircase were used (Table II). In determining the required cadences we assumed a basal oxygen consumption of 3 ml/kg•min, a mechanical efficiency of climbing of 16%, and an energy yield of approximately 21 joules (5 Cal) per litre of oxygen consumed. On this basis the net maximum oxygen intake of 44 ml/kg•min in a 25-year-old man would provide steady-state energy for 32.9 ascents of a double 22.5-cm step every minute, and three quarters of the $\dot{V}O_2$ max would be demanded by 24.2 ascents/min.

To minimize the number of bands on the long-playing record, some of the cadences were rounded slightly further.

Table I — Pulse rates at which the Canadian Home Fitness Test (CHFT) should be terminated, and corresponding percentages of aerobic power ($\dot{V}O_2$ max)

Age (yr)	After 3 minutes of stepping		After 6 minutes of stepping	
	10-second pulse rate*	% of $\dot{V}O_2$ max	10-second pulse rate†	% of $\dot{V}O_2$ max
15 — 19	> 29	80	> 26	70
20 — 29	> 28	80	> 25	70
30 — 39	> 27	80	> 24	70
40 — 49	> 25	75	> 23	67
50 — 59	> 24	75	> 22	67
60 — 69	> 23	75	Always terminated after 6 minutes	

*Values are based on expected pulse rates at 80% of $\dot{V}O_2$ max for next youngest age group and 75% of $\dot{V}O_2$ max for people over 40.
†Values are set at 70% and 67% of $\dot{V}O_2$ max, for men and women, respectively, and are a more cautious ceiling; they are suggested as suitable for unsupervised administration of the test.

Table II—Basis of the CHFT

Age (yr)	Anticipated gross $\dot{V}O_2$ max[2] (ml/kg·min)		Required* rate of climbing (ascents/min)		Corresponding 6-beat cadence (rounded data) (beats/min)†	
	M	F	M	F	M	F
(Spare band of music)	—	—	—	—	156	132
15 — 19	—	—	—	—	156 (144)‡	120
20 — 29	47	38	24.2	19.1	144	114
30 — 39	43	39	21.9	19.7	132	114
40 — 49	38	35	19.1	17.4	114	102
50 — 59	33	30	16.3	14.6	96 (102)‡	84
60 — 69	27	24	12.9	11.2	78 (84)‡	66 (84)‡
Warm-up for oldest age group	—	—	—	—	60 (66)‡	60 (66)‡

*To yield 75% of $\dot{V}O_2$ max on 22.5-cm steps or 65 to 70% on 20-cm steps.
†On every beat subject takes one pace.
‡To simplify recording, the cadences in parenthesis have been substituted for the theoretically determined values.

Table III—Predictions of aerobic power,[11] based on electrocardiographic recordings of heart rate during final 15 seconds of exercise and 6 to 10 seconds after ceasing exercise[10]

Age (yr)	Predicted $\dot{V}O_2$ max (ml/kg·min at STPD)			
	Men		Women	
	End-exercise	Early recovery	End-exercise	Early recovery
15 — 19	47.7	47.2	39.3	39.2
20 — 29	40.8	40.1	38.3	37.3
30 — 39	38.1	37.2	35.7	34.6
40 — 49	34.9	33.8	32.7	31.8
50 — 59	32.5	32.3	32.4	31.8
60 — 69	30.5	30.7	29.8	30.2

However, an independent comparison between intended and actual rates of oxygen consumption has shown a good correspondence during normal use of the test.[8]

Pulse counts are taken from 5 to 15 seconds after the termination of exercise. Cotton and Dill[9] showed many years ago that there was a close correlation between the exercise heart rate and pulse readings taken in the immediate recovery period. We confirmed this with 1544 adults performing the CHFT in a controlled setting in Saskatoon.[10] At all ages and in both sexes electrocardiographic and cardiotachometric estimates of heart rate obtained 6 to 10 seconds after exercise were close to the final exercise reading, so that almost identical predictions of aerobic power[11] were yielded by the two sets of data (Table III).

The fitness of the subject is categorized on the basis of the test duration and the recovery pulse rate. Original norms based on the 1544 subjects tested in Saskatoon have been published.[10] Within each sex-specific group the subjects of the Saskatoon sample were divided into six categories of fitness, ranging from very poor to very good. Roughly equal numbers of individuals fell into each of the categories, and there was a systematic gradation of the predicted aerobic power from the best to the worst category. Subsequently the six categories were combined into three fitness categories for the CHFT (Table IV).

Table IV—Physical fitness evaluation chart for the CHFT

Age (yr)	10-second pulse rate: After first 3 minutes of exercise	After second 3 minutes of exercise
15 — 19	If 30 or more stop. You have an undesirable personal fitness level.	If 27 or more you have a minimum personal fitness level. If 26 or less you have the recommended personal fitness level.
20 — 29	If 29 or more stop. You have an undesirable personal fitness level.	If 26 or more you have a minimum personal fitness level. If 25 or less you have the recommended personal fitness level.
30 — 39	If 28 or more stop. You have an undesirable personal fitness level.	If 25 or more you have a minimum personal fitness level. If 24 or less you have the recommended personal fitness level.
40 — 49	If 26 or more stop. You have an undesirable personal fitness level.	If 24 or more you have a minimum personal fitness level. If 23 or less you have the recommended personal fitness level.
50 — 59	If 25 or more stop. You have an undesirable personal fitness level.	If 23 or more you have a minimum personal fitness level. If 22 or less you have the recommended personal fitness level.
60 — 69	If 24 or more stop. You have an undesirable personal fitness level.	If 23 or more you have a minimum personal fitness level. If 22 or less you have the recommended personal fitness level.

Table V—Comparison between aerobic power predicted from standard bicycle ergometer test[11] and that predicted from recovery pulse rate following performance of the CHFT[10]

	$\dot{V}O_2$ max (ml/kg·min at STPD)					
	Men			Women		
Age (yr)	N	Bicycle	Step	N	Bicycle	Step
15 — 19	74	42.5	47.2	120	33.7	39.2
20 — 29	103	36.3	40.1	136	30.6	37.3
30 — 39	156	32.4	37.1	149	28.1	34.6
40 — 49	83	27.0	33.8	92	24.4	31.8
50 — 59	63	25.7	32.3	88	21.9	31.2
60 — 69	32	22.5	30.7	55	18.9	30.2

Table VI—Relation between CHFT fitness category* and aerobic power, as predicted by results of standard bicycle ergometer test[10]

	$\dot{V}O_2$ max (ml/kg·min at STPD)											
	Men Fitness category						Women Fitness category					
Age (yr)	1	2	3	4	5	6	1	2	3	4	5	6
15 — 19	61	39	56	45	42	35	—	50	45	42	34	28
20 — 29	62	43	47	41	35	30	—	52	35	33	33	26
30 — 39	—	42	38	33	30	24	—	38	34	30	27	23
40 — 49	52	36	30	26	24	22	—	37	30	27	23	18
50 — 59	31	30	27	23	21	—	34	30	25	20	19	15
60 — 69	—	26	22	20	18	12	—	22	18	19	17	14

*Fitness rated from very good (1) to very poor (6).

Validation

Scientific validation of the test has involved (a) a comparison between the CHFT categorizations of physical fitness and bicycle ergometer predictions of aerobic power,[10] and (b) a smaller-scale comparison between the CHFT data and the directly measured maximum oxygen intake — the work of Jetté and colleagues, the results of which are presented in this issue of the Journal (page 680).

In Saskatoon[10] a random sample of 1152 adults returned to the laboratory to carry out a standard submaximal exercise test on a mechanically braked bicycle ergometer.[11] Probably because of problems with quadriceps weakness,[2] bicycle ergometer predictions of $\dot{V}O_2$ max were systematically lower than predictions based on the recovery heart rates recorded electrocardiographically during performance of the CHFT (Table V). This discrepancy increased as the subjects became older. Nevertheless, there was a fairly close correlation between the two sets of data ($r = 0.72 \pm 0.02$ for the 1152 subjects). We may therefore conclude that the procedure would be valid as a simple laboratory assessment of aerobic power, particularly if an electrocardiograph were available to measure the end-exercise or the early recovery heart rate. The test also has reasonable validity when self-administered. Categorizing individual fitness on the basis of step-test endurance and recovery pulse counts, we noted a smooth gradation of aerobic power from very good to very poor fitness ratings, with only a few exceptions (Table VI). Further, there was a close relation between a simple five-point rating of habitual activity and the aerobic power as calculated from the step-test data (Table VII).

The comparison with directly measured maximum oxygen intake was carried out in Ottawa by Jetté and

Table VII—Relation between aerobic power as calculated from CHFT results and reported habitual activity*[10]

	$\dot{V}o_2$ max (ml/kg·min at STPD)									
	Men Reported habitual activity					Women Reported habitual activity				
Age (yr)	1	2	3	4	5	1	2	3	4	5
15 — 19	48	31	38	52	51	44	38	40	43	54
20 — 29	41	39	40	44	48	36	37	37	39	—
30 — 39	35	36	38	40	44	35	34	35	38	51
40 — 49	33	34	34	41	39	29	31	33	30	42
50 — 59	30	32	32	37	—	29	33	31	37	—
60 — 69	26	33	30	29	—	39	39	31	28	—
All subjects	36	37	37	41	46	34	34	35	36	49

*Habitual activity rated as follows: none, 1; occasional, 2; regular, 3; very frequent, 4; specific sports training, 5.

colleagues. The subjects, 35 men and 24 women ranging in age from 15 to 74 years, were individually instructed and supervised in carrying out the CHFT, and at least 30 minutes later they completed a treadmill measurement of maximum oxygen intake. Criteria for completion of the latter were attainment of at least the age-related theoretical maximum heart rate and inability to continue the test. Multiple regression analysis showed that the directly measured maximum oxygen intake could be predicted adequately from the CHFT data, the optimum equation for this purpose being

$$\dot{V}o_2 \text{ max} = 42.5 + 16.6(\dot{V}o_2) - 0.12(W) - 0.12(H) - 0.24(A)$$

where $\dot{V}o_2$ was the oxygen cost (in l/min at STPD) of the last stage of exercise completed at a given rate of stepping, W was the body weight (in kg), H was the recovery heart rate (in beats/min) and A was the age (in years). With the entire equation the discrepancy between the predicted result and the directly measured maximum oxygen intake was 0.4 ± 5.3 ml/kg•min in the men and -0.1 ± 3.3 ml/kg•min in the women. When men and women were considered together the coefficient of correlation between the two sets of data was 0.905. The attained stepping rate and body weight alone yielded a correlation of 0.876, and stepping rate, weight and recovery heart rate, a correlation of 0.881. In this experiment the validity of the fitness categorization was thus independent of the ability of the subjects to count their recovery heart rate accurately.

When the CHFT was first evaluated in Saskatoon[10] the subjects were given no specific instruction in pulse counting and relatively large errors were common (correlation between electrocardiographic or cardiotachometric reading and palpated rate, $r = 0.50$). Nevertheless, we knew from studies of cardiac patients undergoing exercise rehabilitation that middle-aged adults could be trained to palpate their carotid pulse rate with reasonable accuracy.[12,13] In the Ottawa trial the subjects were taught to count their pulse rate until they could do so accurately. Average electrocardiographic readings and palpated pulse rates were 154.1 ± 22.2 and 147.0 ± 23.2, respectively, with a systematic difference of 7.0 ± 5.6 between the two sets of data.

A study by two of us[14] showed a similar difference between actual (134.7) and palpated (127.3) readings in 11- to 14-year-old children who were used to counting their heart rate (track and speed-skating participants). The coefficient of correlation between electrocardiographic and palpated values was 0.94 for such students but was 0.76 when the pulse rate was determined by a partner, and only 0.37 when tests were extended to children with little experience in pulse counting. The systematic error made by experienced observers was approximately one beat in a 10-second pulse count, and in view of the consistency of this error it may prove desirable to augment palpated readings by one beat. Our experience with "postcoronary" patients suggests that accuracy might also be improved by routine taking of the carotid pulse and by a longer period of instruction in pulse taking.

Safety

Recreation Canada has now evaluated the CHFT in over 14 000 adults, with no major problems. The most serious complication in our experience was one individual's fainting before the exercise began, which reflects in part the precautions taken in designing the test. An important first requirement is completion of a brief, self-administered "physical activity readiness questionnaire". Trials of this type of instrument in Saskatoon[7] and Vancouver[15] showed that it eliminated more than half of the patients in whom vigorous exercise would have had above-average risk. A second important feature was the choice of conservative indications for halting the test, including not only untoward symptoms but also the cautious heart rate ceilings that were set for termination at the 3rd or the 6th minute of exercise (Table I). In the initial sample of 1544 subjects all tests were medically supervised. Some 8% of individuals passing the self-administered health questionnaire were not allowed to complete the test because of minor abnormalities in the resting electrocardiogram or an adverse response to exercise, including excessive fatigue, exhaustion and a variety of electrocardiographic abnormalities such as ST-segment depression (41 cases), premature ventricular contractions (19 cases) and supraventricular tachycardia (2 cases). There is currently much discussion regarding the significance of minor ST-segment depression and premature ventricular contractions during effort, and some cardiologists maintain that undue importance has been attached to such phenomena. We will not be able to speak categorically concerning the safety of self-administration of the test until it has been used by several million people, but the lack of complications during use of the procedure by some 14 000 adults suggests that if the exercise is brief and submaximal, minor electrocardiographic abnormalities of this type can generally be ignored.

Possibly undue attention has been focused on the studies of Bruce and McDonough[16] and Rochmis and Blackburn;[17] these authors have set the risk of ventricular fibrillation at one incident for every 10 000 submaximal exercise tests. The risk of such an emergency in these two studies was increased by the selection of a coronary-prone population and by the associated aura of a medical consultation, carrying ominous implications for the future of the individual.[5] In contrast, the CHFT is fun. Therefore, a more appropriate risk comparison might be made with mass participation cross-country ski marathons, which offer data from millions of hours of enjoyable exercise by middle-aged subjects. Despite the duration of individual events, Vuori[18] reported that the incidence of "coronary events" was only about four times the rate anticipated under resting conditions. The ski competitions naturally involve some pleasurable excitement and often preliminary conditioning of the participants. It is difficult to weigh these factors and to assess the added hazards of activity of long duration; however, it seems reasonable to suggest that a long-distance ski race is 5 to 10 times as dangerous as our brief step test on a minute-by-minute basis.[5] With an ostensibly healthy population of 5 million middle-aged adults the risk of a fatality in any given

6 minutes of a ski event is about 0.4, 0.1 due to chance and 0.3 due to the exercise;[5] if 5 million middle-aged adults each performed the CHFT on one occasion, the corresponding risk would be 0.13 to 0.16, 0.1 being attributable to chance and 0.03 to 0.06 to the added risk of the exercise. These calculations imply that if all middle-aged Canadians continued to perform the test once per year without restriction, it would be 16 to 33 years before there was a death attributable to the test; exclusion of half of the "high-risk" patients by the physical activity readiness questionnaire should lengthen the waiting period for a coronary incident to 33 to 66 years. Clearly, we believe the procedure is a safe and rational motivational test.

Consumer acceptance

Recreation Canada sponsored a test marketing of the CHFT[19] in the cities of Guelph, Ont. and Trois Rivières, PQ, using English- and French-language editions of the material, respectively. Questionnaires (3000) were circulated to, and telephone interviews (800) conducted with, the households receiving the kit in each city. Of the respondents 83% were positive, 10% had some reservations, 5% were indifferent and 2% were negative in the evaluation of the test; enthusiasm for the test was more pronounced among the respondents in Trois Rivières than among those in Guelph. Over 78% of respondents read all the information on the record jacket and listened to the record; of this group 54% took the test and a further 9% attempted to do so. Stated reasons for not taking the test included "lack of a record player" (38%), "physical inability" (9%), "lack of steps" (2%) and "indifference" (51%). Of those taking the test 96% encouraged others to try it, the majority indicating use by three or more persons; this suggests that general interest was aroused in households receiving the kit. The instructions seemed at an appropriate level, since 94% of those taking the test found the procedures simple or clear; 90% of subjects also said they would take the test again. The accuracy of the scores obtained is questionable: 54% of the sample rated their fitness as being at the "recommended" level, 22% at the "minimum" level and only 6% at the "undesirable" level, with 10% not completing the test and 8% unable to figure out their scores. This suggests that, as in the validation trials, subjects may have underestimated their postexercise pulse rates; however, further study would be needed to eliminate the alternative hypothesis, that those taking the test and responding to the questionnaire were the more fit members of the communities evaluated.

Current assessment

From the general public acceptance of the CHFT, reactions at several professional meetings, and data suggesting that several members of most households have tried the procedure during test marketing, there seems little question that the CHFT will serve as a useful motivating tool, encouraging public interest in physical fitness and pointing to the need for greater physical activity.

No great precision is claimed for the fitness categorizations yielded by the test. On a population basis there is a reasonable relation between reported activity and fitness category but, as in most submaximal exercise tests, substantial errors are possible in predicting the fitness of the individual. Even if more accurate methods of predicting aerobic power were available, it is still questionable how far one could counsel the individual concerning his physical condition, since a low score in any individual could reflect either lack of activity or a low inherited potential. On the other hand, if an individual increases his activity, scores should improve. The test thus has a potential for providing both initial interest in fitness programs and sustained motivation of the exercise "convert". The long-playing record also offers a convenient method for the large-scale screening of populations by paramedical personnel; in the Saskatoon validation trial[10] we found it practicable to use the CHFT as a means of administering a standard exercise protocol to upwards of 100 subjects per hour. The prediction of aerobic power obtained from this procedure was at least as accurate as other available techniques. We avoided the complication of quadriceps weakness, which distorts bicycle ergometer readings in elderly subjects, and we were able to record good-quality exercise electrocardiograms in all participants at a comparable percentage (65 to 70%) of maximal aerobic power.

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