Musculoskeletal fitness and risk of mortality

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ABSTRACT

KATZMARZYK, P. T., and C. L. CRAIG. Musculoskeletal fitness and risk of mortality. *Med. Sci. Sports Exerc.*, Vol. 34, No. 5, pp. 740–744, 2002. **Purpose:** To quantify the relationship between musculoskeletal fitness and all-cause mortality in the Canadian population. **Methods:** The sample consisted of 8116 people (3933 men and 4183 women), aged 20–69 yr, who participated in the 1981 Canada Fitness Survey. Measures of musculoskeletal fitness included sit-ups, push-ups, grip strength, and sit-and-reach trunk flexibility. In the 13 yr after the Canada Fitness Survey, there were 238 deaths and a total of 101,685 person-years. Proportional hazards regression was used to estimate the risk of mortality across baseline age- and sex-specific quartiles of the musculoskeletal fitness measures. All models included the effects of age, smoking status, body mass, and estimated $\dot{V}O_{2max}$ as covariates, and the upper quartile was set as the reference group. **Results:** There was no pattern of increased risk of mortality across quartiles of trunk flexibility or push-ups; however, there was a significantly higher risk in the lower quartile of sit-ups in both men (relative risk (RR) = 2.72, 95% CI 1.56–4.64) and women (RR = 2.26, 95% CI 1.15-4.43). Grip strength was not predictive of mortality in women, although there was a 49% increased risk of death in the lower quartile of grip strength in males (RR = 1.49, 95% CI 0.86-2.59). **Conclusion:** The results suggest that some components of musculoskeletal fitness, particularly sit-ups (abdominal muscular endurance), are predictive of mortality in the Canadian population. **Key Words:** CANADA FITNESS SURVEY, DEATH, PROPORTIONAL HAZARDS, RISK FACTORS

Musculoskeletal fitness can be operationally defined by measurements of joint flexibility, muscular strength, muscular power, and muscular endurance. There is a limited body of scientific evidence that indicates that musculoskeletal fitness is related to health status (15,27) and is a predictor of mobility, disability, and independent living in the elderly (4,9,16,19,25). Thus, measures of musculoskeletal fitness are often performed as part of health-related fitness tests, such as the Canadian Physical Activity, Fitness and Lifestyle Appraisal (CPAFLA) (3), the most widely used standardized health-related fitness appraisal in Canada.

Although there is consistent evidence that higher levels of physical activity and enhanced aerobic fitness provide protective effects against premature mortality (26), little is known about the relationship between musculoskeletal fitness and risk of early death. To our knowledge, only four studies have prospectively investigated the relationship between musculoskeletal fitness and risk of death (8,12,17,20). Two of the studies were short-term follow-ups (4–5 yr) of participants aged 75 yr and older (12,17), and the results indicated that higher levels of musculoskeletal fitness were associated with survival in the elderly. Among Japanese participants aged 40–85 yr followed prospectively for 6 yr, there was an inverse relation between performance of vertical jump, side step, grip strength, and mortality in men but not in women (8). Further, hand grip strength was also a significant predictor of mortality, independent of body mass index, among Hawaiian men aged 45–68 yr followed prospectively for 30 yr (20). Thus, there is a need for further prospective longitudinal studies of musculoskeletal fitness and mortality in large population-based samples to further define the risk of death associated with poor flexibility and muscular strength.

The purpose of this study was to examine the association among several indicators of musculoskeletal fitness and risk of death in a large representative sample of Canadian men and women. The aim was to extend the findings of previous studies (8,20) by including a measure of trunk flexibility (sit-and-reach) in addition to indicators of muscular strength and endurance (sit-ups, push-ups, grip strength). Further, body mass and aerobic fitness levels were included as covariates to determine the independent effects of musculoskeletal fitness on risk of death.

METHODS

Sample. The Canada Fitness Survey (CFS) of 1981 was based on a representative sample of the Canadian population (7). The total population excluded in the sample was 3%, which included First Nation people (aboriginal Canadians) living on reserves, students living in school dormitories, armed forces personnel living on bases, and residents of the Territories and remote areas. The sample was a survey of households from urban and rural areas of every province, and included all ethnic groups (with the exception of First Nation Canadians living on reserves). In total, 88% of households participated in the survey, totaling 23,400 individuals from rural and urban areas of each province (24).

0195-9131/02/3405-0740/$3.00/0
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Submitted for publication March 2001.
Accepted for publication October 2001.

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TABLE 1. Descriptive characteristics of sample at baseline.

	Men			Women		
	*N**	Mean	SD	*N**	Mean	SD
Age (yr)	3933	35.5	11.7	4183	35.7	11.9
Body mass index ($kg \cdot m^{-2}$)						
20–29 yr	1462	24.0	3.2	1552	21.9	3.1
30–39 yr	1224	25.1	3.4	1278	23.0	3.6
40–49 yr	682	26.0	3.3	700	24.0	3.8
50–59 yr	367	25.8	3.1	445	25.0	3.7
60–69 yr	183	25.8	3.4	195	25.0	3.8
Trunk flexibility (cm)						
20–29 yr	1447	30.7	9.0	1543	32.6	8.3
30–39 yr	1208	28.8	9.1	1260	31.8	8.0
40–49 yr	656	25.3	9.5	675	30.0	8.6
50–59 yr	349	24.1	9.3	413	29.3	8.5
60–69 yr	171	22.0	9.5	181	28.3	7.6
Sit-ups (*N*)						
20–29 yr	1424	33.6	8.3	1497	25.5	9.6
30–39 yr	1176	27.1	7.8	1197	19.2	8.7
40–49 yr	628	22.6	8.7	610	14.4	8.9
50–59 yr	325	18.2	8.0	366	8.8	8.3
60–69 yr	161	12.5	8.5	152	5.9	6.7
Push-ups (*N*)						
20–29 yr	1432	24.5	11.4	1513	16.9	10.3
30–39 yr	1198	18.9	9.7	1214	15.2	10.0
40–49 yr	642	14.7	8.1	631	12.9	9.6
50–59 yr	325	11.8	7.6	376	9.9	9.1
60–69 yr	166	9.1	6.7	158	8.3	8.7
Grip strength (kg)						
20–29 yr	1469	108.4	15.3	1558	62.1	9.3
30–39 yr	1227	107.9	15.5	1282	63.0	10.2
40–49 yr	686	104.4	15.7	700	62.0	10.9
50–59 yr	368	96.7	13.2	446	56.6	9.4
60–69 yr	183	88.6	13.5	197	51.3	9.5
$\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)**						
20–29 yr	1439	46.4	7.8	1523	34.7	4.1
30–39 yr	1201	42.0	5.3	1256	32.0	3.9
40–49 yr	673	36.7	4.5	686	27.5	5.2
50–59 yr	359	32.9	4.8	440	24.7	4.3
60–69 yr	177	27.0	2.6	192	22.0	2.8

* Sample sizes vary from measurement to measurement due to missing values for some participants.
** $\dot{V}O_{2max}$: maximal oxygen uptake estimated from Canadian Standardized Test of Fitness step test.

Approximately 16,000 people 7–69 yr of age participated in the physical measures component of the survey, which included measures of musculoskeletal fitness. The sample considered here includes 8116 adults (3933 men and 4183 women) between the ages of 20 and 69 yr who had measurements of musculoskeletal fitness taken by the survey team. Sample sizes vary from measure to measure because of missing values for some participants (Table 1). Participants were given an explanation of the testing protocol before examination, and informed consent was obtained (24). The protocols were reviewed by a panel of expert exercise physiologists working in the area at the time and were approved.

Measurements. Indicators of musculoskeletal fitness included sit-ups, push-ups, combined left and right hand grip strength, and sit-and-reach trunk flexibility. All measurements were made following the standardized procedures of the Canada Fitness Survey (6). Grip strength was measured with a Stoelting adjustable dynamometer. Participants held the dynamometer at the level of the thigh in line with the forearm and were instructed to squeeze vigorously as to exert maximum force. The maximum grip strengths of three trials for each hand were summed to provide a single measure of grip strength (kg). The number of push-ups completed without time limit (n) and the number of sit-ups performed in 60 s ($n \cdot min^{-1}$) were used as indicators of muscular endurance. Sit-ups were performed from the supine position, with knees flexed 90°. One complete sit-up entailed curling the trunk from the supine position to touching the elbows to the knees and returning to the start position. For push-ups, men balanced from the toes, whereas women balanced from the knees. One complete push-up entailed straightening the elbows and returning to touch the nose to the floor, while keeping the back straight. Finally, a sit-and-reach test was used to assess trunk flexibility. The participant reached toward the toes, with knees flat on the floor. The test was repeated twice, with the maximum value recorded to the nearest 0.5 cm. A trunk flexibility score of 25 cm is equivalent to touching the floor.

Several covariates were also measured and incorporated in the analyses. Age was determined by birth and observation dates, smoking status (yes, no) was assessed by questionnaire, and body mass (kg) was measured in light clothing with a beam balance scale (6). Maximal oxygen uptake ($\dot{V}O_{2max}$) was predicted from the Canadian Aerobic Fitness Test (CAFT; a submaximal step test) rather than by the direct measurement of expired gases. Although direct $\dot{V}O_{2max}$ measurements are preferred for the assessment of aerobic fitness, the CAFT has acceptable validity for population surveys (11,24).

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TABLE 2. Correlations* among musculoskeletal fitness variables, body mass, and estimated $\dot{V}O_{2max}$.

	Trunk Flexibility	Sit-ups	Push-ups	Grip Strength	$\dot{V}O_{2max}$	Body Mass
Women (below diagonal)			**Men (above diagonal)**			
Trunk flexibility		0.31	0.31	0.16	0.25	−0.12
Sit-ups	0.28		0.57	0.24	0.53	−0.18
Push-ups	0.19	0.39		0.23	0.46	−0.24
Grip strength	0.20	0.24	0.19		0.10	0.40
$\dot{V}O_{2max}$	0.18	0.51	0.32	0.09		−0.36
Body mass	−0.07	−0.28	−0.22	0.27	−0.49	

* All correlations statistically significant at $P < 0.001$.

Mortality determination. The CFS database was linked to the Canadian Mortality Database (CMDB) at Statistics Canada. The CMDB contains all recorded deaths in Canada since 1950 and is regularly updated using death registrations supplied by every province and territory. Record linkage was performed using computerized probabilistic techniques, and the potential for death linkages to be missed using the method employed by Statistics Canada is quite small (22,23). All deaths between the end of CFS data collection (1981) through December 31, 1993, were included in the present study. All individuals who died within the first 2 yr of follow-up ($N = 28$) were eliminated from the analyses to control for the potentially confounding effects of occult disease at baseline, leaving 238 deaths, with a total of 101,685 person-years of follow-up. The major causes of death were cancers (39%) and cardiovascular diseases (26%). Unfortunately, the sample sizes were too small to stratify by causes of death.

Statistical analyses. The indicators of musculoskeletal fitness were divided into quartiles in separate sex-specific 10-yr age groups (20–29, 30–39, 40–49, 50–59, and 60–69 yr) and pooled by quartile. Mortality rates were calculated across quartiles, and hazard ratios (relative risks) for mortality were estimated using Cox proportional hazards models. The upper quartile (best performance) was used as the reference group for all regressions. The models were tested under two different adjustment strategies. First, with adjustment for age only, and second, with adjustment for all covariates, including age, smoking status, body mass, and estimated $\dot{V}O_{2max}$. All analyses were conducted using the SAS system and procedures (21).

RESULTS

Table 2 presents the Pearson correlations among the musculoskeletal fitness variables, body mass, and estimated $\dot{V}O_{2max}$. All correlations were significant ($P < 0.001$) and indicated that body mass is positively associated with grip strength and negatively associated with all other musculoskeletal fitness items. On the other hand, estimated $\dot{V}O_{2max}$ was positively associated with all musculoskeletal fitness items.

Table 3 presents the results of the proportional hazard regressions. When adjusted for age, there was an increased risk of all-cause mortality in both men and women in the lower quartile of sit-ups (men, relative risk (RR) = 2.77, 95% CI: 1.64–4.68; women, RR = 2.23, 95% CI: 1.15–4.31). There was also an increased risk of mortality in the second quartile of sit-ups for women (RR = 2.36, 95% CI: 1.15–4.85). Men also had an increased risk of mortality in the lower three quartiles of grip strength, which was statistically significant only in the lower (RR = 1.67, 95% CI: 1.02–2.74) and third (RR = 1.65, 95% CI: 1.00–2.71) quartiles. There was no increased risk of mortality across quartiles of trunk flexibility or push-ups in

TABLE 3. Relative risk of all-cause mortality across quartiles of musculoskeletal fitness measurements.

		Men						Women					
				Age Adjusted		Fully Adjusted*				Age Adjusted		Fully Adjusted*	
Measure	**Quartile**	***N***	**Deaths**	**RR**	**95% CI**	**RR**	**95% CI**	***N***	**Deaths**	**RR**	**95% CI**	**RR**	**95% CI**
Trunk flexibility	1	948	37	1.18	0.73–1.90	1.06	0.64–1.74	1004	26	1.11	0.64–1.94	1.18	0.66 –2.10
	2	973	34	1.06	0.65–1.72	1.01	0.61–1.66	1016	24	0.98	0.56–1.73	1.07	0.60 –1.91
	3	956	37	1.18	0.73–1.90	1.20	0.74–1.95	1024	16	0.69	0.37–1.29	0.77	0.40 –1.46
	4	963	31	1.00	reference	1.00	reference	1033	24	1.00	reference	1.00	reference
Sit-ups	1	948	53	2.77	1.64–4.68	2.72	1.56–4.64	1000	34	2.23	1.15–4.31	2.26	1.15 –4.43
	2	938	26	1.34	0.74–2.43	1.32	0.73–2.41	866	20	2.36	1.15–4.85	2.24	1.07 –4.67
	3	876	30	1.66	0.93–2.94	1.61	0.90–2.87	1035	16	1.36	0.64–2.88	1.27	0.59 –2.72
	4	960	19	1.00	reference	1.00	reference	926	12	1.00	reference	1.00	reference
Push-ups	1	940	40	1.31	0.82–2.10	1.25	0.77–2.05	938	16	0.57	0.30–1.06	0.61	0.32 –1.17
	2	982	36	1.18	0.73–1.90	1.17	0.71–1.90	1028	21	0.80	0.45–1.42	0.81	0.45 –1.47
	3	860	25	1.05	0.62–1.77	0.94	0.55–1.62	978	21	0.87	0.49–1.54	0.87	0.48 –1.58
	4	985	31	1.00	reference	1.00	reference	928	26	1.00	reference	1.00	reference
Grip strength	1	989	43	1.67	1.02–2.74	1.49	0.86–2.59	1035	26	1.14	0.65–2.01	1.08	0.58 –1.99
	2	970	35	1.42	0.85–2.37	1.42	0.82–2.45	1076	20	0.87	0.48–1.59	0.82	0.44 –1.56
	3	988	41	1.65	1.00–2.71	1.59	0.95–2.68	1023	26	1.23	0.70–2.17	1.25	0.70 –2.23
	4	986	25	1.00	reference	1.00	reference	1049	22	1.00	reference	1.00	reference

All deaths in the first 2 yr of follow-up have been eliminated from the analysis.
* Covariates in the fully adjusted model included age, smoking status, body mass, and $\dot{V}O_{2max}$.

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either men or women, and grip strength was not predictive of mortality in women.

When the regression models included the effects of age, smoking, body weight, and estimated $\dot{V}O_{2max}$ (fully adjusted models), the same trends were evident. There was no increased risk of all-cause mortality in the lower quartiles of trunk flexibility or push-ups; however, there was a significantly higher risk in the lower quartile of sit-ups in both men (RR = 2.72, 95% CI: 1.56–4.64) and women (RR = 2.26, 95% CI: 1.15–4.43), and in the second quartile of sit-ups in women (RR = 2.24, 95% CI: 1.07–4.67). Grip strength was not predictive of mortality in women, although there was a 49% increased risk of death in the lower quartile of grip strength in men (RR = 1.49, 95% CI: 0.86–2.59). Note that the RR for grip strength in men was no longer statistically significant under the fully adjusted model, and the hazard ratio had been reduced from 1.67 to 1.49 under this adjustment scheme.

A third model was tested in which all covariates were included with the exception of estimated $\dot{V}O_{2max}$ (results not shown). The results were very similar to the other two models described in Table 3. Sit-ups were significant predictors of mortality in both men and women, and the relative risk for grip strength for men in the lower quartile was midway between that under the other two models (RR = 1.52, 95% CI: 0.89–2.59).

DISCUSSION

This is the first study, to our knowledge, to investigate the relation between musculoskeletal fitness and all-cause mortality in a representative sample of a North American population. The results are similar to those obtained in a similar sized sample of Japanese men and women (8), in that they support a role of muscular strength and endurance in the prediction of early death.

Grip strength is a common field measurement of muscular strength as it is easy to obtain with a small, portable hand dynamometer. In addition, grip strength is highly correlated with other strength measures, including elbow flexion, knee extension, trunk flexion, and trunk extension (18). A recent 30-yr prospective study among Hawaiian men also demonstrated that grip strength was a significant predictor of mortality in men (20). For example, relative risks (adjusted for age, education, occupation, smoking, physical activity, and height) of mortality increased from the low (1.00) to the middle (1.14) to the high (1.25) tertiles of grip strength, in men with a body mass index between 20 and 24.9 $kg \cdot m^{-2}$ (20). The results of the present study indicate that grip strength was predictive of mortality in men, RR = 1.67 (adjusted for age), which confirms the findings of Fujita et al. (8), who calculated a relative risk of 1.92 (adjusted for age) for low grip strength in Japanese men. However, in the present study, the risk ratio was 1.49 (NS) after adjustment for several covariates including $\dot{V}O_{2max}$. Given that aerobic fitness was a covariate in the present study, but not in the Japanese study, this could account for the different results, as it appears that aerobic fitness may be having an influence on the grip strength-mortality relationship.

The results of the present study show consistently increased risks of mortality associated with low performance of sit-ups in both men and women. These results differ from those of Fujita et al. (8), who found no relationship for sit-ups in Japanese women. The RR for men was 1.93 (95% CI: 1.31–2.85) with age adjustment only, which dropped to 1.57 (95% CI: 0.98–2.49) after the inclusion of other covariates. The authors of the Japanese study hypothesized that the reason they found no relationship between the physical strength tests and mortality in women was probably due to lower mortality rates in the women. In the present study, there were fewer deaths among women ($N = 94$) than men ($N = 144$); however, we were still able to demonstrate significant associations in women.

There are a couple of potential mechanisms that could explain why abdominal muscular endurance was related to mortality in this study. First, maintaining adequate strength and endurance is important in maintaining mobility and independence as we age. Second, strength is related to skeletal muscle mass, and the skeletal muscle mass is a significant site of glucose disposal. One study has reported an inverse relationship, both cross-sectionally and prospectively, between grip strength and fasting insulin levels in men (13). Elevated insulin levels are thought to be the central feature of the insulin-resistance syndrome (syndrome X), which is associated with central obesity, hypertension, type 2 diabetes, and dyslipidemia (5,10). Thus, measures of muscular strength and endurance could be markers of the risk of metabolic disorders, which are ultimately related to risk of premature mortality.

Flexibility exercises are thought to be important for maintaining the range of motion around a joint and for maintaining mobility in the elderly, and physical activity programs commonly include stretching exercises to maintain flexibility and the range of motion in several joints (1). Trunk flexibility has also been shown to be a predictor of low back pain (2). The results of the present study indicate that trunk flexibility is not a significant predictor of mortality. Thus, the health effects of flexibility may be more related to maintaining quality of life and independent living in the elderly more so than preventing premature mortality. For example, shoulder flexibility has been shown to be a significant predictor of independent living in the elderly (4). Flexibility is joint specific, and the relationship between flexibility at different joints and health or mortality is an important area for future research.

It is interesting that sit-ups were predictive of mortality whereas push-ups were not. Both measurements relate to muscular strength and endurance, though at different sites. It is unclear why abdominal muscular endurance would be a better predictor of mortality than upper body strength and endurance. We hypothesized that the relationship between sit-ups and mortality could have been due to confounding by central adiposity, as waist circumference has been shown to be related to health status (14). However, when we reanalyzed the data and included waist circumference as a covariate, the

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same results were obtained in both men and women as when body mass was used as a covariate. Thus, the effects of sit-ups on mortality appear to be independent of the effects of central adiposity, as measured by waist circumference.

Investigation of the relative importance of specific aspects of muscular strength and endurance to health and mortality is another important area for future research. The mortality surveillance of surviving participants from the CFS continues, and as the number of deaths increases, we hope to have increased power to further examine the relationships among physical activity, health-related fitness and disease-specific mortality in addition to all-cause mortality.

In summary, abdominal muscular endurance was related to mortality in a nationally representative sample of Canadian adults, after adjustment for aerobic fitness and other covariates. Thus, the results implicate musculoskeletal fitness as playing a role in the maintenance of health. The inclusion of measurements of muscular strength and endurance in health-related fitness appraisals is also recommended.

The authors would like to thank Health Canada for providing the funding for the record linkage by Statistics Canada.

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