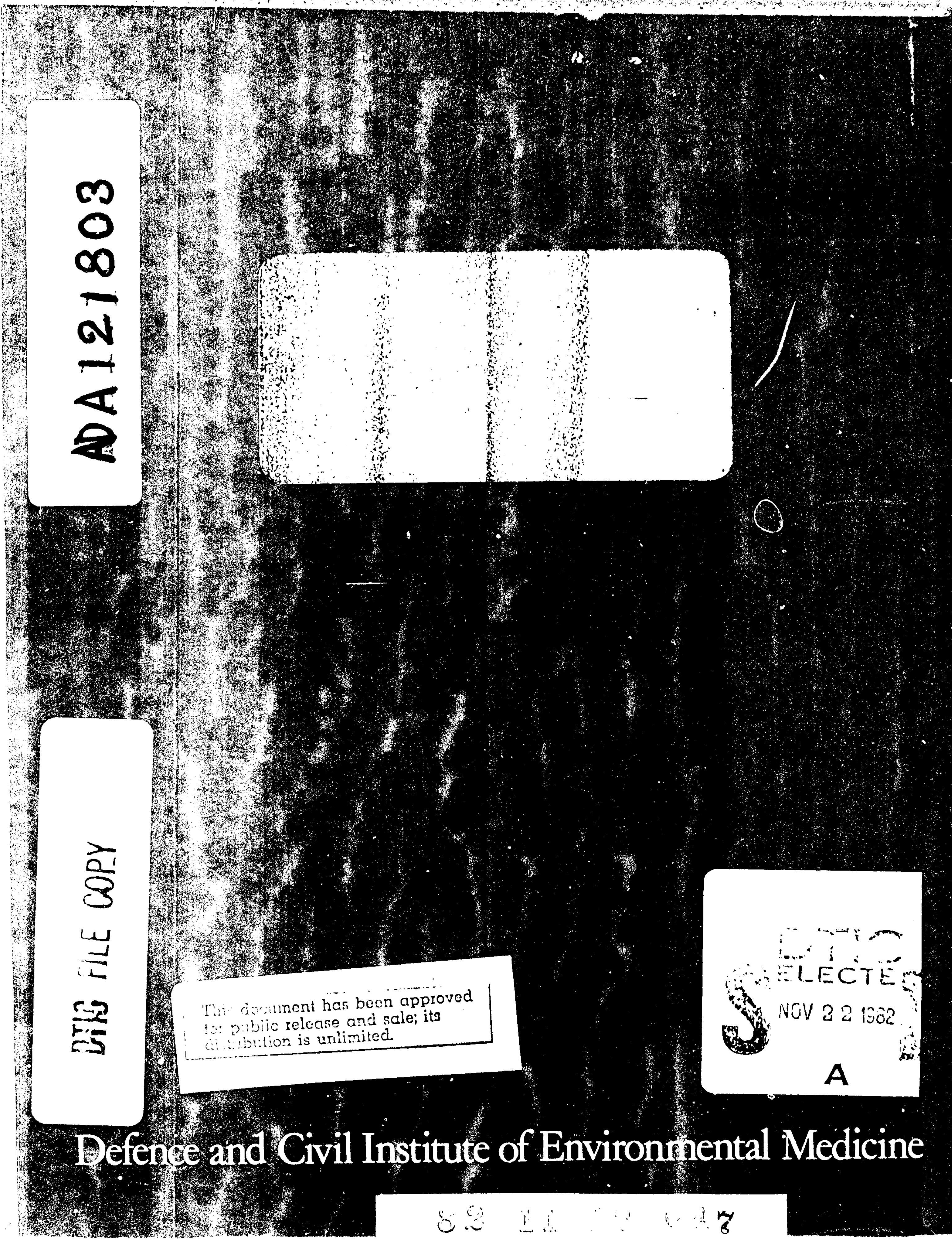

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JUNE 1981 DCIEM Report No. 82-R-29

DEVELOPMENT OF OCCUPATIONAL PHYSICAL SELECTION STANDARDS FOR CANADIAN FORCES TRADES: PERFORMANCE CONSIDERATIONS.

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ABSTRACT

DCIEM is currently undertaking a study to establish occupational physical selection standards (OPSS) for each trade in the Canadian Forces (CF). Work is underway to identify and quantify specific tasks that impose high physical demands on trade personnel. Future work will involve the development of a battery of physical tests from which the most reliable, sensitive, and predictive measures of task performance will be selected for screening purposes. This report presents a discussion of some of the major factors affecting strength, endurance, and work performance, as well as a review of occupational screening procedures and methods. The discussion illustrates the need to account for the effects of factors such as fitness, sex, and age when selecting individuals for physically demanding jobs. It also recommends that task-oriented models to relate individual characteristics to task demands be considered as a potential methodology to establishing standards.

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BACKGROUND

DCIEM is undertaking a study to establish occupational physical selection standards (OPSS) for each trade in the Canadian Forces (CF). Selection tests, related to the physical requirements of the trade, will be developed to screen male and female recruits. Work is underway to identify and quantify specific trade tasks that impose high physical demands on trade personnel. Future work will involve the development of a battery of physical tests from which reliable, sensitive and predictive tests of task performance will be selected for screening purposes. Trade standards will be determined from those physical tests that accurately predict trade task performance.

This report represents the first step towards establishing valid and reliable tests that can be used to screen individuals for physically demanding CF trades. It presents a discussion of some of the major factors affecting strength, endurance; and work performance, as well as a review of occupational screening methods and procedures. Much of the current research in this area is being directed at establishing selection criteria for physically demanding occupations, such as manual materials handling activities (MMHA) in industry (1-5).

This report focuses on the following topic areas:

1) strength and endurance;
2) factors affecting strength, endurance, and work performance (training and fitness, sex, and age);
3) occupational screening and standards.

Strength

A simple definition of strength is the maximum force muscles can exert in a single voluntary effort. However, strength means different things to different people. For example, physiologists think of strength as the maximum force a muscle can exert along its longitudinal axis, and that strength is related to the cross-sectional area of the muscle (this maximum force = 3-4 kg/cm^2) (6). Conversely, to an athlete or worker, strength refers to the force that a muscle can exert on an external object. This is a more practical definition in that it includes consideration of the lever system on which the muscle must operate. Therefore, strength measured as an applied force will vary according to the maximum force produced and the mechanical advantage of the muscle according to the lever principle.

Isometric (static) and isotonic (dynamic) efforts are different kinds of strength, each possessing unique characteristics. Isometric or static strength measures maximal voluntary effort against an immovable resistance (measured usually with cable tensiometers or calibrated load cells), with limb angle and muscle length remaining constant. Isotonic efforts are dynamic in nature and are characterized by limb or segment motion and changing muscle length (3).

Strength is usually expressed in units of force (Newtons), but it has also been reported in pounds, kilograms or kiloponds (5). Forces produced during human movement result in body segment torques, expressed as Newton-meters or pounds-feet. Kroemer (1) stated that the magnitude of these torques depends on:

1) the amount of internal force (muscular);
2) distance between joint and tendon insertion (lever arm);
3) pull angle between vector of muscle force and the limb.

The main problem in measuring strength has been in definition and measurement procedure. Until recently, no single standardized method existed, thus allowing for many different types of efforts and measures to be categorized as strength. Within the past decade, however, a group of researchers standardized a definition and technique for measuring and reporting strength data, to facilitate comparison between studies being conducted worldwide (7). The technique standardizes the subject's body position and limb stabilization, type of effort (isometric), total activity time, instructions to subjects and considerations to safety. No similar procedure for isotonic (dynamic) strength testing has been developed.

Endurance

Endurance has been expressed in many ways in the literature ranging from muscular endurance (ability of an individual muscle or muscle group to sustain work) to whole body endurance (ability of the cardio-respiratory system to deliver oxygen to the total body's working muscular systems, i.e. aerobic capacity). Measures of muscular endurance have not been clearly standardized. Examples of endurance tests (both static and dynamic) reported in the literature illustrate a lack of agreement regarding definition and procedure:

1) Isometric endurance has been defined as the ability to sustain a horizontal arm pull measured at 50%, 60%, 70%, and 80% of a single maximum isometric pull at elbow angles of 80 and 150 degrees (8);

2) Isometric endurance has also been measured as the ability

to sustain 50% of maximal isometric strength (MIS) (9);

3) Dynamic endurance has been defined as the number of times (repetitions) the subject could lift three-eighths of their maximal dynamic strength load (10).

These examples demonstrate that while muscular endurance has been defined as a function of strength, no standardized level (percentage) has been agreed upon.

Muscular endurance is differentiated from strength by the number of repetitions and length of time of an activity. Strength was defined as the maximum force exerted in a single effort, and usually for a very short period of time. Some muscular endurance activities, if they are at a relatively low intensity, may continue for hours, as is the case in working physically for an 8 hour day.

For present purposes, then, muscular endurance will be defined as the ability to repeat or sustain any localized muscular effort. These efforts may range from very light to near maximum while the repetitions may be few or many. Conversely, whole body endurance (aerobic capacity) will be considered to be distinctly different from muscular endurance. The generally accepted measure of aerobic capacity is maximal oxygen uptake (VO2 max) and is not considered to be a function of maximum strength. The measurement procedure has, however, been well documented and standardized (11).

Factors Affecting Strength, Endurance, and Work Performance.

Strength, endurance, and work performance are affected by factors such as training, fitness levels, sex, age, body size, body composition, body shape, motivation, and fatigue (3,6,11,12). A discussion of how some of these factors affect an individual's capability is critical to the development of selection standards.

i) Training and Fitness.

The strength and endurance capabilities of an individual will determine how hard he/she must work to complete any given physically demanding task. Physical work attempted by individuals who do not possess adequate capabilities may result in fatigue and injury. Studies have shown, however, that physical training can enhance strength and endurance levels in individuals, with increases ranging from 5-12% per week in the early stages of a vigorous program (6). Strength gains are dependent upon three major factors:

1) resistance - how much weight is being moved or how much force is being overcome;
2) repetition - how many times a single movement is repeated;
3) rate - how fast the exercise is being done (speed of particular movement or exercise).

DeLorme and Watkins (13) applied these principles to training programs:

1) muscular strength is developed through high resistance, low repetition exercises;

2) muscular endurance is developed through low resistance, high repetition exercises;

3) high speed exercise increases strength whereas low speed exercise increases endurance.

Studies have shown that it is possible to increase strength through either static or dynamic training programs (14,15). However, it has been shown that static training does not produce as great an increase in strength as does dynamic training, nor does it affect as great a muscle range as dynamic training (14). Rasch and Morehouse (16) found that 24 isotonically (dynamic) trained subjects showed greater gains in strength than did 25 isometrically (static) trained subjects, even when evaluated using isometric testing.

As a training method, muscular contractions at or exceeding two-thirds of maximal strength 3 times per week have been recommended to provide a training stimulus and increase strength (14,15). It has been shown, however, that absolute strength and endurance gains increase at a diminishing rate (8). It has been theorized that the limit of one's physical prowess is genetically determined, and that as this 'limit' is approached, it becomes very difficult to realize further gains (6,8).

Physical training can facilitate manual work performance by increasing both strength and endurance reserves resulting in reduced fatigue and risk of injury.

ii) Sex

Sex plays a major role in determining physical capability. Researchers have documented strength and endurance differences between males and females since the early 1900's. Recent studies have attempted to quantify these differences so that designers of equipment could accommodate both male and female operators. In the past, designers and researchers have followed a general rule that female strength was approximately 65% that of males:

> "a review of the literature substantiates the estimate that general muscle strength in women is about two-thirds that in men. This is only an average figure which we can use for general circulation; it does not apply to every muscle group" (17).

In light of recent evidence, this rule appears to be an overgeneralization. Laubach (18) tested women on a series of static strength tests, dynamic tests, and anthropometric measures. The data were compared with a similar study (19) on men with the following results:

1) overall total body strength of women was about 63.5% of that of men, with a range of 35-86%;
2) static strength in the upper extremities of women was 59.5% of men, with a range of 47-79%;
3) static strength in the lower extremities of women was 71.9% of men, with a range of 57-86%;
4) static trunk strength of women was 63.8% of men, with a range of 37-70%;
5) dynamic strength characteristics (primarily muscle strength measurements involving lifting, lowering, pulling, and pushing; these values are median percentage values) of women were 68.8% of men, with a range of 59-84%.

The results indicated that while the mean value for overall body strength was about two-thirds that of males, the range of values was quite large (35-86%). It was also noted that the greatest differences occurred in the upper extremities (mean of 59.5% vs. 71.9% for the lower extremities). Further, the data in Table 1 (from the same studies) clearly show that many 5th percentile values for the males exceed the 95th percentile values for the females for the same measurement variable.

Table 1. Comparison of Cable Tension Strength Values Obtained From Men and Women

Variable	Sex	Mean	S.D.	5%ile	95%ile
SHOULDER FLEXION	F	22.6	3.8	16.3	28.9
	M	50.1	11.4	31.3	68.9
ELBOW FLEXION	F	25.2	4.8	17.3	33.1
	M	57.2	11.6	38.1	76.3
HIP FLEXION	F	50.9	11.9	31.3	70.5
	M	62.6	16.3	35.7	89.5
KNEE EXTENSION	F	58.8	15.2	33.7	83.9
	M	102.8	25.7	60.4	145.2
TRUNK FLEXION	F	33.8	8.8	19.3	48.3
	M	90.9	24.3	50.8	131.0
GRIP STRENGTH	F	26.4	3.8	20.1	32.7
	M	50.4	8.8	35.9	64.9

Table 1 from (18). Comparative male data derived from Laubach and McConville (19). Strength values are reported in kiloponds. Grip Strength was measured with the Smedley hand dynamometer.

Other documented male/female strength data compares grip strengths of various military populations (Tables 2 and 3) (20). These data support the finding that strength differences are greatest in the upper body. As can be seen from Tables 2 and 3, many of the 5th percentile male values exceed 95th percentile female values.

TABLE 2: GRIP STRENGTHS OF VARIOUS MALE/FEMALE MILITARY POPULATIONS (KG)

	METRIC VALUES	MEAN	STD DEV	COEF OF V	-N-	PERCENTILES								
						1ST	5TH	10TH	25TH	50TH	75TH	90TH	95TH	99TH
F	AIR FORCE WMN '68	29.89	5.70	19.07%	1905	18.0	21.0	22.8	26.0	29.7	33.5	37.2	39.6	44.8
	WAF-NURSE OFCRS	30.86	5.79	18.76%	548	17.4	21.7	23.8	27.2	30.8	34.5	38.1	40.5	45.4
	ENSLISTED WAFS/W	29.35	5.55	18.91%	1216	18.0	20.8	22.4	25.5	29.1	32.9	36.5	38.9	43.6
	ENLISTED WAFS/B	31.02	6.07	19.57%	131		21.9	23.9	26.9	30.5	34.8	39.1	41.8	
M	USAF SURVEY 1965	49.48	7.42	15.00%	3869	34.1	38.0	40.3	44.4	49.1	54.1	58.9	62.2	69.3
	OFFICERS 1965	52.80	7.20	13.64%	549	37.1	41.7	44.0	47.8	52.4	57.3	62.2	65.2	70.6
	ENLISTED MEN '65	50.60	7.70	15.22%	792	35.2	38.6	41.0	45.4	50.4	55.3	60.1	63.6	72.3
	BASIC TRAINEE '65	48.40	7.10	14.67%	2527	33.4	37.4	39.7	43.5	48.0	52.9	57.6	60.6	66.7
	USAF FLY PRSNL'67	56.38	7.60	13.48%	2420	39.8	44.4	46.9	51.2	56.1	61.3	66.3	69.6	76.5
	STUDENT PLT '67	56.61	7.76	13.71%	505	40.0	44.7	47.1	51.2	56.1	61.5	67.0	70.4	77.3
	RATED PILOTS '67	56.73	7.76	13.68%	1187	40.2	44.3	46.9	51.4	56.5	61.7	66.7	70.0	77.4
	SDT NAVIGAT '67	54.95	7.35	13.38%	188		43.8	46.3	50.0	54.4	59.9	65.4	68.5	
	RID NAVIGAT '67	55.95	7.10	12.69%	505	39.4	44.3	46.9	51.2	55.8	60.4	65.0	68.2	75.3
	LATIN AMERICANS	41.40	6.90	16.67%	1985		30.0	32.0	36.0	40.0	45.0	50.0	53.0	

F = Female M = Male

TABLE 3: STRENGTHS OF VARIOUS MALE/FEMALE MILITARY POPULATIONS (LBS)

	ENGLISH VALUES	MEAN	STD DEV	COEF OF V	-N-	PERCENTILES								
						1ST	5TH	10TH	25TH	50TH	75TH	90TH	95TH	99TH
F	AIR FORCE WMN '68	65.90	12.57	19.07%	1905	39.7	46.4	50.3	57.3	65.4	73.9	82.0	87.3	98.7
	WAF-NURSE OFCRS	68.04	12.78	18.78%	548	38.4	47.8	52.5	59.9	67.9	76.1	84.1	89.3	100.1
	ENLISTED WAFS/W	64.71	12.23	18.90%	1216	39.7	45.8	49.5	56.2	64.1	72.5	80.6	85.7	96.0
	ENLISTED WAFS/B	68.39	13.39	19.58%	131		48.4	52.6	59.3	67.3	76.7	86.2	92.2	
M	USAF SURVEY 1965	109.08	16.35	14.99%	3869	75.1	83.7	88.9	97.9	108.3	119.2	129.9	137.1	152.8
	OFFICERS 1965	116.40	15.89	13.65%	549	81.8	91.9	97.0	105.4	115.5	126.3	137.1	143.7	155.7
	ENLISTED MEN '65	111.55	16.98	15.22%	792	77.6	85.1	90.4	100.1	111.1	121.9	132.5	140.2	159.4
	BASIC TRAINEES'65	106.70	15.65	14.67%	2527	73.6	82.5	87.5	95.9	105.8	116.6	127.0	133.6	147.1
	USAF FLY PRSNL'67	124.31	16.75	13.47%	2420	87.8	97.8	103.3	112.8	123.6	135.1	146.2	153.5	168.7
	STUDENT PLT '67	124.80	17.11	13.71%	505	88.2	98.5	103.9	113.0	123.7	135.7	147.6	155.2	170.5
	RATED PIKOTS '67	125.07	17.10	13.67%	1187	88.7	97.7	103.4	113.3	124.6	136.0	147.1	154.4	170.5
	SDT NAVIGAT '67	121.15	16.19	13.36%	188		96.5	102.1	110.2	119.9	132.0	144.1	151.0	
	RID NAVIGAT '67	123.34	15.66	12.70%	505	86.9	97.7	103.4	112.8	122.9	133.2	143.4	150.3	166.1
	LATIN AMERICANS	91.10	15.20	16.68%	1985		66.0	70.4	79.2	88.0	99.0	110.0	116.6	

Data from NASA Anthropometric Source Book, Vol II (20)

Sex differences in muscular endurance capabilities have also been studied in an operational context. A USAF study (21) investigated the endurance levels of female pilots operating various aircraft controls. The results provide some guidance as to how long (in seconds) female subjects could exert a force on a particular aircraft control:

1) as low as 2 seconds for maintaining 55 lbs. of elevator,
2) as low as 12 seconds for maintaining 22 lbs. of aileron,
3) as low as 1 second for maintaining 150 lbs. of rudder.

The experimenters suggested that these endurance levels were not adequate to fly large, multi-engine transport aircraft (e.g. C-130, C-141, C-5) that have traditionally been successfully piloted by males.

It has been theorized that strength differences may be due to the fact that women, on the average, are smaller than men (6,11,22). Some researchers have attempted to correct for this size difference [i.e. mathematically normalize their data to account for the difference in size (length)] (22). Asmussen et al. (22) reported that this procedure raised the strength capability of adult women to about 77% of that of men (Figure 2 [curve III]). It was suggested by the authors this difference is probably the true sex difference in muscle strength between men and women. These findings were supported by Snook and Ciriello (2) who found that female subjects had significantly smaller industrial work capacities (both maximal and submaximal) than men even when the results were expressed in terms of body weight (and size) and fat-free body weight (work capacity differences were in the order of 20-25%). In addition, Snook found that the difference was more pronounced in the upper body and that sex differences in muscle strength were greater than the sex differences in body size.

More recent studies, however, have indicated that at the muscular level, there is little strength difference per cross-sectional muscle area unit between adult males and females and that the major discrepancies may be accounted for by different amounts of lean body tissue (6). This would suggest that some other biomechanical and/or physiological factors contribute to the difference in strength generation and work capacity in males and females. In order to further clarify this area, future studies could investigate the strength and endurance differences between males and females of the same height and weight or same lean body mass.

iii) Age

Previous studies (22-26) have investigated the effects of ageing on strength and endurance capabilities of men, women and children. Not surprisingly, ageing trends differ for males and females. Boys and girls, up to about age 12 years or so have approximately the same strength capability. At age 12 or 13 (puberty), strength differences begin to appear, so that by the age of 17, there is a significant sex difference in dynamic muscle strength between boys and girls (27). As ageing continues, the difference in strength between the sexes becomes greater up to about age 30, where males reach their peak and then begin to decline (Figure 1, curve I) (22). At the age of 30, the average strength is about 104% of that of the 20-23 year old, whereas by the age of 60, strength has decreased to about 85-90% of that value (Figure 2).

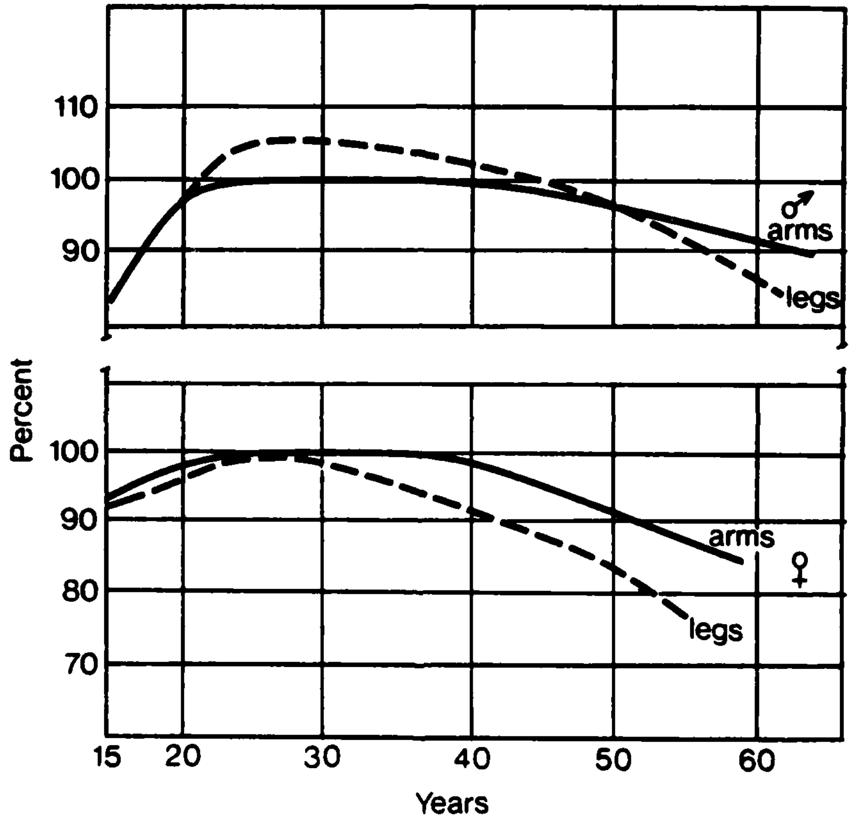

Figure 1.
Isometric strength, arms and legs, as a function of age (men above, women below) [based on data from previous study (22)].

Women tend to have a more constant level of strength throughout their lifetime, in that their peak isometric strength changes very little from ages 20 to 40 (Figure 2) (22). At about age 20-23, the absolute isometric strength of women is about 65% of that of men of the same age. From about age 40, the strength of women decreases faster than men, so that by the age of 55 or so, women have only 55-60% of the isometric strength of men in the same age group (Figure 2) (22).

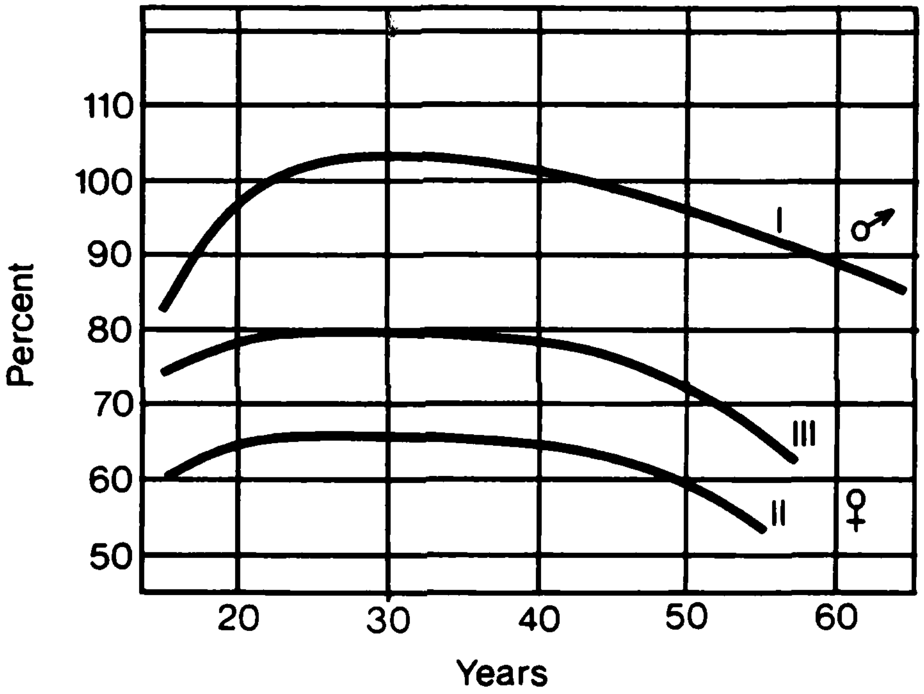

Figure 2.
Isometric strength (all muscles) in percent of strength of 20-22 year old men in relation to age. I males, II females (uncorrected), III females (corrected for height) (22).

Ageing also produces specific changes in aerobic capacity (max VO2). Few studies are available concerning oxygen uptake changes with age and only a few studies have included women (6,11,22,24,25). It has been shown that max VO2 in men decreases with age, so that by the age of 60, it has reduced to about 65-70% of the value it was at the age of 20 to 25 years (11,24). By contrast, women tend to decrease at a slower rate, so that by the age of 60, the aerobic capacity has reduced to about 80% of the value it was at 18-20 years (11). Although these ageing trends are somewhat similar, the absolute difference in max VO2 between males and females changes with age. At age 20, females have approximately 25-30% less aerobic capacity than males, while at age 60, this difference has decreased to about 15-20%. A major factor contributing to the decrease in aerobic capacity is the decrease in maximal heart rate with age. In both cross-sectional and longitudinal age studies, it has been shown that at age 60, the max heart rate of men is lower than that for women (6,11). Because of the direct linear relationship between maximum heart rate and maximum oxygen uptake, the decreased male/female difference in aerobic capacity can be partly explained.

Previous studies on ageing effects concluded that work performance trends paralleled those followed by strength and endurance (muscular and aerobic) capabilities (22,24,25,27,28). The suggestion appears to be that as individuals age, they should not be expected to perform tasks requiring very high strength or endurance components.

Summary

It is apparent that strength and endurance capabilities, and work performance are affected by many factors. The effects of these factors must be accounted for (where possible) when assigning personnel to physically demanding occupations. It was suggested that training and increased fitness would reduce work related fatigue and risk of injury. A significant male/female difference was illustrated, suggesting that perhaps fewer females should be employed in physically demanding roles. Ageing research would suggest that as individuals grow older, they should be assigned to less physically demanding roles.

3) Occupational Screening.

Industrial researchers are concerned with the problem of selecting workers who are capable of performing successfully in physically demanding occupations (2,4,5,17,29,30). The rationale behind occupational screening has been to prevent injuries to workers and to maximize efficiency of the work force (4,5). Many previous screening procedures have relied solely on the use of static strength tests because they were reliable, easy to administer and they were believed to be valid predictors of performance (productivity). In reality, most physical work consists of dynamic efforts (movement) and submaximal isometric efforts; maximal isometric effort is seldom required.

Many researchers are investigating the relationships between strength measures and work performance (1,3,4,8,9,10). Conflicting views on the relationship between static and dynamic strength tests, and between strength and work performance are prevalent in the literature. The following examples demonstrate the lack of agreement on even fundamental relationships (e.g. static strength vs dynamic strength, static strength vs dynamic endurance, dynamic strength vs static endurance, etc):

1) Elbel (31); Test results from 590 pilots and potential pilots revealed low to moderately low relationships between leg endurance and maximum leg strength (-0.26 to 0.40);

2) Tuttle et al. (32); This study looked at the relationship between maximum grip strength and grip endurance and found a wide range of correlations from -0.26 to 0.97;

3) Start et al. (33); Concluded that dynamic strength bore little relationship to static strength.

4) Carlson (34); Looked at the relationship between isometric and isotonic strength of the elbow flexors. The test was reliable in distinguishing between strong and weak persons (r=0.97), but the absolute strength value over the two tests differed (r=0.83);

5) Kroemer (1); His efforts led him to two conclusions: i) strength data are relevant to human engineering problems only when the operator must exert maximal static muscle forces; if submaximal forces are required, then the applicability of strength data is very limited; and, ii) little evidence exists that static force data accurately predict dynamic performance;

6) VanCott and Kincade (35); Muscle strength is situation specific; it varies within the same person according to body position, and up to now, there is no single strength test in one position by which strength in other positions can be predicted;

7) Kroemer (17); It is questionable as to how much predictive value static, short-time maximal strength has with respect to a) dynamic strength and, b) muscular endurance. Many measures of strength correlate positively with each other and with anthropometric data; however, these correlations are too low to have any useful predictive value;

8) Keyserling et al. (36); Actual measurements of strength in specific postures yield a considerably better assessment of a person's musculoskeletal capabilities than prediction based on other anthropologic variables and standard strength tests;

9) Laubach (37); When predicting dynamic strength from static strength, the correlations may be high, but the standard error of estimate may be too high for practical application. In addition, it appears that dynamic force may be more accurately predicted (relatively) from static force measurements when the motion to be evaluated is angular rather than linear;

10) Reilly et al. (38); This study utilized a battery of tests to predict work performance in outdoor telephone craft jobs. The battery consisted of a series of static tests, dynamic tests, and reaction time tests. The results showed that the best indicators of job success were dynamic arm strength and reaction time.

It is evident from this sample that the interrelationships among different kinds of efforts have not been clearly established. As a result, and because of the specificity of strength (17), selection tests may have to incorporate the components (static or dynamic) involved in the job itself.

Standards.

In industrial occupations, the establishment of strength and endurance standards for male and female workers involved in MMHA, has become more important (2,39). Employers, in their efforts to reduce operating costs while ensuring the safety of their workers, are relying more and more on the results of occupational research. Efficiency and safety can be increased by careful selection of workers, adequate training procedures and effective job design (29). In all cases, however, an extensive knowledge of the job demands and the physical capabilities of the user population is required.

Psychophysical methods have been most frequently used to directly establish workload norms (2,30,39). These methods explore the relationship between physical stimuli and their resultant subjective sensations (30). This methodology appears to be effective in identifying the capabilities of a given user population in response to an occupational situation. The use of psychophysics in manual handling tasks requires that subjects adjust task variables (weight of lift, height of push, speed of walk, etc) according to their own perception of effort or force. The activities frequently considered in these studies have been lifting, lowering, pushing, pulling, carrying, and walking. The norms have been expressed as percentiles of the population that can successfully perform the activity over given periods of time (2,39).

Snook et al. (39) reported acceptable workloads for males for six basic manual materials handling tasks; lifting, lowering, pushing, pulling, carrying, and walking. Snook and Ciriello (2) conducted a similar study to outline acceptable workloads for housewives and female industrial workers and compared them with the results of the previous study on men (2). These studies contain work standards, derived from psychophysical testing procedures, on the population percentage capable of performing each task without over exertion or excessive fatigue (2,39). Of the three groups tested in both studies (industrial men, industrial women, housewives), the housewives were able to handle significantly less weight and workload than the industral men and the industrial women. The maximum workloads acceptable to industrial women were significantly less than for the industrial men for most tasks. The performance differences between industrial men and industrial women were greater at a slow rate of work than at a fast rate of work. During the fast rate of work, industrial women selected a weight that on the average, was 85% of the weight selected by the industrial men. During the slow rate of work, they chose a weight that was about 70% of that of the industrial men. The maximum weight (workload) acceptable to the average industrial woman for pushing and pulling tasks was 85% of that for industrial men; for lifting, lowering, and carrying tasks, it was 65%.

On the basis of the work performance results and other documented data on male/female differences, Snook concluded that, "in most cases, one should be more selective in hiring a female for a manual handling task than hiring a male" (2). It is possible, however, to cope with these male/female differences through proper employee selection and considerations toward job design.

Modelling for Predicting Work Performance (Lifting).

Modelling for predicting manual lifting capacity of workers in occupational systems has been the most recent approach to the problem taken by human factors specialists (40). In the past few years, two classes of models which deal with lifting activities have emerged; a) capacity models, and b) biomechanical stress models (40).

Capacity models are primarily concerned with predicting the capacity of the lift using worker characteristics (strength, height, age, etc), task characteristics (weight, distances, etc.), and the environmental characteristics (temperature, humidity, noise, etc). These models can be formulated by having subjects representative of the target population perform the required activities (e.g. lifting) (41,42). For capacity modeling, regression equations can then be derived from the results of the lifting activities and subject physical characteristics (sex, height, weight, etc.), to predict lifting performance by other individuals, providing the conditions are the same. Biomechanical stress models, on the other hand, are concerned with estimating the stresses imposed on the musculoskeletal system (i.e. L5-S1 spinal interface in the lower back) of the worker during lifting. In these models, reactive forces and torques at various joints, including compressive and shear forces in the lumbar spine region, are estimated. These maximum spinal forces have been obtained through studies and experimentation using cadavers. In application, the model can predict how much force is being applied to the lower back in order to determine safe loading limits. However, the model has to assume that all spines will behave in accordance with those used to derive the injury criteria.

Models have been used for employee selection and placement, work place design, and as part of a physical examination given by many companies to their new employees. Both classes of models provide reasonable predictive capability and are somewhat adaptable to individual differences of operators and tasks (primarily lifting). In a manual materials handling environment, the operator (worker), the object being handled, the task (i.e. lifting) and the environmental conditions (temperature, humidity, etc) are all components to be considered in the model (40).

An overriding limitation to the use of models has been oversimplification. Although this makes the model easy to use and understand, it tends to ignore the complexity of the industrial world. In manual materials handling jobs, the methods, operator, weight, size of the working material, and the environmental conditions are constantly changing. Therefore, it is necessary for a predictive model to consider the effects of these variables as well as their interactions. Oversimplification has been evident in previous studies that have only concerned themselves with one-handed lifting in a single plane (e.g. sagittal) (43,44). Such studies are obviously of quite limited application to the industrial world.

CONCLUSIONS.

As a first step towards establishing occupational physical selection standards for CF trades, this paper addressed some of the relevant issues associated with the measurement and interpretation of physical capabilities (strength and endurance), and their effects on work performance. It is obvious from the discussion of the major factors affecting physical ability, that there is a need to account for their effects when selecting and assigning personnel to physically demanding jobs.

The literature was clear in distinguishing between the capabilities of males and females, and suggested that for highly demanding occupational roles, females may not be able to cope with the physical demands as well as their male counterparts. However, it was suggested that the ability to utilize females in these roles could be accomplished through proper selection and training, and effective job design.

Increased specificity would suggest that higher validity could be achieved when a close relationship exists between the physical tests and the job situation. This can be accomplished through careful investigation of the task and effective test design. Toward this end, DCIEM is also in the process of reviewing the literature for specific candidate physical tests and measures that can be used in a testing battery to relate physical capabilities to trade requirements.

The use of task-oriented models in developing regression equations to predict performance based on individual characteristics, seems to be a valid and flexible technique. Care must be taken, however, to effectively select physical tests that reflect the actions and postures involved in the task.

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