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SELF-REPORTED PHYSICAL ACTIVITY COMPARED WITH MAXIMAL OXYGEN UPTAKE

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Maximal oxygen uptake has been used as a measure of physical fitness. This measure increases by approximately 25% when sedentary individuals become more physically active. Oxygen uptake measurement in the laboratory or estimation in fieldwork is complex and costly with finite risk. For the present study, 36 men and 32 women completed the Paffenbarger Physical Activity Index Questionnaire, including a sweat-inducing physical activity frequency question, and had measurement of oxygen uptake during pedal ergometry. Using maximal oxygen uptake as the measure of fitness, the authors found that the Paffenbarger Physical Activity Index, although more detailed, may be less valid than the simpler sweat induction frequency question for estimating fitness. The correlations observed between the sweat question and oxygen uptake were 0.54 for males, 0.26 for females, and 0.46 for the total group. The correlations between the Physical Activity Index and oxygen uptake were 0.26 for males, 0.08 for females, and 0.29 for the total group. The regression relationship (oxygen uptake = 1.92 × (sweat days) + 23.76; standard error of estimate = 8.63 ml/kg/min) is significant for sweat versus oxygen uptake. While the confidence interval limits the practical ability to predict individual values, low cost, absence of risk, and population validity suggest that fitness can be assessed rapidly and simply for epidemiologic studies with a simple "sweat" question.

exertion; physical fitness

Higher levels of regular physical activity have been associated with a reduced likelihood of coronary heart disease (1–3). Studies by Paffenbarger and colleagues (2, 4, 5) have indicated that this reduced likelihood is independent of differences in blood pressure, family history, presence of excess body weight, and smoking status. Regular exercise brings about a number of physiologic adjustments. These include reduced heart rate at rest and at any given level of submaximal exercise, suggestive evidence of reduced resting blood pressure, improved skeletal muscle strength and efficiency, and reduced circulating levels of neurotransmitter bioamines (6–12). Maximal bodily oxygen uptake during exercise is also importantly influenced by habitual levels of exercise. The higher levels of oxygen uptake among athletes compared with

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the levels attainable by sedentary individuals are strongly influenced by the "training effects" produced by regular exercise (13). Maximal oxygen uptake decreases with advancing age and also reflects the basal metabolic rate of the body as well as other inborn but poorly understood factors, in addition to the physical fitness level. Within any individual, maximal oxygen uptake can be increased by approximately 25 per cent by shifting from a sedentary to a very active level of habitual physical activity (14). This attribute has made maximal oxygen uptake a valuable measure of physical fitness.

Many investigators have attempted to assess habitual physical activity using diary, recall, or questionnaire methods. Paffenbarger (5), in his important longitudinal study of college alumni, developed the Physical Activity Index Questionnaire focusing on selected routine as well as extraordinary and leisure-related activities. This questionnaire approach has obvious face validity, assessing flights of stairs climbed, city block equivalents walked, and frequency of sports and recreational activity. The present study was undertaken to test the hypothesis that the Paffenbarger Physical Activity Index Questionnaire yields results which reflect population fitness as assessed by maximal oxygen uptake. Such a questionnaire may also be useful in assessing change in fitness of a population over time.

Materials and Methods

Thirty-six men (mean weight 78 ± 9 kg; mean age 41 ± 14 years) and 32 women (mean weight 64 ± 16 kg; mean age 42 ± 15 years) between the ages of 20 and 70 years volunteered for the present study. All were hospital employees. None were chosen because they were unusually sedentary or unusually active. None were known to have cardiovascular disease.

All subjects visited the Human Performance Laboratory following a minimum of a two-hour fast. They were given the Physical Activity Index Questionnaire to complete and return to the laboratory. This questionnaire ascertains the average number of flights of stairs climbed each day, the average number of city blocks or equivalent walked each day, and the frequency and duration of sports, recreational, or other physical activities during the preceding year and during the preceding week. An additional question determines the number of times per week that vigorous extended activity sufficient to "work up a sweat" is undertaken.

Maximal oxygen uptake ($\dot{V}O_{2max}$) was measured on a cycle ergometer (Monark, Quinton Instruments, Seattle, WA). Subjects pedalled the ergometer at 50 rpm with no resistance for one minute. Thereafter, work rates were increased 150 $kg \cdot min^{-1}$ (25 watts) every minute until the subject indicated that he/she could not continue or until it was evident that they could not maintain the 50-rpm pedal rate. Oxygen uptake ($\dot{V}O_2$) was measured during the last 30 seconds of each minute. Oxygen uptake was accepted as maximal if 1) the respiratory quotient was greater than 1.0 and 2) the oxygen uptake difference between the final two work bouts was less than 250 $ml \cdot min^{-1}$ (15). The highest $\dot{V}O_2$ attained was then considered $\dot{V}O_{2max}$. Oxygen uptake was measured using a pneumotachograph (Hewlett-Packard, Vertek Series, Lexington, MA), an S-3A Oxygen Analyzer (Applied Electrochemistry, Inc., Sunnyvale, CA), and an LB-2 Carbon Dioxide Analyzer (Beckman, Schiller Park, IL). Gas analyzers were calibrated prior to each test with a gas that previously had concentrations of oxygen and carbon dioxide chemically analyzed by the Scholander method (16).

Relationships between estimated maximal oxygen uptake and each of two other parameters were compared. The routine habitual physical activity was converted to kilocalories per week using the method described by Paffenbarger (4). Also, the reported number of times each week of exer-

cise intense enough to cause sweating was tabulated. Regression coefficients and equations were derived, relating the maximal oxygen uptake, the physical activity level, and the frequency of sweating.

RESULTS

The level of fitness of this population compared with that of others can be assessed from the maximal oxygen uptake figures. The mean ± standard deviation for the entire population was 28 ± 9.7 ml·kg^{-1}·min^{-1}. For men, the mean ± standard deviation was 32.4 ± 9.8, while that for women was 23.0 ± 6.9 ml·kg^{-1}·min^{-1}. For men with an average age of 41 years, the expected average maximal oxygen consumption is approximately 34 ml·kg^{-1}·min^{-1}, while for women with an average age of 42 years, the level is approximately 26 ml·kg^{-1}·min^{-1}. These data indicate that the study population, although not randomly selected, was at an approximately average level of fitness when compared with values published by the American College of Sports Medicine (17).

The relationships among the three variables are presented in table 1. As shown, the highest correlation coefficients were found between the maximal oxygen uptake and the sweating frequency. Those for the combined male and female group and for men alone were statistically significant ($p < 0.01$), while that for women did not reach statistical significance ($p > 0.05$). Although a marginally significant relationship was found between maximal oxygen uptake and kilocalories estimated from the Physical

TABLE 1

Regression coefficients relating the Paffenbarger Physical Activity Index (PAI), the frequency of exercise-induced sweating (SWEAT), and maximal oxygen uptake ($\dot{V}O_{2\,max}$)

	Total group	Men	Women
$\dot{V}O_{2\,max}$ vs. PAI	0.29*	0.26	0.08
$\dot{V}O_{2\,max}$ vs. SWEAT	0.46**	0.54**	0.26
SWEAT vs. PAI	0.57**	0.54**	0.60**

* $p < 0.05$.
** $p < 0.01$.

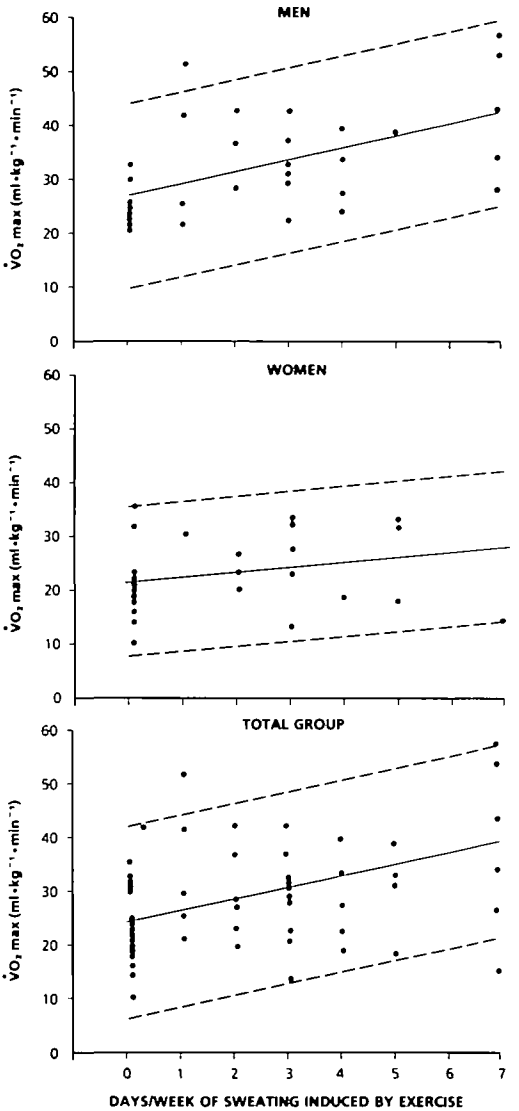

FIGURE 1. Data points from 36 men, 32 women, and the entire group with the regression lines (solid lines) and the 95 per cent confidence limits (dashed lines) relating days per week of sweat-inducing exercise to maximal oxygen uptake for men, women, and men and women combined are shown.

Activity Index Questionnaire, this was true only for the entire group with the larger range of maximal oxygen uptake values and was not demonstrated for either the male or female subsets. A larger population would, in all likelihood, have demonstrated a statistically significant relationship, although one must question the importance

of such weak relationships for predictive utility.

The two self-report measures of habitual physical activity were correlated in men, in women, and in the total group. Those with the highest correlations, days of sweating versus maximal oxygen uptake, are illustrated in figure 1. The relatively large 95 per cent confidence limits restrict precision of prediction for any individual. The relationships, however, particularly in men, indicate potential utility for estimating fitness in population studies.

Discussion

For the purposes of this study, maximal oxygen uptake was taken as the most valid measure of physical fitness. The procedures necessary for measurement or estimation of maximal oxygen uptake are complex, costly, and carry small but finite risk (17). They can be applied to population studies, but the cost is relatively high.

The present study has compared two indices developed by Paffenbarger for the epidemiologic study of regular physical activity levels. (The "sweat" question was obtained directly from Paffenbarger and was a part of his original questionnaire.) Each index has face validity. One is slightly more time consuming. Each correlates with maximal oxygen uptake. Based on the data from this study, however, it appears that the frequency of activity sufficient to generate sweating relates more closely to maximal oxygen uptake than does the more complex Physical Activity Index.

The range of maximal oxygen uptake encountered in this study was similar to the range in the normal population, with the exception of the extremes encountered in highly trained athletes. Similarly, the range of Physical Activity Index values in kilocalories approximates that encountered by Paffenbarger in his work (2, 4, 5). Thus, we feel it is unlikely that truncation of the oxygen uptake range of the Physical Activity Index has contributed to the relatively low correlation levels found between these two variables.

We conclude that precise evaluation of physical fitness in individuals requires either direct measurement or use of validated techniques for estimating maximal oxygen uptake (18, 19). We suggest, however, that these approaches are less feasible for studies of large groups of people and that information derived from questionnaires is valid. The present study strongly suggests that brevity, low cost, and physical activity estimates are all well served by the very simple question, "At least once a week, do you engage in any regular activity similar to brisk walking, jogging, bicycling, etc., long enough to work up a sweat?" Then, if the answer is yes, "How many times per week?".

The present study does not deal with issues of changing levels of population fitness. Change in levels of physical activity may be an important accompaniment of successful application of health promotion programming to large populations (20, 21). Whether maximal oxygen uptake, the Physical Activity Index, or the simple "sweat" question will prove more sensitive to changes in regular physical activity remains for future investigation to clarify.

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