ORIGINAL ARTICLE

$PWC_{75\%}$/kg, a Fitness Index Not Linked to Resting Heart Rate: Testing Procedure and Reference Values

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ABSTRACT. Batcho CS, Thonnard J-L, Nielens H. $PWC_{75\%}$/kg, a fitness index not linked to resting heart rate: testing procedure and reference values. Arch Phys Med Rehabil 2012;93:1196-1200.

Objectives: To develop a fitness index unlinked to resting heart rate and suitable for clinical use, and to obtain reference values of this new index for healthy subjects.

Design: Cross-sectional study.

Setting: Research laboratory.

Participants: A volunteer sample of healthy subjects (N=100; 50 men; age range, 20–70y) randomly recruited from the general community.

Interventions: Not applicable.

Main Outcome Measures: Participants performed a submaximal, multistage cycle ergometer test. A new fitness index, the physical working capacity at 75% of the predicted maximal heart rate per kilogram of body weight ($PWC_{75\%}$/kg), was calculated. Its concordance with a previously described fitness index and its relationship with age were examined, as well as differences attributable to sex and lifestyle. Reference values of the $PWC_{75\%}$/kg (mean ± SD and 95% confidence interval) were calculated and categorized by age classes of 10 years and by sex.

Results: The intraclass correlation coefficient (ICC) between $PWC_{75\%}$/kg and the working capacity index at 65% of the heart rate reserve per kilogram of body weight ($WCI_{65\%HRreserve}$/kg) was very high (ICC=.96, $P<.001$), indicating that the fitness index can be estimated without measuring the resting heart rate. $PWC_{75\%}$/kg decreased as age increased. The average $PWC_{75\%}$/kg was significantly higher in men than in women ($P<.001$), and in active than in inactive subjects ($P<.01$).

Conclusions: This study presents a new fitness index, the $PWC_{75\%}$/kg, which is suitable for measuring fitness in active and sedentary people aged 20 to 70 years. It may also be a suitable fitness index for selected chronically ill individuals. This study also provides reference values of the $PWC_{75\%}$/kg obtained from healthy men and women.

Key Words: Assessment process; Physical fitness; Reference values; Rehabilitation.

PHYSICAL FITNESS IS an important determinant of quality of life, since it largely determines functional capacity.[1,2] Moreover, many studies[3-6] have shown that poor cardiorespiratory fitness is associated with many aspects of poor health. These observations clearly underline the need for valid methods to assess physical fitness in more sedentary, elderly individuals and in patients with selected chronic illnesses. Valid physical fitness assessment methods are also needed to monitor the effectiveness of intervention programs that include physical reconditioning as part of the comprehensive therapeutic approach.[7,8]

Physical fitness is generally defined as a construct of several physical capacities, including cardiorespiratory endurance, muscular strength, balance, flexibility, and body composition.[7,9] One of its most important components is cardiorespiratory endurance,[9] which the American College of Sports Medicine defines as the ability to perform dynamic exercise involving large muscle groups at moderate to high intensity for prolonged periods.[10] The criterion standard for assessing cardiorespiratory endurance and functional aerobic capacity is the estimation of maximum oxygen consumption ($\dot{V}O_2max$) through a maximal exercise test. However, maximal exercise is not recommended or achievable in many sedentary, ill, or elderly individuals.

In a clinical setting, rather than determining the absolute $\dot{V}O_2max$ of patients with high precision, it is more relevant and valid to estimate their physical fitness index using submaximal tests, as these tests provide acceptable alternatives.[7,11] Submaximal tests present relatively lower costs, higher safety, and greater acceptability to a wider age range of individuals than maximal tests, so submaximal tests are preferable in population-based studies.[12] For these reasons, some authors proposed the $PWC_{75\%HRmax}$ as a measure of physical work capacity at 75% of the age-predicted maximal heart rate (HR_{max}).[12,13] The $PWC_{75\%HRmax}$ estimates cardiorespiratory endurance. On the other hand, Nielens and Plaghki[14] conceived the working capacity index at 65% of the heart rate reserve per kilogram of body weight ($WCI_{65\%HRreserve}$/kg), a fitness index that can be obtained from a submaximal, multistage cycle ergometer test.

List of Abbreviations

BMI	body mass index
HR	heart rate
HR_{max}	maximal heart rate
ICC	intraclass correlation coefficient
PAR-Q & You	Physical Activity Readiness Questionnaire & You
$PWC_{75\%}$/kg	physical working capacity at 75% of the predicted maximal heart rate per kilogram of body weight
$\dot{V}O_2max$	maximum oxygen consumption
$WCI_{65\%HRreserve}$/kg	working capacity index at 65% of the heart rate reserve per kilogram of body weight

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This index, expressed in watts per kilogram, takes into account body weight as an indicator of body composition. Indeed, body composition is a key component of an individual's health and physical fitness profile.[9,15] Overweight and obese subjects often perceive increased breathlessness during minor exertion.[16] Nielens et al[14,17,18] described the $WCI_{65\%HRreserve}$/kg as the workload subjects can withstand at a heart rate (HR) value corresponding to 65% of their HR reserve ($65\%HR_{reserve}$). Calculating the $WCI_{65\%HRreserve}$/kg requires measuring the resting HR. Since resting HR may vary considerably between and within subjects, performing accurate measurements in clinical practice may suffer numerous biases. Therefore, the use of resting HR may induce artifactual variability when estimating $WCI_{65\%HRreserve}$/kg in general practice.

Our hypothesis is that a new fitness index that estimates cardiorespiratory endurance independently of resting HR and takes into account body weight may be valid and easily obtainable. This index would therefore be suitable for routine use during physical rehabilitation in a clinical setting as well as in community-based sport centers. The main purpose of the present study was to create a fitness index that accounts for body composition and is not linked to the resting HR, which is difficult to measure reliably. The present study describes the procedure to obtain a fitness index, the physical working capacity at 75% of the predicted HR_{max} per kilogram of body weight ($PWC_{75\%}$/kg), adapted from existing indices. Moreover, since cardiorespiratory endurance is dependent on age and sex, we aimed to obtain reference values of the $PWC_{75\%}$/kg, classified according to age and sex, in a cohort of men and women aged 20 to 70 years.

METHODS

This study was approved by the ethical committee of the Université catholique de Louvain (Belgium). Participants signed an informed consent form before being included.

Participants

One hundred healthy subjects ranging in age from 20 to 70 years were included in the study. Twenty subjects (10 men, 10 women) were recruited in each 10-year age class. Participants were randomly recruited in public places (visitors and workers in a hospital, in a university, and in a shopping mall) from November 2009 to February 2010. Subjects who agreed to participate were included in the study if they met the following criteria: (1) they had no positive answer in the revised Physical Activity Readiness Questionnaire & You (PAR-Q & You),[19] (2) were not taking drugs that influence HR, and (3) were free of self-reported illnesses, such as chronic pain caused by orthopedic conditions, peripheral arterial disease, or cardiac problems, that could interfere with participating in the submaximal cycle ergometer test. Participants who were engaged in any high-level competitive sport and those with any medical condition that would put them at risk during exertion were excluded. Also excluded from the study were participants who did not correctly perform the test.

Testing Procedure

In a quiet room, participants were given instructions on the test procedure. After filling in a questionnaire on their level and type of physical activities, they were given time to familiarize themselves with the equipment. Before starting the cycle ergometer test, subject's weight and height were measured with a portable scale and a tape measure, respectively. Body mass index (BMI) (kg/m^2) was calculated. The preliminary measurements also included the resting HR. After the subject had been equipped with a chest-strap HR monitor, the subject was asked to remain seated and quiet for 15 minutes. During the last 5 minutes of this resting period, HR was continuously monitored. The lowest value obtained was recorded as the resting HR.[9,20,21] The measurement of the resting HR allowed the calculation of $WCI_{65\%HRreserve}$/kg. We calculated both the $PWC_{75\%}$/kg and $WCI_{65\%HRreserve}$/kg for each participant from the data collected during the cycle ergometer test, to compare our new fitness index with the $WCI_{65\%HRreserve}$/kg.

Cycle ergometer test. The cycle ergometer test was performed after obtaining the resting HR. Before starting the test, the handlebars and seats were adjusted according to each subject's height and preference. After a 2-minute warmup period spent pedaling at 60rpm with no resistance (0 watts), the test began. The pedaling rate of 60rpm had to be maintained throughout the entire test. The initial power output of the first stage was 30W. It was increased by 30W every 2 minutes. The HR was continuously monitored, but only the value at the end of each stage was recorded as corresponding to the stage workload.[14,17,18] The last stage of the test was the one during which the subject's HR reached or exceeded the previously calculated value, corresponding to 75% of the subject's predicted HR_{max}. After the final HR was recorded, the subject was allowed to recover by pedaling a few minutes at a low workload (approximately 30W).

$PWC_{75\%}$/kg calculation. A linear regression between the stages workloads (watts) and corresponding recorded HR (bpm) was calculated for each subject by the least-squares method: $PWC = aHR + b$, where a is the slope and b is the intercept of the linear relation.[13,17,18] The physical work capacity at 75% of HR_{max} ($PWC_{75\%}$) was obtained by interpolation of the power (watt) corresponding to 75% of the HR_{max} ($75\%HR_{max}$) on the HR-versus-power linear relation calculated from the data collected during the test. The $75\%HR_{max}$ is calculated as $.75\times(220 - \text{age})$. The fitness index $PWC_{75\%}$/kg was obtained by normalizing $PWC_{75\%}$ for body weight of the subject. This index is expressed in watts per kilogram and may be considered as the power output per kilogram of body weight a subject can generate on a cycle ergometer when exercising in a steady state at the relative work intensity corresponding to 75% of the HR_{max}.[17,18]

$WCI_{65\%HRreserve}$/kg calculation. As mentioned above, the $WCI_{65\%HRreserve}$/kg was also calculated for each participant following a 3-step procedure previously described by Nielens and Plaghki.[14] The first step consists of computing the linear regression between power and HR by a least-squares method. Then, the HR value corresponding to 65% of the HR reserve (65%HRreserve) is calculated using the following formula: $65\%HRreserve = .65\times([220 - \text{age}] - HRresting) + HRresting$, where HRresting is the resting HR value measured as described above. Finally, the power at 65%HRreserve was determined by interpolation and divided by body weight to obtain the $WCI_{65\%HRreserve}$/kg.

Statistics

Descriptive statistics of $PWC_{75\%}$/kg were calculated according to sex and age (classified by 10-year age classes). Data analysis and graphics plotting were performed using PASW Statistics 18.0[a] and SigmaPlot 11.0.[b] Results are presented as mean ± SD when appropriate. The correlation between $PWC_{75\%}$/kg and $WCI_{65\%HRreserve}$/kg was analyzed by using the intraclass correlation coefficient (ICC). A linear regression allowed examination of the link between the $PWC_{75\%}$/kg and age. The difference in fitness index, as measured by the $PWC_{75\%}$/kg, between active and inactive subjects was assessed based on an independent *t* test.

Table 1: Characteristics of the Subjects

Sex and Age Classes (y)*	Age (y)	Body Weight (kg)	Height (m)	BMI (kg/m^2)
Men				
20–29	25.8±2.5	78.3±14.6	1.76±.08	25.1±3.3
30–39	32.7±3.2	76.7±9.3	1.78±.05	23.9±2.6
40–49	44.4±3.0	76.1±6.4	1.77±.03	24.2±2.3
50–59	54.4±2.6	80.3±9.1	1.79±.06	25.2±2.9
60–70	64.3±2.3	82.1±11.5	1.76±.09	26.7±3.3
Women				
20–29	25.1±2.4	65.4±7.5	1.67±.07	23.3±3.4
30–39	32.8±3.2	59.2±9.9	1.64±.10	21.9±2.5
40–49	44.4±3.3	59.6±4.9	1.64±.05	22.1±1.5
50–59	55.1±2.6	71.1±14.9	1.62±.08	27.4±5.9
60–70	64.1±3.3	61.0±10.4	1.65±.05	22.6±3.5

NOTE. Values are mean ± SD.
*Ten subjects per age class.

RESULTS

Twenty-three participants were excluded because they did not succeed in correctly completing the test. The reasons for incorrectly performing the test were the following: (1) inability of the subject to maintain the steady pedaling rate of 60rpm, or (2) the subject wished to interrupt the test because of perceived fatigue or discomfort.

Table 1 presents the characteristics of the 100 participants included in analysis. No difference was observed (t=.007; P=.99) between the mean age in men (44.3±14.4y) and women (44.3±14.6y). The average body weight and height were, respectively, 78.7±10.4kg and 1.77±.06m for men and 63.3±10.7kg and 1.64±.07m for women. There was a significant difference in the BMI values with regard to sex (t=2.22; P=.03). The average BMI value was greater in men (25.02±2.95kg/m^2) than in women (23.44±4.05kg/m^2). Overall, 65% of the participants had a BMI below 25kg/m^2, while the BMI was above 25kg/m^2 in 35% of the subjects. In this study, 58% of participants responded that they regularly practiced physical activities for an average of 3.4±2.1h/wk. The most common activities were walking, jogging, cycling, swimming, gardening, and gym fitness. Thus, with regard to practicing physical activities, the sample could be divided into 2 groups: the active group (58%) and the inactive group (42%).

$PWC_{75\%}$/kg and $WCI_{65\%HRreserve}$/kg were highly correlated (ICC=.96, P<.001) (fig 1). This indicated a very strong correlation between our new cardiorespiratory index and the $WCI_{65\%HRreserve}$/kg previously described and validated by Nielens and Plaghki.[14] Additionally, the results showed that $PWC_{75\%}$/kg decreases with age. Figure 2 illustrates this relation separately for men (n=50) and women (n=50). The average $PWC_{75\%}$/kg was significantly higher (t=4.7; P<.001) in men (1.81±.58W/kg) than in women (1.35±.36W/kg). There was a significant difference (P<.01) in $PWC_{75\%}$/kg between the active and inactive groups, with a higher fitness index observed in active men and women (fig 3). Table 2 presents the reference values (mean ± SD and 95% confidence interval) of the $PWC_{75\%}$/kg by age class and sex.

DISCUSSION

This study was designed to provide a new fitness index and reference values in active and sedentary people aged from 20 to 70 years old. Adapted from the $WCI_{65\%HRreserve}$/kg and the $PWC_{75\%HRmax}$, previously proposed by Nielens and Plaghki[14] and Miyashita et al,[13] respectively, the new fitness index, named $PWC_{75\%}$/kg, accounts for body composition and is independent from resting HR. This index was developed for clinical and community-based use, and reference values were obtained from healthy 20- to 70-year-old subjects. The $PWC_{75\%}$/kg exhibited a significant decrease with age and increase with regular practice of physical activities, confirming previous findings of Gore et al[12] and Miyashita.[13]

Advantages of the $PWC_{75\%}$/kg

$PWC_{75\%}$/kg is a function of HR_{max} alone, and HR_{max} declines with age. This characteristic makes the $PWC_{75\%}$/kg suitable for evaluating fitness in individuals of all ages. In the $PWC_{75\%}$/kg, $HR_{75\%}$ is simply 75% of age-predicted HR_{max}. It was calculated using the following formula: $HR_{75\%} = .75\times(220 - \text{age})$. Hence, its calculation does not require the resting HR. This feature is advantageous because it eliminates the variability of measuring the resting HR. Indeed, it is well known that many factors can influence resting HR. During measurement, the temperature, anxiety, stress, time of day, noise level, and body position can influence the resting HR. Moreover, eating, smoking, drinking coffee, and having exer-

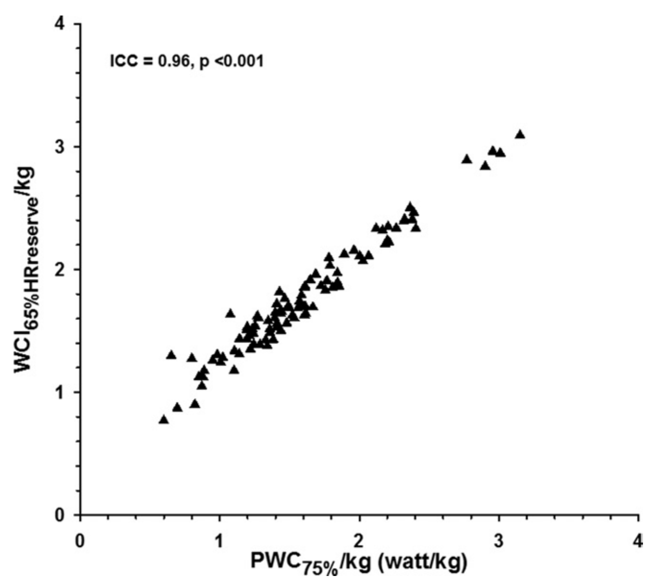

Fig 1. Correlation between $PWC_{75\%}$/kg and $WCI_{65\%HRreserve}$/kg. The fitness indices are highly correlated.

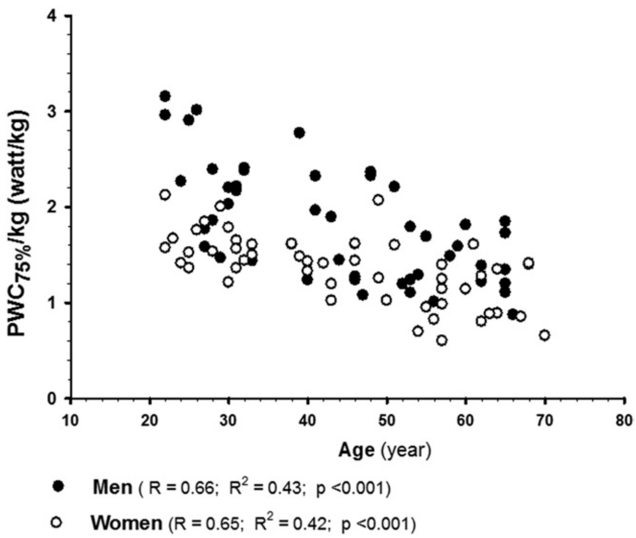

Fig 2. Evolution of $PWC_{75\%}$/kg with age in men and women. The fitness index decreases as the age increases similarly in both men and women.

cised before the measurement can affect the resting HR.[9,17] Many of these factors are commonly present in rehabilitation facilities and gyms where the $PWC_{75\%}$/kg is used to evaluate subjects. Moreover, except in subjects with a high level of physical activity, people are often anxious and stressed when it comes to taking an exertion test, which obviously increases the resting HR. In a clinical setting, this phenomenon commonly applies to patients who have to perform a cardiorespiratory endurance test. Therefore, the inclusion of resting HR in the calculation of a fitness index to be used in routine clinical practice could induce a bias. Another advantage of the present fitness index is that it integrates body weight as a denominator. Therefore, body composition is indirectly assessed with the $PWC_{75\%}$/kg. Indeed, a low $PWC_{75\%}$/kg indicates either a low cardiorespiratory endurance or a high body weight. In individuals with a high body weight and favorable cardiorespiratory endurance, the numerator and denominator will be elevated; hence, the $PWC_{75\%}$/kg will remain in the normative range. On the other hand, in less fit individuals (low numerator) with a high body weight (high denominator), the $PWC_{75\%}$/kg will be very low.

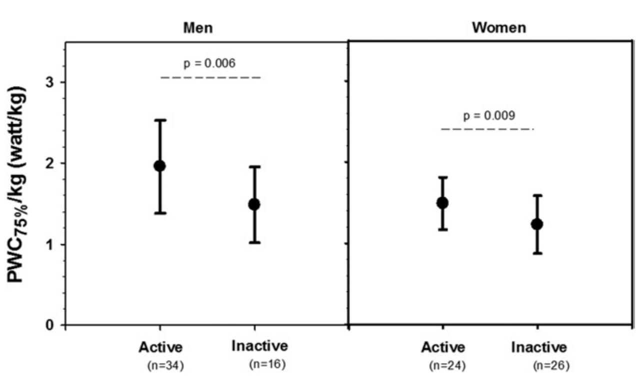

Fig 3. Comparison of $PWC_{75\%}$/kg between active men and women practicing regular physical activities, and inactive male and female subjects who practice no regular physical activities. Higher fitness indices are observed in the active groups of both men and women, compared with the inactive groups. The *P* values were calculated using independent *t* tests.

Table 2: Reference Values of $PWC_{75\%}$/kg by Sex and Age Class

Age Classes* (y)	$PWC_{75\%}$/kg (W/kg)	
	Men	Women
20–29	2.33±.64 (1.87–2.79)	1.68±.25 (1.50–1.86)
30–39	2.14±.38 (1.86–2.41)	1.52±.16 (1.40–1.63)
40–49	1.71±.52 (1.34–2.08)	1.44±.29 (1.23–1.64)
50–59	1.46±.37 (1.20–1.72)	1.05±.31 (0.82–1.27)
60–70	1.39±.32 (1.16–1.62)	1.09±.31 (0.86–1.31)

NOTE. Values are mean ± SD (95% confidence interval).
*Ten subjects per age class and by sex.

Validity of the $PWC_{75\%}$/kg as a Fitness Index

The previous study by Nielens and Plaghki[14] demonstrated the validity of the $WCI_{65\%HRreserve}$/kg. The present study highlights a strong correlation between $WCI_{65\%HRreserve}$/kg and $PWC_{75\%}$/kg, demonstrating the validity of the new fitness index. Moreover, similar to many other valid fitness indices, the $PWC_{75\%}$/kg decreases with age, is higher in men than in women, and higher in active people than in sedentary people. Hence, both procedures can measure the fitness index satisfactorily, but the $PWC_{75\%}$/kg is easier to implement. Consequently, the $PWC_{75\%}$/kg allows valid evaluation of physical fitness where accurate measurement of $\dot{V}O_2max$ is not absolutely necessary.

Participant Recruitment

The present study evaluated subjects in a wider age range and in a larger sample than did Nielens and Plaghki.[14] In fact, Nielens and Plaghki[14] recruited 34 subjects (aged 19–57y) among a hospital's medical staff members and their relatives, whereas the present study involved 100 subjects (aged 20–70y) who were randomly recruited in different settings. This method allowed us to determine reference values for many different age classes of men and women.

Participants were randomly recruited in several public places to ensure a representative sample of Belgian people between 20 and 70 years of age. The appropriateness of the recruitment method was confirmed by the similarity of our findings to reported data in the literature regarding the Belgian physical lifestyle.[22] Nevertheless, the highest refusal rate during recruitment was in the age class of 60 to 70 years, suggesting that only older adults who were confident in their capacity to perform a physical test agreed to participate in the study. Therefore, there is a possible recruitment bias concerning participants older than 60 years. Hence, caution should be taken when using our suggested reference values for this age class.

Study Limitations

The current study has some limitations. First, this new approach was tested in active and sedentary subjects, and even though it might be a suitable method to evaluate fitness in chronically ill subjects, further testing in such patients is needed. Second, we did not observe participants in everyday life. Available data on their physical activities were based on self-reports. Third, it would also be interesting to assess the responsiveness of the new test procedure. Further studies could focus on these purposes.

CONCLUSIONS

A good level of cardiorespiratory endurance is considered an important determinant of quality of life, especially in elderly individuals. There is a need for a valid, reliable, and easily implemented method to assess cardiorespiratory endurance and more generally, fitness in sedentary, elderly, and selected chronically ill individuals. This study presents a new fitness index, the $PWC_{75\%}$/kg. This new index takes into account body composition and does not require the measurement of resting HR, which makes it more suitable and easy to implement in routine use during physical rehabilitation in a clinical setting as well as in a community-based survey. This study also provides reference values of the $PWC_{75\%}$/kg for healthy men and women aged 20 to 70 years.

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Suppliers

a. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
b. Systat Software Inc, 1735 Technology Dr, Ste 430, San Jose, CA 95110.