Original Scientific Paper

Criterion-related validity of the short International Physical Activity Questionnaire against exercise capacity in young adults

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Background Self-reported physical activity (PA) is well associated with cardiorespiratory fitness and exercise capacity. The short International Physical Activity Questionnaire (IPAQ-short) is a frequently used instrument for cross-national assessments of PA in adults. The purpose of this study was to validate IPAQ-short against exercise capacity in Greek young adults.

Design and methods One hundred and thirteen men and 105 women, aged 20–29 years, were randomly selected from a larger population of young health-science students. A Greek version of IPAQ-short (IPAQ-Gr) was administered to all participants before their exercise capacity evaluation with a maximal Bruce treadmill test. Multiple regression and correlation analyses were used to examine the associations between all IPAQ-Gr outcomes with exercise capacity based on maximal treadmill time.

Results Spearman's correlations for total and vigorous PA against maximal treadmill time were significant in all groups examined, ranging from 0.35 to 0.43. Moderate and walking PA correlations were poor and nonsignificant, ranging from near-zero values to 0.19. In multiple linear regression analysis, only sex, smoking, and vigorous PA from all personal and log-transformed IPAQ-Gr data were significantly associated with maximal treadmill time. Partial correlation analysis for the overall population, adjusted for sex and smoking, showed that total PA ($r = 0.37$) and vigorous PA ($r = 0.47$) were significantly associated with exercise capacity.

Conclusion IPAQ-Gr was tested against exercise capacity and showed acceptable validity properties in Greek young adults. Total and vigorous weekly PA expenditure were well associated with exercise capacity, presenting significant validity correlations against maximal treadmill time. *Eur J Cardiovasc Prev Rehabil* 17:380–386 © 2010 The European Society of Cardiology

Introduction

A plethora of epidemiological studies have emphasized the importance of habitual physical activity (PA) in maintaining good health and promoting quality of life [1]. Clinical evidence has indicated that a high level of self-reported PA is inversely related to cardiovascular morbidity and all-cause mortality, reducing the risk of certain types of cancer and metabolic diseases [2,3].

Physical activity questionnaires (PAQs) are the most common and practical approaches used for assessing PA status in large study populations, as they are noninvasive, inexpensive, and easy to administer. The International Physical Activity Questionnaire (IPAQ) is a frequently used instrument, developed in the late 1990s by a multinational working group, with the support of WHO, for the cross-national assessment of PA in adults aged 18–65 years (*http://www.ipaq.ki.se/ipaq.htm*). The IPAQ-short format, covering the last 7 days (last 7-d), has been tested in many countries and has shown good reliability

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and acceptable validity properties in adult populations [4–14]. IPAQ-short has also been used for PA monitoring in the European Physical Activity Surveillance System [15] and in the Eurobarometer survey carried out by the European Union, in which a Greek version of the instrument was included [16]. Recently, after all necessary technical, linguistic, and cultural adaptations, this Greek-language IPAQ-short version (IPAQ-Gr) was tested for repeatability and was found to have very good reliability properties in Greek young adults [17]. However, IPAQ-short has not yet been validated in the Greek population.

It has been noted that the total amount of weekly PA expenditure is well associated with cardiorespiratory fitness [18]. On the basis of this, many widely used 7-day recall PAQs have been validated against exercise capacity [19–25]. However, most of the published IPAQ validation studies have tested IPAQ-short against accelerometry [4–9,12] and pedometry [6,10] readings. Only a few IPAQ studies, to the best of our knowledge, have used exercise capacity as a validation criterion [11,12], whereas IPAQ-short has not yet been validated against exercise capacity in adult women.

The purpose of this study was to test IPAQ-Gr for validity against exercise capacity in young healthy men and women. Our aim is to use this instrument to assess PA in a number of studies seeking associations between physical inactivity, smoking prevalence, and cardiovascular function in the Greek population.

Methods
Study population
The participants were randomly selected from a large population of health science students at the Athens Technological Educational Institute. Three hundred students were invited, but finally 113 men and 105 women fulfilled the inclusion criteria and completed all tests (Table 1). The rest (27%) were either excluded or did not show up. All healthy individuals who were aged between 20 and 29 years and had a body mass index (BMI) of 18.5–29.9 kg/m^2 (WHO criteria for normal and overweight) were eligible for the study. Exclusion criteria were obesity (BMI $\geq$ 30 kg/m^2), high blood pressure at rest (systolic blood pressure $\geq$ 140 mmHg and diastolic blood pressure $\geq$ 90 mmHg), metabolic diseases such as diabetes, hyperlipidemia and thyroid disease, physical disability, recent illness, pregnancy, and alcohol or drug abuse.

Study protocol
All tests and measurements were conducted during morning hours, under constant conditions of temperature and humidity. The participants familiarized themselves with the laboratory and the exercise test equipment before their appointment day. Health status was assessed by a physician through medical history, clinical, and physical examination. Smoking prevalence in young Greeks exceeds by far the mean average of the European countries, while

Table 1 Personal characteristics and physical activity level of the study population

	Total group ($n=218$)	Males ($n=113$)	Females ($n=105$)
Personal data			
Age (years)	23.0 ± 2.3	23.4 ± 2.4	22.6 ± 2.2
Height (cm)	172.9 ± 8.8	179.3 ± 6.0	165.9 ± 5.2
Weight (kg)	68.4 ± 12.7	77.3 ± 9.3	58.9 ± 8.0
BMI (kg/m^2)	22.7 ± 2.7	24.0 ± 2.3	21.4 ± 2.5
Smoking (%)	37.6	38.9	36.2
PA classification			
Low n (%)	81 (37.2)	38 (33.6)	43 (41.0)
Moderate n (%)	107 (49.1)	56 (49.6)	51 (48.6)
High n (%)	30 (13.8)	19 (16.8)	11 (10.5)

Personal data are expressed as mean $\pm$ SD. Smoking prevalence is expressed as percentage of current smokers; PA classification data are expressed as frequencies in numbers and percentages in parenthesis. BMI, body mass index; PA, IPAQ-Gr-assessed physical activity.

smoking has been found to be inversely related to exercise capacity and maximal treadmill time in Greek young adults [26]. Therefore, for the purpose of this study, smoking status was assessed by a standardized questionnaire. Written informed consent was obtained from all participants. The study protocol followed the principles of the Helsinki Declaration and was approved by the research committee of Athens Technological Educational Institute.

On the same appointment day, the participants filled in the IPAQ-Gr and afterwards their exercise capacity was evaluated. Criterion-related validity was assessed by testing all IPAQ-Gr outcomes against maximal treadmill time, based on the duration of a standard Bruce maximal treadmill test.

Physical activity assessment
The original self-answered, last 7-d, IPAQ-short, and a Greek-language IPAQ-short telephone format were kindly provided to us by the IPAQ group. On the basis of these versions, additional amendments were made, mainly on technical, linguistic, and cultural grounds. Finally, IPAQ-Gr was developed and thoroughly tested to examine the potential distribution of responses and comprehension, and to ensure linguistic, face, and content validity [17]. In summary, the purpose of the instrument was to sum up all last 7-d, vigorous, moderate, and walking PAs and to generate a total PA$_{score}$ for the weekly PA expenditure, expressed in metabolic equivalent of the task (MET)-minutes per week (MET-min/week). On the basis of the total and/or vigorous PA$_{score}$, PA status is classified into three categories (PA$_{class}$): low, moderate, and high. (*http://www.ipaq.ki.se/scoring.htm*).

Exercise capacity evaluation
Exercise capacity and its measure, maximum oxygen uptake (VO$_{2max}$), are widely accepted as important markers of PA [18]. In this study, maximal treadmill time, recorded in minutes at the end of a standard Bruce maximal treadmill test, was used as an indirect measure of participants' exercise capacity and VO$_{2max}$. The Bruce

treadmill test is an appropriate exercise test protocol for young healthy adults [18], and maximal Bruce test duration has been used in many studies for VO_{2max} estimation and exercise capacity evaluation [27–29].

Exercise testing followed the guidelines set out by the American Heart Association [30]. Participants abstained from heavy eating, coffee, and alcohol, and smokers from smoking, for at least 6 h before the exercise test. The exercise testing procedures, including electrocardiographic, heart rate, and blood pressure monitoring, have been described elsewhere [26]. Neither the cardiologist who supervised the exercise tests nor the assisting examiner was aware of the participants' PA and smoking status. Testing was terminated at maximal effort, when symptoms such as intense exhaustion, fatigue, dyspnea, or strong muscular leg pain occurred.

Data analysis

Statistical analyses were performed using the SPSS v.14 software package (SPSS Inc., Chicago, Illinois, USA). Personal data, maximal treadmill time, and sitting hours per day were normally distributed (Kolmogorov–Smirnov test) and are presented as mean and standard deviation values. IPAQ-Gr PA_{scores} were not normally distributed and are presented as median and minimum to maximum values. The χ^2 test was used to examine possible PA_{score} differences between men and women.

Spearman's correlations for the nonparametric PA_{scores} and Pearson's correlations for sitting hours were used to test IPAQ-Gr for validity against maximal treadmill time. Multiple linear regression analysis was used to assess the associations between all IPAQ measures and exercise capacity, controlling for confounding variables. As all the PA_{scores} were not normally distributed, they were log-transformed in order to be used in the multiple linear regression and partial correlation analyses. Before log-transforming, the value of 1.0 was added to each PA_{score} to account for zero values, as many participants reported no participation in vigorous or moderate PAs. Preliminary stepwise multiple regression analysis was performed to determine which of the personal characteristics and IPAQ-Gr measures (independent variables) were significantly associated with maximal treadmill time (dependent variable). In addition, it was examined which combination of independent variables provided the best variance explanation of the maximal treadmill time. Partial correlations of the log-transformed PA_{score} and the normally distributed sitting hours, adjusted for sex and smoking, were also computed. In all analyses, the correlation values were characterized as follows: poor, 0.00–0.19; fair, 0.20–0.39; moderate, 0.40–0.59; good, 0.60–0.79; high, 0.80–1.00 [31]. The level of significance was set at P value less than 0.05.

Results

Descriptives

Two hundred and eighteen young healthy adults with a mean age of 23 years participated in this study (Table 1).

On the basis of IPAQ-Gr classification criteria [17], the prevalence of low PA was strikingly high. About 34% of men and 41% of women had a low PA status, whereas only 14% of the overall population was classified in the high PA category (Table 1). About 14% of the participants had a total PA_{score} less than 200 MET-min/week, 52% reported no participation in vigorous PAs, and 36% reported zero moderate PA (data not shown).

Regarding sex differences, more men were classified in the high PA category, whereas more women were in the low PA_{class} (Table 1). In addition, men had significantly higher total PA_{score}, vigorous PA_{score}, and maximal treadmill time compared with women (Table 2).

About 39% of men and 36% of women were current smokers. Nonsmokers had significantly longer maximal exercise test duration compared with current smokers (means: 11.16 vs. 9.74 min, $P < 0.001$). Similarly, nonsmokers had a significantly higher total PA_{score} (medians: 1215 vs. 693, $P = 0.021$) and vigorous PA_{score} (medians: 160 vs. zero, $P = 0.006$) (data not shown).

Validity study

Spearman's correlations for the nonparametric IPAQ-Gr PA_{scores} and Pearson's coefficients for sitting hours are presented in Table 3. In the overall population, total and vigorous PA were significantly associated with maximal treadmill time ($r = 0.36$ and 0.43, $P < 0.001$). Total and vigorous PA Spearman's correlations were moderate for men (0.43 and 0.42, $P < 0.001$) and fair to moderate for women (0.35 and 0.41, $P < 0.001$). In both men and

Table 2 IPAQ-Gr outcomes and maximal treadmill time of the study population

	Total group ($n=218$)	Males ($n=113$)	Females ($n=105$)	P value
IPAQ-Gr outcomes				
Total PA	805 (0–5379)	1250 (0–5379)	693 (0–4782)	<0.05
Vigorous PA	0 (0–4800)	480 (0–4800)	0 (0–3600)	<0.05
Moderate PA	160 (0–2880)	180 (0–2880)	120 (0–1920)	NS
Walking PA	330 (0–2079)	297 (0–2079)	396 (0–1980)	NS
Sitting hours (h)	7.10 ± 2.6	6.93 ± 2.62	7.20 ± 2.55	NS
Maximal treadmill time (min)	10.60 ± 1.57	11.47 ± 1.51	9.65 ± 0.98	<0.001

Maximal treadmill time and sitting hours are presented as the mean ± SD. P, level of significance for the differences between men and women. PA, IPAQ-Gr-assessed physical activity expressed as metabolic equivalent of the task (MET) min/week and presented as the median and (min−max) values.

Table 3 Validity correlations of IPAQ-Gr outcomes against maximal treadmill time (nonadjusted values)

	Total group (n=218)	Males (n=113)	Females (n=105)
PA category[a]	0.34 (<0.001)	0.40 (<0.001)	0.34 (<0.001)
Total PA[b]	0.36 (<0.001)	0.43 (<0.001)	0.35 (<0.001)
Vigorous PA[b]	0.43 (<0.001)	0.42 (<0.001)	0.41 (<0.001)
Moderate PA[b]	0.16 (0.020)	0.18 (0.062)	0.19 (0.055)
Walking PA[b]	0.01 (0.912)	0.02 (0.807)	0.16 (0.109)
Sitting hours[c]	−0.25 (<0.001)	−0.28 (0.002)	−0.25 (0.01)

PA, IPAQ-Gr-assessed physical activity. [a]Spearman's *r* (level of significance) between PA classification based on IPAQ-Gr scores and exercise capacity classification based on maximal treadmill time. [b]Spearman's *r* (level of significance). [c]Pearson's coefficients (level of significance).

Table 4 Multiple linear regression analysis of maximal treadmill time with IPAQ-Gr outcomes and participants' personal data

	β coefficient (standard error)	Standardized β	P value
IPAQ-Gr outcomes			
Vigorous PA	1.644 (0.395)	0.381	<0.001
Moderate PA	−0.126 (0.440)	−0.026	0.776
Walking PA	−0.091 (0.400)	−0.020	0.821
Personal Data			
Age	−0.046 (0.066)	−0.065	0.487
BMI	−0.130 (0.585)	−0.197	0.824
Sex	−1.697 (0.472)	−0.501	0.001
Smoking	−1.240 (0.308)	−0.355	<0.001

BMI, body mass index; *P*, level of significance; PA, IPAQ-Gr-assessed physical activity.

Table 5 Partial correlations of IPAQ-Gr outcomes with maximal treadmill time (adjusted values)

	Total group[c] (n=218)	Males[d] (n=113)	Females[d] (n=105)
Total PA[a]	0.37 (0.001)	0.37 (0.015)	0.36 (0.046)
Vigorous PA[a]	0.47 (<0.001)	0.57 (<0.001)	0.32 (0.077)
Moderate PA[a]	0.08 (0.487)	−0.07 (0.650)	0.26 (0.164)
Walking PA[a]	−0.04 (0.712)	−0.02 (0.901)	0.01 (0.985)
Sitting hours[b]	−0.16 (0.186)	−0.01 (0.977)	−0.31 (0.085)

PA, IPAQ-Gr-assessed physical activity. [a]Partial correlations coefficients of the log-transformed IPAQ scores (level of significance). [b]Partial correlations coefficients (level of significance). [c]The values are adjusted for sex and smoking. [d]The values are adjusted for smoking.

Table 6 The maximal treadmill time and the total and vigorous PA scores of the participants in the three PA categories

	Maximal treadmill time (mean ± SD)	Total PA		Vigorous PA	
		Median	Mean	Median	Mean
Males PA category					
Low (n=38)	10.83±0.83	325	313	0	18
Moderate (n=56)	11.34±1.44	1557	1556	680	688
High (n=19)	13.15±1.62	3450	3608	2400	2502
Females PA category					
Low (n=43)	9.36±0.81	264	308	0	13
Moderate (n=51)	9.62±0.98	1215	1383	0	343
High (n=11)	10.89±0.94	3150	3560	1920	2310

PA, IPAQ-Gr-assessed physical activity.

women, moderate and walking PA were not associated with maximal treadmill time and the respective correlations ranged from poor to near-zero values. Sitting showed a significant and negative association with exercise capacity (total group, $r=-0.25$, $P<0.001$).

Stepwise multiple linear regression analysis indicated that sex and smoking were significant confounding variables for exercise capacity ($P<0.001$, Table 4). Age and BMI were not significantly associated with maximal treadmill time. On the basis of these results, partial correlation analysis of the log-transformed PA$_{scores}$, adjusted for sex and smoking, was performed (Table 5). In the overall population, vigorous PA showed the strongest association with maximal treadmill time among all IPAQ PA$_{scores}$ ($r=0.47$, $P<0.001$). Total and vigorous PAS correlations were higher and significant in men ($r=0.37$, $P=0.015$, and $r=0.57$, $P<0.001$), but lower and marginal or not significant in women ($r=0.36$, $P=0.046$ and $r=0.32$, $P=0.77$). Moderate and walking PAs were not associated with exercise capacity, and their respective partial correlations were found to be poor or near-zero in all population groups (Table 5).

Similar to the Spearman-bivariate and partial correlation analyses, multiple linear regression models indicated that only vigorous PA was significantly associated with exercise capacity ($P<0.001$, Table 4). Moderate and walking PA associations were poor and not significant. Altogether, sex, smoking, and vigorous PA accounted for the 54.5% of the total variance in maximal treadmill time.

To account for other aspects of IPAQ-Gr validity, the mean maximal treadmill time in the three PA categories was computed (Table 6). Maximal exercise test duration increased progressively from the low PA$_{class}$ to high PA$_{class}$, in parallel with the total and vigorous PA$_{score}$. Respectively, when quintiles of the total PA$_{score}$ and quintiles of the maximal treadmill time were compared, it was found that mean maximal exercise test duration increased progressively from the first (lowest PA$_{score}$) total PA quintile up to the fifth (highest PA$_{score}$) total PA quintile (data not shown).

Discussion

Testing IPAQ-Gr for validity showed that the total amount of weekly PA expenditure was significantly associated with exercise capacity in young Greek students. In the overall population, vigorous PA showed the strongest correlations with maximal treadmill time among all IPAQ-Gr outcomes.

Descriptives

In this study, age and BMI did not affect the association between self-reported PA and exercise capacity. That was not a surprise, as all the participants were young, within a small age range, and all participants who were obese or below normal weight were excluded. In contrast, both sex and smoking were significant confounding factors

for the association between PA and exercise capacity in young adults. Men had a significantly longer maximal exercise test duration, in line with many other studies indicating that men have approximately 20% higher VO_{2max} compared with women [18]. Current smokers had significantly lower maximal treadmill time, in line with previously published data [26]. IPAQ-Gr was found to be sensitive in identifying these sex and smoking effects.

This is the first IPAQ-short validation study, to the best of our knowledge, to address these issues in healthy adults. Most studies have tested IPAQ-short against accelerometry or pedometry readings and either noted that sex had no influence on the association between total PA and objectively measured energy expenditure [5,10], or reported no data for possible sex and smoking effects [6–8]. Our results are in line with validation studies of other PAQs, which usually present sex-adjusted correlations between self-reported PA and exercise capacity [19–23,32–34]. However, although it has been indicated that smoking and PA may be inversely related [35], only a few studies [36,37] mention smoking as a possible confounding variable.

Validity study
Despite their extensive use, PAQs are still characterized by certain design and administrative limitations [38,39]. One of the major issues discussed is what might be the most appropriate validation criterion for self-reported PA. Unfortunately, such a 'gold standard' method for objective PA measurement does not exist. In line with Shephard's [38] and Sallis's [39] thoughts on PAQ limitations, Jacobs et al. [20] stated that "there are multiple non overlapping dimensions of PA and these are reflected in multiple non overlapping validation realms". The fair correlations that are usually found between all kinds of PAQs and various validation criteria may imply that either the PAQs give imprecise estimates of PA, or the validation criteria that are used cannot account for all aspects of PA assessment.

As was mentioned before, IPAQ-short is usually validated against accelerometry and pedometry readings. In the study by Craig et al. [4], self-reported PA was tested against accelerometry and the pooled value for 781 participants was $r=0.30$. In line with Craig's data, most of the IPAQ-short studies reviewed have found a fair correlation between total PA and accelerometry [5,8,9] or pedometry [6,10], ranging from 0.30 to 0.38. However, some authors have reported that there is poor agreement between IPAQ-short outcomes and accelerometry [6,7], whereas Kurtze et al. [12] stated that IPAQ-short data did not correlate with objectively measured energy expenditure, except total walking.

Although the total amount of weekly PA expenditure is well associated with cardiorespiratory fitness [18], only a few studies have validated IPAQ-short against exercise capacity in healthy adults. Fogelholm et al. [11] examined the validity properties of IPAQ-short against exercise capacity and several muscular fitness tests in 951 young men. The authors classified their participants into five PA groups based on IPAQ total PA outcomes (least active to most active quintiles). They reported that the estimated VO_{2max} improved from the first IPAQ group (least active) up to the fourth IPAQ group. However, because of possible PA overreporting, the estimated VO_{2max} in the fourth IPAQ group was higher than that in the most active fifth IPAQ group. Kurtze et al. [12] assessed the validity of IPAQ-short in 108 young men against VO_{2max} and energy expenditure, measured by a body position and motion sensor device. Their data showed that vigorous PA and total MET-min/week had acceptable correlations with VO_{2max} (0.41 and 0.30, $P < 0.01$), whereas moderate PA and walking PA coefficients were poor and nonsignificant (0.19 and 0.14, P: NS). Our results in the men's group are in line with the above; moreover, the computed correlations for total, vigorous, and moderate PA_{score} are comparable with those reported by Kurtze et al. [12].

A review of the literature for relatively recent PAQ validation studies against exercise capacity suggests that most of them concur that self-reported PA is significantly correlated with exercise capacity, regardless of whether VO_{2max} is either measured directly [19–22,25,32–34] or estimated [23,24,36,37]. On the basis of the data from several studies published before the 1990s, Paffenbarger et al. [40] also reported that the correlations between self-reported PA and exercise capacity were usually significant, ranging from 0.30 to 0.50. Our results are in line with these findings, showing significant correlations between IPAQ total PA and maximal treadmill time (Spearman $r=0.36$, partial $r=0.37$, $P < 0.001$). In contrast, Singh et al. [23] found nonsignificant associations between self-reported PA and maximal treadmill time, concluding that PA data were not good estimators of participants' fitness level. The authors [23] noted that the importance of the genetic component in exercise capacity may, in part, explain the poor correlations found, although this assumption has been questioned [40].

Singh's implications have also been supported by others, claiming that VO_{2max} measures fitness and not PA and, therefore, it may be a nonsuitable PA validation criterion [23]. However, Paffenbarger [40] opposes this argument, stating that the 'modest correlations' that are usually found between self-reported PA and exercise capacity may rather be because of imprecise estimates of PA by the questionnaires. Jacobs et al. [20] tested 10 commonly used PAQs for validity against treadmill exercise test performance, accelerometer readings, vital capacity, body fat, caloric intake, and PA records. The authors' data seem

to support Paffenbarger's view, because in most cases exercise capacity was found to have the highest validity correlations with PA among the eight validation criteria examined. Nine out of 10 PAQs showed fair to moderate validity correlations between total PA or PA index and exercise capacity, ranging from 0.30 (7-day recall) to 0.54 (Baecke PAQ). In contrast, no questionnaire outcome was related to accelerometry-measured total caloric expenditure, and the total or index accelerometry motion in MET-min/week showed much lower validity correlation values, ranging from 0.18 to 0.33 [20]. Kurtze et al. [12] have also reported that the IPAQ-short-assessed total PA was significantly correlated with exercise capacity, but was not associated with objectively measured energy expenditure.

A common finding of the previously cited studies is that the validity correlations against exercise capacity are usually higher and significant for vigorous PA and much lower and nonsignificant for moderate PA. Recently, Elosua et al. [36,37] tested the validity properties of the Minnesota Leisure Time PAQ against exercise capacity, based on maximal treadmill exercise duration, in Spanish men and women. The authors found significant correlations against exercise test duration for heavy PA (women $r=0.51$, men $r=0.66$, $P < 0.05$), compared with the much lower and poor correlations for moderate PA. Our results are in line with these outcomes, because of all partial PA_{scores}, only vigorous PA showed significant validity correlations against exercise capacity, in both men and women. In addition, when multiple linear regression analysis was used, our findings were comparable with those published by Elosua et al. [36,37] and Aadahl et al. [32] indicating that only vigorous PA was significantly associated with VO_{2max} [32] and exercise test duration [36,37]. Evidence from exercise physiology research may partly explain the comparatively higher correlations found between vigorous PA and exercise capacity, as a significant weekly amount of vigorous (> 6 METs) rather than moderate PA (3–5 METs) is needed to improve exercise capacity [18]. This is especially true for young adults, who must exercise with a vigorous intensity of about 7–11 METs to meet the suggested guidelines (60–85% of VO_{2max}) to enhance their cardiorespiratory fitness [18]. In support of this, Cooper Institute data for younger adults (< 50 years) indicated that weekly vigorous (greater than 6 METs) aerobic PA was substantially associated with exercise capacity in both men ($r=0.66$) and women ($r=0.78$) [40].

Strengths and limitations
The random selection of the participants out of a well-defined and homogenous target population and testing IPAQ-Gr for validity in both men and women are important strengths of this study. In addition, the single-blind design (neither the cardiologist nor the examiner were aware of subjects' PA level and smoking status) and the control for important confounding variables, such as sex and smoking, added strength to our results.

There has been a strong argument whether IPAQ-short outcomes are comparable with other PA surveys [13]. In addition, it is has been shown that IPAQ-short may overreport [5,6,11,41] or underestimate [12,42] PA, when it is compared with other objective PA measures, or with IPAQ-long. Although descriptive analysis of our data did not show signs of overreporting, the design of this study did not allow us to examine this very important issue thoroughly.

There are some other limitations that may influence the generalizability of our results. As there is no consensus on what would be the best validation criterion to use, it would be a better approach to validate IPAQ-Gr against multiple objective PA measures. In addition, IPAQ-Gr was tested for validity only in well-educated young adults, who are more reliable in reporting their PA, because they are usually involved in structured PAs that are easier to recall, such as systematic exercise or team sports activities [17]. Therefore, IPAQ-Gr validation in other study groups of healthy individuals as well as in patients' populations is needed.

Exercise capacity was indirectly assessed by recording maximal treadmill time, instead of directly measuring VO_{2max}. Direct VO_{2max} measurement through gas analyzers is expensive, requires advanced equipment and it was not feasible for us to use. Nevertheless, the error in estimating VO_{2max} of healthy individuals, based on their maximal exercise test duration, is comparatively unimportant [18]. Moreover, Bruce [43], Polloc [44], and Foster [45] have reported that the duration of the standard Bruce maximal treadmill test is strongly correlated (0.92–0.97) with the direct measurement of VO_{2max}.

Conclusion
Exercise capacity is a widely used validation criterion for PA questionnaire testing and it is usually well associated with total and vigorous self-reported PA. In this study, the total amount of weekly PA expenditure measured by IPAQ-Gr was significantly associated with exercise capacity in young Greeks. In the overall population, vigorous PA showed the strongest correlations with maximal treadmill time among all IPAQ-Gr outcomes. Our results suggest that IPAQ-Gr can be a useful tool for assessing PA in Greek young and healthy adults.

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References

1 Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin B, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Circulation 2007; 116:1081–1093.

2 Nocon M, Hiemann T, Muller-Riemenschneider F, Thalau F, Rolland S, Willich SN. Association of physical activity with all-cause and cardiovascular mortality: a systematic review and meta-analysis. Eur J Cardiovasc Prev Rehabil 2008; 15:239–246.

3 Mora S, Cook N, Buring JE, Ridker P M, Lee IM. Physical activity and reduced risk of cardiovascular events. Potential mediating mechanisms. Circulation 2007; 116:2110–2118.

4 Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003; 35:1381–1395.

5 Ekelund U, Sepp H, Brage S, Becker W, Jakes R, Hennings M, et al. Criterion-related validity of the last 7-day, short form of the International physical activity questionnaire in Swedish adults. Public Health Nutr 2006; 9:258–265.

6 Mcfarlane DJ, Lee CCY, Ho EYK, Chan KL, Chan DTS. Convergent validity of six methods to assess physical activity in daily life. J Appl Physiol 2006; 101:1328–1344.

7 Mcfarlane DJ, Lee CCY, Ho EYK, Chan KL, Chan DTS. Reliability and validity of the Chinese version of IPAQ (short, last 7 days). J Sci Med Sport 2007; 10:45–51.

8 Vandelanotte C, Bourdeaudhuij ID, Philippaerts R, Sjöström M, Sallis JF. Reliability and validity of a computerized and dutch version of the international physical activity questionnaire (IPAQ). J Phys Act Health 2005; 2:63–75.

9 Wolin KY, Heil DP, Askew S, Matthews CE, Bennett GG. Validation of the International physical activity questionnaire-short among blacks. J Phys Act Health 2008; 5:746–760.

10 Deng HB, Macfarlane DJ, Thomas GN, Lao XQ, Jiang CQ, Cheng KK, Lam TH. Reliability and validity of the IPAQ-Chinese: the Guangzhou Biobank Cohort study. Med Sci Sports Exerc 2008; 40:303–307.

11 Fogelholm M, Malmberg J, Suni J, Santtila M, Kyrolainen H, Mantysaari M, et al. International physical activity questionnaire: validity against fitness. Med Sci Sports Exerc 2006; 38:753–760.

12 Kurtze N, Rangul V, Hustvedt BE. Reliability and validity of the international physical activity questionnaire in the Nord-Trøndelag health study (HUNT) population of men. BMC Med Res Methodol 2008; 8:63.

13 Rutten A, Vuillemin A, Ooijendijk WT, Schena F, Sjostrom M, Stahl T, et al. Physical activity monitoring in Europe. The European Physical Activity Surveillance System (EUPASS) approach and indicator testing. Public Health Nutrition 2003; 6:377–384.

14 Tehard B, Saris WH, Astrup A, Martinez JA, Taylor MA, Barbe P, et al. Comparison of two physical activity questionnaires in obese subjects: the NUGENOB study. Med Sci Sports Exerc 2005; 37:1535–1541.

15 Rutten A, Ziemainz H, Schena F, Stahl T, Stiggelbout M, Auweele YV, et al. Using different physical activity measurements in eight European countries. Results of the European physical activity surveillance system (EUPASS) time series survey. Public Health Nutrition 2003; 6:371–376.

16 European Commission-European opinion research group. Physical Activity. Special Eurobarometer 183-6/Wave 58.2, December 2003.

17 Papathanasiou G, Georgoudis G, Papanthreou M, Spyropoulos P, Georgakopoulos D, Kalfakakou V, et al. Reliability measures of the short International physical activity questionnaire (IPAQ) in Greek young adults. Hellenic J Cardiol 2009; 50:283–294.

18 American College of Sports Medicine. Guidelines for exercise testing and prescription. 7th ed. Philadelphia: Lippincott Williams &Wilkins; 2006. pp. 66–79. 95–105, 139–154.

19 Ainsworth BE, Leon AS, Richardson MT, Jacobs DR Jr, Paffenbarger JR. Accuracy of the College Alumnus physical activity questionnaire. J Clin Epidemiol 1993; 46:1403–1411.

20 Jacobs DR Jr, Ainsworth BE, Hartman TJ, Leon AS. A simultaneous evaluation of 10 commonly used physical activity questionnaires. Med Sci Sports Exerc 1993; 25:81–91.

21 Berthouze SE, Minaire PM, Castells J, Busso T, Vico L, Lacour JR. Relationship between mean habitual daily energy expenditure and maximal oxygen uptake. Med Sci Sports Exerc 1995; 27:1170–1179.

22 Richardson MT, Ainsworth BE, Jacobs DR, Leon AS. Validation of the Stanford 7-day recall to assess habitual physical activity. Ann Epidemiol 2001; 11:145–153.

23 Singh PN, Fraser GE, Knutsen SF, Lindsted KD, Bennett HW. Validity of a physical activity questionnaire among African-American Seventh-day Adventists. Med Sci Sport Exerc 2001; 33:468–475.

24 Young DR, Jee SH, Appel LJ. A comparison of the Yale physical activity survey with other physical activity measures. Med Sci Sports Exerc 2001; 33:955–961.

25 Kurtze N, Rangul V, Hustvedt BE, Flanders WD. Reliability and validity of self-reported physical activity in the North Trondelag Health Study-HUNT 1. Scand J Public Health 2008; 36:52–61.

26 Papathanasiou G, Georgakopoulos D, Georgoudis G, Spyropoulos P, Perrea D, Evangelou A. Effects of chronic smoking on exercise tolerance and on heart rate-systolic blood pressure product in young healthy adults. Eur J Cardiovasc Prev Rehabil 2007; 14:646–652.

27 Balady GJ, Larson MG, Vasan RS. Usefulness of exercise testing in the prediction of coronary disease risk among asymptomatic persons as a function of the Framingham risk score. Circulation 2004; 110:1920–1925.

28 Peterson PN, Magid DJ, Ross C, Ho PM, Rumsfeld JS, Lauer MS, et al. Association of exercise capacity on treadmill with future cardiac events in patients referred for exercise testing. Arch Intern Med 2008; 168:174–179.

29 Kokkinos P, Myers J, Kokkinos JP, Pittaras A, Narayan P, Manolis A, et al. Exercise capacity and mortality in black and white men. Circulation 2008; 117:614–622.

30 USA Department of Health and Human Services. Centres for Disease Control and Prevention; available at http://www.cdc.gov/

31 Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, et al. ACC/AHA 2002 guideline update for exercise testing: summary article. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2002; 40:1531–1540.

32 Aadahl M, Kjaer M, Kristensen JH, Mollerup B, Jorgensen T. Self-reported physical activity with maximal oxygen uptake in adults. Eur J Cardiovasc Prev Rehabil 2007; 14:422–428.

33 Richardson MT, Leon AS, Jacobs DR, Ainsworth BE, Serfass R. Comprehensive evaluation of the Minnesota leisure time physical activity questionnaire. J Clin Epidemiol 1994; 47:271–281.

34 Wareham NJ, Jakes RW, Rennie KL, Mitchel J, Hennings S, Day NE. Validity and repeatability of the EPIC-Norfolk physical activity questionnaire. Intern J Epedimiol 2002; 31:168–174.

35 Kaczynski AT, Manske SR, Mannell RC, Grewal K. Smoking and physical activity: a systematic review. Am J Health Behav 2008; 32:93–110.

36 Elosua R, Marrugat J, Molina L, Pons S, Pujol E, MARARTHOM Investigators. Validation of the minnesota leisure time physical activity questionnaire in Spanish men. Am J Epidemiol 1994; 139:1197–1209.

37 Elosua R, Garcia M, Aguilar A, Molina L, Covas MI, Marrugat J. Validation of the Minnesota leisure time physical activity questionnaire in Spanish women. Med Sci Sports Exerc 2000; 32:1431–1437.

38 Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. Br J Sport Med 2003; 37:197–206.

39 Sallis JF, Saelens BE. Assessment of physical activity by self report: status, limitations and future directions. Res Q Exerc Sport 2000; 71:S1–S14.

40 Paffenbarger RS, Blair SN, Lee IM, Hyde RT. Measurement of physical activity to assess health effects in free-living populations. Med Sci Sports Exerc 1993; 25:60–70.

41 Rzewnicki R, Auweele YV, De Bourdeaudhuij I. Addressing overreporting on the International Physical Activity Questionnaire (IPAQ) telephone survey with a population sample. Public Health Nutr 2003; 6:299–305.

42 Hallal PC, Victora CG, Wells JCK, Lima RC, Valle NJ. Comparison of short and full-length International physical activity questionnaires. J Phys Activity Health 2004; 1:227–234.

43 Bruce RA, Kusumi F, Hosmer D. Maximal oxygen uptake and nomographic assessment of functional aerobic impairment in cardiovascular disease. Am Heart J 1973; 85:546–562.

44 Pollock ML, Bohannon RL, Cooper KH, Ayres JJ, Ward A, White SR, et al. A comparative analysis of four protocols for maximal treadmill stress testing. Am Heart J 1976; 92:39–46.

45 Foster C, Jackson AS, Pollock ML, Taylor MM, Hare J, Sennett SM, et al. Generalized equations for predicting functional capacity from treadmill performance. Am Heart J 1984; 107:1229–1234.