Outdoor circuit test: construction and validation of an instrument for the prediction of cardiorespiratory capacity for older adults

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Abstract

Objective: the present study aimed to construct, validate and verify the reliability of a protocol for assessing the cardiorespiratory capacity of older adults attending the Rio ao Ar Livre (Open Air Rio, or RAL) project entitled the "Outdoor Circuit Test" (OCT). *Method*: validity and reliability tests were carried out to assess the accuracy of the OCT, with 50 older adults (70.6 ± 6.3 years) of both sexes who regularly attended the RAL. Validity was tested by collecting VO_{2max} data under maximal cardiopulmonary exercise test conditions, and the OCT variables: a) Circuit Execution Time; b) Heart Rate; c) Subjective Perception of Exertion; d) Average Heart Rate (HRméd). Reliability was tested through the reproducibility of the measurements of the OCT variables, expressed by the Intraclass Correlation Coefficient (ICC). The predictive capacity of VO_{2max} was given by multiple linear regression and the final stability of the model by the analysis of the residues and the calculation of Cook's distances, with a value of $P \leq 0.05$ adopted for statistical significance. *Results:* the predictive model based on age, sex, waist circumference, BMI and circuit execution time explained 41% of VO_{2max} variance, with a standard error of estimate of 18.5%. *Conclusion*: the OCT exhibited satisfactory reproducibility (0.62 to 0.93), and proved to be valid, reliable, and specific for predicting the cardiorespiratory fitness of older adults attending RAL, demonstrating adequate reproducibility and a positive association with the physical fitness of older adults.

Keywords: Aging. Public policy. Physical Exercise. Oxygen Consumption.

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INTRODUCTION

The human aging process involves physiological changes that cause a decline in physical capacities, which can result in a reduction in the overall functionality of older adults[1,2]. To ensure active and healthy population aging, public policies aimed at the practice of physical exercises have been implemented in Brazil[3-5].

The project "Rio ao Ar Livre" (Open Air Rio, or RAL) was created in the city of Rio de Janeiro with the objective of guaranteeing access to and encouraging regular physical exercise among older adults through the construction of public gymnasium spaces with equipment operated by the user's own weight and strength[6]. The project has a training session protocol which takes the form of a mixed circuit (composed of aerobic and muscle strength exercises) guided by Physical Education professionals and applied in all its centers. However, it lacks an instrument for assessing physical fitness suitable for the specific characteristics of the circuit and its equipment[7].

The use of a physical fitness assessment instrument in exercise programs is important for guiding planning and adjustments aimed at achieving improved performance results among the subjects involved[7]. Thus, the implementation of a cardiorespiratory assessment instrument in RAL would be a simple and effective way to monitor the effect of this program[6,7].

Maximum oxygen consumption (VO_{2max}) is considered the best indicator of cardiorespiratory fitness[1]. Its direct measurement is obtained through maximum tests carried out in laboratories and requires specific[8] and expensive equipment, which prevents its use in public policies[9]. However, VO_{2max} can be calculated indirectly through field tests performed with submaximal exertion, a more accessible and applicable method for large populations[10].

In this context, the objective of the present study was to construct, validate and verify the reliability of a protocol for assessing the cardiorespiratory capacity of older people attending RAL, called the Outdoor Circuit Test (OCT).

METHODS

The present study adopted a cross-sectional approach, as it evaluates an instantaneous section of a population by means of sampling[11], in which the accuracy of the Outdoor Circuit Test (OCT) was determined by evaluating its validity and reliability. Validity was determined by comparing the data from the maximal cardiopulmonary exercise test (CPET) and the OCT, while reliability was defined through the reproducibility of the OCT measurements.

The sample consisted of all 50 older people (70.6±6.3 years) who attended the RAL center of the Universidade Federal do Estado do Rio de Janeiro (the State University of Rio de Janeiro) (UERJ), of both sexes and who performed different levels of physical exercise. The following exclusion criteria were adopted: a) presence of musculoskeletal problems that could impair exercise performance; b) lack of medical clearance to perform physical activities.

The study was carried out in accordance with Resolution 466, dated December 17, 2012 and approved by the Ethics Committee of the Hospital Universitário Pedro Ernesto (Pedro Ernesto University Hospital) of the Universidade do Estado do Rio de Janeiro (opinion No. 1,359,995).

Data collection was carried out by a single evaluator and took place at the Physical Activity and Health Promotion Laboratory (or LABSAU), of the UERJ Institute of Physical Education and Sport from March to July 2016. Data collection for the total sample was carried out in two visits, separated by intervals of 48-72 hours. On the first visit, an Informed Consent Form was signed; and anamnesis (where information was collected about the diagnosed diseases and the use of medicines) was carried out; height, body mass and waist circumference were measured; and the CPET was performed; on the second visit the OCT was performed. To determine the reproducibility of the OCT measurements, seven days after the second visit, a third assessment was performed with 20% of the sample, who repeated the test. As all the research subjects were active participants in RAL and their medical clearance was obtained via the CPET, they were already familiar with the data collection procedures of the present study.

The body mass and height measurements were performed following the standardized protocols of Gordon et al.[12], using a digital scale with a stadiometer with precision of 0.1 kg (Filizola, São Paulo, Brazil), while Body Mass Index (BMI) was determined by the quotient body mass (Kg) / (height, m)^2. Waist circumference, measured at its widest point, was measured in centimeters with an anthropometric measuring tape (Sanny, São Paulo, Brazil).

The CPET was performed on a cycle ergometer (Inbrasport, Porto Alegre, Rio Grande do Sul, Brazil) using an individualized ramp protocol[8]. Although this ergometer is considered unsuitable by some authors, as it induces greater peripheral fatigue[13], some studies support its use with older adults, since treadmills do not consider changes in gait, reduced levels of cardiorespiratory capacity, balance and strength, in addition to presenting a greater risk of falls, which accompany the aging process and influence its results[13-15].

The maximum ramp load was estimated from a non-exercise model to predict VO_{2max}[16]. The reason for the increase in loads was to allow a duration of the tests between 8 and 12 minutes. During the application of the tests, the temperature was between 18ºC and 22ºC and the relative humidity was between 50% and 70%, measured through a digital hygrometer HM-01 (São Paulo, Brazil). The test was considered to have reached maximum levels based on three of the following criteria: a) maximum voluntary exhaustion; b) obtaining a plateau for oxygen consumption with the evolution of loads at the end of the test; c) R>1.1; d) a Heart Rate (HR) greater than 95% of that predicted for age or the stabilizing of peak HR with the evolution of loads at the end of the test; e) a subjective perceived exertion scale (SPE) value greater than 9[17]. The gas exchange variables were measured by an Ultima gas analyzer (Medical Graphics, USA) and HR by an electrocardiogram (Welch Allyn, USA). For safety, the test was performed in the presence of a cardiologist.

The OCT consists of the performance, in the shortest possible time, of a mixed circuit[7] of aerobic and resistance exercises performed on RAL devices, at all facilities.

Figure 1 shows the division of the circuit into seven stations: four aerobic exercises (AE) - 1st, 3rd, 5th and 7th, and three resistance exercises (RE) - 2nd, 4th and 6th. The AE stations had a fixed time of five minutes each. The RE stations were performed alternating the upper and lower limbs. In the 2nd and 4th stations, six RE were performed with one series of 15 repetitions. The 6th season consisted of three exercises with two sets of 15 repetitions to balance the number of repetitions. The 2nd and 4th station REs were: vertical bench press, chair extension, pulley, free squat (sit and stand up from a bench), shoulder press, and flexor chair. Those from the 6th season were: seated leg press, seated rowing, calf leg press.

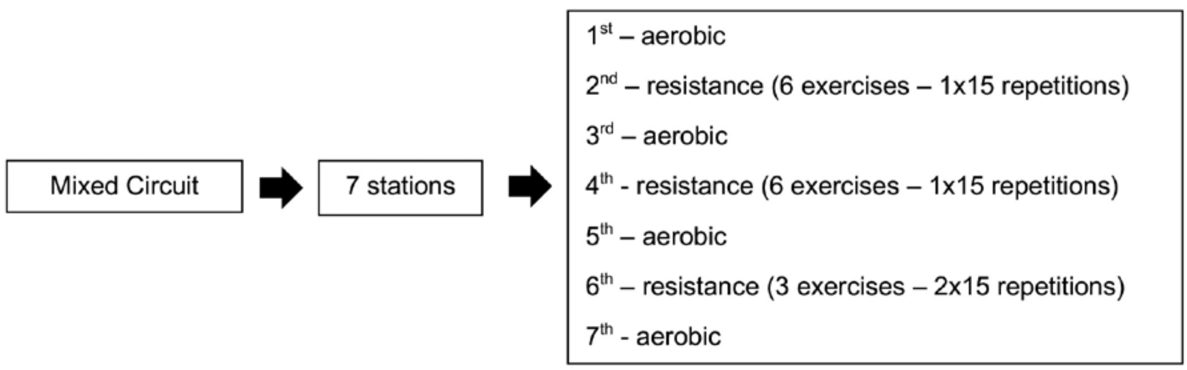

Figure 1. Mixed circuit carried out in Open Air Rio in the city Rio de Janeiro, RJ, 2014.

The circuit variables collected for possible inclusion in the predictive model were: a) Circuit Execution Time (CET) in seconds; b) Heart rate during final 30 seconds of the circuit (HR_{30s}) in beats per minute; c) SPE; d) Mean Heart Rate (HR_{mean}); e) Maximum Heart Rate (HR_{max}). These were chosen as they are easy to measure, since the predictive model developed is aimed at meeting government policy.

The SPE was identified using the Borg-Adapted Scale 0-10[17] at the end of each aerobic station (1st, 3rd, 5th and 7th) on the circuit. HR and CET were measured using the Polar V800 monitor (Polar, Kempele, Finland).

The normality of the variables was confirmed by the Kolmogorov-Smirnov test and its data was described by mean and standard deviation, minimum and maximum value. The reproducibility of the CET, HR and SPE was assessed by the Intraclass Correlation Coefficient (ICC), which considers R values above 0.90 as high; from 0.80 to 0.89 moderate; and below 0.80 questionable for physiological data[18]. Student's t test for independent samples was used to test differences between older people who used beta-blockers and those who did not.

To evaluate the predictive capacity of the circuit in relation to VO_{2max}, the stepwisefoward method of multiple linear regression was used. The variables were included in the model according to the significance of their contribution to the estimate and redundancy. The regression equation was calculated after testing for bias due to the potential presence of outliers and extreme cases. The final stability of the model was tested by analyzing residuals and calculating Cook distances. A value of $p \leq 0.05$ was adopted for statistical significance.

RESULTS

The characterization of the sample is shown in Table 1. Men represented 34% of the sample, while women made up 66%. The HR_{max}, HR_{mean} and HR_{30s} achieved during the circuit were 86±12%, 75±11% and 76±12% of the HR_{max} of the exertion test, respectively. The variation in terms of the HR_{max} during the circuit was 65 to 138%; the HR_{mean} variation was 55 to 120% and the HR_{30s} variation was 56 to 129% of the HR_{max} achieved in the exertion test.

In the CPET, no significant difference was observed between the VO_{2max} index of older adults who used beta-blockers and those who did not (16.2±1.9 *vs.* 16.1±4.0 ml/kg/min, respectively; p=0.92), while the HR_{max} of those who used such medication was lower (118±15 *vs.* 140±18 bpm, respectively; p=0.003). Likewise, in the OCT the HR was lower in the beta-blocker group (HR_{max}: 101±11 *vs.* 119±14 bpm; p=0.001; Average HR: 90±10 *vs.* 103±12 bpm; p=0.006; HR30s: 89±9 *vs.* 105±14 bpm; p=0.003).

Table 2 shows the reproducibility of the CET, HR and SPE measurements during the OCT. Reproducibility was satisfactory only for the variables CET, HR_{max} and HR_{30s}, as no significant differences were found between the average test and retest values (p-value) for these variables, and their ICC values were equal to or above 0.90.

The model generated the following prediction equation (R=0.64, R^2=0.41, SEE=2.86 ml.kg-^{1}.min^{-1}, F (5.43)=5.90, p<0.001): VO_{2max} (ml.kg^{-1}.min^{-1})=38.77 - 4.11 (sex; M=0, F=1) - 0.12 (age, years) + 0.19 (BMI, kg.m^2) - 0.13 (CET, min) - 0.13 (waist circumference, cm), according to the results shown in Table 3. In summary, our model was able to explain 41% of the variance in VO_{2max} (moderate association - r=0.64), with an approximate error of 3 ml.kg^{-1}.min^{-1}. After testing for outliers, only one case was excluded (female, 72 years old, 54.4 kg) to achieve maximum stability and precision of the model (final n=49).

Beta coefficients demonstrated that the relative contribution of each variable ranged between 7% and 56% (Table 3). Despite the minimal contribution of CET, the maintenance of this variable in the model is justified by the fact that it was able to increase R^2 and reduce SEE (Table 3).

Table 1. Sample characterization (n=50; M=17; W=33). Rio de Janeiro, 2020.

Variable	Mean (+sd)	Minimum-Maximum
General characteristics		
Age (years)	70.6±6.3	60-88
Body Mass (Kg)	69.3±11.2	45.6 – 99
Height (m)	1.59±0.08	1.45 - 1.77
Body Mass Index (Kg/m2)	27.2±3.9	19.0 - 36.1
Waist (cm)	95.7±10.2	79 - 119.5
Heart Rate (bpm)	68±11	41-98
Maximum Exercise Cardiopulmonary Test		
VO_{2max} (ml.kg^{-1}.min^{-1})	16.2±3.7	10 - 30.6
HR_{max} (bpm)	137±20	94 – 170
SPE	6.8±1.5	5 – 10
Outdoor circuit testing		
CET (min)	27.8±2.0	25.1 - 34.4
HR_{max} (bpm)	116±15	85 – 148
HR_{mean} (bpm)	101±13	78 – 132
HR_{30s} (bpm)	103±14	79 – 138
SPE	4.7±0.8	3.6

Source: author. Characterization based on mean, standard deviation, minimum and maximum values; M=Men; W=Women; VO_{2max}=maximum oxygen consumption; HRmax=maximum heart rate; SPE=subjective perception of exertion scale; CET=circuit execution time; HRmean=mean heart rate; HR30s=heart rate of the last thirty seconds of the circuit.

Table 2. Reproducibility of the circuit execution time (CET), maximum heart rate (HR_{max}), mean heart rate (HRmean), heart rate during the last thirty seconds of the circuit (HR_{30s}) and subjective perception of exertion (SPE) when performing the OCT (n=10; M=17, W=33). Rio de Janeiro, 2020.

Variables	Measurement 1 Mean (+sd)	Measurement 2 Mean (+sd)	p-value	ICC (95% CI)
CET (min)	27.6±1.2	27.4±1.2	0.25	0.93 (0.72 - 0.98)
HR_{max} (bpm)	118±15	116±14	0.55	0.90 (0.60 - 0.97)
HR_{mean} (bpm)	101±11	104±13	0.41	0.62 (-0.51 - 0.90)
HR_{30s} (bpm)	103±17	99±13	0.10	0.93 (0.72 - 0.98)
SPE	5.3±0.5	4.8±0.7	0.20	0.24 (-1.90 - 0.88)

Source: author, 2020. Reproducibility performed using the intraclass correlation coefficient (ICC) and paired t test for difference between means of test and retest measures; M=Man; W=Woman; 95% CI=confidence interval; CET=circuit execution time; HRmax=maximum heart rate; HRmean=mean heart rate; HR30s=heart rate of the last thirty seconds of the circuit. SPE=subjective perception of exertion.

Table 3. Predictive model of VO_{2max} in older adults (n=50; M=17; W=33). Rio de Janeiro, 2020.

Predictor variables	Nonstandard Coefficients		Standardized Coefficient	t(43)	*p*
	B	Standard Error	β		
Intercept	38.76	7.66		5.06	<0.001 *
Sex (female)	-4.11	0.96	-0.55	-4.27	<0.001 *
Age (years)	-0.12	0.07	-0.22	-1.79	0.08
BMI (Kg/m²)	0.18	0.17	0.21	1.07	0.29
Waist Circumf. (cm)	-0.13	0.06	-0.38	-2.12	0.04*
CET (min)	-0.13	0.22	-0.07	-0.58	0.56

Source: author. *Statistical significance (*p*-value<0.001); Multiple linear regression model – stepwise forward method; BMI=body mass index; CET=circuit execution time.

The adequacy of the predictive model was performed by testing residuals and calculating Cook distances; the model produced small residuals and low amplitude Cook distances.

DISCUSSION

The present study proposed the construction of an instrument to assess the cardiorespiratory capacity of older adults, considering the specific characteristics of the RAL project. This process consisted of testing the accuracy and reliability of OCT.

VO_{2max} can be accurately predicted from field tests, when a determined number of independent variables is used through multiple linear regression procedures[10]. However, previous studies with older people used step or walking protocols that have little specificity in relation to the exercises proposed in RAL[10,19-22].

The predictive model developed, based on age, sex, waist circumference, BMI and CET, explained 41% of VO_{2max} variance, with a standard error of the estimate of 18.5%, and exhibited adequate reproducibility.

However, although the model is significant for predicting the VO_{2max} of older adults, the multiple correlation coefficient (R=0.64) and the associated common variance (R2=0.41) suggest that, although valid, the percentage of explanation of the VO_{2max} of the model is low, compared to previous studies[14,19-23]. A probable explanation for this may be the use of a cycle ergometer to determine the direct measurement of VO_{2max}, as this equipment can induce greater peripheral fatigue[13]. However, its use is defended here as treadmills do not consider that changes in the gait of older adults, and their reduced levels of cardiorespiratory capacity, balance and muscle strength, influence results[13-15].

Another important fact that may have influenced the results is that the OCT involves performing combined, not just aerobic exercises. However, in view of the ideal of developing an assessment tool approximate to the reality of RAL, this proposal represents an option for professionals working in the project, despite its limitations[6,7,9].

It should be noted that there are VO_{2max} prediction protocols that do not involve exercise, but use information about the level of physical activity of older adults, which offer reasonable estimates about their cardiorespiratory fitness, and are widely accepted in this area[24]. However, they are not closely suited to the specific characteristics of RAL[10].

One positive point of the OCT prediction model is that the standard error of estimate observed (2.86 $ml.kg^{-1}.min^{-1}$) was lower than those observed in other proposed field tests[20-23], but the mean VO_{2max} of the sample represented 18.5% of the measured average, unlike other studies, which observed values from 9 to 15%[21,23]. Inaccuracy values close to 20% were also observed in older people in a bench test, in which the sample was similar in size to this study[14].

The variables sex, age, BMI and CET were also used in previous studies with older adults, which proposed VO_{2max} prediction equations based on submaximal bench tests[19] and walking[20-22]. The variables sex, age and BMI are also very common in VO_{2max} prediction equations which do not involve exercise, although models that contain information on the level of physical activity of the individuals provide more accurate estimates[24].

Among the studies included in the systematic review by Venturini et al.[10], only that by Jetté et al.[19] presented explanatory coefficients for each variable in the model. In the present study, it was found that the variables with the greatest explanatory power were sex and waist circumference. The variables: age, BMI and CET were added to the final model to provide a better fit.

In relation to the sample, 66% of the subjects were women, 16% used beta-blockers, and the average VO_{2max} values were 16.2 $ml.kg^{-1}.min^{-1}$, ranging from 10 to 30 $ml.kg^{-1}.min^{-1}$, representing low cardiorespiratory fitness. In previous studies, mean VO_{2max} values between 24-26 $ml.kg^{-1}.min^{-1}$ and 29.5-35.7 $ml.kg^{-1}.min^{-1}$ were observed[21]. It therefore cannot be stated that the present equation applies to older adults with higher levels of physical fitness. The study by Oja et al.[21], for example, found that the VO_{2max} prediction equation from the 2km walk test was not valid for highly active individuals.

It should also be noted that the regression model included both older adults who used beta-blockers and those who did not, as no significant differences were observed in their VO_{2max} levels in the maximum exertion test. A priori, this does not seem to be a problem, given that in the cross-validation sample of the study by Petrella et al.[23], no difference was observed between hypertensive and post-hip arthroscopy patients and healthy individuals.

The reproducibility analyzes found that the scores of the variables measured in the OCT were closely correlated in the two attempts made, presenting an intraclass correlation coefficient of between 0.62 to 0.93. Variables with ICC values above 0.90 were included in the model, as this was considered high for physiological data[18]. The variables that showed the highest reproducibility were CET and HR_{30s} (ICC=0.93). In addition to being valid, tests must be reproducible, as it is important to have stability in their measurements, helping to minimize measurement error. Tests with high reproducibility are important in studies involving interventions, as they provide confidence about their real effects[25].

Among the variables of the predictive model, CET is notable as it is an easily measured variable, which does not require specific equipment, keeping the cost of the test low. The CET reproducibility coefficient is similar to those observed in other studies with older adults, such as those that used the 6-minute walk test (r=0.88)[22] and the 2-km walk test (r=0.90)[21]. HRmean and SPE did not exhibit consistency in the measurements. A possible explanation for this is that the predictive relationship between SPE and HR in older adults has not been clearly defined. Even in the study by Oja et al.[21], SPE was not considered a predictor of VO_{2max} in the 2km walk test.

Limitations of the present study include the lack of sample calculation, the lack of a cross-validation step to verify the external validity of the OCT, the generalization of the model in terms of sex, and possibly the use of the cycle ergometer in the execution of the CPET. In the present study, we chose to form the sample only with the regular users from the UERJ hub, as this had the status of an Academy School at the time of data collection, the objective of which was precisely to develop studies to scientifically support the project. However, a sample calculation would have been important to guarantee the representativeness of the older adult population using RAL. Likewise, cross-validation could show whether the OCT has external validity[18], which is important considering that the project covers different regions of Rio de Janeiro. Furthermore, a gender-specific model could increase the explanatory power of VO_{2max} of older people attending RAL[18], considering the biological differences between men and women. Finally, the use of the treadmill in the performance of the CPET, while it also represents limitations in the case of older adults, could provide greater coefficients for explaining the variance of VO_{2max}[8].

CONCLUSION

The present study constructed a valid and reliable assessment tool for predicting the cardiorespiratory capacity of older adults attending RAL.

As a field test, the OCT has the advantage of being simple, easy to apply and specific to the RAL project. It may be a viable alternative when direct measurement of VO_{2max} is not possible. Thus, it is understood that the OCT can be used to obtain results capable of comparing and classifying the conditioning of the participants of the RAL project, which is essential for improving the effectiveness of the training provided. It is not enough that a practice is guided, but, especially, that such guidance should be based on the real physical conditions of each practitioner.

Another advantage that should be highlighted is that the OCT serves especially to motivate participants and monitor their physical condition from the moment when the reduction in the time needed to execute the circuit implies an improvement in their physical condition, which may impact on the behavioral change of the older adults, in order to optimize the performance of the exercises to increase their physical conditioning. In this sense, this study has great potential for practical application.

A suggestion for future studies is to include the level of habitual physical activity as a possible predictor of VO_{2max} in older adults in new models, as it is known that the nature and intensity of daily physical activities influence the cardiorespiratory fitness of individuals.

Finally, it is emphasized that the implementation of the RAL project already represents, in itself, a major advance in terms of public health for the older population of the city of Rio de Janeiro, and the undertaking of studies that seek to contribute in some way to improving the project is important to give it a scientific basis, making the practice of physical exercises in these spaces more effective and safer for older adults.

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