Universidade de Aveiro Escola Superior de Saúde
2015

Tânia Maria Pereira de Pinho

Equação Preditiva para o Teste de Marcha com Carga Progressiva em Adolescentes

Predictive Equation for Incremental Shuttle Walk Test in Adolescents

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Fisioterapia, realizada sob a orientação científica da Doutora Alda Sofia Pires de Dias Marques, Professora Adjunta da Escola Superior de Saúde da Universidade de Aveiro.

O júri

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Palavras-chave Condição Cardiorrespiratória; Teste de Marcha com Carga Progressiva; Equação Preditiva; Adolescentes.

Sumário

Enquadramento: O teste de marcha com carga progressiva (TMCP) é das medidas mais usadas para a avaliação da condição cardiorrespiratória em contexto clínico e de investigação. Têm sido estabelecidas equações de referência para prever a distância percorrida no TMCP em diferentes populações. No entanto, não existe uma equação para adolescentes Portugueses.

Objetivos: Este estudo teve como objetivo desenvolver uma equação de referência para prever a distância do TMCP para adolescentes portugueses.

Métodos: Participaram neste estudo transversal adolescentes saudáveis com idades compreendidas entre os 12-17 anos. Foram recolhidos dados sócio-demográficos (sexo e idade) e antropométricos (índice de massa corporal - IMC) dos participantes. A função pulmonar foi avaliada por espirometria e a força muscular do quadricípite (FMQ) foi medida com dinamometria manual digital. O nível de atividade física foi avaliado com o Índice de Atividade Física (IAF). O TMCP foi realizado duas vezes, de acordo com as recomendações internacionais. A melhor performance foi utilizada para análise descritiva e inferencial.

Resultados: Um total de 125 participantes (56 masculino, 69 feminino; 14,6±1,3 anos de idade) com função pulmonar normal (volume expiratório máximo no primeiro segundo=104.8±14.9% previsto) completaram a avaliação. De acordo com a pontuação do IAF, 54.4% (n=63) dos participantes eram moderadamente ativos e a média da FMQ foi de 20.7±6.8 kgf. Os participantes percorreram em média 1254.0±280.9 (760-2250) metros no TMCP. Um modelo de regressão linear múltipla mostrou que o sexo, IMC, FMQ e IAF contribuem independentemente para o TMCP, explicando 54% da sua variabilidade ($p<0.05$). A equação de referência encontrada foi: TMCP= 814.49 + (286.80 x sexo) - (3.05 × IMC) + (8.83 × FMQ) + (22.30 × IAF), sexo: feminino = 0, masculino = 1.

Conclusão: Sexo, IMC, FMQ e IAF integraram a equação preditiva do TMCP para adolescentes, permitindo uma referência simples para prever a sua condição cardiorrespiratória. A equação preditiva é uma ferramenta valiosa para interpretar os resultados do TMCP em populações pediátricas, saudáveis ou com patologia.

Keywords Cardiorespiratory Fitness; Incremental Shuttle Walk Test; Predictive Equation; Adolescents.

Abstract

Background: The incremental shuttle walk test (ISWT) is one of the most used measures to assess cardiorespiratory fitness in clinical and research settings. Reference equations to predict ISWT distance (ISWD) in different populations have been established. However, an equation for Portuguese adolescents is not available.

Aim: This study aimed at developing a reference equation to predict the ISWD for Portuguese adolescents.

Methods: Healthy adolescents aged 12–17 years old participated in this cross-sectional study. Participants' socio-demographic (sex and age) and anthropometric (body mass index (BMI)) data were collected. Lung function was assessed through spirometry and quadriceps muscular strength (QMS) was recorded with a hand-held dynamometer. Physical activity level was scored with Physical Activity Index (PAI). The ISWT was performed twice as recommended. The best ISWD was used for descriptive and inferential analysis.

Results: A total of 125 (56 male, 69 female; age 14.6±1.3 years old) participants with normal lung function (forced expiratory volume in one second=104.8±14.9% predicted) completed the assessment. According to PAI score, 54.4% (n=63) of the participants were moderately active and QMS mean was 20.7±6.8 kgf. Participants walked on average 1254.0±280.9 (760–2250 m) meters in the ISWT. A multiple regression model showed that sex, BMI, QMS and PAI were independent contributors to the ISWD, explaining 54% of the variability ($p<0.05$). The derived reference equation was: ISWD= 814.49 + (286.80 × sex) - (3.05 × BMI) + (8.83 × QMS) + (22.30 × PAI), sex: female=0, male=1.

Conclusion: Sex, BMI, QMS and PAI score were found to be contributors to the ISWD predictive equation for adolescents, providing a simple reference to assess their cardiorespiratory fitness. The predictive equation is a valuable tool to interpret ISWT results obtained from paediatric populations, both healthy and with pathology.

Abbreviations and/or acronyms

BMI: body mass index

BP: blood pressure

COPD: chronic obstructive pulmonary disease

CPET: cardiopulmonary exercise test

CRF: cardiorespiratory fitness

FEV_1: forced expiratory volume in one second

FVC: forced vital capacity

HHD: hand held dynamometer

$HR_{max.\ pred.}$: maximal heart rate predicted

HR: heart rate

ICC: intraclass correlation coefficient

ISWD: incremental shuttle walk distance

ISWT: incremental shuttle walk test

mBS: modified Borg Scale

MID: minimal important difference

PAI: physical activity index

QMS: quadriceps muscular strength

r: Pearson coefficient

R^2: R–squared

r_{pb}: point-biserial correlation

RR: respiratory rate

SD: standard deviation

SpO_2: peripheral oxygen saturation

VO_2: oxygen uptake

VO_{2peak}: peak oxygen uptake

% $HR_{max.\ end.}$: percentage of HR achieved in the end of the test

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1. Introduction

Evaluation of exercise capacity and cardiorespiratory fitness (CRF) is a common practice in preventive and rehabilitative exercise programmes to establish prognosis and response to treatment (1).

Laboratory tests, such as cardiopulmonary exercise test (CPET), are largely recognised as the gold standard to assess CRF (1). However, in routine clinical practice, they can be unviable (2–4), due to the high cost involved, the need for sophisticated equipment and human resources (5). Quite the reverse, field tests require minimal equipment and are easy to perform (6). The time- and distance-limited tests to assess walking capacity are quick to apply, simple and can be administered in both clinical and research settings (7). The incremental shuttle walk test (ISWT) is among the most used field tests (8) to evaluate exercise capacity.

The ISWT was designed by Singh and colleagues (9) based on the 20 metre shuttle run test (10) to assess functional exercise capacity of patients with chronic obstructive pulmonary disease (COPD). The objective of this field test is to walk as long as possible in a 10 metre length course, maintaining the speed required by the audio signals (11). The test is defined as an externally paced maximal exercise test, ordered by a series of pre-recorded signals, and incremental, in which the walking speed increases until the participant can no longer continue (9).

The incremental nature of the ISWT stresses the cardiopulmonary system and generates a physiological response to exercise (12), replicating, in the field, a similar response as a CPET (11). Previous validation studies in populations with COPD showed a strong relationship between oxygen uptake (VO_2) in both CPET and ISWT (r from 0.75 to 0.88) (13–16). Moreover, there was no difference in measured VO_2 between CPET and ISWT (5,17,18). Physiological parameters, such as carbon dioxide production and minute ventilation, are usually lower during the ISWT performance (19). A peak oxygen uptake (VO_{2peak}) minute-by-minute analysis verified a linear response between ISWT and CPET (5). This indicates that both tests generate a similar cardiopulmonary response (19). Recent literature suggests that the ISWT is a valid measure of cardiopulmonary exercise capacity in populations with COPD (19). A study on its reliability has also been conducted in patients with COPD (n=30) and reported an intraclass correlation coefficient of 0.88 with a 95% CI of 0.83–0.92 (20). The minimal important difference (MID) for ISWT, in adults with chronic respiratory diseases is a change of 47.5 meters (19).

The ISWT has been largely used to assess exercise capacity in patients with COPD (21–25). However, it has also been applied in other adult populations with bronchiectasis (3,26), cancer

(27–29), cardiac disease (4,30–34), critical illness (35), cystic fibrosis (36), intellectual disabilities (37), interstitial lung disease (38), obesity (39) and pulmonary hypertension (40). Yet, in younger populations, ISWT has only been used in healthy and with cystic fibrosis children (41) or with cerebral palsy (42). Nonetheless, references values are needed to interpret the ISWT performance in paediatric populations.

Recently, reference values and regression equations for predicting ISWT distances in adult healthy individuals from 18 to 90 years have been published (8,12,43–45). In paediatrics, only one study has published preliminary ISWT reference values for the Brazilian population (46). For the Portuguese population, an academic work (non published) has recently contributed for the development of a paediatric predictive equation (47). Although commonly used in adults, the ISWT is less explored as a tool for assessment of exercise capacity in paediatric population. However, given its advantages a paediatric reference equation to predict the distance may contribute to overcome this gap in literature.

Therefore, the aim of this study was to establish an ISWT reference equation for the Portuguese healthy adolescent population.

2. Methods

2.1. Ethics

Ethical approval was previously obtained from the Ethics Committee of the Research Unit of Health Sciences at the School of Nursing in Coimbra, Portugal (P 246-12/2014) (Annex I). Further authorisations to apply the study were requested and obtained from School Boards of two schools in Aveiro, Portugal (Annex II). Prior to any data collection, written informed consents were obtained from adolescents and their legal representatives (48).

2.2. Design and Participants

A cross-sectional study was conducted. Two schools from the region of Aveiro were contacted and both accepted to participate. Each school director nominated a responsible from the school board to assist with the study implementation. A meeting was then arranged with each responsible to provide further explanations and deliver written information about the study (Appendix I) as well as distribute informed consents (Appendix II).

Adolescents were eligible if: i) aged 12 to 17 years old; ii) provided their informed consent and iii) presented an informed consent form signed by the legal representative. Exclusion criteria included: i) existence of neurological impairment or significant cardiopulmonary and/or musculoskeletal disorders and ii) any other significant contraindication that could affect physical tests performance, such as visual or hearing impairments.

2.3. Procedures

Socio-demographic, clinical and anthropometric data were first collected to characterise the sample. A questionnaire to evaluate the level of physical activity was filled in. A spirometry was performed to ensure normal lung function. Then, quadriceps muscle strength (QMS) was measured. Finally, two ISWTs were performed with, at least, 30 minutes of resting between them, as recommended (3,45).

2.4. Measures

A structured questionnaire was used to collect socio-demographic (sex and age), general clinical information (medication, exposure to environmental risk factors and clinical history), anthropometric data (weight and height to calculate body mass index (BMI) percentile) and physical activity level to characterise the sample.

Weight (in kilos) and height (in centimetres) were assessed, with participants in underwear and barefoot, using a Jofre® mechanical weight and height counter scale, to the nearest 0,1 kg and 0,5 cm, respectively. For children and adolescents (5-19 years old), BMI is age- and sex-specific and is frequently referred to as BMI-for-age (49). Percentiles are the most frequently used indicator to assess size and growth patterns of individual children and adolescents (49). In order to accurately determine the BMI percentile of each participant, an application tool available in the World Health Organization website (http://www.who.int/growthref/tools/en/), with an anthropometric calculator, was used (50). All BMI referred in this study are age- and sex-specific and will be mentioned as BMI. The percentile ranges correspond to a weight status category: less than the 5th percentile–underweight, 5th percentile to less than the 85th percentile–healthy weight, 85th to less than the 95th percentile–overweight and equal to or greater than the 95th percentile–obese (49).

The physical activity level was collected using the Physical Activity Index (PAI) (51). The PAI is composed of 5 questions and answers are scored from 1 to 4 points. Final score ranges from 5 to 20 points, in which high values indicate a higher physical activity level, and can be divided in 4 categories: 5 sedentary, 5–10 low active, 10–15 moderately active and 15–20 vigorously active (51). This questionnaire has been validated to the Portuguese population (51,52), demonstrating excellent values of test-retest reliability (intraclass correlation coefficient=0.92–0.96) and good internal consistency (Cronbach's alpha=0.87) (52).

Lung function was assessed with a spirometric test performed as described by Miller *et al* (53), to ensure normal lung function of all participants. Spirometry is a simple and non-invasive test and is indicated to assess health status before vigorous physical activity exercise to identify the presence of restrictive or obstructive respiratory abnormalities (1). The most frequently measurements considered in spirometry include the forced vital capacity (FVC), forced expiratory volume in one second (FEV_1) and FEV_1/FVC ratio (1). Spirometry was performed before the ISWTs using a portable spirometer (MicroLab 3500, CareFusion, Kent, UK). The participant was encouraged to execute a maximal inspiration, then a blast of exhalation and maintain the exhalation until completely breathing out (53). The best out of three tests was considered (53).

Hand held dynamometry allows the assessment of muscular strength, is easy to use and only requires a portable and compact size equipment (54). Muscle strength is a parameter to determine the presence of pathological muscle weakness or to evaluate the efficacy of an intervention (55). Quadriceps muscular strength was assessed with a hand held dynamometer (Hoggan MicroFET2 Muscle Tester, Model 7477, Pro Med Products, Atlanta, GA), in kilogram of force (kgf). Participants were sitting on a chair, with the knee flexed 90°, hip flexed 90° and straight trunk. The hand held dynamometer was placed in the anterior surface of the dominant leg, proximal to the ankle (5 cm above lateral malleolus). The participant performed at least one practice trial to understand the movement and the adequate stabilisation. Then, two trials were performed with a ten seconds contraction followed by a sixty second rest period. The mean of the values acquired was considered for analysis (56).

Incremental shuttle walk test protocol was applied as described by Singh *et al* (9) and Probst *et al* (45). This is an externally paced maximal exercise test, controlled by pre-recorded signals that command the walking speed (43). The walking speed increases 0.17m/s each minute, starting at 0.5m/s, until the participant can no longer carry on with the test. The audio signals continued until subjects reach their maximal effort, exceeding the 12 levels of speed recommended by Singh *et al* (9) protocol (45). This proposed adaptation was needed to avoid a ceiling effect, considering that participants were healthy and could possibly reach more than the 12^{th} level to get their maximal performance(45). The ISWT is a valid and reliable test when assessing maximal exercise capacity in individuals with chronic respiratory diseases (19,57). Previous research showed that ISWT is a reproducible and valid measure to assess the function-limited aerobic capacity also in children with cystic fibrosis (6 to 16 years) (58). A brief standard explanation about the test was previously provided by an audio record (11). Participants were instructed to walk or run if necessary between the two markers (Figure 1) in time ordered by audio signals, for as long as possible until being too breathless or could not perform the distance within the beep time in two consecutive times. The ISWT was performed twice for the learning effect and the best result was considered for analysis (6,19). Thirty minutes of rest were allowed between the two tests. The distance (in meters), the level and the number of shuttles achieved were recorded. The reason to end the test was also registered.

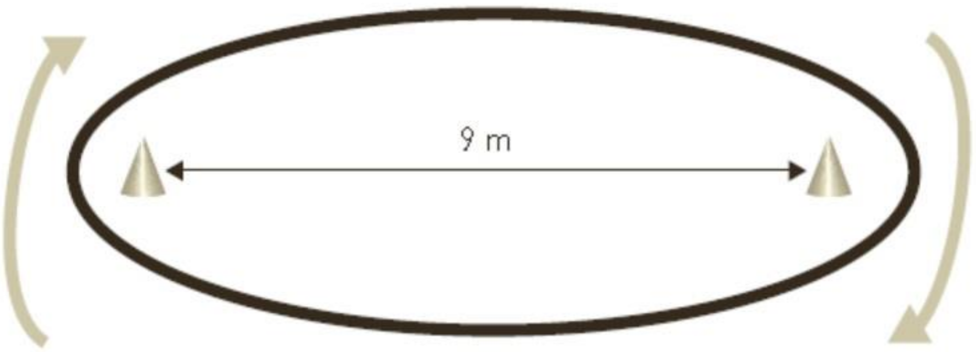

Figure 1 Course layout scheme for the ISWT. Cones are inset 0.5 m from either end (Adapted from (11)).

To ensure participants' safety, physiological responses to ISWT performance such as dyspnoea, fatigue, heart rate, peripheral oxygen saturation, arterial blood pressure and respiratory rate (RR) were monitored before and after the two ISWTs, in sitting position (1). Dyspnoea and fatigue were measured with the modified Borg Scale (mBS), due to the good correlation with the VO_{2peak} (59). The mBS ranges from 0–10 points, where 0 means no difficulty at all and 10 a maximal difficulty in either breathing or fatigue (60,61). The heart rate and peripheral oxygen saturation were measured by a pulse oximeter (PULSOX-300i, Konica Minolta Sensing, Inc., Osaka, Japan) in the non-dominant hand indicator and arterial blood pressure with a blood pressure monitor (Elite, Medel, Parma, Italy). Arterial blood pressure was measured at heart level in the left harm, with the participant in sitting position; harm and hand were relaxed and supported by a table (1). Respiratory rate was measured through clinical observation, in 15 seconds intervals and then multiplied by 4, to determine the number of respiratory cycles for 1 minute (20).

2.5. Data Analysis

Data were analysed using IBM SPSS Statistics version 22 (SPSS Inc., Chicago, Illinois, IL). Descriptive statistics was first applied to characterise the sample (*i.e.*, socio-demographic and anthropometric data, PAI score, lung function and QMS and the best performance of ISWT (*i.e.*, distance, number of shuttles, level and physiological responses). Data were described as mean±standard deviation (SD) or as frequencies. The predicted maximal heart rate ($HR_{max.\ pred.}$) for each participant was calculated according to the formula 206.9 - (0.67 × age) (62) as well as the percentage of the $HR_{max.\ pred.}$ achieved in the end of the test. The normality of data distribution was confirmed with Shapiro-Wilk tests (63).

Pearson correlation coefficients (r) were used to measure the strength of association between continuous variables (age, weight, height, BMI, $HR_{max.\ prev.}$, QMS and FEV_1%) and incremental shuttle walk distance (ISWD). The point-biserial correlation coefficient (r_{pb}) is a special case of Pearson correlation in which one variable is dichotomous and nominal (sex) and the other variable is quantitative (ISWD) (64). The value of the correlation coefficient, for both Pearson and point-biserial coefficients, varies between +1 and -1. If the value of the correlation coefficient lies around ±1, a strong association between the two variables is confirmed. As the correlation coefficient value goes towards 0, the relationship between the two variables is weaker. Correlation can be categorised in accordance with absolute value of r or r_{pb}: ≤0.35 weak correlation; 0.36–0.67 modest correlation; 0.68–1.0 strong correlation; ≥0.90 very high correlation (65).

A model of multiple linear regression, using the Enter mode, was applied to estimate the best predictor model for ISWT distance. ISWD was the dependent variable and demographic and anthropometric data, PAI score and QMS were the independent variables. The assumptions of linearity, independence of errors, homoscedasticity, unusual points and normality of residuals were analysed. ANOVA and R-squared (R^2) were used to assess the performance of the model.

Measured ISWDs were compared with the values obtained with the predicted equation proposed in the present study and with other two predictive equations from Silva (47) and Lanza *et al.* (46) using paired-samples t-tests. Correlations were also explored with Pearson correlation coefficients.

The level of significance considered was set at $p<0.05$.

3. Results

3.1. Participants' characteristics

A total of 125 healthy participants (56 male and 69 female) completed the assessment. Participants' detailed characterisation is summarised in Table 1. Participants' mean age was 14.6±1.3 years old. Most participants had a normal BMI (n=102; 81.6%) and lung function (FEV_1 104.8±14.9% predicted) according to their age and sex. Based on the PAI score, 54.4% of the participants (n=63) were moderately active.

Table 1 Characteristics of the sample (n=125).

Characteristics	Value
Male/Female	56/69
Age (years)	14.6 ± 1.3 (12 – 17)
Weight (kg)	55.9 ± 11.7 (32 – 99)
Height (m)	1.6 ± 0.1 (1.4 – 1.9)
BMI-for-age (percentile)	50.3 ± 28.44 (0.2 – 99.1)
PAI score	12.9 ± 3.4 (5 – 19)
$FEV_{1\ predicted}$ (%)	104.8 ± 14.9 (55 – 135)
$FVC_{predicted}$ (%)	98.6 ± 13.2 (51 – 125)
FEV_1/FVC (%)	94.1 ± 8.9 (79 – 118)
QMS (kgf)	20.7 ± 6.8 (7.1 – 34.0)

Data are presented as mean ± SD (range), unless otherwise indicated.

BMI: body mass index; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; PAI: Physical Activity Index; QMS: quadriceps muscular strength.

3.2. Characterisation of the ISWT

Table 2 presents the outcomes of the best performance on the ISWT and the respective physiological responses. The mean ISWD was 1254.0±280.9 meters. The mean number of shuttles performed was 125.4±28.1 and the level achieved 13.9±1.7.

Table 2 Outcomes of the Incremental Shuttle Walk Test (n=125).

Parameters	Mean ± SD (range)
Distance (m)	1254.0 ± 280.9 (760 – 2250)
Number of Shuttles	125.4 ± 28.1 (76 – 225)
Level	13.9 ± 1.7 (11 – 19)
Pre Dyspnoea	0.2 ± 0.5 (0 – 3)
Post Dyspnoea	5.8 ± 2.3 (0 – 10)
Pre Fatigue	0.3 ± 0.9 (0 – 5)
Post Fatigue	6.6 ± 2.1 (0 – 10)
Pre HR (bpm)	79.7 ± 13.7 (48 – 110)
Post HR (bpm)	132.7 ± 35.4 (65 – 207)
$HR_{max.\ pred.}$ (bpm)	197.1 ± 0.9 (195.5 – 198.9)
% $HR_{max.\ end.}$ (%)	67.3 ± 18.0 (33.0 – 105.5)
Pre SpO_2 (%)	97.5 ± 2.4 (84 – 100)
Post SpO_2 (%)	95.8 ± 3.0 (83 – 100)

BP: blood pressure; HR: heart rate; RR: respiratory rate; SpO_2: peripheral oxygen saturation; % $HR_{max.\ end.}$: percentage of HR achieved in the end of the test.

3.3. Associations with ISWD

Table 3 presents the correlations between the ISWD and several variables collected within this study. There was no correlation between the ISWD and age, weight, $HR_{max.\ pred.}$ or FEV_1, $p > 0.05$. Correlations were weak between the ISWD and height (r=0.30) and BMI (r=-0.20); and moderate between the ISWD and sex (r=0.53), PAI score (r=0.40) and QMS (r=0.38).

Table 3 Pearson Correlation Coefficients between ISWD and its determinants.

	r	*p*-value
Sex	0.53	<0.001
Age (years)	0.06	0.497
Weight (kg)	0.00	1.000
Height (m)	0.30	0.001
BMI-for-age (percentile)	-0.20	0.029
FEV_1 (%)	0.07	0.497
$HR_{max. pred.}$ (bpm)	-0.61	0.497
PAI score	0.40	<0.001
QMS (kgf)	0.38	<0.001

BMI: body mass index; FEV_1: forced expiratory volume in one second; $HR_{max. pred.}$: heart rate maximum predicted; PAI: Physical Activity Index; QMS: quadriceps muscular strength.

3.4. ISWD predictive equation

The assumptions of linearity, independence of errors, homoscedasticity, unusual points and normality of residuals were verified. A multiple linear regression was run to predict ISWD from sex, BMI, PAI score and QMS. These four variables were statistically significant predictors of the ISWD (ANOVA $p<0.001$) and together explained 54% of their variability ($R^2=0.54$). Unstandardised regression coefficients (B), standard errors of the coefficients and standardised coefficients (β) are presented in Table 4.

Table 4 Summary of multiple regression analysis for ISWT distance as dependent variable.

Variable	B (95% CI)	*Std. Error*	β	*p*-value
(Constant)	814.49 (628.65 – 1000.33)	93.62		<0.001
Sex	286.80 (202.55 – 371.05)	42.44	0.48	<0.001
BMI-for-age (percentile)	-3.05 (-4.46 – -1.64)	0.71	-0.30	<0.001
PAI score	22.30 (10.67 – 33.93)	5.86	0.27	<0.001
QMS (kgf)	8.83 (2.60 – 15.07)	3.14	0.21	0.006

BMI: body mass index; PAI: Physical Activity Index; QMS: quadriceps muscular strength.

Based on the multiple linear regression model, the equation to predict ISWD from sex, BMI, PAI score and QMS was:

$$ISWD = 814.49 + (286.80 \times sex) - (3.05 \times BMI) + (8.83 \times QMS) + (22.30 \times PAI)$$, sex: female=0, male=1.

BMI: body mass index; PAI: Physical Activity Index score; QMS: quadriceps muscular strength.

3.5. Comparisons with other predictive equations

Paired-samples t-test showed that the ISWDs measured and the predictive ISWDs obtained from the proposed equation of this study were not significantly different (mean difference 26.9±219.9m; p=0.174) (**Erro! A origem da referência não foi encontrada.**). Nevertheless, the ISWDs measured in the present study and the predictive ISWDs from Silva (47) (mean difference 232.2±274.3 m; p<0.001) and from Lanza et al. (46) (124.4±281.3m; p<0.001) were, however, significantly different. ISWDs achieved in this study were higher (1254.0±25.1m), than the predicted from the equations from Silva (47)(1221.8±19.9 m) and Lanza et al. (46)(1129.6±3.6 m).

Table 5 Summary of the Paired-samples t-test between the ISWDs and other two predictive equations.

Paired-samples	*Mean difference (95% CI)*	*Std. Deviation*	*p-value*
Actual ISWDs – Present study's equation	26.9 (-12.013 – 65.853)	219.9	0.174
Actual ISWDs – Silva's equation (47)	232.2 (183.7 – 280.8)	274.3	<0.001
Actual ISWDs – Lanza's *et al.* equation (46)	124.4 (74.6 – 174.2)	281.3	<0.001

ISWDs: distances performed in the ISWT by the participants in the present study

Modest correlations were found between the ISWDs measured in the present study and the predicted values with the equation proposed in this study (r=0.64; *p*<0.001) and the equation established by Silva (47) (r=0.43; *p*<0.001). The correlation between the ISWDs measured in the present study and the predicted values with the equation from Lanza *et al.* (46) was weak and not statistically significant (r=0.06; *p*=0.497). These correlations are shown in Figure 2.

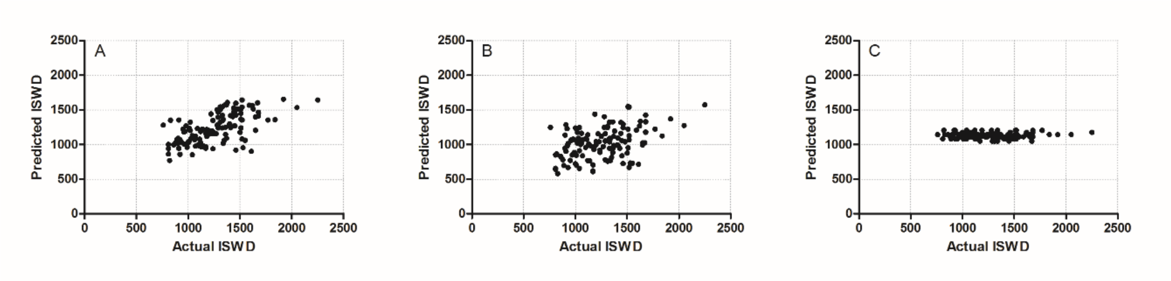

Figure 2 Scatterplots of the correlations between the ISWDs performed and the predicted ISWDs from the equations proposed (A) in this study, (B) by Silva (47) and (C) by Lanza *et al.* (46).

4. Discussion

The present study established a predictive equation for ISWT distance in healthy adolescents. The predictive equation included sex, BMI, QMS and PAI score as independent variables. Results of the present study demonstrated that the mean ISWT distance for healthy adolescents aged 12–17 years old was 1254.0±280.9 meters, with a large variability (760–2250 meters). This variability can be explained by different demographic and anthropometric variables such as sex, height and body weight, muscular strength condition and physical activity levels. Large variability in ISWD has also been reported due to similar reasons, in a study with healthy adults aged 18–83 years old (45).

A regression equation was established using contributors such as sex, BMI, QMS and PAI score. These independent variables explained 54% of the ISWT variance. Recent literature reported similar R^2 values in predictive equations for ISWD in healthy adults; one study using age, height, weight and sex (R^2=71%) (45) and the other using age, BMI, FEV_1, quadriceps muscular voluntary contraction and an activity status index (R^2=50%) (43). Previous studies, with different samples, (8,12,44,45), support the integration of sex in predictive equations for ISWD. The negative weak correlation observed between ISWD and BMI means that, for higher values of BMI, the distance covered in the ISWT was smaller. This may be related to the effort required to perform the walking test due to higher participants' weight. Kantanista (66) and colleagues suggested a relationship between the increase of body fat in the adolescence and the lower levels of physical activity. Besides socio-demographic and anthropometric variables, muscular strength was also considered, through the QMS and a moderate correlation (r=0.38) with ISWT distance was observed. Recently, Harrison (43) has also measured additional variables, which have not been considered previously, such as quadriceps muscular voluntary force, to explain a greater percentage of the variance of a predictive equation in healthy individuals. This relationship had already been proposed by Steiner (67) in a study with patients with COPD.

A good correlation has also been observed between ISWD and PAI score (r=0.40) suggesting that a higher PAI score indicates a better physical fitness and consequently a better performance in the walk test. This relationship was expected considering that it was reported in prior study with adult population. (43). The variables with higher correlations with the ISWD also had a higher contribution in the predictive equation for ISWD, with higher regression coefficients: sex with 286.80 and PAI score with 22.30. Other studies also showed sex as the strongest predictor in their equations (44,45). In the present study, variables with weak correlations with ISWD, such as QMS and BMI, also had weak contributions in the predictive equation.

Recently, a research group published preliminary results for a reference equation for the ISWD in Brazilian children (mean age 8±1 years), using age as independent variable, with a low coefficient of variation (R^2=13%) (46). When applying their equation to the sample of the present study, the actual distance performed was greatly underestimated. This may be due to the different age-range used, since the sample of the present study was composed of adolescents (12-17 years old), whereas the Lanza and colleagues study (46) included children (mean age 8 years old). The specific anthropometric characteristics, such weight and height, of children can also justify the verified underestimation. This underestimation was not observed when the equation established in this study was used. In addition, other comparison was performed with a predictive equation for the ISWD, which included the variables sex, age, weight and QMS, in Portuguese children aged 5–17 years old (47). This equation also underestimated the predictive distance for ISWT. Although both samples are from paediatric Portuguese population, they refer to different age ranges, with specific anthropometric characteristics and physical activity levels. This highlights the need and importance of establishing reference equations adapted to socio-demographic, anthropometric and cultural contexts of the population, which can be easily applied in clinical and research settings.

As supported by Jürgensen (44), reference equations are valuable tools for evaluating ISWT results obtained from patients with chronic diseases as much as in other populations, considering the external paced nature of the walk test and the inexistence of interference of external factors, such as operator encouragement. This emphasises the application of predictive equations established for healthy individuals as well as to individuals with any condition. Other motivation to establish reference equations is the simplicity to predict the ISWD to any adolescent without having to perform the ISWT, requiring simple measures obtained in clinical practice. This allows physiotherapists to prescribe individualised aerobic exercises and adequate levels of physical activity to adolescents' physical condition, as well as its adjustment when necessary. Other use to the predictive equations is to follow the evolution in rehabilitation programmes and easily compare healthy and other conditions' populations.

Some limitations of this study should be considered. As observed in other studies, it was expected that age influenced the model of the predictive ISWD equation, which did not occur. This may be due to the low variability in the age range considered in this study (12–17 years old). In previous investigations, age was retained in the predictive model, with samples with larger age variability (8,12,44,45). The obtained coefficient of determination was modest (54%), increasing the chance of bias in predicting the walking distance in the ISWT. This finding confines the generalisation of the predictive equation to the Portuguese adolescents' population. In future research, it is recommended that this protocol is replicated with a larger sample. Other recommendation to strengthen the predictive model equation found and to generalise it, is to add samples of adolescents from different regions of the country. In alternative to the mathematical multiple linear regression model used in the present study, it might be interesting to compare it with an artificial neural network-based equation model. This mathematical model is based on some properties of the biological nervous system and on the analogies of adaptive biological learning (68). This method uses a networks' combination of the inputs and the learning effect to find the best functional fit for a set of input-output examples (69).

5. Conclusions

This study established a predictive equation for ISWT distance, where Sex, BMI, QMS and PAI score were major contributors, accounting for 54% of the variability of the ISWD. This predictive equation is a valuable tool to interpret ISWT results obtained from paediatric populations, both healthy and with chronic diseases. Furthermore, this predictive equation can be used to support the design of interventions for healthy adolescents and adolescents with impaired exercise capacity or with chronic diseases.

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Annex I – Ethics’ approval

COMISSÃO DE ÉTICA

da **Unidade Investigação em Ciências da Saúde - Enfermagem** (UICISA: E)

da **Escola Superior de Enfermagem de Coimbra** (ESEnfC)

Parecer Nº 246-12/2014

Título do Projecto:
Promoção da actividade física pediátrica através da monitorização e feedback de uma aplicação de *smartphone*

Identificação do Proponente

Nome(s): Joana Batista de Castro Pinto; Tânia Maria Pereira de Pinho

Filiação Institucional: Escola Superior de Saúde da Universidade de Aveiro
Investigador Responsável/Orientador: Profª Doutora Alda Sofia Pires de Dias Marques

Relator: José Carlos Amado Martins

Parecer

As proponentes pretendem desenvolver estudo que tem como objectivos "avaliar a actividade física nos adolescentes, antes e após uma intervenção baseada na monitorização e feedback dado por uma aplicação móvel de contagem de passos; avaliar o impacto de uma intervenção de prescrição de exercício físico incluindo consciencialização e adoção de estilos de vida e comportamentos saudáveis, realizada através das redes sociais, na actividade física dos adolescentes; caracterizar a actividade física dos adolescentes, utilizando uma aplicação móvel de contagem de passos". Para atingir os objectivos propõem-se a realizar "estudo randomizado controlado" junto de adolescentes com idades entre os 12 e os 17 anos, nos agrupamentos de escolas de Aveiro e de Esgueira. A randomização será realizada entre escolas.

O estudo inclui um momento de avaliação inicial, a monitorização da actividade física em ambos os grupos num período ininterrupto de 8 semanas e uma avaliação final. O grupo experimental participará de rede social fechada onde acontecerá um programa educativo sobre comportamentos e estilos de vida saudáveis. Os critérios de inclusão e exclusão são definidos. O critério de inclusão, "que possuam *smartphone* e façam uso diário do mesmo" será válido apenas para a análise de dados propriamente dita, não se aplicando às crianças para os processos de avaliação, formação e programa de actividade física.

São definidas as variáveis a avaliar, que incluem dados antropométricos, de força muscular, dados relativos ao exercício físico e sinais vitais e vários indicadores físicos e funcionais a avaliar pelas investigadoras.

A informação é colhida de forma anónima e confidencial, codificando-se os questionários. A base de dados será de acesso restrito pela equipa de investigação. A transmissão semanal de dados entre as crianças e os investigadores acontecerá por "descarga" anónima (codificada) no site. É apresentado exemplar dos instrumentos de colheita de dados.

É apresentado documento para informação aos encarregados de educação e mencionado a necessidade de consenso entre adolescente e encarregado de educação relativamente à participação no estudo. É apresentado também documento para

COMISSÃO DE ÉTICA

da **Unidade Investigação em Ciências da Saúde - Enfermagem** (UICISA: E)

da **Escola Superior de Enfermagem de Coimbra** (ESEnfC)

obtenção do consentimento que prevê a assinatura de ambos (adolescente e seu encarregado de educação). Ambos os documentos cumprem os requisitos para uma investigação deste tipo.
É apresentada cópia de ofício enviado aos responsáveis dos agrupamentos de escolas, e a respectiva resposta autorizando.

Face ao exposto, e tal como nos é apresentado, esta Comissão de Ética é de parecer favorável à concretização do estudo.

O relator: ______________

Data: 28/01/2015 Presidente da Comissão de Ética: ______________

FCT Fundação para a Ciência e a Tecnologia

Annex II – Institutions' approval

Autorização Institucional

Eu, Carlos Alberto Ventura Magalhães responsável pela instituição Agrupamento de Escolas de Aveiro declaro que fui informado dos objetivos do estudo científico intitulado: "Promoção da atividade física pediátrica através da monitorização e feedback de uma aplicação de *smartphone*", e concordo em autorizar a execução do mesmo nesta instituição, desde que o mesmo tenha um parecer positivo por uma Comissão de Ética independente. Caso necessário, a qualquer momento como instituição CO-PARTICIPANTE desta investigação poderemos revogar esta autorização, se comprovadas atividades que causem algum prejuízo a esta instituição ou ainda, a qualquer dado que comprometa o sigilo da participação dos integrantes desta instituição. Declaro também, que não recebemos qualquer pagamento por esta autorização bem como os participantes também não receberão qualquer tipo de pagamento.

Representante da Instituição	25.11.2014 Data	Assinatura
Tânia Pinho Investigador	25.11.2014 Data	Tânia Pinho Assinatura

FW: Projeto de investigação

Agrupamento de Escolas de Esgueira <ag.esgueira@esjml.edu.pt>

qua 17-09-2014 11:44

Inbox

Para:Tânia Pinho <taniamariapinho@ua.pt>;

Importância:Alto

Informo que estão autorizadas.

Helena Libório
Diretora

Agrupamento de Escolas de Esgueira
Escola Básica e Secundária Dr. Jaime Magalhães de Lima
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De: Tânia Pinho [mailto:taniamariapinho@ua.pt]
Enviada: terça-feira, 16 de Setembro de 2014 23:18
Para: direcao@esjml.edu.pt
Assunto: Projeto de investigação

Bom dia Professora Helena Libório!
Somos duas alunas do mestrado em Fisioterapia da Escola Superior de Saúde da Universidade de Aveiro, Joana Pinto e Tânia Pinho. Para prosseguir com os nossos estudos e melhoria do nosso conhecimento, propomo-nos no ano de dissertação (em curso) a realizar investigação na área da atividade física nos adolescentes, que infelizmente ainda é pouco estudada.
Para isso precisamos do seu apoio de forma a podermos contactar e recolher dados nos adolescentes entre os 12 e os 18 anos do Agrupamento de Escolas de Esgueira.
Em anexo enviamos a apresentação do projeto e a devida autorização, caso concorde com a parceria.
Estamos disponíveis para qualquer esclarecimento, seja via mail (taniamariapinho@ua.pt), telemóvel (963293726) ou presencialmente.
A nossa orientadora, a Prof. Alda Marques também estará à sua disponibilidade para qualquer esclarecimento!

Grata pela atenção!
Com os melhores cumprimentos,

Tânia Pinho

Appendix I – Information sheets

Folha de Informação ao Encarregado de Educação

As investigadoras Joana Batista de Castro Pinto e Tânia Maria Pereira de Pinho, a frequentar o Mestrado em Fisioterapia da Escola Superior de Saúde da Universidade de Aveiro, sob a orientação científica da Professora Doutora Alda Sofia Pires de Dias Marques, vêm por este meio solicitar-lhe a autorização para a participação do seu educando no estudo clínico intitulado: "Caracterização e estabelecimento de valores normativos de condição física em adolescentes".

Mas, antes de decidir, é importante que compreenda porque é que a investigação está a ser realizada e o que é que a mesma envolve. Por favor, leia a informação com atenção e discuta a participação do seu educando, com outros se assim o entender. Se houver algo que não esteja claro para si ou necessitar de informação adicional, por favor não hesite em contactar a aluna ou a sua orientadora (contactos no final deste documento).

Muito obrigado desde já por ler a informação.

Qual é o propósito do estudo?

Este estudo visa estabelecer valores de referência para a condição física em crianças com patologia respiratória e saudáveis (12-17 anos). Estes testes permitem uma avaliação objetiva e segura da condição física de adolescentes sendo por isso largamente utilizados pelos fisioterapeutas para prescrever exercício físico em adolescentes com várias patologias como por exemplo, com asma, fibrose cística, patologia oncológica ou condições neuromusculares. No entanto, ainda não se encontram estabelecidos valores de referência que permitam diferenciar com segurança a normalidade das condições patológicas. Para que seja possível determinar estes valores de referência, vimos então solicitar-lhe autorização para que o seu educando participe neste estudo que será realizado na instituição de educação por ele frequentada.

Porque foi o meu educando escolhido?

O seu educando foi escolhido porque:

- se encontra a frequentar uma escola do distrito de Aveiro que deu permissão institucional para a realização do estudo,
- não apresenta qualquer tipo de contra-indicação à participação no mesmo.

Tenho de aceitar a participação do meu educando?

A decisão de autorizar a participação do seu educando ou não é completamente sua. Se decidir autorizar vai-lhe ser pedido que assine dois consentimentos informados, um para si e outro para as investigadoras. No entanto, é totalmente livre de desistir a qualquer momento, sem que para tal tenha de dar qualquer justificação. A decisão de desistir ou de não participar, não afetará a qualidade dos serviços de educação, ou quaisquer outros, prestados ao seu educando agora ou no futuro.

O que acontecerá se autorizar a participação do meu educando?

Se decidir participar vai-lhe ser pedido que preencha o documento anexo a esta folha de informação relativamente à saúde do seu educando e que o entregue, bem como o consentimento informado, ao docente que entrou em contacto consigo.

Após receber o consentimento informado devidamente assinado, as alunas dirigir-se-ão à instituição de educação do seu educando e procederão à recolha de algumas medidas muito simples como o peso e a altura, e testes para avaliar a sua condição física. Estes testes consistem em avaliar a composição corporal, a força muscular, a flexibilidade, condição neuromuscular e a função cardiorrespiratória. Ser-lhe-á também pedido que responda a um questionário para avaliar as atividades físicas que o seu educando realiza dentro e fora da instituição.

A aplicação do protocolo terá a duração de aproximadamente 40 minutos e será realizado em horários compatíveis com as atividades educacionais, de forma a não afetar o programa letivo de atividades.

Quais são os efeitos secundários dos procedimentos do estudo?

Não existem efeitos secundários de participar no estudo.

Quais são as possíveis desvantagens e riscos se resolver autorizar a participação do meu educando?

Não existem quaisquer desvantagens ou riscos de participar no estudo.

Quais são os possíveis benefícios se eu resolver autorizar a participação do meu educando?

Não existem benefícios diretos de participar no estudo. No entanto, todas as medidas recolhidas na avaliação ser-lhe-ão comunicadas para que fique informado acerca do estado de saúde e físico do seu educando. Para além disso, a informação obtida neste estudo poderá ajudar a desenvolver valores de referência para testes largamente utilizados na fisioterapia, permitindo uma melhor avaliação e monitorização de adolescentes.

A participação será confidencial?

Toda a informação recolhida no decurso do estudo será mantida estritamente confidencial. Os dados recolhidos serão salvaguardados com um código, para que ninguém os possa identificar. Apenas as alunas responsáveis pelo projeto e a sua orientadora terão acesso aos dados.

O que acontecerá aos resultados do estudo?

Os resultados do estudo serão analisados e incorporados em dissertações de Mestrado e alguns serão publicados em Jornais e/ou conferências de finalidade científica. No entanto, em nenhum momento o seu educando será identificado. Se pretender obter uma cópia de qualquer relatório ou publicação, por favor solicite-o enviando *e-mail* para as alunas responsáveis pelo projeto.

Contacto para mais informações sobre o estudo

Se pretender obter mais informações sobre o estudo, pode telefonar ou escrever para:

Joana Pinto, Tânia Pinho e Alda Marques

Escola Superior de Saúde da Universidade de Aveiro,

Universidade de Aveiro,

Campus de Santiago,

Edifício III, 3810-193, Aveiro

Telefone: 234 247 113 ou 234 372 462

e-mail: pinto.joana@ua.pt; taniamariapinho@ua.pt; amarques@ua.pt

Muito obrigado por ter lido esta informação.

✄____

Se pretender obter uma cópia de qualquer relatório ou publicação, por favor indique o seu contacto de e-mail no espaço seguinte: ______________________________

Appendix II – Informed Consent

Consentimento Informado

Título do Projeto: Promoção da atividade física pediátrica através da monitorização e feedback de uma aplicação de smartphone

Orientadora: Prof. Doutora Alda Sofia Pires de Dias Marques

Alunas de Mestrado: Joana Batista de Castro Pinto e Tânia Maria Pereira de Pinho

Por favor leia e assinale com uma cruz (X) os quadrados seguintes.

Eu confirmo que percebi a informação que me foi dada e tive a oportunidade de questionar e de me esclarecer. ☐

Eu percebo que a participação do meu encarregando é voluntária e que ele é livre de desistir, em qualquer altura, sem dar nenhuma explicação, sem que isso afete qualquer serviço de educação ou saúde que lhe seja prestado. ☐

Eu compreendo que os dados recolhidos durante a investigação são confidenciais e que só os investigadores responsáveis pelo projeto têm acesso a eles. E dou portanto, autorização para que os mesmos tenham acesso a esta informação. ☐

Eu compreendo que os resultados do estudo serão publicados numa dissertação de mestrado e jornais e/ou conferências de finalidade científica sem que haja qualquer quebra de confidencialidade e anonimato. E dou portanto, autorização para a utilização dos dados para esses fins. ☐

Eu confirmo que o meu encarregando foi questionado acerca da sua vontade em participar no estudo e que nenhuma avaliação foi realizada contra a sua vontade, sendo assim respeitada a sua autonomia.

Eu concordo então em participar no estudo. ☐ ☐

______________________	______________________	__________	______________________
Assinatura do Participante	Encarregado de Educação	Data	Assinatura do Encarregado de Educação

______________________		__________	______________________
Investigador		Data	Assinatura