PREDICTIVE EQUATIONS OF MAXIMUM OXYGEN CONSUMPTION BY SHUTTLE RUN TEST IN CHILDREN AND ADOLESCENTS: A SYSTEMATIC REVIEW

Equações preditivas do consumo máximo de oxigênio por meio do teste shuttle run em crianças e adolescentes: uma revisão sistemática

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ABSTRACT

Objective: To systematically review the literature as for the level of evidence of predictive equations of VO2peak through the 20-meter shuttle run test (20m-SRT) in children and adolescents.

Data sources: Searches were conducted independently by two researchers, according to the procedures adopted by PRISMA, in the electronic databases MEDLINE via PubMed, ScienceDirect, Web of Science, LILACS and SciELO, for articles published until September 2017 in English and Portuguese. The inclusion criteria were: original studies, abstract available, using predictive equations of VO2peak through 20m-SRT, conducted with adolescents and/or children, non-athletes, and mentioning correlation analysis between predicted and measured VO2peak. The level of evidence of equations was based on the risk of bias of the studies using the following criteria: sample number, sample characteristics, and statistical analysis.

Data synthesis: Eighteen studies were selected, in which fifteen equations were found and analyzed. The studies had been conducted with samples composed of subjects of both sexes, aged 8 to 19 years. Equations of Léger and Matsuzaka had their level of evidence classified as high, and estimation ranged between r=0.54–0.90 and r=0.65–0.90. Equations by Ruiz, Barnett and Matsuzaka had their level of evidence classified as moderate, and estimation ranged between r=0.75–0.96, r=0.66–0.84 and r=0.66–0.89, respectively.

Conclusions: Matsuzaka’s equation presented satisfactory parameters for estimates of VO2peak in children and adolescents. Although not explored in equations, body adiposity and pubertal stage are significantly associated with cardiorespiratory fitness in children and adolescents.

Keywords: Cardiopulmonary Exercise Test; Cardiorespiratory fitness; Adolescents; Children.

RESUMO

Objetivo: Revisar sistematicamente na literatura o nível de evidência das equações preditivas do pico de consumo de oxigênio (VO2pico) por meio do teste de shuttle run de 20 metros (SR-20m) em crianças e adolescentes.

Fonte de dados: As buscas foram conduzidas nas bases de dados eletrônicas Medical Literature Analysis and Retrieval System Online (MEDLINE) via PubMed, ScienceDirect, Web of Science, Literatura Latino-Americana e do Caribe em Ciências da Saúde (LILACS) e Scientific Electronic Library Online (SciELO), de agosto a setembro de 2017, nos idiomas inglês e português. Os critérios de inclusão utilizados foram: estudos originais, com resumo disponível, com equações para predição do VO2pico por meio do SR-20m, adolescentes e/ou crianças, não atletas e com análise correlacional do VO2pico predito e mensurado. O nível de evidência das equações foi caracterizado com base no risco de viés dos estudos, no qual se adotou os seguintes critérios: número da amostra, características da amostra e análise estatística.

Síntese dos dados: Dezoito estudos foram selecionados, nos quais 12 equações foram encontradas e analisadas. Os estudos foram conduzidos com amostras de ambos os sexos com idades de oito a 19 anos. As equações de Léger e Matsuzaka foram classificadas com forte nível de evidência, com variação de amplitude de estimativa entre r=0,54–0,90 e r=0,65–0,90. Enquanto as equações Ruiz, Barnett e Matsuzaka foram consideradas de evidência moderada, com variação de amplitude de estimativa entre r=0,75–0,96, r=0,66–0,84 e r=0,66–0,89, respectivamente.

Conclusões: A equação de Matsuzaka apresentou parâmetros satisfeitos para estimar o VO2pico em crianças e adolescentes. Embora não explorados em equações, a adiposidade corporal e o estágio puberal demonstram associações relevantes com a aptidão cardiorrespiratória em crianças e adolescentes.

Palavras-chave: Teste de esforço; Aptidão cardiorrespiratória; Adolescentes; Crianças.

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INTRODUCTION
Cardiorespiratory fitness (CRF) is an important health marker in children and adolescents, as it reflects cardiopulmonary efficiency for oxygen and musculoskeletal distribution during exercise or physical activity. Studies have shown that children with low CRF tend to maintain this condition over the years, which adversely affects their functional capacity to perform daily activities and quality of life. In addition, low CRF is associated with an increase in risk factors for cardiovascular diseases and metabolic changes related to pediatric morbidity and mortality in adults.

Thus, CRF analysis is a measure of health status of the child and adolescent population. It provides relevant information to the diagnosis and prognosis of cardiometabolic risk factors. Moreover, it serves as an instrument in individualized therapeutics and exercise prescription. Oxygen consumption (VO2) is considered the main index to determine CRF. In children and adolescents, the peak of oxygen consumption (VO2peak) is generally used, defined as the peak of VO2 reached at the end of maximum effort period.

VO2peak can be measured by direct methods by ergospirometric analysis in maximum tests conducted in laboratory with different ergometers or in field, by sport activity simulation. From direct testings, authors have proposed equations that assess VO2peak by indirect methods, which can be performed in maximum or submaximal tests, thus increasing practicality and reducing the costs of evaluations.

In epidemiological studies, indirect field tests are mostly indicated because they usually require low cost, short time of execution and ease of simultaneous application in a larger number of individuals. The 20-meter shuttle run test (20m-SRT), conceived and described by Léger et al. for the adult population, is one of the field protocols most used in children and adolescents. 20m-SRT is considered a simple method, as it requires few equipment, can be performed in space-limited environments, and allows to assess several individuals at the same time, which can increase participants’ motivation. A systematic review including about 319,000 children and adolescents from 32 countries reported the performance achieved at the 20m-SRT as directly related to health indicators in children and adolescents.

In the last decades, the 20m-SRT was included in several batches of physical fitness tests such as EUROFIT and FITNESSGRAM, resulting in the need to improve VO2peak predictive equations through this test for the child and adolescent population. Equations were therefore developed using mathematical regression models or artificial neural networks, and including biological characteristics such as age, sex, body mass and performance in the test.
Some characteristics of the samples were highlighted in the studies, such as age, gender and number of subjects. The values of correlation coefficient ($r$) and standard estimation error (SEE) in mL/kg.min were extracted when available. Estimate range variation ($\Delta ER$) of each equation was determined by the description from the lowest to the highest correlation coefficient obtained by the equation between the studies. To facilitate identification, we chose to name the equations with the name of the first author of the study in which it was validated. When one author had identified two or more equations in a single study, each equation was accompanied by (a), (b) or (c).

The steps of the process of research, selection, analysis, application of bias risk parameters, and data extraction were independently performed by two researchers (FJMJ and ICJ), and, in case of disagreement, a third researcher (NL) was asked to decide on divergent points.

RESULTS

In total, 2,125 studies were found using the combination of selected descriptors, but 194 were discarded for being duplicates. Afterwards, the inclusion and non-inclusion criteria were applied and 64 studies were considered eligible in full, ending the selection with 14 articles for qualitative synthesis. In addition, four studies relating to the theme identified in other reference lists of articles selected were included, so 18 studies were selected. The process of studies selection is outlined in Figure 1.

Following criteria adapted by Batista et al., nine studies were classified as low risk of bias, and other nine as moderate risk of bias. The details of risk assessment criteria are shown in Table 1.

The samples of studies selected had subjects aging 8 to 19 years, most of them with nutritional status classified as euotrophic, except for two overweight studies.

We identified studies that aimed to develop equations using variables in mathematical regression models and artificial neural networks. The variables used in equations were gender, age, body mass index (BMI), body mass, stature and triceps skinfold, besides performance in 20m-SRT (final speed in km/h, number of laps, number of stages and number of laps squared). The equations identified had their characteristics detailed in Tables 2 and 3.

In addition, some studies had a cross-validation of equations as objective: Léger, Barnett (a), Barnett (b), Barnett (c), Matsuzaka (a), Matsuzaka (b), Mahar (a), Mahar (b), Mahar (squared), Burns.
Studies identified in search on PubMed, LILACS, ScienceDirect, SciELO and Web of Science (n = 2,125)

Duplicates excluded (n = 194)

Studies chosen based on title and abstract reading (n = 1,935)

Studies excluded by inclusion or non-inclusion criteria: not original articles, no abstract available, no equations for VO_{2peak} prediction in 20m-SRT, adults and/or elderly, athletes in the sample, and no predicted versus measured VO_{2peak} correlation analysis (n = 1,871)

Full-text studies assessed for eligibility (n = 64)

Complete studies excluded by eligibility criteria: pathology diagnosed, adapted shuttle run protocol, no direct measurement of VO_{2peak}, no correlation analysis and/or no VO_{2peak} prediction (n = 46)

Articles included in a qualitative synthesis (n = 18)

20m-SRT: 20-meter shuttle run test; VO_{2peak}: peak of oxygen consumption.

Figure 1 PRISMA flowchart.
and Fernhall.23,32 Among all equations, two had a strong level of evidence,23,29 three had moderate level17,23,31 and seven had limited level of evidence.18,27,31,33,35

Among the equations with strong level of evidence, Léger29 was the most commonly applied in cross-validations, however it shows considerable ΔER and lower values of estimates for girls. The equation by Matsuzaka (a)23 is considered strong-evidence, and able to generate estimates with lower ΔER and higher correlation values for boys.

As for moderate evidence, the equation by Ruiz16 showed a low ΔER, while Barnett’s (a)31 and Matsuzaka’s (b)23 resulted in high association values, but low ΔER, respectively. In addition, Barnett’s equation (a)31 had higher correlation values for girls.

Finally, the equations by Barnett (b),31 Barnett (c),31 Mahar (a),31 Mahar (b),33 Mahar (squared),18 Silva (a),25 Silva (b),25 Burns,27 Fernhall35 and Quinart36 were classified as limited evidence. The level of evidence of equations and respective ΔER are listed in Table 4.

**DISCUSSION**

This systematic review gathered 18 studies in which fifteen equations were identified. Among these, different variables were employed, including sample characteristics and performance in 20m-SRT. Two equations had a strong level of evidence,23,29 three were classified as moderate evidence17,23,31 and nine as limited evidence.18,25,27,31,33,35 Our findings show that Matsuzaka’s (a)23 equation tends to have higher predictive reliability and a high level of evidence for both genders and may be a potential equation to estimate the VO$_{2peak}$ in eutrophic boys.

As previously presented, children and adolescents with high VO$_{2peak}$ levels tend to have risk factors related to cardiovascular diseases, obesity and the metabolic syndrome reduced.5,7 Thus, the accuracy of equations to estimate VO$_{2peak}$ is relevant, since it provides valuable information for the diagnosis and prognosis of cardiometabolic risk factors.6,8 Access to a practical and inexpensive method is important; the 20m-SRT has fulfilled this requirement with strong level of evidence.6,19 This test requires cheap resources and infrastructure that is easily accessible in schools, clubs and academies. In addition, it can be considered practical and efficient, as it allows the evaluation of several people at the same time.6

According to our findings, Léger’s equation29 was primary to estimate VO$_{2peak}$ in children and adolescents in the literature. This equation, which uses age and performance in 20m-SRT

Table 1 Classification of bias risk of each study.

| Studies              | Number of subjects | Sample characteristics | Statistical analysis | Bias risk |
|----------------------|--------------------|------------------------|----------------------|-----------|
| Léger et al.29       | 2                  | 0                      | 1                    | Moderate  |
| Liu et al.30         | 1                  | 2                      | 1                    | Moderate  |
| Barnett et al.31     | 2                  | 1                      | 1                    | Moderate  |
| Pitetti et al.32     | 2                  | 1                      | 1                    | Moderate  |
| Suminski et al.22    | 2                  | 2                      | 1                    | Low       |
| Matsuzaka et al.33   | 2                  | 2                      | 2                    | Low       |
| Mahar et al.33       | 2                  | 1                      | 1                    | Moderate  |
| Ruiz et al.17        | 2                  | 1                      | 2                    | Low       |
| Ruiz et al.15        | 1                  | 1                      | 2                    | Moderate  |
| Boiarskaia et al.34  | 2                  | 1                      | 0                    | Moderate  |
| Mahar et al.18       | 2                  | 1                      | 1                    | Moderate  |
| Melo et al.24        | 2                  | 2                      | 1                    | Low       |
| Silva et al.25       | 2                  | 2                      | 2                    | Low       |
| Batista et al.26     | 2                  | 2                      | 2                    | Low       |
| Quinart et al.37     | 1                  | 2                      | 2                    | Low       |
| Burns et al.27       | 2                  | 1                      | 2                    | Low       |
| Ernesto et al.28     | 2                  | 1                      | 2                    | Low       |
| Sain-Maurice et al.16| 2                  | 1                      | 1                    | Moderate  |

5 or 6: low bias risk; 3 or 4: moderate risk of bias; 1 or 2: high risk of bias.
as variables, was more popular in studies and presented strong evidence. However, it presents a considerable ΔER between correlation values, being frequently inferior to $r = 0.60$.\textsuperscript{15,18,22,32-34} This variation can be explained by differences in gender between subjects in the sample. Although Léger et al.\textsuperscript{29} found no significant predictive value for gender, other studies demonstrate a strong association between this component and cardiorespiratory fitness in children and adolescents.\textsuperscript{18,32}

On the other hand, the Matsuzaka's equation (a)\textsuperscript{23}, with strong evidence, obtained values of estimate validity with lower

| Table 2: Equations for prediction of maximal oxygen consumption upon the 20-meter shuttle run test in children and adolescents (equations by Léger et al., Ruiz et al., Barnett et al.) |
|---|
| **Equation** | **Study** | **n** | **age range** | **(predicted versus measured VO\textsubscript{2})** | **Variables in equation** |
| | | | | | |
| | | | | | |
| Léger et al.\textsuperscript{29} | Liu et al.\textsuperscript{30} | (62) 12–15 | 0.72 (5.2) | |
| | Barnett et al.\textsuperscript{31} | (55) 12–17 | 0.72 (5.4) | |
| | Pitetti et al.\textsuperscript{32} | (61) 8–15 | 0.57 | |
| | Suminski et al.\textsuperscript{22} | (125) 10–12 | 0.62 (3.9) | 0.58 (4.7) | 0.55 (3.1) |
| | Suminski et al.\textsuperscript{22} | (81) 10–12 | 0.54 (4.2) | |
| | Suminski et al.\textsuperscript{22} | (44) 10–12 | 0.81 (3.2) | |
| | Mahar et al.\textsuperscript{33} | (135) 12–14 | 0.54 (6.6) | |
| | Ruiz et al.\textsuperscript{17} | (193) 13–19 | 0.90 (4.2) | |
| | Ruiz et al.\textsuperscript{15} | (48) 13–19 | 0.58 (6.5) | |
| | Boiariskaia et al.\textsuperscript{34} | (135) 12–14 | 0.54 | 0.46 | 0.39 |
| | Mahar et al.\textsuperscript{18} | (244) 10–16 | 0.58 (7.6) | |
| | Melo et al.\textsuperscript{24} | (90) 8–10 | 0.88 | |
| | Silva et al.\textsuperscript{25} | (114) 10–18 | 0.67 (7.1) | |
| | Batista et al.\textsuperscript{26} | (115) 11–13 | 0.60 (7.5) | 0.60 (7.7) | 0.49 (6.4) |
| | Ernesto et al.\textsuperscript{28} | (90) 13–17 | 0.76 (4.1) | 0.53 (2.4) | |
| Ruiz et al.\textsuperscript{17} | Ruiz et al.\textsuperscript{17} | (193) 13–19 | 0.96 (2.8) | Gender; age; BM; stature; stage |
| | Ruiz et al.\textsuperscript{15} | (48) 13–19 | 0.75 (5.3) | |
| | Silva et al.\textsuperscript{25} | (114) 10–18 | 0.86 (6.2) | |
| Barnett et al.\textsuperscript{31} (a) | Barnett et al.\textsuperscript{31} | (55) 12–17 | 0.84 (3.7) | Gender; BM; final speed |
| | Ruiz et al.\textsuperscript{15} | (48) 13–19 | 0.75 (5.3) | |
| | Mahar et al.\textsuperscript{18} | (244) 10–16 | 0.66 (7.0) | |
| | Melo et al.\textsuperscript{24} | (90) 8–10 | 0.68 | |
| | Batista et al.\textsuperscript{26} | (115) 11–13 | 0.79 (5.81) | 0.77 (6.0) | 0.72 (5.1) |
| Barnett et al.\textsuperscript{31} (b) | Barnett et al.\textsuperscript{31} | (55) 12–17 | 0.82 (4.0) | Gender; age; final speed |
| | Ruiz et al.\textsuperscript{15} | (48) 13–19 | 0.72 (5.6) | |
| | Mahar et al.\textsuperscript{18} | (244) 10–16 | 0.64 (7.2) | |
| | Silva et al.\textsuperscript{25} | (114) 10–18 | 0.71 (6.8) | |
| | Ernesto et al.\textsuperscript{28} | (90) 13–17 | 0.76 (4.1) | 0.66 (4.2) | |
| Barnett et al.\textsuperscript{31} (c) | Barnett et al.\textsuperscript{31} | (55) 12–17 | 0.85 (3.7) | Gender; triceps skinfold; final speed |
| | Melo et al.\textsuperscript{24} | (90) 8–10 | 0.62 | |

n: sample size; r: correlation coefficient; SEE: standard estimate error; VO\textsubscript{2}: oxygen consumption; ♀: male; ♂: female; *overweight; BM: body mass;
ΔER. The authors23 included gender, age, BMI and 20m-SRT performance in the equation, that is, theirs was the first study to include BMI in prediction equations. This equation can be considered the one with greater estimation precision.

On the other hand, although the equations by Ruiz,17 Barnett (a)31 and Matsuzaka (b)23 were classified with moderate level of evidence, they showed relevant estimates of validity. In particular, Ruiz’s17 equation presented the lowest ΔER among the estimation results. In addition, it matched Matsuzaka’s (a)23, taking the greater number of characteristics of the sample included into account (sex, age, body mass, height and 20m-SRT performance). This equation was evaluated by a few studies, but seems to be a promising tool that should be better studied.

When considering only studies with low risk of bias, findings become more evident. Léger’s equation29 continues to present higher ΔER compared to Matsuzaka’s (a)23, among equations with strong evidence; Ruiz17 obtained higher correlation

### Table 3 Equations for prediction of maximal oxygen consumption upon the 20m-SRT test in children and adolescents (Matsuzaka et al., Mahar et al., Silva et al., Burns et al., Fernhall et al., And Quinart et al.)

| Equation | Study | (n) age range | r (SEE mL/kg.min) | Variables in equation |
|----------|-------|---------------|-------------------|-----------------------|
| Matsuzaka et al.23 | Matsuzaka et al.23 | (132) 8–17 | 0.90 (3.3) | Gender; age; BMI; final speed |
| | Ruiz et al.15 | (48) 13–19 | 0.73 (5.5) | |
| | Mahar et al.18 | (244) 10–16 | 0.65 (7.1) | |
| | Melo et al.24 | (90) 8–10 | 0.72 | |
| | Batista et al.26 | (115) 11–13 | 0.77 (5.9) | |
| Matsuzaka et al.23 | Matsuzaka et al.23 | (132) 8–17 | 0.89 (3.4) | |
| | Mahar et al.18 | (244) 10–16 | 0.66 (7.0) | |
| | Melo et al.24 | (90) 8–10 | 0.80 | |
| Mahar et al.33 | Mahar et al.33 | (135) 12–14 | 0.64 (6.44) | Gender; laps; BMI |
| | Boiarskaia et al.34 | (135) 13 | 0.57 | |
| | Mahar et al.18 | (244) 10–16 | 0.66 (6.99) | |
| | Batista et al.26 | (115) 11–13 | 0.80 (5.69) | |
| Mahar et al.33 | Mahar et al.33 | (135) 12–14 | 0.64 (6.4) | |
| | Boiarskaia et al.34 | (135) 13 | 0.65 | |
| | Mahar et al.18 | (244) 10–16 | 0.71 (6.6) | |
| | Burns et al.27 | (90) 13–16 | 0.78 | |
| Mahar et al.18 | Mahar et al.18 | (135) 13 | 0.65 | |
| | Boiarskaia et al.34 | (244) 10–16 | 0.71 (6.3) | |
| | Burns et al.27 | (90) 13–16 | 0.74 | |
| | Saint-Maurice et al.16 | (310) 10–18 | 0.36 | |
| | Burns et al.27 | (90) 13–16 | 0.77 | |
| Silva et al.25 | Silva et al.25 | (114) 10–18 | 0.80 (5.7) | Gender; BMI; Stage |
| Silva et al.25 | Silva et al.25 | (114) 10–18 | 0.86 (5.0) | |
| Burns et al.27 | Burns et al.27 | (90) 13–16 | 0.77 | Age; laps |
| | Saint-Maurice et al.16 | (310) 10–18 | 0.36 | |
| | Fernhall et al.35 | (51) 8–15 | 0.66 | Gender; BMI; final speed |
| | Pitetti et al.32 | (90) 8–10 | 0.56 | |
| | Melo et al.24 | (90) 8–10 | 0.56 | |
| Quinart et al.36 | Quinart et al.37* | (30) 12–17 | 0.77 | |

n: sample size; r: correlation coefficient; SEE: standard estimate error; VO2: oxygen consumption; ♂: male; ♀: female; *overweight; BMI: body mass index; laps: number of laps; laps2: number of laps squared; MC: body mass.
values and lower ΔER, in comparison to the other equations of moderate evidence.

When analyzing data by gender in samples, only the Léger’s equation reached strong evidence, despite having low correlation values and high ΔER, showing underestimation of VO2peak prediction for females and males. Therefore, it was not possible to define the validity of the specific equations by gender, since few studies have provided isolated correlational information and analysis with this variable. Despite this, Barnett’s (a) may be a potential equation to estimate VO2peak in girls and Matsuzaka’s (a) in boys, since they were shown to have higher correlational values for the respective groups.

Among equations with strong and moderate level of evidence, the Matsuzaka’s (a), (b) and Ruiz’s equations were the ones that used the largest number of variables from the sample and obtained a lower ΔER with high correlation values. Léger and Barnett (a) inserted fewer variables and found higher ΔER values. The use of more than one characteristic of the sample, such as gender, body mass, stature or BMI, in equations tends to result in higher values of association between predicted and measured VO2peak. This trend was also noted in other studies. From this point of view, moderate associations between VO2peak and BMI, body mass and gender were identified.

According to Saint-Maurice et al., BMI tends to have a larger influence on CRF in children and adolescents, which can explain 30 to 34% of the variance between VO2peak estimates found with predictive equations. In this perspective, equations that do not take BMI into account tend to overestimate the CRF of individuals in high nutritional status.

Although not yet explored in prediction equations, the body fat percentage shows a significant association with CRF in both children and adolescents. Correlational values of r=-0.60 for both genders, r=-0.48 to -0.53 for boys and r=-0.24 to -0.40 for girls evidence this variable as a strong predictor for males and moderate predictor for females.

Although chronological age has often been used to characterize physical fitness profile, the different stages of sexual maturation tend to relate to different physical fitness characteristics in children and adolescents. Girls, specifically, demonstrate significant differences in CRF in different stages of sexual maturation, often presenting decreased VO2peak as their stages of sexual maturation progress. However, this variable has not yet been tested in prediction equations.

In addition, children and adolescents of different economic classes, sedentary behavior profiles and habitual physical activity levels may present differences as to health-related parameters. However, information about the use of these variables

Table 4 Classification of level of evidence and estimate range variation of the equations

| Equations                  | Low risk of bias | Moderate risk of bias | Level of evidence | ΔER All studies | ΔER Studies with low risk of bias |
|---------------------------|------------------|-----------------------|-------------------|----------------|---------------------------------|
| Léger et al.              | 5                | 9                     | Strong            | r=0.54–0.90    | r=0.54–0.90                     |
| Ruiz et al.               | 2                | 1                     | Moderate          | r=0.75–0.96    | r=0.86–0.96                     |
| Barnett et al. (a)        | 2                | 3                     | Moderate          | r=0.66–0.84    | r=0.68–0.79                     |
| Barnett et al. (b)        | 2                | 3                     | Limited           | r=0.64–0.82    | r=0.71                          |
| Barnett et al. (c)        | 1                | 1                     | Limited           | r=0.62–0.85    | r=0.62                          |
| Matsuzaka et al. (a)      | 3                | 2                     | Strong            | r=0.65–0.90    | r=0.72–0.90                     |
| Matsuzaka et al. (b)      | 2                | 1                     | Moderate          | r=0.66–0.89    | r=0.80–0.89                     |
| Mahar et al. (a)          | 1                | 3                     | Limited           | r=0.57–0.80    | r=0.80                          |
| Mahar et al. (b)          | 1                | 3                     | Limited           | r=0.64–0.78    | r=0.78                          |
| Mahar et al. (c)          | 1                | 2                     | Limited           | r=0.67–0.74    | r=0.74                          |
| Silva et al. (a)          | 1                | 0                     | Limited           | r=0.80         | r=0.80                          |
| Silva et al. (b)          | 1                | 0                     | Limited           | r=0.86         | r=0.86                          |
| Burns et al.              | 1                | 1                     | Limited           | r=0.77         | r=0.77                          |
| Fernhall et al.           | 1                | 1                     | Limited           | r=0.56–0.66    | r=0.56                          |
| Quinart et al.            | 1                | 0                     | Limited           | r=0.77         | r=0.77                          |

ΔER: estimate range variation; strong evidence: more than three studies with low risk of bias; moderate evidence: two studies with low risk of bias; limited evidence: several studies with high risk of bias, wide range of variation or only one study.
to predict VO$_{2\text{peak}}$ in children and adolescents is still limited, and new studies on the topic should be developed to better understand the influence of these variables on VO$_{2\text{peak}}$ prediction.

This study has some limitations for analysis that should be listed, such as lack of information on sample characteristics, adiposity level, level of physical activity and sedentary behavior; especially related to correlation analyses for samples adjusted by gender. These limitations have turned the identification of the best predictive equation for different groups of children and adolescents into a challenge.

Therefore, future research should be able to provide more information on the sample, such as ethnicity, length of time with sedentary behavior, physical activity level, aspects of body composition and stage of sexual maturation, as well as to promote correlations with CRF. Thus, doubts about the association between these variables and VO$_{2\text{peak}}$ prediction can be better understood, allowing more accurate equations to be elaborated. It is also important that further research be conducted to verify the reproducibility of the equations proposed by Ruiz, Barnett (a), Matsuzaka (a) and Matsuzaka (b) identified in this review as promising, as well as to improve the understanding about the relationship between anthropometric variables, body composition components and sexual maturation stages with VO$_{2\text{peak}}$ prediction in children and adolescents.

In conclusion, our findings suggest that using more than one sample feature in equations tends to exert higher association values between predicted and measured VO$_{2\text{peak}}$. Matsuzaka’s equation (a), in this sense, tends to have the strongest level of evidence with greater precision of estimation in children and adolescents. Although not explored in prediction equations, body fat percentage and sexual maturation stage are shown to have relevant associations with CRF in children and adolescents and further analyses of these variables in other equations are encouraged. However, new research should be conducted to evaluate the reproducibility of equations considered by this review as promising, as well as to improve the understanding about the relationship between anthropometric variables, body composition components and sexual maturation stages with VO$_{2\text{peak}}$ prediction in children and adolescents.

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Prediction of VO2peak through the SR20m test

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