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Criterion-related validity of perceived exertion scales in healthy children: a systematic review and meta-analysis

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ABSTRACT

Introduction. Physiological parameters used to measure exercise intensity are oxygen uptake and heart rate. However, perceived exertion (PE) is a scale that has also been frequently applied. The objective of this study is to establish the criterion-related validity of PE scales in children during an incremental exercise test.

Methods. Seven electronic databases were used. Studies aimed at assessing criterion-related validity of PE scales in healthy children during an incremental exercise test were included. Correlation coefficients were transformed into z-values and assessed in a meta-analysis by means of a fixed effects model if I^2 was below 50% or a random effects model, if it was above 50%.

Results. Twenty-five articles that studied 1418 children (boys: 49.2%) met the inclusion criteria. Children's average age was 10.5 years old. Exercise modalities included bike, running and stepping exercises. The weighted correlation coefficient was 0.835 (95% confidence interval: 0.762-0.887) and 0.874 (95% confidence interval: 0.794-0.924) for heart rate and oxygen uptake as reference criteria. The production paradigm and scales that had not been adapted to children showed the lowest measurement performance ($p < 0.05$).

Conclusion. Measuring PE could be valid in healthy children during an incremental exercise test. Child-specific rating scales showed a better performance than those that had not been adapted to this population. Further studies with better methodological quality should be conducted in order to confirm these results.

Key words: *validity, children, scales, cognition, exercise.*

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INTRODUCTION

Physical exercise is important to maintain an adequate health status. An adequate method to assess exercise intensity helps to establish physiological thresholds that allow to stimulate exercise-induced adaptation mechanisms.[1] Physiological outcome measures usually considered to assess and prescribe exercise are oxygen uptake (VO_2), heart rate (HR), blood lactate concentration, and respiratory rate (RR).[1] However, given that measuring such outcomes requires costly equipment and expert supervision, perceived exertion (PE) has been frequently applied.[2]

PE can be considered as a configuration of symptoms: strain, aches and fatigue, involving the muscles and the cardiovascular and pulmonary systems during exercise.

As exercise intensity increases, there are corresponding and interdependent increases in response intensities along perceptual and physiological continua, demonstrating a strong positive correlation.[2] Such association has allowed to use PE as an outcome measure, both to estimate workload and to produce a given level of intensity during exercise. For this reason, PE has become a clinically useful instrument, because it is a simple and cost-effective method that allows to establish and dose exercise intensity with a high degree of certainty.[2,3]

The Borg scale is one of the most commonly used PE rating scales and has demonstrated to be a valid tool in adult subjects.[3] However, in children, this scale has not proven to have favorable psychometric properties.[4-7] Accordingly, several linear scales have been developed for children on the basis of common expressions and a limited number range (0-10). All of these scales have been used with varying degrees of success as a means to measure PE.[2] They have seemingly demonstrated adequate psychometric properties in children.

As per our knowledge, there are no studies aimed at establishing these scales' validity in children by means of meta-analyses. Therefore, the objectives of this study are to establish the criterion-related validity of PE rating scales in children, as well as to assess the impact of certain covariates associated with this measurement property.

METHODS

Design: Systematic review (SR).[8]

Article eligibility criteria: Studies conducted in humans, with a correlational design, and published in English, Portuguese, French or Spanish. Participants were defined as healthy male and female subjects younger than 18 years old. Studies that pooled data on adults or children with a concomitant pathology were excluded. Studies had to focus on establishing a correlation between PE and physiological outcome measures (reference criteria) during the incremental exercise test (IET). HR, VO_2, workload, RR, minute ventilation (VE), ventilatory equivalent ratio for oxygen (VE/VO_2), and respiratory ratio (VCO_2/VO_2) were defined as reference criteria.

Article search: Articles in the following databases were considered since their inclusion up to April 2015: Pubmed, ProQuest, Scientific Electronic Library Online (SciELO), SPORTDiscus, Rehabilitation and Sports Medicine Source (R&SMS), Cumulative Index to Nursing & Allied Health Literature (CINAHL), and Trip Database. Medical Subject Headings (MeSh) (children, adolescents, exercise, exercise test, dyspnea, cognition, heart rate, oxygen uptake, tidal volume, pulmonary ventilation, and respiratory rate) and free terms (perceived exertion, exercise intensity, validity, concurrent validity) were used. The Boolean operators AND and OR were also used. In addition, reference lists of primary articles were reviewed. The search took place between February and April 2015.

Article identification: Titles and abstracts from relevant articles were reviewed. Next, full texts corresponding to abstracts that met eligibility criteria and relevant articles from reference lists were obtained. Data were blindly collected by two independent investigators (IR and LZ) and recorded in a special worksheet. Year and language of publication, sample size, participants' age, exercise test, assessed PE rating scale, correlation coefficient (CC), and reference criteria were recorded.

Methodological quality and risk of bias assessment: Methodological quality (MQ) was assessed in an independent manner by two reviewers (IR and LZ) using the Consensus-based Standards for the Selection of Health Measurement Instruments (COSMIN). The COSMIN scale allows to establish the methodological quality of studies aimed at assessing psychometric properties of health measurement parameters. Only the COSMIN section focused on assessing the methodological quality of criterion-related validity studies was considered for the purpose of this study.[9]

The risk of bias was assessed by establishing the correlation between CC and sample size. To this end, a funnel plot[3,10] (*Annex*) was developed and the Kendall rank correlation coefficient was estimated (Begg and Mazumdar's rank correlation test).

Statistical analysis. When VO_2 was reported both in absolute (mL/min) and relative (mL/kg/min) values in the same article, the weighted average CC was estimated (as per the sample size). Additionally, when the result of such association was presented as a coefficient of determination (R_2), the square root was estimated to obtain Pearson's r CC.

A meta-analysis was done as per the Hedges-Olkin's method, whereby CCs were tested using the Fisher z-transformation.[3] In addition, inconsistency was estimated using I^2 statistics as $I^2 = 100\% (Q - DF)/Q$, where Q is Cochran's heterogeneity index and DF accounts for degrees of freedom. A value of 0% indicates lack of heterogeneity, any higher value indicates its presence. For analyses where I^2 was below 50%, a fixed effects model was used and, if I^2 was above 50%, a random effects model was applied. General criterion-related validity was established using the weighted correlation between PE and HR, and between PE and VO_2. The statistical analysis was done using the MedCalc Statistical Software v. 14.12.0 statistical package (MedCalc Software bvba, Ostend, Belgium), and a 95% confidence interval (95% CI) was considered statistically significant.

RESULTS

Study selection: The search obtained 3338 articles from the seven databases. *Figure 1* describes the systematic search sequence and the reasons for exclusion. A total of 25 articles were considered for review (*Figure 1*).

Study characteristics: All articles were written in English. The year of publication ranged from 1986 to 2014. Sample size in these studies ranged between 283 and 14 participants; 1418 subjects completed the IET in the 25 studies, 699 (49.2%) were boys, and 721 (50.8%), girls. Average participant age was reported in 24 articles (n = 1355, 95.5%); 15 (n = 923, 65.0%) described age ranges. The weighted average age was 10.5 years old (maximum and minimum weighted average age: 13.1 and 9.7 years old). In addition, a continuous progressive exercise protocol was used in 21 articles (n = 1271, 89.6%), while an intermittent progressive protocol was implemented in 4 (n = 147, 10.3%). Exercise modality was bike in 13 articles (n = 831, 58.6%), running in 9 (n = 387, 27.2%), and stepping test in 3 (n = 200, 14.1%).

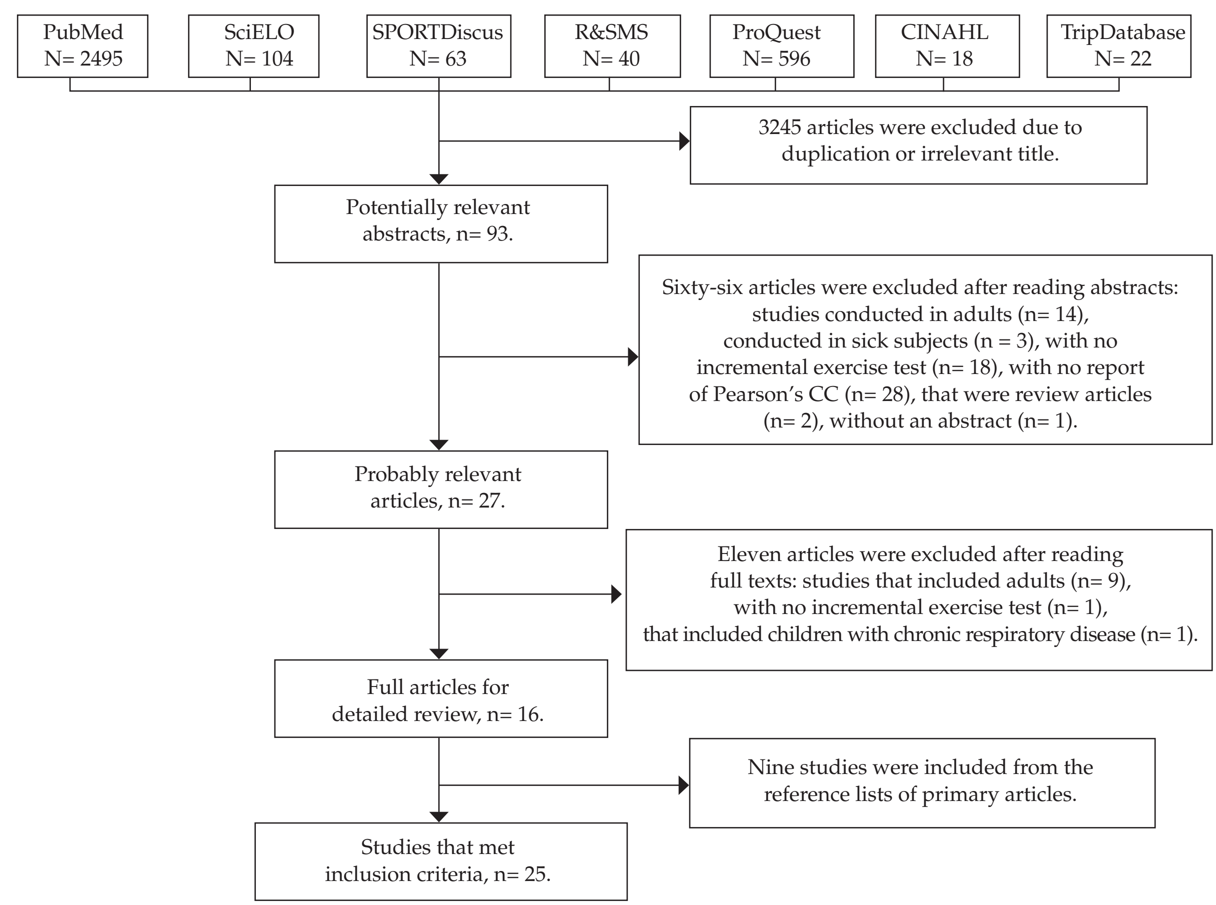
Besides, 23 articles assessed validity as per the estimation paradigm (n = 1332, 93.9%) and 1 article used the production paradigm (n = 70, 4.9%). One article assessed both paradigms (n = 16, 1.1%).

In relation to the reference criterion used, 25 studies contemplated HR (n = 1418, 100%); 16, VO^2 (n = 732, 51.6%); 7, VE (n = 297, 20.9%); 7, workload (n = 302, 21.2%); 4, RR (n = 218, 15.3%); 3, VCO^2/VO^2 (n = 155, 10.9%); and 2, VE/VO^2 (n = 120, 8.4%).

Lastly, 4 studies (5, 11-13) reported results on children with a concomitant disease and adults. However, only data regarding the population of interest were considered (*Table 1*).

Methodological quality and risk of bias: An intraclass CC (ICC) > 0.85 was estimated among reviewers. For dissenting articles, decisions were made based on consensus. Thus, methodological quality was classified as "adequate" in 6 studies (24%); "reasonable" in 9 (36%); and "poor" in 10 (40%). No study was classified as having an "excellent" methodological quality. In relation to the risk of bias, CCs were observed to have a symmetrical distribution in the funnel plot; there was no evident concentration of studies on any side of the weighted mean (*Annex 1*). In addition, a weak correlation between CCs and sample size

FIGURE 1. *Flow chart*



R&SMS: Rehabilitation and Sports Medicine Source.
CC: correlation coefficient.

(τ = -0.148, 95% CI: -0.438-0.203) was observed. This suggests that studies had a low risk of bias.

Criterion-related validity of identified scales: Twelve assessment instruments were identified during the search: (**1**) 15-point Rate of Perceived Exertion (RPE 6-20) (4-7, 12, 14, 15); (**2**) Children's Effort Rating Table (CERT) (6, 7, 14, 16-18); children's OMNI scale of perceived exertion and its three variations: (**3**) OMNI-bike (11, 19-21), (**4**) OMNI-run (15, 22-25) and (**5**) OMNI-step (26); (**6**) 15-point Rate of Perceived Exertion-Children (RPE-C);13 (**7**) Pictorial Children's Effort Rating Table (PCERT);23,27,28 (**8**) Cart and Load Effort Rating (CALER) (20); (**9**) Children's Rating of Perceived Exertion Scale (C-RPES);29 (**10**) Borg ratings of perceived exertion scale (CR-10) (27); (**11**) Eston-Parfitt curvilinear Ratings of Perceived Exertion (EP-RPE);[30,31] (**12**) marble dropping task (MDT).[30,31]

The random effects model showed a weighted CC between PE and physiological outcome measures of 0.835 (95% CI: 0.762-0.887) and 0.874 (95% confidence interval: 0.794-0.924) considering HR and VO^2 as reference criterion (*Figures 2 and 3*).

In addition, a specific meta-analysis was developed only for 7 of the 12 scales (RPE 6-20, CERT, OMNI-bike, OMNI-walk/run, PCERT, EP-RPE and MDT). The RPE 6-20 showed the lowest level of weighted correlation compared to the OMNI-bike and the EP-RPE (HR and VO_2). Besides, the RPE 6-20 also showed the lowest weighted CC compared to the CERT and PCERT when considering only HR and VO_2 as reference criterion, respectively. No significant difference was observed in any of the other analyzed scales. In turn, in relation to studies not subjected to meta-analysis, it was possible to verify that the RPE-C and CR-10 had the lowest weighted CCs and a significant difference from the CALER and C-RPES. Only the CR-10 evidenced a lower validity than the OMNI-step in relation to the VO_2 criterion. In contrast, the C-RPES demonstrated a higher validity than the CERT in relation to the VO_2 criterion (*Table 2*).

Table 3 shows criterion-related validity as per covariates. Significant differences were observed only in the assessment paradigm and other reference criteria. In this regard, both VE/VO_2 and the production paradigm showed a lower and statistically significant correlation. The rest of the covariates evidenced a moderate to high correlation, with no significant differences among their categories.

DISCUSSION

This study demonstrated that there is a strong overall correlation between PE and physiological outcome measures (HR and VO_2) during exercise. This suggests that measuring PE would be valid in children.

In relation to the specific analysis of identified scales, the RPE 6-20, RPE-C and CR-10 evidenced the lowest correlation levels. It is worth noting that the RPE 6-20 and CR-10 were developed for the adult population, so they do not include intuitive, pictorial descriptors for children.[4,5,12,14,15,27] Many studies have compared the Borg scale with pediatric scales, and it has been demonstrated that adapted scales have a better performance.[6,14,15,27] For its part, the RPE-C is an adapted version of the Borg RPE 6-20 scale that includes pictures; however, it has demonstrated only a moderate correlation with physiological outcome measures during exercise.[13] Although the RPE-C has not been compared to other instruments, it probably does not exceed the validity of other scales for children given its complex category range (6 to 20). Besides, higher CCs were observed for the OMNI scales (bike, walk/run and step), the EP-RPE, C-RPES, MDT, CALER and PCERT. Such scales include numerical, verbal and pictorial descriptors that are adequate for children, and this may account for their high validity.[11,15,19-24,26,29-34]

In our study, and based on the covariate analysis, sex, age, exercise modality and protocol did not affect the validity of PE measurement. Our results are not consistent with the systematic review conducted by Chen, et al., who observed that some covariates may affect PE validity.[3] However, Chen's study included adults, subjects with concomitant pathologies and other types of non-standardized exercise, and this may account for such differences.

Many lines of evidence indicate that there is a strong association between the stage of development and the ability to express PE in children.[2,32,34] Recently, Rice, et al. observed that the validity of measuring PE increased proportionally with age.[34] In our study, a lower correlation was observed in children younger than 7 years old when compared to children aged 13-15 years old; this suggests a possible association between cognitive development and the validity of PE measurement. The production modality also showed a lower validity level than the estimation modality ($p < 0.05$). However, only two primary studies that assessed this paradigm

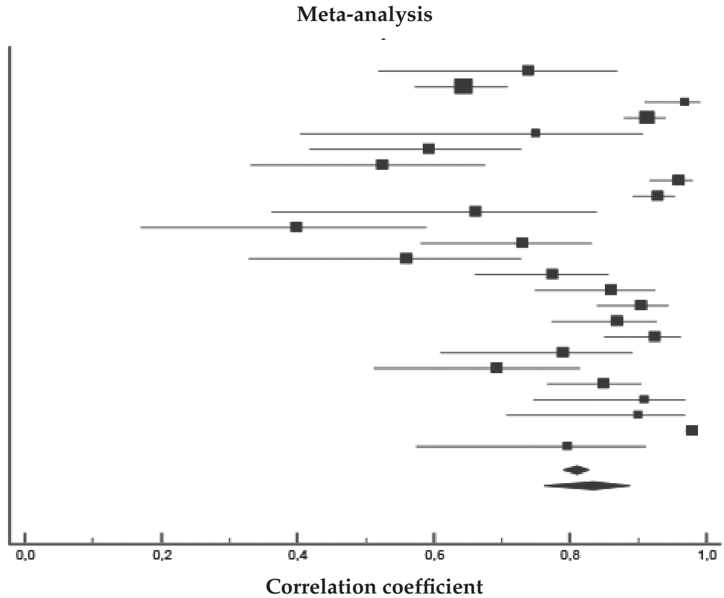
TABLE 1. *Study characteristics*

Author	Sample size (M/F)	Age	Exercise protocol	Exercise modality	Assessment paradigm	PE scale	Physiological criterion	Methodological quality
Eston et al., 1986	30 (30/0)	16.0	Continuous progressive	Bike	Estimation	RPE 6-20	HR, load	Reasonable
Gillach et al., 1989	283 (144/139)	11.0	Continuous progressive	Bike	Estimation	RPE 6-20	HR	Reasonable
Eakin et al., 1992	15 (7/8)	13.3	Continuous progressive	Run	Estimation	RPE 6-20	HR, VO_2	Poor
William et al., 1994	112 (56/56)	7.1	Continuous progressive	Step	Estimation	CERT	HR	Reasonable
Eston et al., 1994	16 (8/8)	10.0	Continuous progressive	Bike	Estimation and production	CERT	HR, load	Poor
Lamb, 1995	70 (28/42)	9.5	Continuous progressive	Bike	Estimation	RPE 6-20, CERT	HR, load	Reasonable
Lamb, 1996	70 (28/42)	9.5	Intermittent progressive	Bike	Production	RPE 6-20, CERT	HR, load	Reasonable
Cassady et al., 1998	30 (17/13)	9.6	Continuous progressive	Bike	Estimation	C-RPES	HR, VO_2, RR, VE, VCO_2/VO_2	Reasonable
Robertson et al., 2000	80 (40/40)	10.0	Continuous progressive	Bike	Estimation	OMNI-Bike	HR, VO_2	Adequate
Groslambert et al., 2001	25 (13/12)	9.8	Continuous progressive	Run	Estimation	RPE-C	HR	Reasonable
Utter et al., 2002	63 (32/31)	13-6*	Continuous progressive	Run	Estimation	OMNI-walk/run	HR, VO_2, RR, VE, VE/VO_2	Reasonable
Pfeiffer et al., 2002	57 (0/57)	15.3	Continuous progressive	Run	Estimation	RPE 6-20, OMNI-walk/run	HR, VO_2, RR, VE, VE/VO_2, VCO_2/VO_2	Adequate
Yelling et al., 2002	48 (24/24)	13.8	Intermittent progressive	Step	Estimation	PCERT	HR	Reasonable
Leung et al., 2002	69 (34/35)	10.3	Continuous progressive	Bike	Estimation	RPE 6-20, CERT	HR, VO_2, load	Adequate
Robertson et al., 2005	40 (20/20)	11.1	Continuous progressive	Step	Estimation	OMNI-step	HR, VO_2	Reasonable
Rommeich et al., 2006	51 (26/25)	11.2	Continuous progressive	Run	Estimation	OMNI-walk/run PCERT	HR, VO_2	Adequate
Robertson et al., 2006	44 (22/22)	12.8	Continuous progressive	Run	Estimation	OMNI-walk/run	HR, VO_2	Reasonable
Barkley et al., 2008	32 (16/16)	9.5	Continuous progressive	Bike	Estimation	OMNI-Bike, CALER	HR, VO_2	Reasonable
Marinov et al., 2008	50 (25/25)	10.4	Continuous progressive	Run	Estimation	CR-10, PCERT	HR, VO_2, VE	Reasonable
Suminski et al., 2008	68 (32/36)	10.2	Continuous progressive	Run	Estimation	OMNI-walk/run	HR, VO_2, RR, VCO_2/VO_2, VE	Adequate
Leung et al., 2008	32 (17/15)	10.5	Continuous progressive	Bike	Estimation	CERT	HR, load	Reasonable
Eston et al., 2009	15 (6/9)	7.6	Intermittent progressive	Bike	Estimation	EP-RPE, MDT	HR, VO_2, load, VE	Poor
Lambrick et al., 2011	14 (8/6)	7.9	Intermittent progressive	Run	Estimation	EP-RPE, MDT	HR, VO_2, VE	Poor
Balasekaran et al., 2012	81 (45/36)	13.8	Continuous progressive	Bike	Estimation	OMNI-Bike	HR, VO_2	Adequate
Balasekaran et al., 2014	23 (23/0)	13.8	Continuous progressive	Bike	Estimation	OMNI-Bike	HR, VO_2	Poor

* Only a range is reported; PE: perceived exertion; 15-point Rate of Perceived Exertion (RPE 6-20); Children's Effort Rating Table (CERT); children's OMNI scale of perceived exertion; 15-point Rate of Perceived Exertion-Children (RPE-C); Pictorial Children's Effort Rating Table (PCERT); Cart and Load Effort Rating (CALER); Children's Rating of Perceived Exertion Scale (C-RPES); Borg ratings of perceived exertion scale (CR-10); Eston-Parfitt curvilinear Ratings of Perceived Exertion (EP-RPE); marble dropping task (MDT);HR: heart rate; VO_2: oxygen uptake; RR: respiratory rate; VE: minute ventilation; VCO_2/VO_2: respiratory ratio; VE/VO_2: ventilatory equivalent ratio for oxygen.

FIGURE 2. *Meta-analysis of studies that consider heart rate as a reference criterion*

Study	n	r	95% CI
Eston et al., 1986	30	0.740	0.518-0.869
Gillach et al., 1989	283	0.645	0.571-0.708
Eakin et al. 1992	15	0.970	0.910-0.990
Willia m et al., 1994	112	0.915	0.879-0.941
Eston et al., 1994	16	0.750	0.405-0.908
Lamb, 1995	70	0.594	0.417-0.727
Lamb, 1996	70	0.525	0.331-0.677
Cassady et al., 1998	30	0.960	0.917-0.981
Robertson et al., 2000	80	0.930	0.893-0.955
Groslambert et al., 2001	25	0.663	0.363-0.838
Utter et al., 2002	63	0.400	0.169-0.589
Pfeiffer et al., 2002	57	0.730	0.580-0.832
Yelling et al., 2002	48	0.560	0.328-0.728
Leung et al., 2002	69	0.776	0.661-0.855
Robertson et al., 2005	40	0.860	0.749-0.924
Rommeich et al., 2006	51	0.905	0.839-0.945
Robertson et al., 2006	44	0.870	0.773-0.927
Barkley et al., 2008	32	0.925	0.851-0.963
Leung et al., 2008	32	0.790	0.609-0.893
Marinov et al., 2008	50	0.692	0.513-0.814
Suminski et al., 2008	68	0.850	0.767-0.905
Eston et al., 2009	15	0.910	0.745-0.970
Lambrick et al., 2011	14	0.900	0.707-0.968
Balasekaran et al., 2012	81	0.980	0.969-0.987
Balasekaran et al., 2014	23	0.798	0.575-0.911
Total (fixed effects)	**1386**	**0.810**	**0.791-0.828**
Total (random effects)	**1386**	**0.836**	**0.761-0.889**



Heterogeneity test
Q= 318.8134.
DF= 24.
Significance level= $p < 0.0001$.
I^2 (inconsistency)= 92.47%.
95% CI I^2 = 90.08-94.29

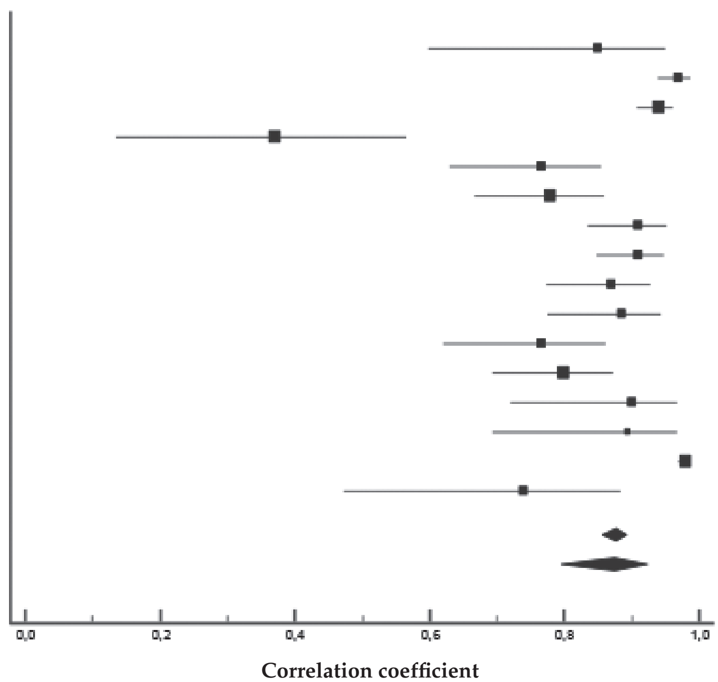
95% CI: confidence interval; r: weighted correlation coefficient; *considering the random effects model.
Q: Cochran's heterogeneity index; DF: degrees of freedom.

FIGURE 3. *Meta-analysis of studies that consider oxygen uptake as a reference criterion*

Study	n	r	95% CI
Eakin et al., 1992	15	0.850	0.598-0.949
Cassady et al., 1998	30	0.970	0.937-0.986
Robertson et al., 2000	80	0.940	0.908-0.961
Utter et al., 2002	63	0.370	0.135-0.566
Pfeiffer et al., 2002	57	0.765	0.630-0.855
Leung et al., 2002	69	0.780	0.666-0.858
Robertson et al., 2005	40	0.910	0.835-0.952
Rommeich et al., 2006	51	0.910	0.847-0.948
Robertson et al., 2006	44	0.870	0.773-0.927
Barkley et al., 2008	32	0.885	0.776-0.943
Marinov et al., 2008	50	0.766	0.621-0.861
Suminski et al., 2008	68	0.800	0.694-0.872
Eston et al., 2009	15	0.900	0.719-0.967
Lambrick et al., 2011	14	0.895	0.694-0.967
Balasekaran et al., 2012	81	0.980	0.969-0.987
Balasekaran et al., 2014	23	0.740	0.858-0.892
Total (fixed effects)	**732**	**0.876**	**0.857-0.892**
Total (random effects)	**732**	**0.874**	**0.794-0.924**

Q: Cochran's heterogeneity index;
DF: degrees of freedom.

Heterogeneity test
Q= 180.2103.
DF= 15.
Significance level= $p < 0.0001$.
I^2 (inconsistency)= 91.68%.
95% CI I^2= 88.09-94.18



95% CI: confidence interval; r: weighted correlation coefficient;
*considering the random effects model.

by establishing a correlation between PE and physiological parameters were identified.[4,7] Studies using different statistical approaches, such as an analysis of variance (ANOVA) were excluded from the systematic review because they have shown inconsistent results,[33,35] probably due to the complex psychophysical process required to produce exercise intensity based on PE.[2] Further studies are necessary to verify all such hypotheses.

When analyzing reference criteria, and except for VE/VO_2 (*Table 3*), outcome measures could also work as useful criteria to establish criterion-related validity of PE, just like HR and VO_2.

One of the limitations of this systematic review is that the methodological quality of 18 studies (75%) was "reasonable" or "poor". The main reasons for this are associated with weaknesses in methodological design and a small sample size, which affect the statistical power of results. A high level of heterogeneity was also observed, probably due to methodological differences among studies. In this context, differences in sample size, incremental protocol design, duration and number of intensity intervals, and methodology used to measure PE were observed in primary studies. This may have contributed to the high levels of heterogeneity observed here.

Given the high external validity of this research design, results allow to support the use of PE to monitor intensity during exercise in subjects younger than 18 years old. Nevertheless, it is still necessary to verify its psychometric properties in children with concomitant pathologies and using other exercise modalities.

Lastly, this study's results suggest that measuring PE would be valid in healthy children during an incremental exercise test. In addition,

Table 2. *Criterion-related validity of identified scales*

Scale	Criterion	Average r	k	n	95% CI	*p*	Q	I^2 (*p*-value)
RPE (6-20)	HR	0.697[a]	7	523	0.649-0.739	< 0.001	11.3393	47.09% (0.0078)
	VO_2	0.695[a]	3	106	0.578-0.785	< 0.001	2.2748	12.08% (0.3207)
CERT	HR	0.778[b]	6	301	0.572-0.892	< 0.001	49.1602	89.83% (< 0.0001)
	VO_2	0.870	1	35	0.756-0.933	NA	NA	NA
OMNI-bike	HR	0.935[b]	4	216	0.843-0.974	< 0.001	30.9730	90.31% (< 0.0001)
	VO_2	0.926[b]	4	216	0.804-0.973	< 0.001	38.0031	91.11% (< 0.0001)
OMNI-walk/run	HR	0.806[b]	5	283	0.637-0.901	0.001	36.3875	89.01% (< 0.0001)
	VO_2	0.819[b]	5	283	0.627-0.917	< 0.001	48.0952	91.68% (< 0.0001)
OMNI-step	HR	0.860	1	40	0.749-0.924	NA	NA	NA
	VO_2	0.910	1	40	0.835-0.952	NA	NA	NA
RPE-C	HR	0.663	1	25	0.363-0.838	NA	NA	NA
	VO_2	-	-	-	-	-	-	-
PCERT	HR	0.769[b]	3	149	0.482-0.907	< 0.001	17.6863	88.69% (0.0001)
	VO_2	0.861[a]	2	101	0.798-0.904	< 0.001	1.5549	35.69% (0.2124)
CALER	HR	0.920	1	32	0.841-0.961	NA	NA	NA
	VO_2	0.880	1	32	0.767-0.940	NA	NA	NA
C-RPES	HR	0.960	1	30	0.917-0.981	NA	NA	NA
	VO_2	0.970	1	30	0.937-0.986	NA	NA	NA
CR-10	HR	0.634	1	50	0.432-0.775	NA	NA	NA
	VO_2	0.710	1	50	0.538-0.825	NA	NA	NA
EP-RPE	HR	0.916[a]	2	29	0.820-0.962	< 0.001	0.7532	0.0% (0.3854)
	VO_2	0.906[a]	2	29	0.798-0.957	< 0.001	0.6074	0.0% (0.4358)
MDT	HR	0.866[a]	2	29	0.721-0.939	< 0.001	0.08211	0.0% (0.7745)
	VO_2	0.870[a]	2	29	0.728-0.940	< 0.001	0.0000	0.0% (1.0)

k: number of articles; n: sample size; Q: heterogeneity index; I2: inconsistency index; NA: no meta-analysis done; a: using the fixed effects model; b: using the random effects model; 15-point Rate of Perceived Exertion (RPE 6-20); Children's Effort Rating Table (CERT); children's OMNI scale of perceived exertion; 15-point Rate Of Perceived Exertion-Children (RPE-C); Pictorial Children's Effort Rating Table (PCERT); Cart and Load Effort Rating (CALER); Children's Rating of Perceived Exertion Scale (C-RPES); Borg ratings of perceived exertion scale (CR-10); Eston-Parfitt curvilinear Ratings of Perceived Exertion (EP-RPE); marble dropping task (MDT); HR: heart rate; VO2: oxygen uptake; VE: minute ventilation; VCO2/VO2: respiratory ratio; VE/VO2: ventilatory equivalent ratio for oxygen.

scales that have been specifically adapted to children seem to have a better performance than those that have not been adapted. Notwithstanding, further studies with better methodological quality should be conducted in order to confirm these conclusions. ■

TABLE 3. *Criterion-related validity of perceived exertion measurement*

Covariates	Average r	k	n	95% CI	*p*	Q	I² (*p*-value)
Sex							
Boy	0.847[b]	14	370	0.780-0.895	< 0.001	75.8810	73.64% (< 0.0001)
Girl	0.851[b]	13	391	0.774-0.903	< 0.001	117.9435	83.04% (< 0.0001)
* Age							
< 7 years old	0.821[b]	2	41	0.450-0.950	0.001	7.5838	73.63% (0.0226)
8-12 years old	0.863[b]	18	1040	0.803-0.906	< 0.001	285.2875	90.89% (< 0.0001)
13-15 years old	0.937[b]	4	131	0.828-0.978	< 0.001	39.9800	87.49% (< 0.0001)
> 15 years old	0.723[b]	3	81	0.493-0.858	< 0.001	8.6094	76.77% (0.0135)
Exercise test							
Continuous progressive	0.875[b]	21	1271	0.812-0.918	< 0.001	414.6569	93.01% (< 0.0001)
Intermittent progressive	0.760[b]	4	147	0.602-0.860	< 0.001	37.7057	81.44% (< 0.0001)
Exercise modality							
Bike	0.865[b]	13	831	0.784-0.917	< 0.001	273.6051	92.69% (< 0.0001)
Run	0.807[b]	9	387	0.722-0.867	< 0.001	66.4815	80.45% (< 0.0001)
Step	0.907[b]	3	200	0.704-0.973	< 0.001	140.7281	95.74% (< 0.0001)
Assessment paradigm							
Estimation	0.868[b]	23	1348	0.815-0.906	< 0.001	452.3205	91.60% (< 0.0001)
Production	0.550[a]	2	86	0.427-0.653	< 0.001	2.3499	14.89% (0.3088)
Other reference criteria							
Workload	0.811[b]	7	303	0.724-0.873	< 0.001	43.0231	75.01% (< 0.0001)
RR	0.695[b]	4	218	0.437-0.847	< 0.001	40.4234	90.10% (< 0.0001)
VE	0.828[b]	7	297	0.698-0.906	< 0.001	98.2091	89.82% (< 0.0001)
VCO_2/VO_2	0.732[b]	3	155	0.556-0.845	< 0.001	14.2162	78.90% (0.0026)
VE/VO_2	0.260	2	120	-0.0103-0.495	0.059	6.6834	70.08% (0.0354)

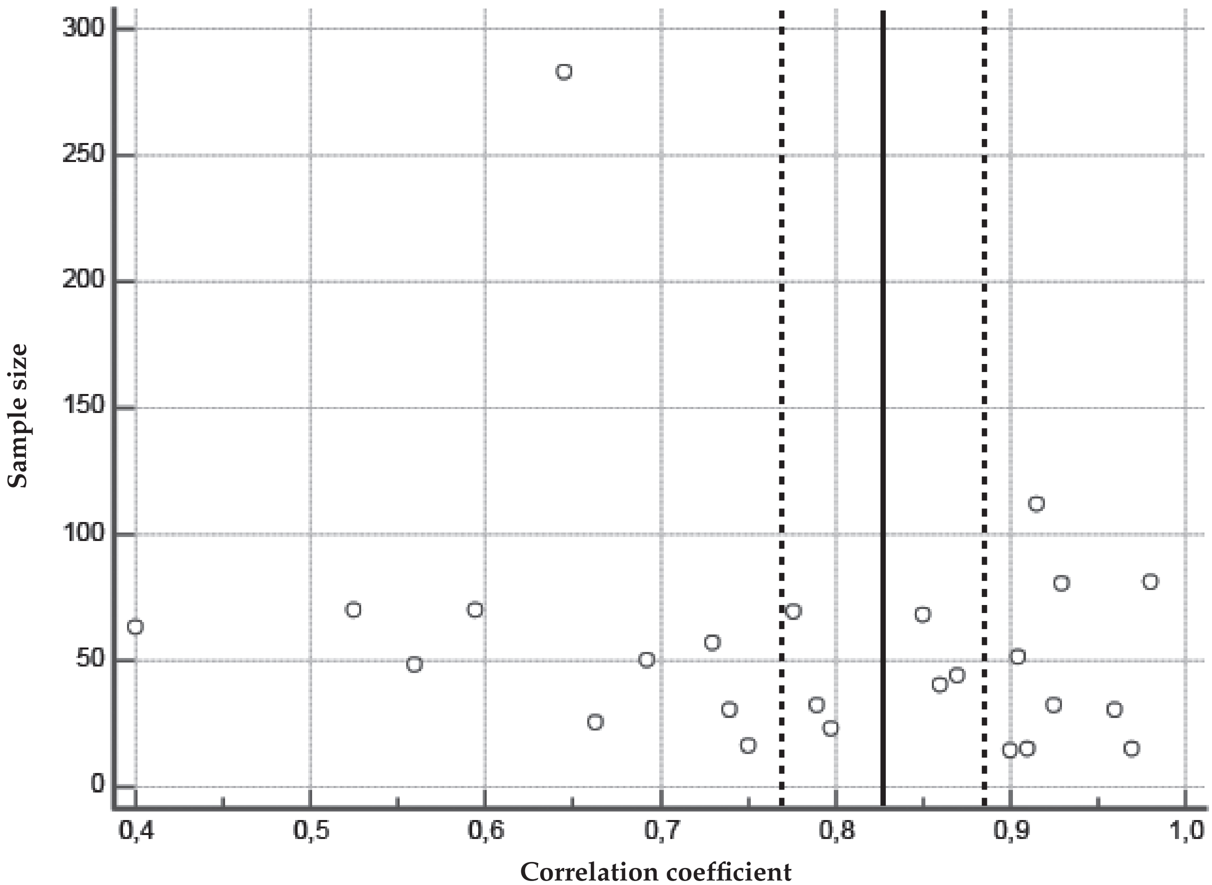
k: number of articles; n: sample size; Q: heterogeneity index; I2: inconsistency index; NA: no meta-analysis done; a: using the fixed effects model; b: using the random effects model; 15-point Rate of Perceived Exertion (RPE 6-20); Children's Effort Rating Table (CERT); children's OMNI scale of perceived exertion; 15-point Rate Of Perceived Exertion-Children (RPE-C); Pictorial Children's Effort Rating Table (PCERT); Cart and Load Effort Rating (CALER); Children's Rating of Perceived Exertion Scale (C-RPES); Borg ratings of perceived exertion scale (CR-10); Eston-Parfitt curvilinear Ratings of Perceived Exertion (EP-RPE); marble dropping task (MDT); HR: heart rate; VO_2: oxygen uptake; VE: minute ventilation; VCO_2/VO_2: respiratory ratio; VE/VO_2: ventilatory equivalent ratio for oxygen.

REFERENCES

1. Garber CE, Blissmer B, Deschenes MR, Franklin BA, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc* 2011;43(7):1334-59.
2. Groslambert A, Mahon AD. Perceived exertion: influence of age and cognitive development. *Sports Med* 2006; 36(11):911-28.
3. Chen MJ, Fan X, Moe ST. Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *J Sports Sci* 2002;20(11):873-99.
4. Eston RG, Williams JG. Exercise intensity and perceived exertion in adolescent boys. *Br J Sports Med* 1986;20(1):27-30.
5. Gillach MC, Sallis JF, Buono MJ, Patterson P, et al. The relationship between perceived exertion and heart rate in children and adults. *Pediatr Exerc Sci* 1989;1(4):360-8.
6. Lamb KL. Children's ratings of effort during cycle ergometry: an examination of the validity of two effort rating scales. *Pediatr Exerc Sci* 1995;7(4):407-21.
7. Lamb KL. Exercise regulation during cycle ergometry using the Children's Effort Rating Table (CERT) and Rating of Perceived Exertion (RPE) scales. *Pediatr Exerc Sci*1996;8(4):337-50.
8. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg* 2010;8(5):336-41.
9. Mokkink LB, Terwee CB, Patrick DL, Alonso J, et al. The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. *J Clin Epidemiol* 2010;63(7):737-45.
10. Sterne JA, Sutton AJ, Ioannidis JP, Terrin N, et al. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ* 2011;343:d4002.
11. Balasekaran G, Loh MK, Govindaswamy VV, Cai SJ. Omni

Scale Perceived Exertion responses in obese and normal weight male adolescents during cycle exercise. *J Sports Med Phys Fitness* 2014;54(2):186-96.
12. Eakin BL, Finta KM, Serwer GA, Beekman RH. Perceived exertion and exercise intensity in children with or without structural heart defects. *J Pediatr* 1992;120(1):90-3.
13. Groslambert A, Hintzy F, Hoffman MD, Dugué B, et al. Validation of a rating scale of perceived exertion in young children. *Int J Sports Med* 2001;22(2):116-9.
14. Leung ML, Chung PK, Leung RW. An assessment of the validity and reliability of two perceived exertion rating scales among Hong Kong children. *Percept Mot Skills* 2002;95(3 Pt 2):1047-62.
15. Pfeiffer KA, Pivarnik JM, Womack CJ, Reeves MJ, et al. Reliability and validity of the Borg and OMNI rating of perceived exertion scales in adolescent girls. *Med Sci Sports Exerc* 2002;34(12):2057-61.
16. Eston RG, Lamb KL, Bain A, Williams AM, et al. Validity of a perceived exertion scale for children: a pilot study. *Percept Mot Skills* 1994;78(2):691-7.
17. Williams JG, Eston R, Furlong B. CERT: a perceived exertion scale for young children. *Percept Mot Skills* 1994;79(3 Pt 2):1451-8.
18. Leung R, Pak-Kwong C, Bower G. Validation of a translated children perceived exertion rating scale. *Int J Fit* 2008;4(2):49-56.
19. Balasekaran G, Loh MK, Govindaswamy VV, Robertson RJ. OMNI Scale of Perceived Exertion: mixed gender and race validation for Singapore children during cycle exercise. *Eur J Appl Physiol* 2012;112(10):3533-46.
20. Barkley JE, Roemmich JN. Validity of the CALER and OMNI-bike ratings of perceived exertion. *Med Sci Sports Exerc* 2008;40(4):760-6.
21. Robertson RJ, Goss FL, Boer NF, Peoples JA, et al. Children's OMNI scale of perceived exertion: mixed gender and race validation. *Med Sci Sports Exerc* 2000;32(2):452-8.
22. Robertson RJ, Goss FL, Aaron DJ, Tessmer KA, et al. Observation of perceived exertion in children using the OMNI pictorial scale. *Med Sci Sports Exerc* 2006;38(1):158-66.
23. Roemmich JN, Barkley JE, Epstein LH, Lobarinas CL, et al. Validity of PCERT and OMNI walk/run ratings of perceived exertion. *Med Sci Sports Exerc* 2006;38(5):1014-9.
24. Suminski RR, Robertson RJ, Goss FL, Olvera N. Validation of the Omni Scale of Perceived Exertion in a sample of Spanish-speaking youth from the USA. *Percept Mot Skills* 2008;107(1):181-8.
25. Utter AC, Robertson RJ, Nieman DC, Kang J. Children's OMNI Scale of Perceived Exertion: walking/running evaluation. *Med Sci Sports Exerc* 2002;34(1):139-44.
26. Robertson RJ, Goss FL, Andreacci JL, Dubé JJ, et al. Validation of the children's OMNI RPE scale for stepping exercise. *Med Sci Sports Exerc* 2005;37(2):290-8.
27. Marinov B, Mandadjieva S, Kostianev S. Pictorial and verbal category-ratio scales for effort estimation in children. *Child Care Health Dev* 2008;34(1):35-43.
28. Yelling M, Lamb KL, Swaine IL. Validity of a pictorial perceived exertion scale for effort estimation and effort production during stepping exercise in adolescent children. *EurPhyEduc Rev* 2002;8(2):157-75.
29. Cassady SL, Kaufman BA, Kelly CE, Eisenmann SC, et al. Validity of a New Perceived Exertion Scale for Children. *Cardiopulm Phys Ther J* 1998;9(1):3-8.
30. Eston RG, Lambrick DM, Rowlands AV. The perceptual response to exercise of progressively increasing intensity in children aged 7-8 years: validation of a pictorial curvilinear ratings of perceived exertion scale. *Psychophysiology* 2009;46(4):843-51.
31. Lambrick DM, Rowlands AV, Eston RG. The perceptual response to treadmill exercise using the Eston-Parfitt scale and marble dropping task, in children age 7 to 8 years. *Pediatr Exerc Sci* 2011;23(1):36-48.
32. Groslambert A, Monnier Benoit P, Grange CC, Rouillon JD. Self-regulated running using perceived exertion in children. *J Sports Med Phys Fitness* 2005;45(1):20-5.
33. Parfitt G, Shepherd P, Eston RG. Reliability of effort production using the children's CALER and BABE perceived exertion scales. *J Exerc Sci Fit* 2007;5(1):49-55.
34. Rice KR, Gammon C, Pfieffer K, Trost SG. Age related differences in the validity of the OMNI perceived exertion scale during lifestyle activities. *Pediatr Exerc Sci* 2015;27(1):95-101.
35. Ward DS, Jackman JD, Galiano FJ. Exercise intensity reproduction: children versus adults. *Pediatr Exerc Sci* 1991;3(3):209-18.

Annex. Funnel plot



The solid line shows the weighted mean; the dotted line shows the 95% confidence interval.