

## Validation of EPInfant scale in children: Estimation and production paradigms, using VO<sub>2</sub> as reference criteria

### Validación de la escala EPInfant en niños: Paradigmas de estimación y producción, considerando VO<sub>2</sub> como estándar de referencia

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#### What do we know about the subject matter of this study?

The EPInfant scale has been validated to evaluate the perceived exertion in Chilean children and adolescents during exercise, considering heart rate and workload as reference criteria.

#### What does this study contribute to what is already known?

The EPInfant scale showed adequate validity to estimate and reproduce submaximal exercise intensity in children, considering oxygen consumption as the reference standard. The linear model best explained the nature of these relationships.

#### Abstract

The EPInfant scale was developed to quantify perceived exertion (PE) during exercise in children and adolescents. **Objective:** to determine the criterion validity of the EPInfant scale in children in the estimation and production paradigm considering oxygen consumption (VO<sub>2</sub>) as the reference standard. **Subjects and Method:** Twenty healthy boys, aged  $9.8 \pm 1.5$  years, were selected. They all performed an incremental shuttle walking test (ISWT) followed by a perceptual regulated-exercise test (PRET). VO<sub>2</sub> and heart rate (HR) were recorded during both exercise tests. Average VO<sub>2</sub> and HR values were considered as a perceptual reproduction test (PRT). EPInfant's validity in estimating the exercise intensity was evaluated by regression analysis between VO<sub>2</sub>, HR, and PE during ISWT and PRET. **Results:** All regression analysis models showed a robust positive relationship between PE and benchmarks ( $r^2 > 0.90$ ). The intraclass correlation coefficient for VO<sub>2</sub> and HR was 0.89 (0.70 to 0.96) and 0.64 (0.08 to 0.86), respectively. Low mean discordance for VO<sub>2</sub> and HR was observed in the Bland-Altman analysis. **Conclusion:** The EPInfant scale presented adequate criterion validity for estimating and regulating running exercise intensity in boys between 8 and 12 years.

#### Keywords:

Perceived Exertion;  
Exercise;  
EPInfant Scale;  
Validity;  
Reliability;  
Children

## Introduction

Perceived exertion (PE) is a set of sensations related to fatigue, exertion, and dyspnea, caused by metabolic changes in various physiological systems during exercise<sup>1,2</sup>. Considering the psychic character of the perceptual stimulus, its measurement requires a psychophysical transcription process that allows quantifying the magnitude of PE generated during exercise. This requires the use of a discrete scale of numbers or symbols distributed incrementally, which allows one to attribute a quantifiable unit of magnitude to the level of perceived exertion<sup>2</sup>. To this end, several scales designed to quantify PE have been created and validated in different populations and exercise modalities<sup>3</sup>.

PE scales are traditionally used from two application paradigms: estimation and production<sup>4</sup>. The first approach seeks to use PE to quantify the intensity of a given exercise. In this paradigm, the validity of the PE scales is analyzed through the correlation (linear or curvilinear) between the numerical values of PE and one or more physiological reference criteria [heart rate (HR) or oxygen consumption ( $\text{VO}_2$ )]<sup>4,5</sup>. In the production approach, on the other hand, the individual is trained to perceptually self-regulate exercise intensity. In this modality, the validity of the PE scales is analyzed by the reproducibility of the physiological reference criteria during a perceptually regulated exercise test<sup>4</sup>.

It is still not clear as to how the brain interprets afferent feedback to induce PE. The available evidence suggests that a structure of different signals may indirectly and unconsciously influence PE during exercise, where mechanisms such as teleoanticipation and perceptual transduction of internal stress seem to participate in the perceptual process<sup>6-9</sup>. There is also uncertainty regarding the nature of the relationship between PE and the physiological response to acute exercise in children. Despite these questions, the evidence supports the importance of cognitive maturation for the effective perception of exertion during exercise, which explains the need for measurement instruments appropriate to the maturational stages of individuals<sup>6,10</sup>.

In the last 30 years, several PE scales adapted for the pediatric population have been created and validated in different exercise modalities, including cycling, running, step aerobics, and strength, among others, showing moderate to high correlations in linear and exponential regression models<sup>5,11,12</sup>. In the Chilean population, the EPInfant scale has shown adequate validity and reliability for estimating exercise intensity in healthy children and adolescents<sup>12-16</sup>. However, it has been scarcely evaluated in other application approaches, such as the production paradigm. A preliminary study conducted by our group showed that the EPInfant scale would have moderate to high validity

to reproduce HR at low, medium, and high intensities in children aged 8 to 12 years<sup>17</sup>. However, so far, its validity has not been verified by considering  $\text{VO}_2$  as a reference standard.

The primary objective of this study was to evaluate the criterion-associated validity of the EPInfant scale in the paradigm of estimation and production of exercise intensity in healthy children, considering  $\text{VO}_2$  and HR as reference standards. The secondary objective was to analyze the nature of relationships between PE and the physiological reference standards considered in this study.

## Subjects and Method

### Design

The study was conducted based on the estimation-production paradigm. This approach seeks to determine the concurrent criterion validity of the PE scale through two statistical approaches: (i) correlation analysis between PE and physiological reference criteria (HR and  $\text{VO}_2$ ), during a standardized exercise test (estimation paradigm); and (ii) reproducibility analysis of HR and  $\text{VO}_2$  between two exercise tests, one with pre-established load and the other perceptually regulated (production paradigm)<sup>12</sup>.

### Subjects of study

Healthy male volunteers between 8 and 12 years of age, from an amateur soccer club in Talcahuano, Chile, were selected. The exclusion criterion was the existence of any neurocognitive, musculoskeletal, neuromuscular, or chronic cardiorespiratory disease. Individuals with obesity, defined according to WHO criteria, were also excluded. Exclusion criteria were verified using a checklist completed by the child's parent.

To estimate the sample size, we used data from a study previously published by our group<sup>17</sup>. Thus, considering 95% of statistical power and 5% of risk type I error, the minimum sample required was 17 individuals.

Before entering the study, the participants signed an informed ascent form and their respective parents or guardians signed an informed consent form. The study was approved by the Scientific Ethical Committee of the Faculty of Medicine of the *Universidad de Concepción*, Chile (Cod: CEI.38-17).

### Measurements

Weight, fat percentage, and lean mass were determined through a bioimpedance analysis (InBody 270, Anaheim, CA, USA). Height was measured using an analog tape. Body mass index was calculated by divi-

ding weight (kg) by height (m) squared. All anthropometric assessments were performed with participants barefoot and wearing light clothing.

HR ( $\text{beat} \cdot \text{min}^{-1}$ ) was measured continuously using a Polar V800 monitor paired with the H7 Heart Rate Sensor (Polar Electro Oy, Kempele, Finland). Respiratory gas analysis was performed breath-by-breath using a spirometry system connected to a size S face mask (Metalyzer 3B, Cortex Biophysik, Leipzig, Germany). The system was calibrated before each test according to the manufacturer's recommendations.  $\text{VO}_2$  was expressed in absolute values ( $\text{ml} \cdot \text{min}^{-1}$ ) and body weight-adjusted values ( $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ).

The EPIInfant scale was used to assess PE. Each participant was asked to provide an estimated value of their overall PE, according to the recommendations published by Rodríguez-Núñez et al<sup>16</sup>. Considering the communication difficulties caused by the use of the face mask, each child was asked to indicate with their finger their PE level on a color-printed version of the scale. The scale was placed in a visible position throughout the exercise test. Also, PE and physiological variables (HR and  $\text{VO}_2$ ) were masked and recorded by two investigators independently, during the last 30 seconds of each minute of each exercise test.

### Experimental protocol

The study was arranged in three stages: (i) orientation; (ii) estimation protocol; and (iii) production protocol. All stages were performed on the same day, with a 30-minute interval between them.

#### Orientation stage

Consisted of the presentation of the experimental protocol to the children and their parents or guardians, the recording of general history, and the evaluation and recording of anthropometric data. Also, participants were familiarized with the equipment and instructed on the interpretation of the EPIInfant scale.

#### Estimation protocol

In this stage, subjects performed an incremental shuttle walking test (ISWT) on a treadmill (Mercury® Med, H/P/Cosmos®, Germany), according to the modified Bruce protocol<sup>18</sup>. Briefly, the ISWT had 7 levels of incremental intensity every 3 minutes, with an initial speed of 2.7 km/hr (0% elevation), until reaching a maximum of 10.5 km/hr and 20% elevation. The ISWT total time was 21 minutes. Cardiorespiratory variables (HR and  $\text{VO}_2$ ) and PE were masked and recorded by two independent evaluators during the last 30 seconds of each minute. Peak  $\text{VO}_2$  was defined as the average  $\text{VO}_2$  during the highest running level reached during the ISWT<sup>18</sup>.

A PE of 10 associated with an HR higher than 195

bpm, with signs of fatigue, such as excessive sweating and facial flushing, unsteadiness, and inability to continue running<sup>19</sup> were considered as criteria for stopping the ISWT. At the end of the ISWT, participants completed a cool-down and recovery period.

#### Production protocol

After 30 minutes of rest, participants performed a perceptual regulated exercise test (PRET) consisting of 5 minutes of warm-up at low intensity, 5 minutes of running at a perceptually regulated intensity equivalent to the highest PE achieved during the ISWT (perceptual regulation period), and 5 minutes of cooling-down.

The instructions regarding the interpretation of the EPIInfant scale were identical to those provided in the estimation protocol, however, during the PRET, a member of the research team regulated the intensity of the exercise by modifying the treadmill speed according to the child's indications. For this, participants were instructed to use visual cues to adjust running speed every 15 seconds. These signs indicated to increase speed (thumbs up image), decrease speed (thumbs down), or to maintain speed (side-to-side hand image) to maintain the required PE level. The EPIInfant scale remained visible throughout the PRET and exercise intensity adjustments were made following the sequence of ISWT loads<sup>20</sup>.  $\text{VO}_2$  and HR were recorded during the last 30 seconds of each minute. The average values of  $\text{VO}_2$  and HR calculated during the perceptual regulation period were considered as the magnitude of the perceptually reproduced intensity during PRET<sup>17</sup>.

### Statistical analysis

After verifying the normality of the distribution of quantitative variables with the Shapiro-Wilk test, descriptive analysis was performed by calculating the mean and standard deviation (SD).

Repeated measures analysis of variance (ANOVA) was used to analyze changes in physiological variables and PE during ISWT. The Greenhouse-Geisser or Huynh-Feldt correction method was used to estimate sphericity, if  $\epsilon$  was  $< 0.75$  or  $> 0.75$ , respectively. Then, the Bonferroni correction for multiple comparisons was used. Additionally, the correlation between cardiorespiratory variables and intensity stages during ISWT was analyzed using Pearson's  $r$  correlation coefficient.

The criterion validity of the EPIInfant scale in the estimation paradigm was evaluated by regression analysis, considering the physiological reference criteria (HR and  $\text{VO}_2$ ) as independent variables and PE as the dependent one, both variables measured during ISWT. This analysis was performed in two ways: (i) total sample analysis (sample validity) and (ii) individual

analysis (individual validity). The first one included all members of the sample, obtaining an  $r^2$  for the total sample and the second one analyzed the relationship between the variables individually, obtaining an  $r^2$  for each study subject. All analyses were performed using the Forward Euler method based on three relationship adjustment models: linear ( $y = a + bx$ ), logarithmic ( $y = a + b \log[x]$ ), and exponential ( $\log[x] = a + bx$ ). Repeated measures ANOVA was then used, as previously described, in order to compare the mean values of the  $r^2$  of the individual validity analysis among the three relationship models.

Besides, the validity analysis in the production paradigm was performed based on the methodology previously published by our group<sup>17</sup>. Briefly, during PRET, the reproducibility of the  $\text{VO}_2$  and HR values corresponding to the maximum PE achieved in the ISWT was analyzed. The mean difference was analyzed by T-Student for paired samples. The intraclass correlation coefficient (ICC) was then calculated to estimate the relative reliability and the Bland-Altman analysis was used to estimate the mean discordance and the limits of agreement (LoA) of the HR and  $\text{VO}_2$  values, between the ISWT and the PRET.

All analyses were performed using MedCalc software version 19.8 (MedCalc Software Ltd, Ostend, Belgium, 2021). A value of  $p < 0.05$  was considered statistically significant.

## Results

The study included 20 healthy male children, with a mean age of  $9.8 \pm 1.5$  years (range 8 to 12 years). All children completed the seven stages of the ISWT and correctly interpreted the EPIInfant scale. Repeated measures analysis revealed significant increases in PE values [ $F(2.581) = 66.69$ ;  $p < 0.001$ ;  $\varepsilon = 0.430$ ] during the estimation protocol, reaching a mean value of  $6.9 \pm 2.6$  at the end of the ISWT. Significant increases were also observed in HR [ $F(2.2) = 271.63$ ;  $p < .001$ ;  $\varepsilon = 0.367$ ],  $\text{VO}_2$  [ $F(3.466) = 145.77$ ;  $p < 0.001$ ;  $\varepsilon = 0.578$ ], and RER [ $F(2.497) = 43.24$ ;  $p < 0.001$ ;  $\varepsilon = 0.416$ ] during ISWT (Figure 1). Table 1 shows the general characteristics of the sample and the maximum physiological parameters at the end of the ISWT.

### Estimation paradigm

Table 2 shows the regression analysis of the total sample. PE showed a strong positive correlation with physiological baseline criteria during ISWT ( $r^2 > 0.90$ ).

Table 3 presents the mean  $r^2$  values calculated in the individual regression analysis. The results confirmed the strong correlation between PE and physiological reference criteria. However, the repeated measures

ANOVA showed significant differences between the analysis models, with the logarithmic analysis model showing the lowest  $r^2$  for both reference standards. No significant differences were observed between the linear and exponential analysis models.

### Production paradigm

Table 1 shows the physiological response in the production protocol. No statistically significant differences were observed between PRET and ISWT for the defined PE levels. Absolute differences for  $\text{VO}_2$  and HR were  $1.7 \pm 6.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  ( $t = 1.18$ ;  $p = 0.25$ ) and  $2.7 \pm 15.0 \text{ bpm}\cdot\text{m}^{-1}$  ( $t = 0.81$ ;  $p = 0.43$ ), respectively.

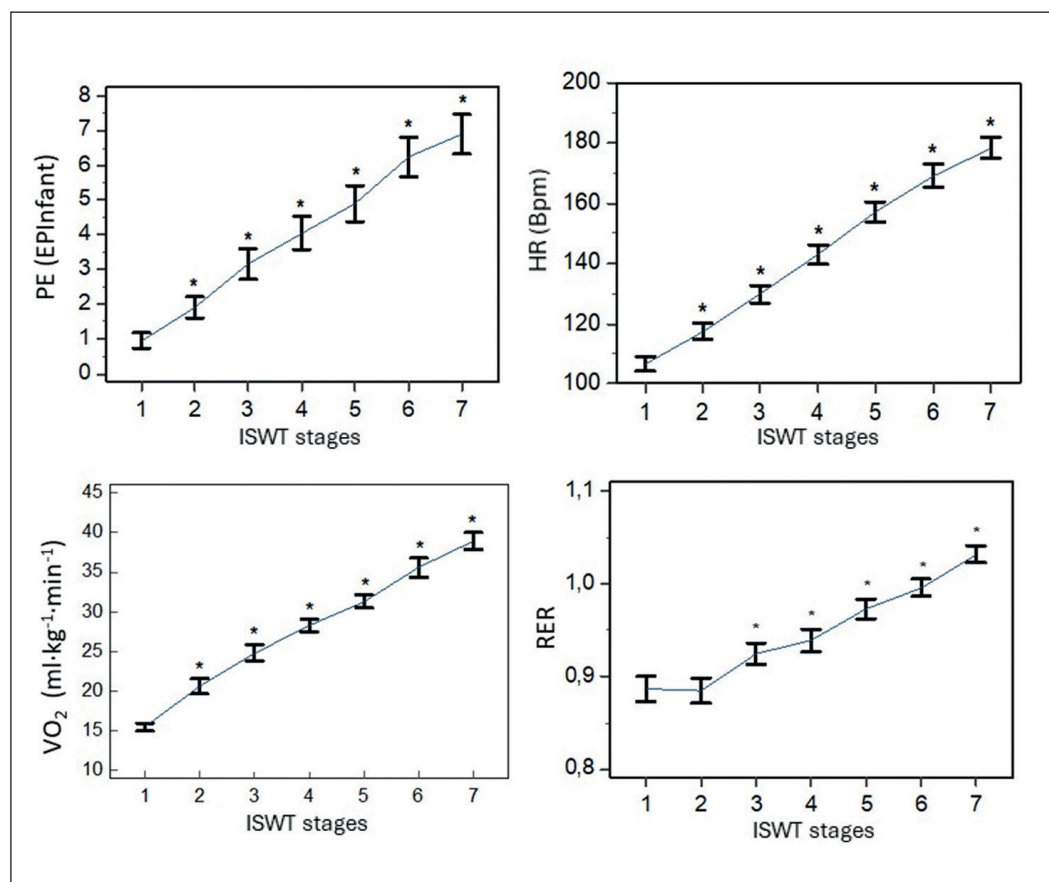
Reproducibility analysis confirmed these observations. The ICC for  $\text{VO}_2$  and HR was 0.89 (0.70 to 0.96) and 0.64 (0.008 to 0.86), respectively. Also, the Bland-Altman analysis showed a mean discordance for  $\text{VO}_2$  of  $-1.7 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  (LoA =  $-14.3$  to  $10.9$ ) (Figure 2 A) and for HR of  $-2.7 \text{ bpm}\cdot\text{min}^{-1}$  (LoA =  $-32.7$  to  $26.7$ ) (Figure 2 B).

## Discussion

This study analyzed the criterion validity of the EPIInfant scale in the estimation and production paradigms, considering  $\text{VO}_2$  and HR as reference criteria. The efficacy of the EPIInfant scale as a tool for the psychophysical transcription of exercise intensity was confirmed based on the close correspondence between increases in PE and physiological variables during the ISWT. The relationships between these variables showed  $r^2$  values higher than 0.9, independent of the fit model and reference criterion.

These results coincide with validation studies of the EPIInfant scale previously performed in children of similar age, in other exercise modalities. In step aerobics modality,  $r^2$  values of 0.98 and 0.96 have been reported, considering HR and workload as reference criteria<sup>16</sup>. In running modality, previous reports showed lower validity indices than those estimated in this study<sup>15</sup>. Rodríguez-Núñez et al, in sedentary children aged between 13 and 15 years, reported an  $r^2$  of 0.74 in the relationship between PE and the reference standard<sup>15</sup>. This difference can be explained by the differences in the physical activity habits of the individuals studied. While the cited study included children with a low level of physical activity<sup>15</sup>, in our study the individuals were soccer players. This hypothesis is backed by several lines of evidence that have supported the importance of the experiential dimension and the psychomotor ability of children as factors that could optimize the perceptual process of exercise intensity<sup>6,12</sup>.

It is worth mentioning that the performance of the EPIInfant scale in the estimation paradigm is compa-



**Figure 1.** Physiological variables during ISWT. ISWT: Incremental shuttle walking test; PE: Perceived exertion; HR: Heart rate; VO<sub>2</sub>: Oxygen consumption; RER: Respiratory exchange ratio ( $\text{VO}_2 \cdot \text{VO}_2^{-1}$ ).

table to that of other PE scales. Robertson et al. observed a high correlation ( $r^2 > 0.80$ ) between PE measured with the OMNI exertion scale and physiological reference criteria (VO<sub>2</sub> and HR) in children aged 12.8 years<sup>(21)</sup>. Besides, Roemmich observed that increases in perceptual scores on the PCERT and OMNI scale were correlated with VO<sub>2</sub> ( $r^2$  [children] = 0.81 and 0.84) and with HR during an incremental running test in 11.2-year-old children<sup>22</sup>.

In addition, the one-factor ANOVA showed significant differences between the adjustment models, with the logarithmic analysis model showing the lowest  $r^2$  in both reference standards. Interestingly, no significant difference was observed between the linear and exponential analysis models, even in the PE:VO<sub>2</sub> ratio, the linear model showed slightly higher indices than the exponential, which differs from the existing evidence<sup>19,20</sup>. Previous studies carried out in children under 8 years of age, found that the nature of the relationship between PE and physiological parameters, such as VO<sub>2</sub> and HR, would be exponential, independent of the exercise modality performed<sup>19,20</sup>. This phenomenon could be explained by the fact that in pre-schoolers and prepubertal schoolchildren, PE seems to

**Table 1. Biodemographic characteristics and physiological responses during the ISWT and PRT**

| Variables                                                   | Results         |
|-------------------------------------------------------------|-----------------|
| <i>Biodemographic characteristics</i>                       |                 |
| Age, Years                                                  | 9.8 ± 1.5       |
| Weight, kg                                                  | 37.6 ± 7.4      |
| Height, cm                                                  | 143.1 ± 8.7     |
| BMI, kg/m <sup>2</sup>                                      | 18.2 ± 2.5      |
| Fat mass, %                                                 | 6.7 ± 3.7       |
| Fat free mass, kg                                           | 16.3 ± 3.4      |
| <i>Results of ISWT</i>                                      |                 |
| PE, EPInfant                                                | 6.9 ± 2.6       |
| HR, Bpm                                                     | 178.4 ± 15.8    |
| HR, % pred                                                  | 88.7 ± 7.8      |
| VO <sub>2</sub> , ml · kg <sup>-1</sup> · min <sup>-1</sup> | 38.9 ± 4.9      |
| VO <sub>2</sub> , ml · min <sup>-1</sup>                    | 1.473.0 ± 397.4 |
| RER                                                         | 1.03 ± 0.04     |
| <i>Results of PRT</i>                                       |                 |
| HR, Bpm                                                     | 181.1 ± 13.0    |
| HR, % pred                                                  | 90.0 ± 6.5      |
| VO <sub>2</sub> , ml · kg <sup>-1</sup> · min <sup>-1</sup> | 40.5 ± 6.3      |
| VO <sub>2</sub> , ml · min <sup>-1</sup>                    | 1.495.0 ± 397.3 |
| RER                                                         | 1.1 ± 0.08      |

BMI: Body mass index; PE: Perceived exertion; HR: Heart rate; VO<sub>2</sub>: Oxygen consumption; RER: Respiratory exchange ratio ( $\text{VO}_2 \cdot \text{VO}_2^{-1}$ ); ISWT: Incremental shuttle walking test; PRT: Perceptual reproduction test.

**Table 2. Simple regression analysis by linear, exponential, and logarithmic fix model between PE and physiological variables during the ISWT**

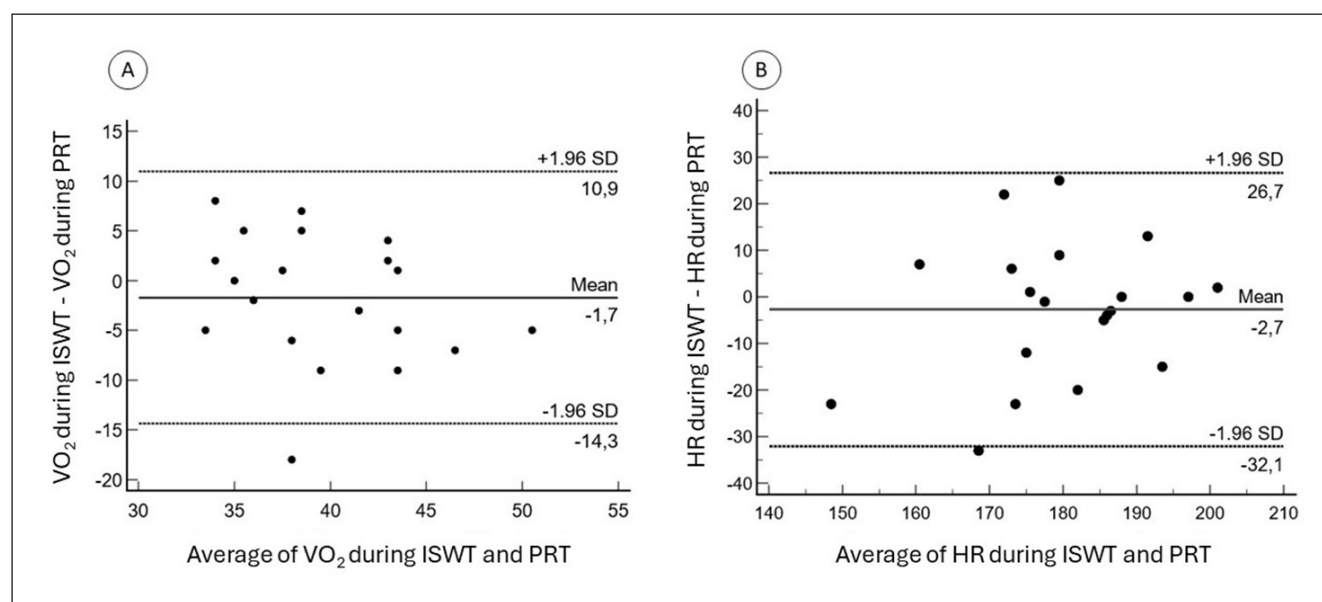
| Independent variables |                                                           | intercept | Slope | r <sup>2</sup> | P value  |
|-----------------------|-----------------------------------------------------------|-----------|-------|----------------|----------|
| Criteria              |                                                           |           |       |                |          |
| Linear model          | FC (lpm)                                                  | -7.70     | 0.08  | 0.99           | < 0.0001 |
|                       | VO <sub>2</sub> (ml·kg <sup>-1</sup> ·min <sup>-1</sup> ) | -3.34     | 0.26  | 0.99           | < 0.0001 |
| Exponential model     | FC (lpm)                                                  | -1.0      | 0.011 | 0.91           | 0.0001   |
|                       | VO <sub>2</sub> (ml·kg <sup>-1</sup> ·min <sup>-1</sup> ) | -0.48     | 0.036 | 0.94           | 0.0002   |
| Logarithmic model     | FC (lpm)                                                  | -52.55    | 26.32 | 0.99           | < 0.0001 |
|                       | VO <sub>2</sub> (ml·kg <sup>-1</sup> ·min <sup>-1</sup> ) | -17.91    | 15.37 | 0.97           | 0.0001   |

PE: Perceived exertion; ISWT: Incremental shuttle walking test; HR: Heart rate; VO<sub>2</sub>: Oxygen consumption; VE: Minute ventilation; r<sup>2</sup>: Determination coefficient.

**Table 3. Comparison of individual determination coefficients (r<sup>2</sup>) estimated from linear, exponential, and logarithmic fix models.**

| Variables            | Individual regression |                            |             | F-value | Valor P |
|----------------------|-----------------------|----------------------------|-------------|---------|---------|
|                      | Linear                | logarithmic                | Exponential |         |         |
| PE : HR              | 0.87 ± 0.03           | 0.78 ± 0.04 <sup>a,b</sup> | 0.87 ± 0.03 | 11.54   | < .003  |
| PE : VO <sub>2</sub> | 0.87 ± 0.03           | 0.79 ± 0.04 <sup>c</sup>   | 0.83 ± 0.03 | 6.00    | < .0019 |

PE: Perceived exertion; FC: Heart rate; VO<sub>2</sub>: Oxygen consumption; r<sup>2</sup>: Determination coefficient. <sup>a</sup>p = 0,0022 compared with linear model; <sup>b</sup>p = 0,0185 compared with exponential model; <sup>c</sup>p = 0,0052 compared with linear model. Repeated measured ANOVA with Bonferroni correction was used.

**Figure 2.** Reliability of VO<sub>2</sub> and HR during the PRT. In A, Bland-Altman plot for VO<sub>2</sub>. In B, Bland-Altman plot for HR. ISWT: Incremental shuttle walking test; PRT: Perceptual reproduction test; VO<sub>2</sub>: Oxygen consumption; HR: Heart rate.

be strongly determined by minute ventilation<sup>20</sup>. In this context, considering that respiratory rate (RR) at moderate to high exercise intensities correlates inversely with age in children<sup>23</sup>, it is likely that the older age of the participants in this study (between 8 and 12 years) associated with a lower RR, may have dampened the disproportionate increases in PE at moderate to high exercise intensities, contributing to rectify the nature of the relationship between PE and physiological variables. However, studies with larger sample sizes should confirm these hypotheses.

Regarding the production paradigm, the results coincided with previous studies<sup>6</sup>, as no significant differences were observed between ISWT and PRET in the  $\text{VO}_2$  and HR values. Additionally, the relative reliability was moderate and high in HR and  $\text{VO}_2$  (ICC 0.64 and 0.85, respectively). Specifically, HR presented wider limits of agreement than  $\text{VO}_2$ , which explains the difference in the ICC value between both physiological parameters. These results indicate that the EPIInfant scale was effective in translating the magnitude of physiological stress produced into quantifiable units, allowing adequate self-regulation of intensity during PRET.

Among the limitations of this study, it should be mentioned that individuals did not reach the maximum PE level (PE 10) during the ISWT, which reduced the statistical precision of the estimates, especially at PE values above 7. Also, the reproduction of a single perceptual category of intensity did not allow the evaluation of the discriminative capacity of the workload of the EPIInfant scale, which should be explored in further studies.

Finally, it is possible to conclude that the EPIInfant scale presented adequate criterion validity in the estimation and production modalities, in healthy children

aged between 8 and 12 years, during running exercise. Future studies should be conducted to evaluate the psychometric properties of the EPIInfant scale in other scenarios and exercise modalities, as well as in girls and people with chronic health conditions.

## Ethical Responsibilities

**Human Beings and animals protection:** Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

**Data confidentiality:** The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

**Rights to privacy and informed consent:** The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondence author.

## Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

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