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Borg's category ratio-scale (CR-10) is useful to predict the onset of blood lactate accumulation (OBLA) in young Mexicans adults, regardless their body mass

La escala Borg (CR-10) sirve para predecir el inicio de la acumulación de lactato sanguíneo (OBLA) en adultos jóvenes mexicanos, independientemente de su masa corporal

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ABSTRACT

Aim: To evaluate the predictive value of Borg's category ratio-scale (CR-10; 1-10) toward the onset of blood lactate accumulation (OBLA). **Methods:** 91 young Mexicans performed three non-consecutive sub-maximal exercise tests. Heart rate (HR), blood lactate and oxygen uptake were recorded at each CR-10 rating. Regression equations, reliable HR and CR-10 cut-off points of OBLA were then calculated. **Results:** HR (86 beats/min) and CR-10 (4.5) predicted OBLA with the same certainty, regardless the subject's body mass. CR-10, HR and oxygen uptake, independently explained more than 60% of the associated variance to OBLA. **Conclusions:** CR-10 is useful to predict OBLA with almost the same certainty that HR, regardless the subject's body mass.

KEYWORDS: exercise physiology, metabolism, obesity, physical fitness, youth.

RESUMEN

Objetivo: evaluar el valor predictivo de la escala de Borg (CR-10; 1-10) para el inicio de la acumulación de lactato en sangre (OBLA). **Métodos:** 91 jóvenes mexicanos realizaron tres pruebas de ejercicio submáximas no consecutivas. La frecuencia cardíaca (FC), el lactato en sangre y el consumo de oxígeno se registraron en cada determinación del CR-10. Se calcularon ecuaciones de regresión y los puntos de corte de FC y al OBLA. **Resultados:** La FC (86 lat/min) y el CR-10 (4.5) predijeron el OBLA con la misma certeza, independientemente de la masa corporal del sujeto. CR-10, la FC y el consumo de oxígeno explicaron independientemente más de 60% de la varianza asociada al OBLA. **Conclusiones:** CR-10 es útil para predecir el OBLA con casi la misma certeza que la FC, independientemente de la masa corporal del sujeto.

PALABRAS CLAVE: fisiología del ejercicio, metabolismo, obesidad, aptitud física, juventud.

INTRODUCTION

Overweight/obesity [body mass index ≥ 25 kg/m²] is a prodromal condition for many metabolic derangements closely related to several non-communicable chronic diseases in young adults around the globe, including Mexicans (Wall-Medrano *et al.*, 2016). The Mexican government is pushing for a more “ecological/systemic” agenda to reduce the economic burden associated to this condition, implementing structural (e.g. primary prevention of chronic diseases and taxation of energy-dense foods), physical (e.g. exercise equipment in public spaces), communication (e.g. front package nutrition labelling) and surveillance (e.g. 6 year-spaced health & nutrition surveys) policies. A high rate of sedentarism has contributed to the alarming rates of obesity in young Mexicans but multi-stakeholder organizations have financed several programs to promote physical activity, in order to reduce this unhealthy behavior (Jauregui *et al.* 2015). Effective weight-loss programs often include personalized counseling and prescription of systematic physical activity, being aerobic exercise in private facilities the most common. According to the 2016 *International Fitness Industry Trend Report* (Club Intel, 2016), high intensity interval exercise, group cycling (constant intensity), spinning (incremental intensity) and traditional yoga classes have reached the “mature state” as exercising strategies for people with normal and excess body weight.

However, health organizations such as the *American College of Sports Medicine*, *American College of Chest Physicians*, *American Heart Association* and the *American Thoracic Society*, recommend several standards for exercise prescription prior to its systematic performance (American Thoracic Society, 2003; Fletcher *et al.*, 2013), a fact that is not followed in most fitness centers. From a primary and secondary prevention stand point, exercise prescription should be initially based on people’s fitness parameters which differ by age, gender and body weight status (Edvardsen *et al.*, 2014; Loe *et al.* 2013). Specifically, the physical performance under submaximal exercise tests using stationary bicycles, treadmills and cycle-ergometers is commonly evaluated in clinical and research settings by measuring people’s heart rate (HR), maximal oxygen uptake ($\text{VO}_{2\text{max}}$) and respiratory exchange ratio (VCO_2/VO_2), since all of them show a parallel increase with exercise intensity, reaching a steady state at a submaximal workload (Jones *et al.*, 1985; Ramos-Jiménez *et al.*, 2008). These physiological parameters objectively evaluate the body’s maximal aerobic capacity and so, more reliable and safe exercise protocols can be prescribed (American Thoracic Society, 2003; Fletcher *et al.*, 2013).

Blood lactate ($[\text{LA}^-]_{\text{b}}$) has been also used in exercise testing (Beneke *et al.*, 2011) since it is very sensitive to exercise intensity and duration and it is also useful to evaluate the passive and active recovery post-exercise (Ramos-Jiménez *et al.*, 2013a). The onset of blood lactate accumulation (OBLA) occurs at $[\text{LA}^-]_{\text{b}} = 4$ mM and encompasses the psychomotor fatigue threshold, a sign of metabolic response to exercise tolerance and endurance training (Chmura & Nazar, 2010). However, without acknowledging their usefulness, the above-mentioned fitness parameters are time & resource consuming for fitness centers.

The relationship between self-perceived physical exertion (PE), HR, $\text{VO}_{2\text{max}}$ and $[\text{LA}^-]_{\text{b}}$ in heavy indoor exercising has been well established (Borg, 1982; Ramos-Jiménez *et al.*, 2013b). Among PE scales, the ten-point Borg’s category ratio-scale (CR-10) increases linearly with HR while its relationship with submaximal workload, perception of leg pain, anaerobic threshold and $[\text{LA}^-]_{\text{b}}$ follows a non-linear function (Borg *et al.*, 1985; Zamunér *et al.*, 2011). Although Borg & Kaijser (2006) have developed other PE scales initially proposed to give data that grow linearly with stimulus intensity (e.g. HR and VO_2 in aerobic work of steady-state character on a cycle-ergometer) within the 4-6 min after initiation but CR-10 seems to fit more properly with $[\text{LA}^-]_{\text{b}}$ and the anaerobic threshold (attained at a $[\text{LA}^-]_{\text{b}}$ higher than OBLA and where its clearance is reduced) in incremental cycle-ergometer tests (Muyor, 2013; Zamunér *et al.*, 2011). Moreover, CR-10 is particularly useful in clinical settings and epidemiological studies to evaluate programmed exercising and recreational physical activity.

However, the reliability of CR-10 to predict $[\text{LA}^-]_{\text{b}}$ levels depends on the type of exercise (e.g. valid for bench stepping but not aerobic dance; Muyor, 2013) and adequate large-scale validations on this matter have

not been reported yet. Moreover, it is well known that non-proper (self-selected or prescribed) exercise intensity affects PE in overweight/obese (endomorph) subjects, reducing their motivation and adherence to any exercise program (Ekkekakis & Lind, 2006), a fact that could be minimized with the timely detection of pre-maximal PE in people with excess body weight. This study aimed to take a step forward on the validity of CR-10 to predict OBLA, since OBLA precedes maximal PE and is the breaking point on body fuel utilization (from fat to carbohydrates), determining an efficient weight-loss. Convergent validity of CR-10 against HR and prospective equations to predict and $[LA^-]_b$ is also reported.

1. MATERIALS AND METHODS

1. 1. Experimental design

An observational cross-sectional study was performed from January-April 2017. The *Strengthening the Reporting of Observational studies in Epidemiology* statement was considered when drafting this report.

1. 2. Subjects and setting

One hundred and thirty college students (24 ± 4 y) were enrolled in the study. Since the physiological response (e.g. body temperature, blood pressure and HR) to exercise is gender-specific in this type of population (Loe *et al.*, 2013; Ramos-Jiménez *et al.*, 2013b), just male subjects were included. Other inclusion criteria were a stable body weight in the last month, not have smoked, drunk alcohol and consumed any drug nor sport supplement six months before participation. No participant reported a dangerous health condition in the physical activity readiness questionnaire (Dinger *et al.*, 2006). Ninety-one participants fulfilled these criteria and were formerly enrolled in the study. 85% of all participants spent ≤ 3 h/week to moderate-vigorous physical activity while 15% were athletes out of competition season. All participants underwent a physical examination and were instructed to avoid moderate-to-high physical activity 48 h before any session. All experiments were performed in a well-ventilated laboratory at standard room conditions (23 °C and 23% of relative humidity).

2. ANTHROPOMETRY & BODY COMPOSITION

Each participant came to the laboratory between 8:00 - 10:00, either fasted or having eaten a light standard breakfast (25-30% of the subject's daily energy requirement) in five separate (72 h) occasions during two and a half weeks. Body weight (kg) & height (m) (test-retest, $r = 0.98$) and waist & hip circumferences (cm) were taken in session one, by three trained anthropometrists as previously described (Wall-Medrano *et al.*, 2016). The following body composition indexes were calculated: Body mass index (BMI; kg/m^2), waist-to-hip ratio and body adiposity index using the validated equation reported by Bergman *et al.*, (2011). Lastly, each subject's somatotype [endomorph, mesomorph, ectomorph] was calculated according to the *Heath & Carter* method (Carter, 2002) based on the following body measurements (right-side; test-retest, $r \geq 0.90$): body weight, height, skinfolds (triceps, subscapular, supraspinale, medial calf corrected for height), biepicondylar breadths (humerus, femur), girths (upper arm, calf), following all recommendations from the *International Society for the Advancement of Kinanthropometry*.

3. CARDIORESPIRATORY FITNESS

In session two, each subject performed a preliminary short cycle ergometer test (Monark ergomedic 828 E; Monark exercise AB, 105 Vansbro, Sweden) during which HR ($\text{beats} \cdot \text{min}^{-1}$) was measured with a Polar H7

sensor (Polar Electro, Lake Success, NY), VO_2 ($\text{mL.kg}^{-1}.\text{min}^{-1}$ or L.min^{-1}) with a gas analyzer (Cortex MetaLyzer® 3B, Germany) (Ramos-Jiménez *et al.*, 2008; Ramos-Jiménez *et al.*, 2013a). The gas analyzer was calibrated and corrected for barometric pressure, temperature and humidity before and during each test by using certified gas mixtures of known concentrations [4% (CO_2) - 16% (O_2) - 80% (N_2); 26% (O_2) - 74% (N_2)]. The equipment complied with all minimal requirements stated by the *American Thoracic Society* and the *American College of Chest Physicians* (American Thoracic Society, 2003) for dynamic exercise testing devices. Maximal threshold values for HR [HR_{MAX} (beats.min^{-1})] and VO_2 [measured ($_{\text{Peak}}$) / calculated ($_{\text{MAX}}$) VO_2 ($\text{mL.kg}^{-1}.\text{min}^{-1}$ or L.min^{-1})] were used to define the subject's fitness condition, following the *American Heart Association* standards for exercise testing and training (Fletcher *et al.*, 2013; Jones *et al.*, 1985).

4. SUBMAXIMAL EXERCISE TEST

From the 3rd to the 5th session, participants performed three non-consecutive submaximal exercise tests for considering intra-individual variations in PE, HR and $[\text{LA}^-]_{\text{b}}$. The cycle-ergometer was fixed to the subjects' preferred hip angle in upright position, in order to avoid any discomfort that may affect its physical performance and PE during the test (Ashe *et al.*, 2003). The submaximal exercise test consisted of the following protocol: Firstly, all subjects warmed up to 5 minutes while pedaling with no load. Afterwards, the exercise was initiated at a workload of 50-75 watts with increments of 20 (unfit subjects) or 30 (fit subjects) watts (Ramos-Jiménez *et al.*, 2008) every three minutes for up to 15 minutes until evident exhaustion or when the subject pedaled at ≤ 40 revolutions/min. The exercise was stopped when reaching 90% of the age-determined HR_{MAX} .

5. BORG'S CATEGORY RATIO-SCALE (CR-10)

CR-10 scale was explained in session two before evaluating the subject's cardiorespiratory fitness (sessions 3-5). Psychosomatic fatigue was evaluated every three minutes using the verbal expressions for CR-10 (table 1) suggested by Borg (1982; *et al.*, 1985). The scale (with no PE "labels") was wall-mounted just in front of the participant, and the rating was recorded every three minutes.

TABLE 1
Borg's category ratio-scale (CR-10)

Level	Perceived exertion ("label")	Level	Perceived exertion ("label")
0	Nothing at all	5.0	Strong
0.5	Very very weak (just noticeable)	6.0	
1.0	Very weak	7.0	Very strong
2.0	Weak (light)	8.0	
3.0	Moderate	9.0	
4.0	Somewhat strong	10.0	Very very strong (almost max)

Source: Borg (1982; *et al.*, 1985; & Kaijser, 2006). "Labels" are not displayed to the participant.

6. BLOOD LACTATE

$[\text{LA}^-]_{\text{b}}$ level (mM) was assayed in an YSI 1500 Sport Lactate Analyzer (YSI life sciences, OH, U.S.A) as previously described (Ramos-Jiménez *et al.*, 2013a). The onset of blood lactate accumulation (OBLA) was defined at $[\text{LA}^-]_{\text{b}} = 4$ mM (Chmura & Nazar, 2010) while the anaerobic threshold was defined in this study as the $[\text{LA}^-]_{\text{b}}$ at which the 90% of the age-determined HR_{MAX} was reached.

7. STATISTICAL ANALYSIS

Anthropometric data was firstly analyzed by using Software LifeSize version 2.0 (Nolds Sports Scientific; Australia). The following records were included in the statistical analysis: *a*) Records with complete anthropometric and physiological data (BMI + HR + VO₂ + [LA⁻]_b + CR-10) and *b*) Records derived from complete submaximal exercise tests were the subject reached 90% of the age-determined HR_{Max} (Jones *et al.*, 1985). Descriptive data were generated and reported as mean ± SD after testing for normality. Differences in both anthropometric and physiological variables between normal weight (BMI = 18.5-24.9 kg/m²) and overweight/obese (BMI ≥ 25 kg/m²) were analyzed using 2-tailed, paired t tests. Relationships between all physiological parameters and CR-10 ratings during submaximal exercise were examined firstly by using Pearson's product moment correlation coefficients. The best predicting equations (linear, quadratic, cubic, exponential or power) for CR-10 *vs.* HR and CR-10 *vs.* [LA⁻]_b, were further generated by regression analysis using the maximum R² (goodness-of-fit) procedure as previously described (Wall-Medrano *et al.* 2016).

The reliability of HR (as %HR_{max}) and CR-10 cut offs as independent predictors of OBLA was analyzed by their sensitivity (low false negatives) and specificity (low false positives) using crosstabs and receiving operating characteristic (ROC) curves. Stepwise linear regression was used to explore all possible relationships between CR-10, physiological (HR, VO_{2max}) and anthropometric (mesomorphy, waist/hip ratio) variables and [LA⁻]_b. All statistics were performed using IBM SPSS statistics 21.0 (Armonk, NY: IBM Corp). The alpha level was set at *p* < 0.05.

8. RESULTS

According to table 2, 49.5% of all participants were overweight/obese (29.3 ± 3.0 kg/m²), with a higher waist (+16 cm), hip (+10.2 cm), waist/hip (+0.1) and body adiposity index (+4%) than normal-weight

TABLE 2
Anthropometric and physiological characteristics of participants

	Total	Normal weight	Overweight-obese
N	91	46	45
Age (y)*	24±4	23±3	25±5
Body weight (kg)**	78.1±15.1	68.0±8.3	88.3±13.6
Height (m)	1.7±0.1	1.7±0.1	1.7±0.1
Body mass index (kg/m ²)**	25.9±4.2	22.5±1.7	29.3±3.0
Waist circumference (cm)**	82.1±11.0	74.9±5.9	90.9±9.1
Hip circumference (cm)**	97.0±7.4	92.4±4.6	102.6±6.2
Waist-to-hip ratio**	0.8±0.1	0.8±0.05	0.9±0.1
Waist-to-height ratio	0.04±0.00	0.04±0.00	0.04±0.02
Body adiposity index (%) **	24.3±3.5	22.5±2.6	26.5±3.2
VO ₂ Max (L.min ⁻¹)	3.8±0.3	3.8±0.3	3.9±0.4
VO ₂ Peak (L.min ⁻¹)	3.7±0.8	3.6±0.8	3.7±0.8
VO ₂ Peak (mL.kg ⁻¹ .min ⁻¹)**	46.6±11.9	51.8±12.3	40.7±8.3
VO ₂ 3min (L.min ⁻¹)	2.0±0.7	2.0±0.6	2.1±0.7
HR _{max} (beats.min ⁻¹)*	184.8±3.1	185.8±2.3	183.9±3.5
HR _{3min} (beats.min ⁻¹)	129.9±20.1	131.0±22.5	128.8±69.4
HR _{3min} (% HR _{max})	70.0±9.1	70.6±9.9	69.4±8.3
[LA ⁻] _b 3min (mM)	2.6±0.9	2.7±0.9	2.5±0.9

Data is expressed as mean ± SD. Statistical differences between normal and overweight/obese individuals at *p* ≤ 0.002 (*) or *p* < 0.0001 (**); heart rate (HR), oxygen uptake (VO₂) and/or lactate [LA⁻]_b measured at minute three (3 min) or highest measured (Peak) or calculated (Max) level.

subjects ($p < 0.001$). The two-dimensional somato chart (figure 1) shows two clearly differentiated somato types for normal-weight (1-central; $x = 0, y = 2.8$) and overweight/obese (2- endomorph/mesomorph; $x = -4, y = 6.8$) subjects with a quasi-linear distribution along the mesomorph axis. Although overweight/obese subjects showed a lower HR_{Max} ($-1.9 \text{ beats}\cdot\text{min}^{-1}$) and $VO_2 \text{ Peak}$ ($-11.4 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) at the end of submaximal exercise test than normal-weight subjects ($p \leq 0.002$), all other cardiorespiratory fitness indicators were not different ($p > 0.05$) including their physiological response three minutes after being initiated the submaximal exercise protocol: $HR_{3 \text{ min}}$ ($\sim 130 \text{ beats}\cdot\text{min}^{-1}$; $\sim 71\% HR_{max}$), $[LA^-]_b$ (2.6 mM). Both, normal weight and overweight subjects performed submaximal exercise tests at a $VO_2 \text{ peak (experimental)} / VO_2 \text{ max (calculate)}$ ratio of 95%.

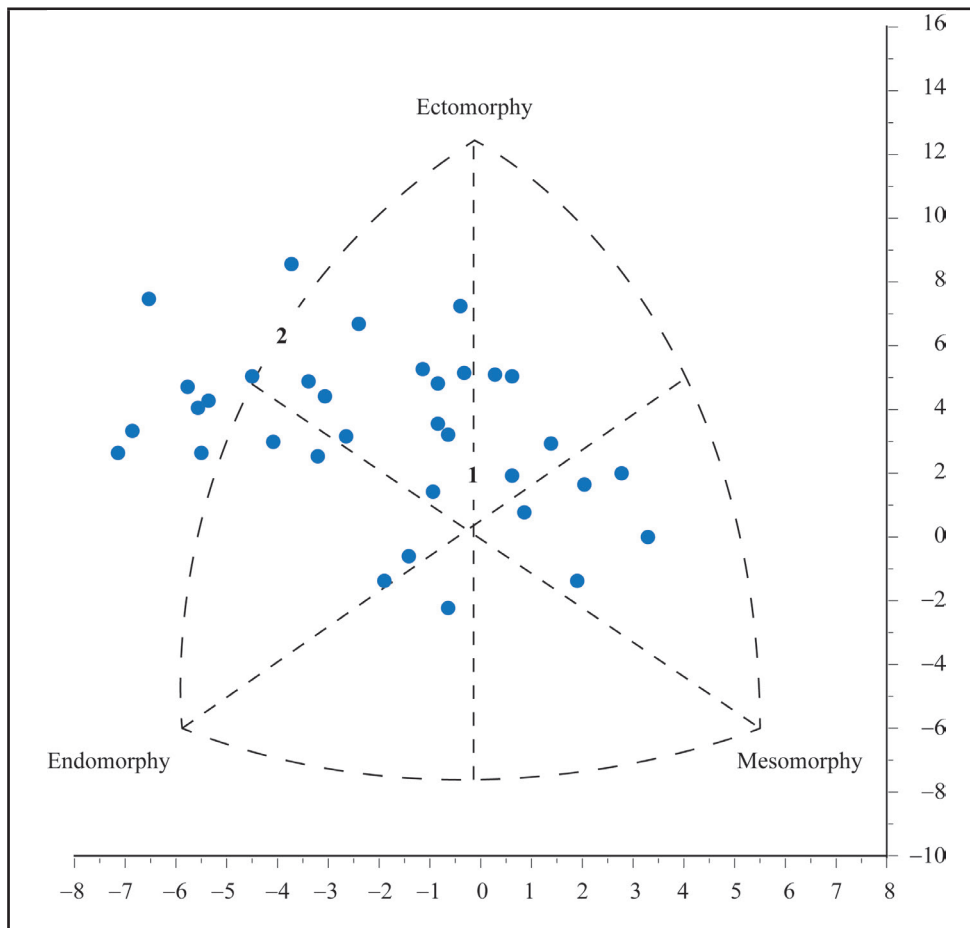


FIGURE 1

Somatochart of participants.

Footnote: Mean somatotype for normal weight (1) and overweight/obese (2) subjects.

Simple linear regression analysis (figure 2) showed coefficients of determination (R^2) between 0.65-0.73 ($HR / CR-10$), 0.54-0.66 ($[LA^-]_b / CR-10$) and 0.25-0.34 ($VO_2 \text{ max} / CR-10$) (figure 1) with no significant effect related to body weight status ($p > 0.05$). Further regression analyses using the R^2 -goodness of fit procedure confirmed the linear relationship between HR and $CR-10$ (see equation in figure 1) while $[LA^-]_b$ vs. $CR-10$ fitted a polynomial model: $[LA^-]_b = 2.10 (CR-10) - 0.36 (CR-10)^2 + 0.023 (CR-10)^3$ ($R^2 = 0.92$; $p < 0.01$) with no significant effect related to body weight status. However, the $VO_2 \text{ max} / CR-10$ statistical relationship did not improve with the R^2 -goodness of fit method.

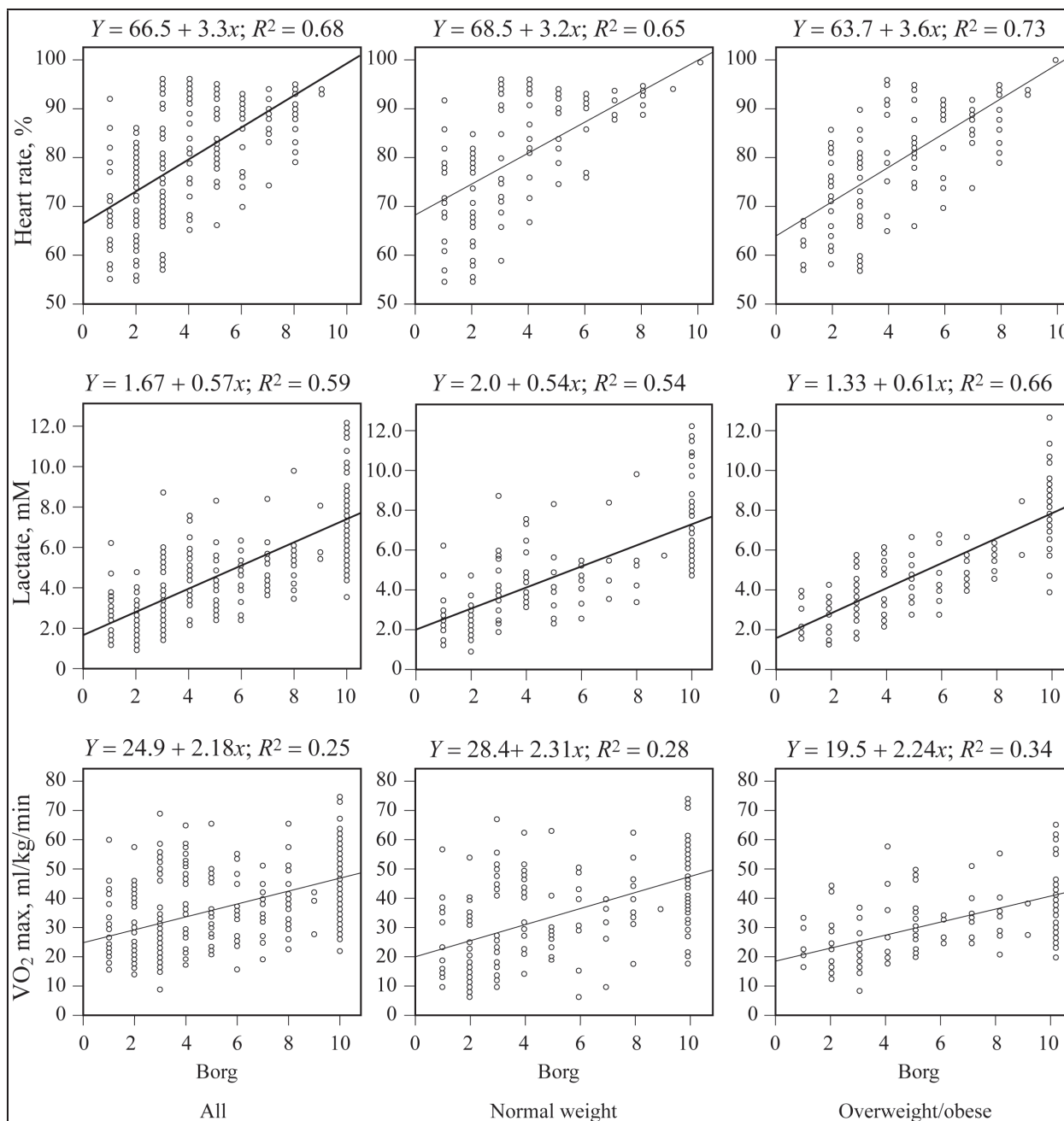


FIGURE 2

Linear regression between Borg's category ratio-scale (CR-10), heart rate (HR), blood lactate [LA⁻]_b and maximal oxygen uptake (VO₂ max).

TABLE 3
Onset of blood lactate accumulation (OBLA)

	HR ^a	CR-10 ^b
OBLA cutoff	86.5	4.5
Sensitivity	0.84	0.80
Specificity	0.90	0.81
Area under the curve	92.3	90.2

Footnote: ^a % of maximal heart rate (HR_{max}). ^b Borg's category ratio-scale (CR-10)

OBLA related cutoffs for % HR_{max} and CR-10 were 86.5 and 4.5, respectively (table 3), showing almost the same sensitivity and specificity ($r = 0.80-0.91$, AUC > 90%). In fact, subjects that specifically declared a CR-10 rating of 4 or 5, did it 6-9 minutes after having initiated the submaximal exercise, although overweight/obese subjects (figure 3, circles) reached this PE at a little bit lower % HR_{max} than normal weight subjects (figure 3, diamonds).

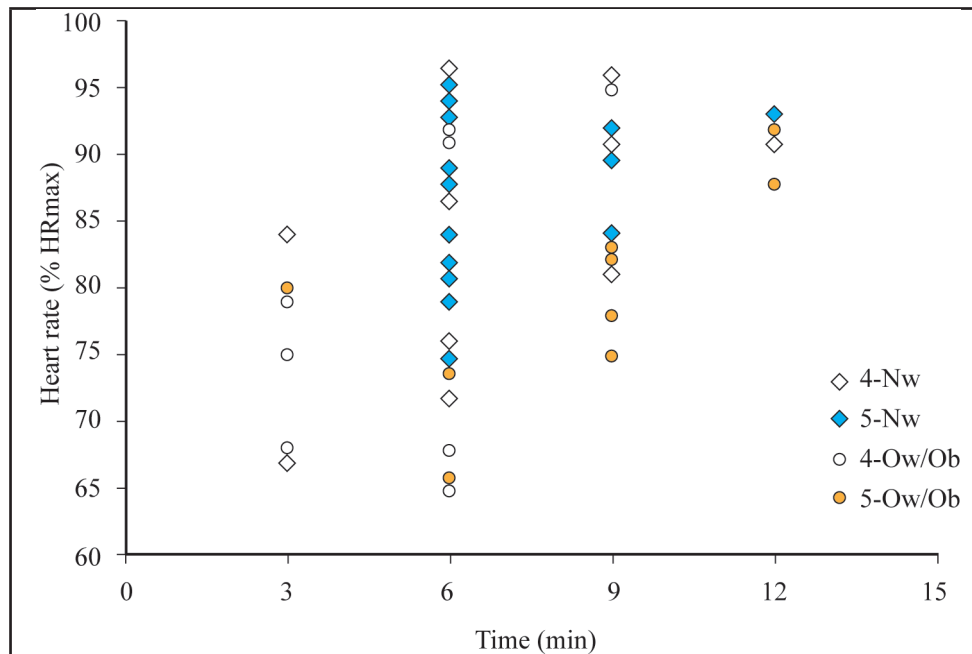


FIGURE 3

CR-10 ratings at OBLA for normal (Nw) and overweight/obese (Ow/Ob) subjects

Footnote: Onset of blood lactate accumulation (OBLA) CR-10's range (4-5).

Lastly, CR-10, % HR_{max}, mesomorphy and VO_{2 max}, independently explained > 60% of the associated variance to [LA⁻]_b, according to the following equations: A) [LA⁻]_b = 0.38(CR-10) + 0.14 (mesomorphy) + 0.033(HR) - 3.17 ($R^2 = 0.64$) and, B) [LA⁻]_b = 5.78(waist/hip) + 0.38(CR-10) + 0.06(VO_{2 max}) + 0.01(HR) - 6.44; ($R^2 = 0.69$).

9. DISCUSSION

The public invitation strategy used in this study led to the recruitment of 91 subjects from which ~50% was overweight/obese with a central adiposity and endomorph/mesomorph phenotype. Obesity is a major health problem for the Mexican health system (Wall-Medrano *et al.*, 2016); due to its high prevalence and negative outcomes, physicians often recommend increasing the level of physical activity plus several dietary modifications, as part of an overall lifestyle change (Galaviz *et al.*, 2015; Jauregui *et al.*, 2015). The *National Agreement for Nutritional Health* has provided the basis to create a sustainable national policy toward a healthier food system while other proactive actions have been implemented by the private sector to promote systematic physical activity (Jauregui *et al.*, 2015). However, there is still a long way to go in terms of reducing the trend of sedentary lifestyle among young Mexicans despite the fact that at this age body image dissatisfaction is an important determinant for sports practicing (Ramos-Jiménez *et al.*, 2017) and exercising in fitness centers (Baile Ayensa *et al.*, 2011).

It is noteworthy that young subjects are more prone to modify their physical activity level than adults (Hallal *et al.*, 2012), since it is a more socially-accepted way for body weight management; this is why

the fitness market focuses on the young user of these services (Club Intel, 2016). However, desertion and attrition to physical activity programs by subjects with excess body weight is high (Ekkekakis & Lind, 2006; Miller & Brennan, 2015), particularly in those performed at a high intensity such as spinning and high-intensity interval exercise. Moreover, the odds of injuries attributed to exercise increases 6-10% for each BMI unit, regardless the type of prescribed exercise (Janney & Jakicic, 2010), a fact that affect the subject's perception of risk/benefit of practicing systematic exercise. Anyhow, the observed high participation in this study probably resulted from the health awareness efforts made by the program *healthy university*, a comprehensive program that fosters academic performance by improving health and quality of life of students (Wall-Medrano *et al.*, 2016), in which promotion of physical activity is a straightforward component.

The fitness status of overweight/obese and normal-weight subjects was quite similar at the beginning but not at the end of the submaximal exercise test, where a lower HR_{max} and $VO_2 Peak$ was observed in overweight/obese subjects; this in turn seemed to affect their PE since both groups declared the same CR-10 rating (4 to 5) at almost the same time frame (6-9 min) but with a little bit different % HR_{max} . According to Ekkekakis & Lind (2006), self-selected and imposed (10% > self-selected) intensity affect the PE and pleasantness of a constant (20 min) treadmill exercise in overweight adult women; they also demonstrated that overweight women exercised at a higher $VO_2 Peak$ than their normal-weight counterparts. However, the relationship between PE with HR_{max} or $VO_2 max$ is also age and sex specifically (Loe *et al.*, 2013). According to Hetlelid *et al.* (2015) the cardiorespiratory performance (93-95% HR_{max}) and PE of well-trained and recreationally-trained male subjects after a session of high intensity interval exercise, is quite similar, increasing their $[LA^-]_b$ to the same extent (~6.3 mM) but differing in their fat utilization. In our study both groups behave the same in the submaximal exercise test ($VO_2 peak / VO_2 max$ ratio ~95%), but the extent to which body fat was used is unknown.

From a physiological stand point, any exercise should be performed at a sufficient intensity in as much time as possible (≥ 30 min), allowing an energy expenditure mainly from body fat reserves (Horowitz & Klein 2000). To achieve this, the person should work at enough submaximal workload without exceeding the anaerobic threshold, since above this point the body switches its substrate utilization increasing the use of carbohydrates instead of fats (Ramos-Jiménez *et al.*, 2008; Zamuner *et al.*, 2011). In this sense, $[LA^-]_b$ becomes the parameter of choice to detect with a greater sensitivity and specificity the anaerobic threshold. It should be clarified that a VO_2 above when the energy is supplied by anaerobic mechanisms (lactate/pyruvate ratio increases) causing a steady-state $[LA^-]_b$ level, glycogen depletion and metabolic acidosis is known as anaerobic threshold while OBLA (4 mM) is a preceding condition (Beneke *et al.*, 2011; Borg *et al.*, 1985). In fact, the exercise intensity at OBLA is 60-70% of submaximal workload while for anaerobic threshold is $\geq 83\%$ where the threshold of psychomotor fatigue occurs (Chmura & Nazar, 2010) associated to a higher pCO_2 and adrenaline/nor-adrenaline response (Munch *et al.*, 2014). In this study, $[LA^-]_b$ was similar among groups three minutes after the submaximal exercise test started; however, $[LA^-]_b$ level increased more homogenous in the overweight/obese group although at a higher rate ($m = 0.61$) than normal-weight subjects ($m = 0.54$), reaching a maximal PE with a wider range of $[LA^-]_b$ level than normal-weight subjects. Many physiological factors can explain this differential $[LA^-]_b$ response including differences in glucose oxidative capacity associated to insulin resistance, mitochondrial functionality and the fact that adipose tissue is a significant source of lactate (Adeva-Andany *et al.*, 2014; Jansson *et al.*, 1994), particularly in overweight/obese individuals.

Besides $[LA^-]_b$, there are other ways to evaluate the exercise intensity; mean blood pressure, body temperature, HR, VO_2 are just some examples (Borg, 1982; Ramos-Jiménez *et al.*, 2013b). However, despite the fact that most of them show a good correlation with $[LA^-]_b$ (Adeva-Andany *et al.*, 2014), their usefulness in the daily practice in most fitness centers is questionable because of their invasiveness. In this case, PE scales

such as those developed by Borg (*et al* 1985; & Kaijser, 2006) could be very useful. It should be remembered at this point, that PE results from integrating many symptoms associated with homeostatic to increasing exercise, come from the skeletal muscle (e.g. $[LA^-]_b$), cardiovascular (e.g. HR, blood pressure), respiratory (e.g. $VO_{2\max}$ and RER) and nervous (e.g. discomfort) systems (Chmura & Nazar, 2010). That is why, CR-10 has been particularly useful for exercise prescription, training and rehabilitation in addition, its correlation with other PE scales such as the visual analogue scale (Capodaglio, 2001) is high.

The linear relationship between PE, HR, $VO_{2\max}$ and $[LA^-]_b$ in heavy exercising has been studied in healthy active subjects (Borg, 1982; Dantas *et al.*, 2015; Ramos-Jiménez *et al.*, 2013b) and aerobic-compromised people (Coquart *et al.*, 2015). However, studies on the relationship of $[LA^-]_b$ at AT or OBLA points are scarce (Chmura & Nazar, 2010; Zamuner *et al.*, 2011). In this investigation we observed that a CR-10 cutoff value of 4.5 (somewhat strong-to-strong) or 86.5% of the HR_{\max} are both reliable to predict OBLA. Both validated cutoffs are useful to prescribe and even evaluate the exercise intensity before reaching the AT (50-70%, $VO_{2\max}$) (Ramos-Jiménez *et al.*, 2013a) for people who wishes to get cardiorespiratory fitness or to lose weight. Moreover, CR-10 is useful to predict OBLA regardless the subject's body weight: when substituting the CR-10 optimized value (4.5) in the lineal and polynomial equations generated in this study, a $[LA^-]_b$ level of 4.24 and 4.26 is obtained respectively and the stepwise-lineal regression equations developed in this study supports CR-10 as the most influencing variable on $[LA^-]_b$. To our knowledge, this is the first report on the statistical relationship between body shape indicators (mesomorphy and waist/hip ratio) and $[LA^-]_b$. In support of this, it is well-known that the higher the muscularity (endomorph) (Van Hall, 2010) or body fat (Adeva-Andany *et al.*, 2014; Jansson *et al.*, 1994) the higher the $[LA^-]_b$ level and we also observed an inverse relationship between waist circumference and $VO_{2\max}$ ($r = -0.25, p < 0.01$; data not shown), which in turn justifies why body organs from overweight/obese subjects may have produced more lactate than normal-weight subjects.

In conclusion, a CR-10 cutoff of 4.5 is useful to predict OBLA (4 mM) with almost the same reliability than HR (convergent validity) during a submaximal exercise test, regardless the subject's body weight. All prospective equations developed in this study sustain the positive relationship between CR-10 ratings and $[LA^-]_b$ but specific body shape indicators of muscularity (mesomorphy) or central adiposity (high waist circumference) are important predictors.

10. STRENGTHS & LIMITATIONS

Lastly, the authors recognize that this study has sources of potential bias or imprecisions that may comprise the generalizability of its results. *First*, the promotion strategy used to recruit participants, caused a higher prevalence of overweight/obesity in the sample than that observed for the same student community (Villalobos-Molina *et al.*, 2015; Wall-Medrano *et al.*, 2016). *Second*, cleaning data records derived from submaximal exercise tests that did not reach 90% of the subject's age-determined HR_{\max} (Jones *et al.*, 1985) this may have resulted in the selection of "fit but fat" cases (Loprinzi *et al.*, 2014). *Third*, the submaximal exercise test was performed in a cycle-ergometer and so, the results could only be applied to exercises of the same nature performed at low (group cycling) or high (spinning) intensity. *Fourth*, it is well-known targeting OBLA (or any specific $[LA^-]_b$ level; Held & Marti, 1999) or pre-fixing a standard submaximal exercise test does not merely mean the same exercise intensity or PE rating among well *vs.* poorly endurance-trained subjects and so the ratio of 15%-to-85% of trained *vs.* un-trained individuals could be underrating the power of CR-10 in the case of trained individuals. Despite these limitations, the value of this study not only relies on the fact that CR-10 is useful to predict OBLA in similar populations (young adults) but also provides a startup platform to evaluate the effect of the aforementioned counterpoints, in order to test the external validity of CR-10 *vs.* OBLA.

PROSPECTIVE ANALYSIS

Exercise science should be available to anyone who wants to physically exercise. The Borg scale is a subjective, however practical instrument and simple to use, which allows us to graduate the exercise, so that we can work at known intensities, aerobic or anaerobic, either to lose weight, to strengthen the cardiovascular system or both. Given its usefulness, any coach and sports center that is considered respectable should include this tool when imparting physical activity. However, in order to maximize the OBLA-predicting value of CR-10 reported here, further studies are required in young people from other regions of Mexico; without doubt, more than a limitation of the study, it is a contribution that will prompt other research groups of Mexico to extend the external validation of CR-10.

ETHICAL CONSIDERATIONS

The submaximal exercise protocol (including all secondary physiological outcomes) was initially approved by the Institutional Ethics Committee of the Autonomous University of Ciudad Juárez. After receiving a detailed explanation of all experimental procedures and purpose of the observational study, including information on the nature of the submaximal exercise test, end-point symptoms and possible complications (Fletcher *et al.*, 2013), each participant signed a written and informed consent in compliance with the declaration of Helsinki.

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ABBREVIATIONS

BMI: Body mass index

CR-10: Borg's category ratio-scale

HR: Heart rate

HR_{max}: maximal HR

[LA⁻]_b: Blood lactate

OBLA: Onset of blood lactate accumulation

PE: Perceived exertion

ROC: Receiving operating characteristics

VO₂: Oxygen uptake

VO_{2 max}: Maximal VO₂ (calculated)

VO_{2 peak}: Maximal VO₂ (measured)

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