Validity and reliability of rating perceived exertion in women with fibromyalgia: exertion-pain discrimination

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Abstract
The present study aimed (1) to assess the validity and reliability of the Borg category-ratio (CR-10) scale for monitoring exercise intensity in women with fibromyalgia (FM) and (2) to examine whether women with FM can discriminate between perceived exertion and exercise-induced pain. Thirty-three women with FM performed two incremental treadmill tests (1 week separated). Heart rate, oxygen uptake, minute ventilation and respiratory quotient were measured. The ratings of perceived exertion (RPE: CR-10 scale) and exercise-induced pain were obtained at each workload. The Spearman’s correlation of RPE with the physiological responses ranged from 0.69 to 0.79. The regression models explained ~50% of the variability of the studied physiological responses. We found “perfect acceptable” agreement in 69% of the observations. Weighted Kappa was 0.66 (95% confidence interval [CI]: 0.59–0.72). There were differences between RPE and pain at workloads 3 (1.50; 95%CI: 0.85–2.16), 4 (2.10; 95%CI: 1.23–2.96), 5 (3.40; 95%CI: 1.29–5.51) and 6 (3.97; 95%CI: 1.61–6.33). The main findings of the present study suggest that the Borg CR-10 scale is valid and moderately reliable for monitoring exercise intensity in women with FM, and these patients were able to discriminate between exertion and exercise-induced pain.

Keywords: chronic pain, health, cardiorespiratory fitness, heart rate control, exercise intensity

Introduction
Fibromyalgia (FM) is a disorder of pain regulation characterised by an increased sensitivity to painful stimuli (hyperalgesia) and lowered pain threshold (allodynia) (Staud, 2002). The prevalence of FM in Europe (2.9%) is considerably higher in women (3.6%) than in men (2%) (Branco et al., 2010). Although the hallmark of FM is pain, several coexistent symptoms such as fatigue, stiffness, non-restorative sleep or cognitive difficulties are commonly reported (Rahman, Underwood, & Carnes, 2014). FM patients often incur substantial extra health care costs (Sicras-Mainar et al., 2009), and the management of this chronic condition is a complicated process that requires a multidisciplinary approach, including pharmacological treatment, cognitive behavioural therapy, patient education and physical exercise (Rahman et al., 2014).

There is growing evidence suggesting that aerobic exercise plays a key role in the management of FM (Brosseau et al., 2008; Busch, Barber, Overend, Peloso, & Schachter, 2007; Rahman et al., 2014), since it might increase cardiorespiratory fitness (Hooten, Qu, Townsend, & Judd, 2012) and improve acute (Segura-Jiménez et al., 2013, 2014) and long-term pain (Busch et al., 2007; Hooten et al., 2012) and quality of life (Kaleth, Saha, Jensen, Slaven, & Ang, 2013). These health-related benefits are likely to be the result of an improvement of the mechanisms that lead to central sensitisation (Hooten et al., 2012). Exercise intensity is an essential component of exercise intervention programmes, which must be individualised according to the severity of the FM-related symptoms and the patient’s physical function.

Exercise intensity for aerobic conditioning is generally established as a percentage of the maximum oxygen uptake (VO2max) or heart rate (HR). However, clinicians and patients with FM rarely have access to devices to monitor these physiological...
parameters. As an alternative, the ratings of perceived exertion (RPE) represent an inexpensive tool for monitoring exercise intensity (Soriano-Maldonado et al., 2014). In the model described by Borg (1998), it is observed that as exercise performance increases along an intensity-dependent continuum, a positive relationship appears between the reported RPE and several physiological responses such as HR, VO\(_2\), minute ventilation (V\(_E\)) or respiratory quotient (RER).

Although the CR-10 scale is commonly used in patients with FM (Nielens, Boisset, & Masquelier, 2000; Nielens & Leon, 1994) as it is intuitive and simple to understand, its validity and reliability for monitoring exercise intensity in women with FM is unclear. In addition, it has been suggested that patients with FM might not be able to discriminate between perceived exertion and exercise-induced pain (Mengshoel, Vøllestad, & Forre, 1995) while exercising (Nielens et al., 2000). Provided its practical interest as a tool for monitoring exercise intensity in research and clinical settings, the aim of the present study was twofold: (1) to assess the validity and reliability of the Borg CR-10 scale for monitoring exercise intensity in women with FM and (2) to examine whether women with FM are able to discriminate between perceived exertion and exercise-induced pain during exercise.

**Methods**

We sent a formal invitation to participate in the study to all women aged 18–60 years (n = 250) from a local association of FM (Seville, Spain). Thirty-seven potentially eligible patients responded and gave written informed consent to participate after receiving detailed information about the aims and study protocol. The inclusion criteria were (i) to be previously diagnosed of FM by a rheumatologist; (ii) to meet the 1990 American College of Rheumatology criteria for the diagnosis of FM (Wolfe et al., 1990); (iii) not to have either acute or terminal illness, nor severe dementia; (iv) not being morbid obese (body mass index [BMI] ≥ 40) and (v) not being at risk for adverse events while exercising. Four patients were excluded, two were morbid obese and two did not attend both test and retest evaluations. Thirty-three participants were finally included in the study. The experimental procedure was reviewed and approved by the Committee on Biomedical Ethics of the University Pablo de Olavide (Seville, Spain).

During the first appointment, the medical records and anthropometric characteristics of the study participants were examined by a physician at the university facilities, and the diagnosis of FM was confirmed (Wolfe et al., 1990). A detailed description on the use of the Borg CR-10 scale (Noble & Robertson, 1996) and the visual analogue scale (VAS, which assessed the immediate experience of pain) (Price, McGrath, Rafii, & Buckingham, 1983), and a careful explanation of the differences between the two constructs, was provided to the participants so as to guarantee that they clearly understood the nature of the two differential constructs. An incremental treadmill test was then performed. During a second appointment (7 days later), the participants completed the same incremental treadmill test (retest) as they did a week earlier.

Weight was measured with participants in under-wear, to the nearest 100 g, and height to the nearest 0.1 cm with an electronic balance with an incorporated stadiometer (Seca 780; SECA Hammer Steindamm, Hamburg, Germany) The participant’s BMI was calculated as weight (kg) divided by squared height (m\(^2\)).

The testing protocol has been previously used in women with FM (Munguia-Izquierdo, Santalla, & Legaz-Arrese, 2012). The test consisted of walking and jogging at incremental workloads on a treadmill (Pulsar 4.0; Cosmos, Am Sportplatz 8, DE 83365 Nussdorf-Traunstein, Germany). A 3-min warm-up period at a speed of 2.5 km · h\(^{-1}\) was performed before starting the incremental test. The test comprised 6 incremental workloads starting at 2.5 km · h\(^{-1}\) and increasing by 2.5 km · h\(^{-1}\) every 3 min up to 7.5 km · h\(^{-1}\). Thereafter, only the inclination increased by 2.5% every 3 min up to 7.5%, which was maintained until the test termination. The duration of each workload was 3 min so as that the physiological responses achieved a steady state before starting the following workload. All participants were verbally encouraged by the research staff throughout the test. Participants voluntarily terminated the test when they felt they were not able to further sustain the effort (none of the participant tolerated the effort further than completing stage 6). During the test, HR (in beats · min\(^{-1}\)) and gas exchange data were continuously collected with an automated breath-by-breath system (CPX; Medical Graphics Corporation 350 Oak Grove Parkway St. Paul, MN 55127). The physiological criterion measures were HR, relative VO\(_2\), V\(_E\) and RER.

The participant’s RPE was obtained at each workload with the Borg CR-10 scale (Borg, 1990; Grant et al., 1999), which is a 10-point scale ranging from 0 (“nothing at all”) to 10 (“very, very strong”) (Borg, 1990). At the end of each workload, the research staff presented the CR-10 scale on a white sheet of paper and the participants pointed at the number representing the overall exertion perceived during the actual workload.

The exercise-induced pain was registered on a 10-cm VAS (without sequential numbering) (Price,
et al., 1983) annotated with the words “no pain” and “maximum of pain” at the appropriate ends and presented on a white sheet of paper. The distance between the beginning of the line representing “no pain” and the fingerprint mark of the patients at each workload was measured and used in further analyses.

The physiological and perceptual responses obtained during the final 30 s of each workload level were used in the subsequent analyses. As exertion and pain represent differential constructs, and in order to avoid “cross-scale demand bias”, the participants were consistently asked to report perceived exertion first (by the right side of the treadmill) and then the perception of exercise-induced pain (by the left side of the treadmill).

The validity of the Borg CR-10 scale for monitoring exercise intensity was assessed with several tests: the Spearman’s rank correlation coefficient evaluated the association of RPE with HR, relative VO\(_2\), \(V_E\) and RER. In addition, a linear regression model was fitted to predict each physiological variable as a function of RPE and other covariates and to estimate the per cent variability (\(R^2\)) of each physiological variable explained by the models. A stepwise method was used to fit the models with the best set of explanatory variables. The covariates included in the models were age and weight. In addition, the exercise-induced pain and the interaction between RPE and exercise-induced pain were also included in the models in order to estimate their potential to improve the per cent variability explained by the models. In order to test whether the physiological and perceptual responses were sensitive to exercise intensity changes and whether they followed an incremental linear tendency, a repeated measures analysis of variance (rANOVA) with polynomial contrasts assessed the linear, quadratic and cubic component of RPE; exercise-induced pain; HR; relative VO\(_2\); \(V_E\) and RER, across the first 4 increasing workloads (\(n = 20\)). Although assuming an important loss of statistical power, a similar analysis was performed including only those participants who completed all 6 workloads (\(n = 8\)) in order to examine whether there was a similar trend on the perceptual and physiological responses at the highest exercise intensities. Data from the retest were used to analyse the validity, since it has been shown that a familiarisation period improves the association of the RPE with different physiological responses (Chen, Fan, & Moe, 2002; Soriano-Maldonado et al., 2014).

The test–retest reliability of the Borg CR-10 scale during incremental treadmill exercise was assessed with per cent agreement and Cohen’s weighted Kappa (\(k\)) coefficient, since this scale represents ordered categorical data (Cohen, 1968). For per cent agreement, the methodology employed by Ortega et al. (2011) was followed. The difference between the reported RPE at the initial test (RPE\(_1\)) and the reported RPE at the retest (RPE\(_2\)) was computed for each participant and workload level. A difference (RPE\(_2\) – RPE\(_1\)) equal to 0 was called “perfect” agreement (same test–retest answer), a difference of 0 ± 1 was called “perfect acceptable” agreement (Ortega et al., 2011) and a difference of 0 ± 2 was called “moderate” agreement. The weighted \(k\) coefficient not only accounts for strict agreement (as the “unweighted” \(k\)) but also provides weighting to adjacent categories (Cohen, 1968). For example, exact agreements might be given full weight, one-category difference given weight \(\frac{1}{2}\) and so on (Ortega et al., 2011). Linear (instead of quadratic) weights were chosen because it is recommended when the difference across categories is equally important.

To assess whether women with FM are able to discriminate between perceived exertion and exercise-induced pain, the difference between reported RPE and exercise-induced pain was computed for each participant and workload. A one-sample \(t\)-test was performed to examine whether the differences between RPE and pain at each workload were statistically significant. In addition, in order to determine if exercise intensity might influence the participants’ ability to discriminate between RPE and pain, a one-way analysis of covariance (ANCOVA; adjusted for age and weight) with the Bonferroni’s correction for multiple comparison assessed the differences between RPE and pain across workloads.

The statistical analysis was performed with SPSS (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY, IBM Corp), and the statistical significance was set at \(\alpha = 0.05\).

**Results**

The participant’s flow diagram is presented in Figure 1. Thirty-three participants (mean age 48.1, \(s_x = 7.9\) years; mean BMI: 27.0, \(s_x = 5.8\) kg · m\(^{-2}\)) completed stages 1 and 2; 28 (84.8%) completed stage 3; 20 (60.6%) completed stage 4; 11 (33.3%) completed stage 5 and 8 (24.2%) completed stage 6. The average values and the linear trend of the perceptual and physiological responses at the first 4 workloads (\(n = 20\)) are displayed in Table I.

The linear association of RPE with the physiological responses is presented in Figure 2. The correlations ranged from 0.69 to 0.79 (all \(P < 0.001\)). The regression models explained ~50% of the total variance from the studied physiological responses (Figure 2). Exercise-induced pain (\(P > 0.05\)) and the RPE × pain interaction (\(P > 0.05\)) were not included in the final models since the predictive
The capacity of the models was unchanged after their inclusion (Figure 2).

The rANOVA revealed a statistically significant linear increase of perceptual (RPE and exercise-induced pain) and physiological (HR, relative VO$_2$, VE and RER) responses during the first 4 incremental workloads (Table I). Similar results were obtained when the 6 workloads were included in the analysis ($n$ = 8; Table II).

Regarding the reliability of the CR-10 scale, “perfect” agreement was observed in 41.9% (95% confidence interval [CI]: 25.7–58.9%) of the observations, “perfect-acceptable” agreement in 69.0% (95% CI: 52.2–83.6%) and “moderate” agreement in 83.7% (95% CI: 69.7–95.3%) for the test–retest reported RPE. The weighted $k$-coefficient of the test–retest reported RPE was 0.66 (95% CI: 0.59–0.72; $P < 0.001$).

The difference between RPE and exercise-induced pain across workloads is represented in Figure 3. There were no differences between the reported RPE and pain during the first 2 workloads (in which exercise intensity was rather low). However, the difference between the two constructs was statistically significant from workload 3 (in which the treadmill speed was 7.5 km · h$^{-1}$).

Table I. Repeated measures ANOVA examining the linear trend of the average perceptual and physiological responses across the first 4 workloads of the incremental treadmill test in women with fibromyalgia.

<table>
<thead>
<tr>
<th></th>
<th>Workload 1 ($n$ = 20)</th>
<th>Workload 2 ($n$ = 20)</th>
<th>Workload 3 ($n$ = 20)</th>
<th>Workload 4 ($n$ = 20)</th>
<th>$P$ (ANOVA*)</th>
<th>Partial $\eta^2$</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
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<td>Mean</td>
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<td>Mean</td>
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<tr>
<td>RPE (CR-10 scale)</td>
<td>0.65</td>
<td>0.221</td>
<td>1.20</td>
<td>0.268</td>
<td>3.90</td>
<td>0.416</td>
</tr>
<tr>
<td>Exercise-induced pain (VAS)</td>
<td>0.59</td>
<td>0.126</td>
<td>0.94</td>
<td>0.158</td>
<td>2.56</td>
<td>0.361</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>96.3</td>
<td>3.220</td>
<td>106.0</td>
<td>3.530</td>
<td>135.0</td>
<td>4.290</td>
</tr>
<tr>
<td>Relative VO$_2$ (mL × kg$^{-1}$ × min$^{-1}$)</td>
<td>7.75</td>
<td>0.460</td>
<td>9.59</td>
<td>0.491</td>
<td>14.49</td>
<td>0.734</td>
</tr>
<tr>
<td>RER</td>
<td>0.798</td>
<td>0.015</td>
<td>0.867</td>
<td>0.018</td>
<td>1.045</td>
<td>0.024</td>
</tr>
<tr>
<td>VE (L · min$^{-1}$)</td>
<td>13.7</td>
<td>0.836</td>
<td>17.4</td>
<td>0.923</td>
<td>31.1</td>
<td>1.931</td>
</tr>
</tbody>
</table>

Notes: RPE, ratings of perceived exertion; CR-10, 10-point category ratio scale; VAS, visual analogue scale (range 0–10); % HR max, percentage of the maximal heart rate; % HRR, percentage of the heart rate reserve; VO$_2$, oxygen uptake; RER, respiratory quotient; VE, minute ventilation.

*The ANOVA was performed only with the data from the participants who completed workload 4 ($n$ = 20).
onwards. The ANCOVA revealed that the difference between RPE and exercise-induced pain followed a linear trend with workload increases (Figure 3).

Discussion

The main findings of the present study indicate that the CR-10 scale represents a valid and moderately reliable tool for monitoring exercise intensity in women with FM. In addition, women with FM were able to discriminate between perceived exertion and exercise-induced pain while exercising, especially as exercise intensity increased.

The correlations of RPE with physiological responses observed in our study ($r$: 0.69–0.79; Figure 2) concur with those observed in healthy people (Coquart et al., 2009; Scherr et al., 2013). Coquart et al. (2009) found RPE correlations of 0.75, 0.77 and 0.74 with HR, VO$_2$ and $V_{E}$ respectively. In the same line, Scherr et al. (2013) observed an RPE-HR correlation of 0.74. Although the above-mentioned studies (Coquart et al., 2009; Scherr et al., 2013) used the Borg 6-20 RPE scale, the association of perceptual and physiological responses seems to be similar to those observed in the present study with the CR-10 scale. Previous research compared the Borg 6-20 RPE scale with the CR-10 scale and concluded that both are similarly valid for monitoring exercise intensity, with the CR-10 scale presenting excellent properties (Borg & Kajser, 2006). We observed that the reported RPE explained more than 50% of the variance from most of the studied physiological responses (Figure 2), in agreement with Scherr et al. (2013), who showed that the RPE explained 55% of the HR variability in healthy people. In addition, the perceptual and physiological responses followed an increasing linear trend as exercise intensity increased, suggesting that the studied outcomes (and specifically the RPE obtained with the Borg CR-10 scale) are sensible to exercise intensity changes. Our results therefore indicate that the Borg CR-10 scale represents a valid tool for monitoring exercise intensity in women with FM.

The test–retest reliability analysis revealed “perfect acceptable” agreement in 69% of the observations and the weighted $k$ coefficient ranged from 0.59 to 0.72, suggesting that the Borg CR-10 scale is moderately reliable (Landis & Koch, 1977) for
monitoring exercise intensity in women with FM. These results are in line with previous research in healthy people (Grant et al., 1999). It is important to note that women with FM commonly suffer from cognitive disturbances (Dick, Verrier, Harker, & Rashiq, 2008) and depression (Goldenberg, Burckhardt, & Crofford, 2004). As perceived exertion at the same exercise intensity might vary from one day to another as a result of physical and emotional negative factors even in healthy people (Borg, 1982), it is suggested that the percentage of observations with a test–retest difference over 2 units (~17% observations) could be partially explained by the different emotional states commonly observed in women with FM.

Whether patients with FM are able to discriminate between RPE and exercise-induced pain during exercise, and especially as exercise intensity increases, is unclear. Several studies found that the RPE responses to exercise of patients with FM are higher in comparison to those of healthy participants even at low intensities (Mengshoel et al., 1995; Nielens et al., 2000). This finding has been explained by the fact that patients with FM might not be able to discriminate between perceived exertion and exercise-induced pain during exercise (Nielens et al., 2000). In this line, as a result of an enhanced exercise-induced pain with workload increments (Mengshoel et al., 1995), women with FM might have been expected to overestimate perceived exertion (Nielens et al., 2000). In contrast to this hypothesis, our results suggest that women with

Table II. Repeated measures ANOVA examining the linear trend of the average perceptual and physiological responses across the 6 workloads of the incremental treadmill test in women with fibromyalgia.

<table>
<thead>
<tr>
<th>Workload 1 (n=8)</th>
<th>Workload 2 (n=8)</th>
<th>Workload 3 (n=8)</th>
<th>Workload 4 (n=8)</th>
<th>Workload 5 (n=8)</th>
<th>Workload 6 (n=8)</th>
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<tr>
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</tr>
<tr>
<td>RPE (CR-10 scale)</td>
<td>0.88</td>
<td>0.706</td>
<td>1.25</td>
<td>0.973</td>
<td>6.13</td>
</tr>
<tr>
<td>Exercise-induced pain (VAS)</td>
<td>0.44</td>
<td>0.616</td>
<td>1.16</td>
<td>1.429</td>
<td>4.65</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>97.1</td>
<td>106.6</td>
<td>131.6</td>
<td>142.9</td>
<td>151.1</td>
</tr>
<tr>
<td>Relative VO₂ (mL × kg⁻¹ × min⁻¹)</td>
<td>7.70</td>
<td>12.85</td>
<td>14.54</td>
<td>17.05</td>
<td>18.96</td>
</tr>
<tr>
<td>RER</td>
<td>0.786</td>
<td>0.979</td>
<td>1.003</td>
<td>1.034</td>
<td>1.019</td>
</tr>
<tr>
<td>V̇E (L · min⁻¹)</td>
<td>13.8</td>
<td>16.8</td>
<td>18.11</td>
<td>21.63</td>
<td>24.50</td>
</tr>
</tbody>
</table>

Notes: RPE, ratings of perceived exertion; CR-10, 10-point category ratio scale; VAS, visual analogue scale (range 0–10); % HR max, percentage of the maximal heart rate; % HRR, percentage of the heart rate reserve; VO₂, oxygen uptake; RER, respiratory quotient; V̇E, minute ventilation. The ANOVA was performed only with the data from the participants who completed workload 6 (n=8).

Figure 3. Differentiation between ratings of perceived exertion (RPE) and exercise-induced pain across workloads during an incremental treadmill test in women with fibromyalgia. Common superscripts indicate significant (P < 0.05) differences between the workloads with the same letter (ANCOVA adjusted for age and weight). *Comparison (one-sample t-test vs. 0) between RPE and exercise-induced pain at each workload.
FM are able to discriminate between RPE and exercise-induced pain, since the differences between both constructs were increasingly higher, especially from workloads 3 to 6. These results indicate that there must be other factors explaining the higher perceived exertion observed in patients with FM in comparison to healthy people (Mengshoel et al., 1995; Nielsen et al., 2000). The implicit fatigue generally observed as one of the main symptoms in women with FM, which has been recently suggested to be of central instead of muscular origin (Bandak, Amris, Bliddal, Danneskiold-Samsøe, & Henriksen, 2013), could partially explain the above-mentioned results.

The present study had some limitations. We examined the validity of the Borg CR-10 scale for monitoring exercise intensity following an estimation RPE paradigm, in which participants estimated their RPE at predetermined incremental workloads and the reported RPEs were plotted against physiological responses. Further research is warranted to determine the validity and reliability of the Borg CR-10 scale for exercise intensity prescription using a production paradigm. This study was conducted only in women because FM predominantly affects women. The CR-10 scale and the VAS had the same scoring range (0–10) and the participants alternatively estimated both exertion and pain at each workload. This might be seen as a limitation of the study in the thought that the patients might have been confused when estimating exertion and pain during the test. However, our results demonstrate that the patients clearly discriminated between the two constructs, suggesting that the scoring system had no influence on the results. These findings might have been the result of the careful explanations about the differences between exertion (CR-10 scale) and pain (VAS) that the research team provided to the patients, as well as the consistent protocol followed during the incremental test to obtain the patient’s estimations.

The results of the present study have clinical implications. The Borg CR-10 scale might be used in research and clinical settings to monitor the intensity of exercise intervention programmes for the management of FM in women with this chronic condition. This scale represents a very accessible and practical tool that might be implemented by physicians and exercise professionals dealing with women with FM.

In conclusion, the results of the present study indicate that the Borg CR-10 scale is a valid and moderately reliable tool for monitoring exercise intensity in women with FM. In addition, women with FM are able to discriminate between exertion and exercise-induced pain while exercising, especially as exercise intensity increases.

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