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Original Research

Rate of force development and muscle activation of trunk muscles in women with and without low back pain: A case-control study

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ABSTRACT

Objective: To evaluate the rate of force development (RFD) and the rate of electromyography rise (RER) of global and local trunk muscles in women with and without low back pain.
Design: Cross-sectional study.
Setting: Laboratory setting.
Participants: Twenty-eight women divided into low back pain (LBP, n = 14) and control groups (CG, n = 14) participated in this study.
Main outcome measures: Subjects performed isometric contractions of trunk using an isokinetic dynamometer, and simultaneously the electromyography (EMG) signals were collected for global (rectus abdominis and longissimus thoracic) and local (internal oblique and multifidus) muscles. All variables were calculated using Matlab software.
Results: Symptomatic subjects showed lower RFD during trunk extension and it was correlated to a reduced RER mainly in the trunk extensor musculature ($p < 0.05$). During trunk flexion, LBP exhibited a delayed time to reach peak RFD ($p < 0.05$) compared to CG. RER for global anterior muscle was higher than for local muscle ($p < 0.05$) and it was more persistent in asymptomatic women. CG also presented greater activation amplitude for both agonist and antagonist trunk muscles, mainly the global ones.
Conclusion: Symptomatic women showed lower RFD and it was correlated to a reduced capacity of rapid muscle activation mainly in the trunk extensor musculature.

1. Introduction

Chronic low back pain is one of the most common musculoskeletal symptoms and affects about 60%–80% of the Western population at some point in life (Gaskell, Enright, & Tyson, 2007). The high rate of disability and its consequent high economic costs to health systems make low back pain a musculoskeletal problem often investigated by the scientific community (Stier-Jarmer, Cieza, Borchers, & Stucki, 2009). Studies suggest a higher prevalence of musculoskeletal pain, including the low back, in women than in men (Bailey, 2009; Wijnhoven, de Vet, & Picavet, 2006). Although the reasons remain unclear, the sex differences have been related to psychosocial and physiological factors such as, women are more willing to report pain, more exposure to risk factors and have different pain sensitivity (Bailey, 2009; Wijnhoven et al., 2006). Furthermore, low back pain is a complex phenomenon with numerous causal factors, which need to be better understood. Detailed assessments and investigations of possible causes of low back pain are needed to assist in prescribing intervention programs (Stier-Jarmer et al., 2009).

The literature has shown that subjects with chronic back pain may have reduced strength and endurance of trunk muscles (Gruther et al., 2009; Yahia et al., 2011). Moreover, these subjects can present failures or delays in specific muscle activation (Marshall & Murphy, 2010; Mehta, Cannella, Smith, & Silfies, 2010), which can transmit abnormal overload to joint surfaces and cause joint damage and recurrent pain (Lee, Cholewicki, Reeves, Zazulak, & Mysliwiec, 2010; Newcomer et al., 2002; Oddsson & De Luca,

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2003; Yilmaz et al., 2010).

In situations with unexpected loads or postural disturbances, a rapid response of trunk control system is required in order to avoid spine injuries (Reeves, Narendra, & Cholewicki, 2007). The RFD is used to evaluate the ability of subjects to quickly generate force and is usually measured during isometric contractions and single-joint tasks. Although dynamic contractions or multiple-joint movements are more representative of functional tasks, the RFD and its determinants may be influenced by the non-linear mechanisms of dynamic contractions, such as the torque-angle-velocity relationship (Maffiuletti et al., 2016). Moreover, as related to the maximal voluntary contraction, the RFD offers even more sensitivity to detect alterations in neuromuscular function (Peñailillo, Blazevich, Numazawa, & Nosaka, 2015).

RFD was first studied in athletes, who need rapid muscle responses. RFD, obtained by calculating the slope of the torque-time curve, may be affected by structural muscle and neural factors (Corvino, Caputo, Oliveira, de Greco, & Denadai, 2009; Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002). The maximum values of RFD are reached at the beginning of muscle contraction, in a time interval between 100 and 300 milliseconds (Aagaard et al., 2002; Corvino et al., 2009).

RFD has been widely investigated in other populations as a functional parameter in strong and fast contractions, such as in postural balance in the elderly (Lovell, Cuneo, & Gass, 2010), and in conditions of chronic musculoskeletal pain (Andersen, Holtermann, Jørgensen, & Sjøgaard, 2008). Andersen et al. (2008) evaluated RFD and RER in patients with trapezius myalgia. This study suggested that the ability to rapidly generate force in synergistic muscles in pain and no-pain conditions is more severely impaired than maximum muscle activation and strength capacity (Andersen et al., 2008). Furthermore, by comparing voluntary contraction and electrical stimulation, literature has shown a strong association between the ability to develop force rapidly and the increase of the agonist muscle activation at the onset of contraction (Blazevich, Cannavan, Horne, Coleman, & Aagaard, 2009). Additionally, as the recruitment and discharge rate vary depending of the contraction speed, the lower recruitment thresholds evidenced during rapid contractions seems to even inferior for slow-contracting muscles compared to fast contracting muscles (Maffiuletti et al., 2016).

As for the trunk muscles, the literature indicates functional differences, dividing them into local and global. Smaller muscles including the internal oblique (IO) and multifidus (MU) are the principal contributors to the local stabilization system (Bergmark, 1989; Hodges, 2003). Because the local muscles play a stabilizing role acting in the coordination and control of motion segments, they have shown a symmetrical activation even in asymmetric lifting tasks (Borghuis, Hof, & Lemmink, 2008). The global stabilization system is composed by longer moment arms muscles, such as the rectus abdominis (RA) and longissimus thoracic (LT), that provide more powerful movements and enables the work needed for functional and sport activities (Bergmark, 1989; Hodges, 2003).

Literature supports that strength training can improve the rapid force capacity in different populations (Maffiuletti et al., 2016), including in chronically painful muscles (Andersen et al., 2009). Therefore, investigating the RFD and muscle activation of trunk muscles associated with low back pain symptoms could not only contribute to existing knowledge from a physiological standpoint but also help health professionals to develop rehabilitation strategies based on different types of training for this population. The aims of this study were to evaluate the RFD and the RER for local and global trunk muscles in women with and without chronic low back pain. We hypothesized that subjects with low back pain would have reduced RFD and RER in trunk muscles compared to asymptomatic subjects. Considering the functional role differences, we also hypothesized that greater RER would be produced by global muscles than by local muscles mainly in asymptomatic subjects.

2. Methods

2.1. Subjects

Subjects for this case-control study were female college students between the ages of 18 and 30 with no history of pregnancy. Twenty-eight female volunteers were divided into two groups, one made up of women with low back pain (LBP, n = 14) (mean ± standard deviation; age 24.14 ± 3.13 year, mass 61.68 ± 7.19 kg, height 1.66 ± 0.05 m, body mass index 22.31 ± 2.12 kg/m^2), and the other a control group (CG) with no history of low back pain (mean ± standard deviation; age 22.21 ± 3.40 year, mass 58.2 ± 8.73 kg, height 1.61 ± 0.06, body mass index 22.23 ± 1.98 kg/m^2). An effect size of 0.99, a probability error of $\alpha = 0.05$, and a power of 0.80 were used to estimate the sample based on peak trunk extensor torque value from a pilot study. Each participant read and signed an informed consent form approved by the local Ethics Research Committee (protocol number 084/2011).

Inclusion criteria for LBP was a reported history of persistent back pain (pain between T12 and the gluteal fold) for longer than 6 months. Exclusion criteria included body mass index higher than 29.9 kg/m^2, history of spinal fracture or surgery, spinal deformity (Larivière, Arsenault, Gravel, Gagnon, & Loisel, 2003), rheumatologic disorders, neurological symptoms, and vertebral tumors (Gruther et al., 2009).

The assessment protocol was carried out in one day, during which volunteers performed isometric contractions alternating between trunk flexion and extension using an isokinetic dynamometer. Simultaneously, EMG signals were collected bilaterally for anterior and posterior trunk muscles.

2.2. Isokinetic dynamometer

Assessment was performed using an isokinetic dynamometer (Biodex®, New York, USA) and special chair (Dual position Back Ex/Flex Attachment) in the Seated-Compressed mode. Special belts were used to stabilize the participants on the chest, hip, and in the middle third of the thigh. The anterior superior iliac spine was aligned with the dynamometer mechanical axis.

The trunk was maintained at 60 ° flexion, and volunteers performed six isometric contractions, three for trunk flexion and three for trunk extension, starting in a random order and alternating (Gruther et al., 2009). Each contraction was maintained for five seconds, with 30 s rest intervals. Subjects were verbally encouraged by the same examiner to expend the greatest and fastest possible effort. The torque signal was corrected for the effect of gravity prior to the assessment. The signal was recorded at 2000 Hz sample rate, and it was synchronized with EMG signal by a synchronization board (NorBNC, Noraxon®, Phoenix, USA).

2.3. Electromyography

EMG signals were collected using an 8-channel telemetered electromyogram (TM900, Noraxon®, Phoenix, USA) and Ag/AgCl surface active electrodes (Miotec®, Porto Alegre, Brazil) in bipolar configuration. Before placing the electrodes, the skin was shaved and cleaned with alcohol (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000).

The electrodes were positioned on both sides of the trunk, right (r) and left (l), for global muscles: rectus abdominis (RA) (Marshall & Murphy, 2003) and longissimus thoracic (LT) (Hermens et al.,

2000), and local muscles: internal oblique (IO) (Marshall & Murphy, 2003) and multifidus (MU) (Hermens et al., 2000) (Fig. 1). The reference electrode was located at the radial styloid process.

2.4. Data analysis

The RFD and RER were obtained through specific routines developed in Matlab software (Mathworks®, Natick, Massachusetts, USA). A 4th order Butterworth digital filter with a cutoff frequency of 15 Hz was used to process the torque signal.

RFD was calculated by the slope of the torque-time curve (Δtorque/Δtime) over time intervals of 0–30 ms, 0–50 ms, 0–100 ms, 0–200 ms relative to the onset of contraction (Fig. 2). The onset was determined by the value of 2.5% from baseline to maximum voluntary contraction (MVC) (Aagaard et al., 2002). In addition, the time needed to reach peak RFD was measured.

The EMG signal was analyzed in the time domain by linear envelope values. The signal was digitally filtered using a 2nd order Butterworth 20 Hz high-pass filter and a 4th order 500 Hz low-pass filter. Then, the resulting signal was full-wave rectified and smoothed using a 4th order low-pass Butterworth digital filter with a cutoff frequency of 5 Hz to create a linear envelope. The EMG onset was determined from two standard deviations from the baseline. Then, RER was calculated from the slope of the rising part of the EMG-time curve at the time intervals of 0–30 ms, 0–50 ms, 0–100 ms, 0–200 ms relative to the onset of contraction (Aagaard et al., 2002) (Fig. 2). The RER values were normalized using the root mean square (RMS) peak of the maximal isometric contraction.

The comparisons of the peak torque, RMS, RFD and RER variables between groups were done with a SAS software. A Student *t*-test was used to compare the peak torque and RMS peak. A linear regression mixed model (random intercept and fixed coefficients) was applied on RDF and RER variables which incorporated groups as fixed factor and time intervals (30, 50, 100 and 200 ms) as random factors. For the RER variable, the model included orthogonal contrasts to compare different trunk sides (right and left) and muscles (local and global). Log transformation was applied to the non-normally distributed relative to RFD and RER data. Significance level was set at 0.05. The effect size was calculated by dividing the difference between group mean scores (CG and LBP) by the pooled standard deviation of the 2 groups. The magnitude of the effect size was described as 0.2, 0.5, and 0.8 as small, moderate and large respectively (Cohen, 1988). Bivariate two-tailed Spearman correlation analyses were conducted to determine the relation between RFD and RER at each time interval. The average between right and left side was applied on RER values of each trunk muscle.

3. Results

3.1. Trunk extension

The CG showed higher peak torque, 203.72 (44.46) Nm, compared to LBP group, 157.35 (48.52) Nm ($p = 0.014$). As illustrated in Fig. 3, asymptomatic subjects were able to produce 42.36% and 34.83% higher RFD than subjects with low back pain, in time intervals of 0–100 ms ($p = 0.02$), 0–200 ms ($p = 0.04$) relative to onset of contraction. No difference was found between groups ($p = 0.077$) in the time required to reach peak RFD during trunk extension task.

This study found that people with low back pain exhibited a reduced EMG activation of the LT muscle bilaterally, and the OI muscle left side only (Table 1). Another finding was an increased antagonist activation of the global muscles in CG during trunk extension (RA muscle bilaterally) and trunk flexion (LT muscle bilaterally and MU muscle left side) (Table 1). The symptomatic group also presented different patterns in the RER for extensor trunk muscles. Both sides of the MU muscle showed lower values in LBP compared to those in asymptomatic subjects at 0–30 ms (left MU), 0–50 ms (left MU), and 0–100 ms (right MU). Symptomatic people also showed decreased RER for the right muscle LT at 0–30 ms and 0–50 ms. Differences in RER values between right and left sides were found for MU at 0–30 ms and at peak in the LBP group (Table 2). No differences were observed in the RER between global and local posterior muscles in trunk extension task for either group.

3.2. Trunk flexion

There was no evidence of difference between groups for peak torque, with the CG producing 106.36 (20.33) Nm and the LBP group producing 91.92 (35.89) Nm ($p = 0.113$). Subjects with low back pain showed a delayed time (0.23 ± 0.16 s) to reach peak RFD compared to asymptomatic subjects (0.17 ± 0.07 s) ($p = 0.047$, effect size = 0.49). However, the trunk flexion task did not differ in the RFD between people with and without low back pain (Fig. 3).

As for the activation pattern of the abdominal muscles during the trunk flexion task, this study found differences for the RER values between symptomatic and asymptomatic subjects only for one time interval of the right OI muscle (Table 3).

Supporting our hypotheses, the RER differed between global and

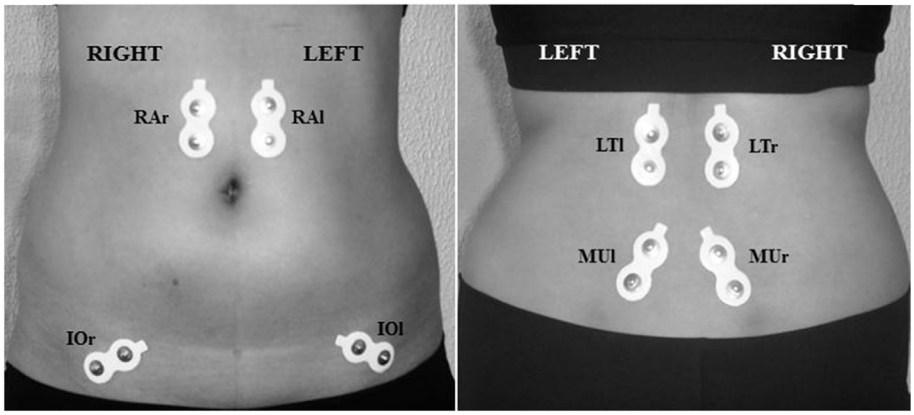

Fig. 1. Placement of electrodes for flexor and extensor trunk muscles. Rectus abdominis right (RAr), rectus abdominis left (RAl), internal oblique right (IOr) and internal oblique left (IOl), longissimus thoracic right (LTr), longissimus thoracic left (LTl), multifidus right (MUr), and multifidus left (MUl).

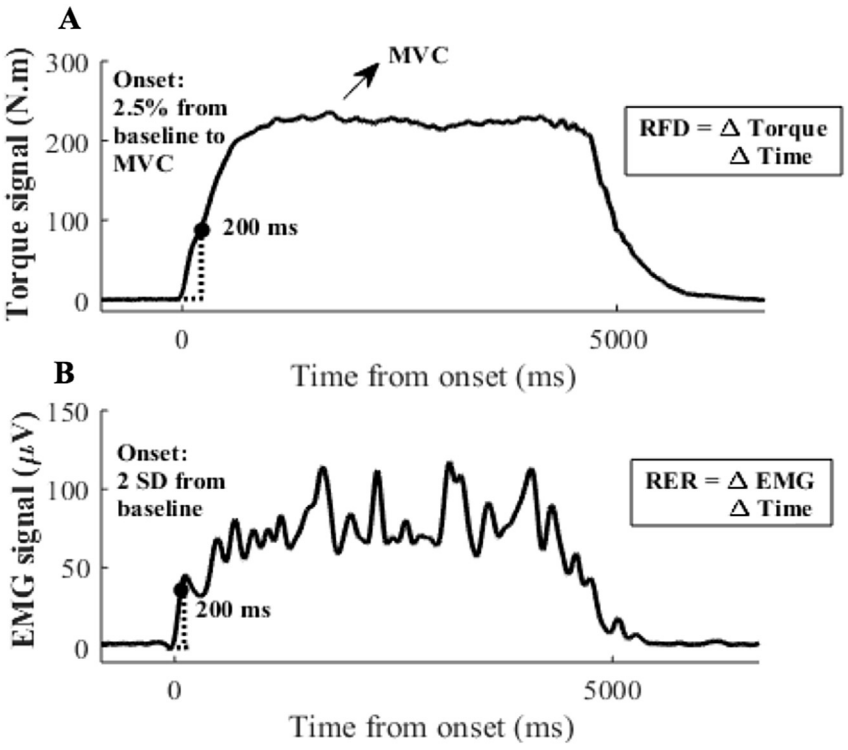

Fig. 2. **A** Torque signal recorded during maximal isometric voluntary contraction (MVC) of the trunk extension. Time = 0 corresponds to the onset of muscle contraction defined as 2.5% from baseline to MVC. Rate of force development (RFD) defined as the slope of the torque-time curve at time interval relative to the onset of contraction. **B**. Electromyography (EMG) signal of the multifidus muscle during the trunk extension task. Time = 0 corresponds to the EMG onset determined from 2 standard deviations (SD) from the baseline. Rate of EMG rise (RER) defined as the slope of the EMG signal-time curve at time intervals relative to the onset of contraction. Dotted vertical line indicates the time period of 200 ms relative to the onset of contraction as an example of how these variables are extracted.

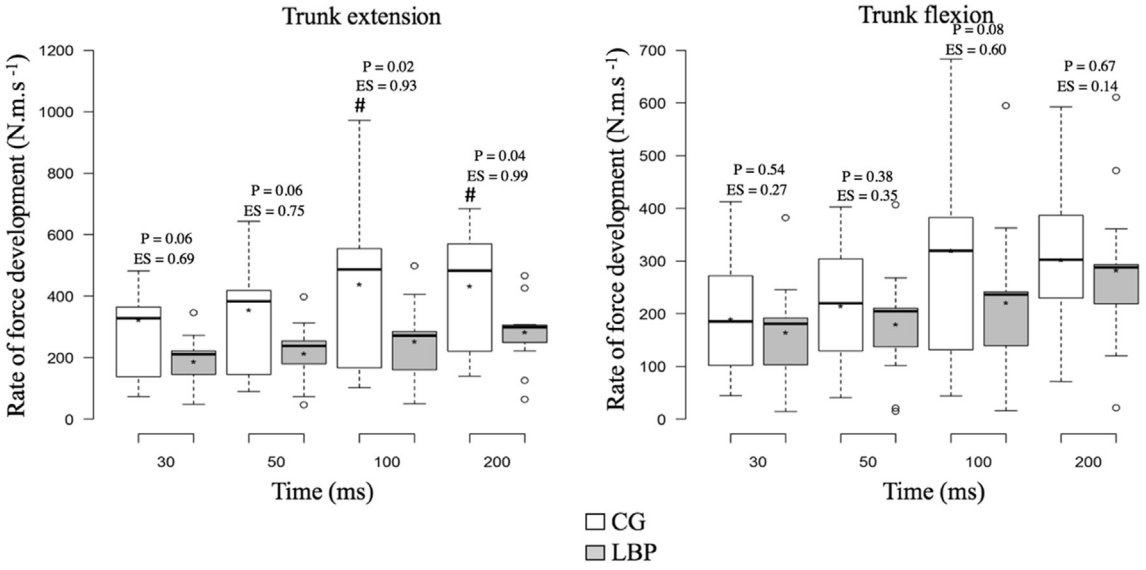

Fig. 3. Comparison of the rate of force development in trunk extension and flexion at time intervals from 0 to 30 ms, 0–50 ms, 0–100 ms and 0–200 ms. Control group (CG), Low back pain (LBP), Effect size (ES), P value (P). #p < 0,05 to CG higher than LBP.

local anterior muscles in both groups. CG and LBP groups showed higher RER of global muscle than of local muscle, but it was more persistent for subjects without low back pain. The global muscle RA left in asymptomatic subjects indicated a higher RER compared to IO left during most time intervals, 0–30 ms, 0–50 ms, 0–100 ms, and at peak. On the other hand, subjects with low back pain presented differences in the RER in the flexion task between global and local anterior muscles only for the right RA at 0–50 ms.

Significant positive correlation was detected between the RFD and RER for both groups during trunk extension and flexion (Fig. 4). The correlation was more consistent for the CG, mainly during the trunk extension task (Fig. 4).

Table 1
Comparison of RMS peak of the maximal isometric contraction of agonist and antagonist muscles during trunk extension and flexion. Mean (Standard Deviation). Values in μV, Mean (Standard Deviation), Mean Difference between groups with 95% Confidence Interval.

		CG (n = 14)	LBP (n = 14)	Mean difference CI (95%)	Effect Size	P value
Trunk Extension	LTr	108.33 (39.10)	68.62 (21.27)	39.71 (15.25; 64.16)	1.26	0.003*
	LTl	136.20 (84.53)	63.54 (28.56)	72.66 (23.64; 121.68)	1.15	0.005*
	MUr	70.32 (44.04)	50.14 (15.14)	20.17 (−5.41; 45.76)	0.61	0.117
	MUl	68.33 (40.28)	57.57 (50.60)	10.76 (−24.77; 46.30)	0.24	0.539
	RAr	14.61 (6.56)	8.68 (2.70)	5.93 (2.03; 9.83)	1.18	0.004*
	RAl	18.83 (11.53)	8.07 (3.44)	10.76 (4.14; 17.36)	1.32	0.002*
	OIr	35.74 (27.17)	19.64 (11.06)	16.10 (−0.02; 32.21)	0.78	0.050
	OIl	36.55 (28.41)	29.21 (17.84)	7.34 (−11.09; 25.77)	0.31	0.420
Trunk Flexion	RAr	101.22 (89.65)	74.59 (95.57)	26.63 (−45.38; 98.63)	0.29	0.454
	RAl	92.83 (86.41)	48.01 (36.38)	44.81 (−6.69; 96.32)	0.68	0.085
	OIr	155.92 (82.79)	125.45 (47.47)	30.47 (−62.44; 123.38)	0.45	0.506
	OIl	211.88 (132.92)	92.22 (51.25)	119.66 (26.88; 212.44)	1.19	0.013*
	LTr	27.57 (13.4)	14.58 (8.53)	12.99 (4.26; 21.10)	1.16	0.005*
	LTl	27.13 (16)	14.92 (6.88)	12.21 (2.64; 21.78)	0.99	0.014*
	MUr	23.43 (14.4)	19.29 (14.3)	4.14 (−7.00; 15.29)	0.29	0.451
	MUl	26.26 (10.8)	12.74 (5.09)	13.52 (6.97; 20.08)	1.60	0.001*

Control group (CG), low back pain (LBP), longissimus thoracic right (LTr), longissimus thoracic left (LTl), multifidus right (MUr), multifidus left (MUl), confidence interval (CI).
*p < 0.05 to CG higher than LBP.

Table 2
Comparison of rate of electromyography rise (RER) of trunk posterior muscles in the extension at time intervals of 0–30, 0–50, 0–100 and 0–200 ms. Values in %pEMGs^{-1}, Mean (Standard Deviation), Mean Difference between groups with 95% Confidence Interval.

	Time	CG (n = 14)	LBP (n = 14)	Mean Difference CI (95%)	Effect Size	P value
LTr	30	355.10 (164.04)	217.99 (142.79)	137.11 (18.83; 255.39)	0.89	0.023*
	50	372.78 (177.77)	245.60 (154.39)	127.18 (8.90; 245.46)	0.71	0.035*
	100	330.60 (171.93)	271.34 (171.67)	59.27 (−59.01; 177.54)	0.34	0.325
	200	184.15 (86.10)	198.35 (135.39)	−14.20 (−132.48; 104.07)	−0.13	0.814
LTl	30	272.38 (131.28)	222.87 (105.53)	49.51 (−68.77; 167.79)	0.42	0.411
	50	293.48 (150.86)	248.31 (112.45)	45.16 (−73.11; 163.44)	0.34	0.453
	100	280.31 (158.49)	267.05 (118.11)	13.26 (−105.02; 131.54)	0.09	0.826
	200	155.04 (68.94)	219.14 (110.99)	−64.10 (−182.38; 54.18)	0.0.70	0.288
MUr	30	362.19 (223.65)	271.76 (182.51) €	90.42 (0.13; −27.85)	0.44	0.134
	50	389.14 (231.12)	286.54 (180.53)	102.60 (−15.68; 220.88)	0.49	0.089
	100	379.58 (217.72)	261.09 (154.22)	118.49 (0.21; 236.77)	0.63	0.049*
	200	251.95 (160.69)	206.22 (92.59)	45.74 (−72.54; 164.02)	0.35	0.448
MUl	30	319.63 (162.25)	172.07 (130.07)	147.57 (29.29; 265.85)	1.00	0.015*
	50	340.45 (182.74)	199.48 (144.30)	140.96 (22.69; 259.24)	0.86	0.019*
	100	327.45 (196.54)	232.05 (146.38)	95.39 (−22.88; 213.68)	0.55	0.114
	200	222.79 (113.01)	205.62 (117.39)	17.17 (−101.10; 135.45)	0.15	0.776

Control group (CG), low back pain (LBP), longissimus thoracic right (LTr), longissimus thoracic left (LTl), multifidus right (MUr), multifidus left (MUl), confidence interval (CI).
*p < 0.05 to CG higher than LBP.
€ p < 0.05 to right higher than left side.

4. Discussion

Our findings indicate that asymptomatic subjects have greater ability to generate force quickly during trunk extension compared to subjects with chronic low back pain. The RFD is suitable to determine neuromuscular function and strongly governed by diverse physiological mechanisms such as the capacity of rapid muscle activation in the early phase of an explosive contraction (Maffiuletti et al., 2016; Peñailillo et al., 2015). In agreement with the evidence that the MVC force is also a potential determinant mainly in a late-phase RFD (Maffiuletti et al., 2016), this study found a reduced peak torque during trunk extension task in the LBP group. A strength deficit of these muscles is also demonstrated in the literature in subjects with chronic low back pain compared to asymptomatic subjects (Gruther et al., 2009; Yahia et al., 2011).

Evidence of difference between groups was found in a late-phase RFD, i.e., on time intervals at 100 ms and 200 ms, suggesting contractile factors as critical determinants to muscle strength (Maffiuletti et al., 2016). At the beginning of muscle contraction (<75 ms) of a rapid contraction, the RFD is influenced by intrinsic muscle properties, which relate to the intensity of efferent motor neuron production, or to the frequency of activation and the recruitment of motor neurons. A greater inter-subject variability has been suggested during the early phase of the contraction which the neural factors are predominant (Folland, Buckthorpe, & Hannah, 2014). For later time intervals (>75 ms), changes in RFD have a strong relationship to aspects related to the production of maximum muscular strength, muscle size, relative area of fast twitch fibers, and muscle fiber distribution (Andersen & Aagaard, 2006; Blazevich, Horne, Cannavan, Coleman, & Aagaard, 2008; Folland et al., 2014).

Despite the lack of evidence of difference between groups in RFD values in trunk flexion, this study suggests temporal differences, in which asymptomatic subjects reached peak RFD in a shorter time than subjects with low back pain. The literature has shown that subjects with this symptom present changes in motor control such as delayed onset of trunk muscle activation during rapid movements of the upper limbs that cause disturbances in the body's balance (Marshall & Murphy, 2010; Mehta et al., 2010).

Regarding muscle activation, this study found that during the

Table 3
Comparison of rate of electromyography rise (RER) of trunk anterior muscles in flexion at time intervals of 0–30, 0–50, 0–100 and 0–200 ms. Values in %pEMGs^{-1}, Mean (Standard Deviation), Mean Difference between groups with 95% Confidence Interval.

	Time	CG (n = 14)	LBP (n = 14)	Mean difference CI (95%)	Effect Size	P value
RAr	30	391.25 (197.95)	274.76 (218.21)	116.50 (−19.57; 252.58)	0.66	0.093
	50	407.86 (221.66)	306.50 (235.32) #	101.36 (−34.72; 237.44)	0.60	0.144
	100	371.27 (203.01)	312.09 (207.98)	59.18 (−76.89; 195.26)	0.35	0.393
	200	188.98 (88.50)	167.39 (74.92)	21.59 (−114.49; 157.66)	0.18	0.755
RAl	30	361.43 (280.14) #	286.72 (124.21)	74.71 (−61.37; 210.79)	0.33	0.281
	50	393.67 (305.83) #	318.49 (128.94)	75.18 (−60.90; 211.25)	0.32	0.278
	100	371.64 (267.50) #	317.45 (125.00)	54.19 (−81.88; 190.28)	0.26	0.434
	200	172.93 (95.93)	176.18 (58.04)	−3.25 (−139.32; 132.83)	−0.04	0.962
IOr	30	307.22 (197.40)	178.89 (135.22)	128.33 (−7.75; 264.40)	0.76	0.065
	50	341.80 (215.55)	204.91 (151.31)	136.89 (0.80; 272.96)	0.74	0.048*
	100	350.48 (208.58)	230.19 (177.06)	120.29 (−15.78; 256.37)	0.62	0.083
	200	208.74 (114.80)	149.38 (109.70)	59.36 (−76.72; 195.43)	0.53	0.392
IOl	30	246.55 (164.51)	209.70 (121.81)	36.84 (−99.23; 172.92)	0.25	0.595
	50	267.50 (179.64)	235.73 (142.95)	31.77 (−104.31; 167.85)	0.20	0.646
	100	255.95 (177.10)	251.05 (166.99)	4.90 (−131.18; 140.98)	0.03	0.944
	200	130.91 (86.48)	157.45 (88.92)	−26.53 (−162.61; 109.54)	−0.30	0.701

Control group (CG), low back pain (LBP), rectus abdominis right (RAr), rectus abdominis left (RAl), internal oblique right (IOr), internal oblique left (IOl), confidence interval (CI).
* $p < 0.05$ to CG higher than LBP.
# $p < 0.05$ to global higher than local.

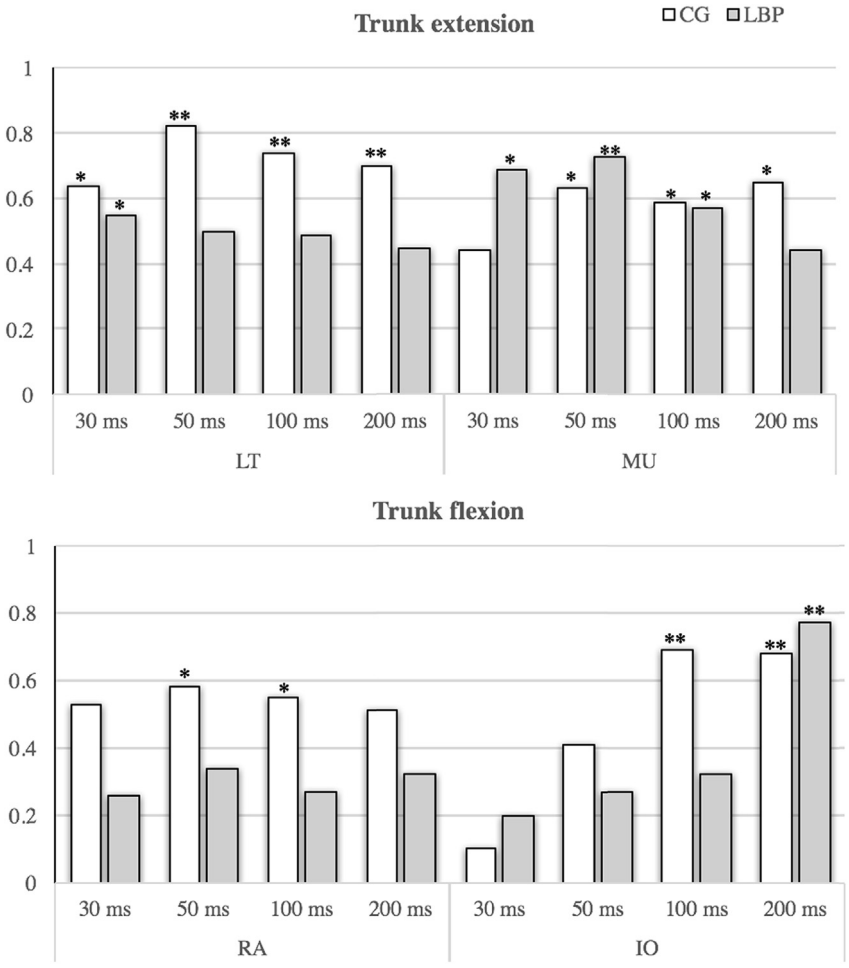

Fig. 4. Correlations between the rate of force development and the rate of EMG rise for control group (CG) and low back pain (LBP) of each trunk muscle at each time interval (30 ms, 50 ms, 100 ms and 200 ms). Longissimus thoracic (LT), multifidus (MU), rectus abdominis (RA) and internal oblique (IO).
Correlation is significatn at the 0.01 level.
*Correlation is significant at the 0.05 level.

trunk extension, the CG produced higher amplitude activation of the global agonist muscles (LT bilaterally) and also higher antagonist muscle activation (RA bilaterally) compared to LBP. During trunk flexion, the CG presented higher antagonist muscle activation of LT muscle bilaterally and MU left side compared to the LBP group. In agreement with our results, Hirata, Salomoni, Christensen, and Graven-Nielsen (2015) have also evidenced an increased antagonist activation of abdominal muscles (RA and external oblique) while increasing the force level during isometric trunk extension as a suggested strategy to improve stability in pain free situations (Hirata et al., 2015). Furthermore, during a pain experimental condition, decreased antagonist muscle activity during trunk extension has been reported, which may impair trunk stiffness (Hirata et al., 2015). A strong association has also been reported between proportional changes in RER and RFD after a resistance training program in both agonist and antagonist knee muscles. This increased rate of antagonist activation after training has been suggested as a protective mechanism in response to the increased agonist RER (Blazevich et al., 2008).

The RER of trunk extensor global muscle and local muscle activity was also higher in asymptomatic subjects than in women with low back pain in this study. Additionally, a strong association between RER and RFD, mainly for CG during trunk extension, was found, suggesting that the increased motoneuron excitability and the decreased presynaptic inhibition might increase the capacity to generate force quickly (Aagaard et al., 2002; Blazevich et al., 2008).

A reduced capacity to generate rapid force during a MVC has already been demonstrated in painful conditions. Specifically, women with trapezius myalgia have been reported to present with reduced RFD and RER compared to healthy controls (Andersen et al., 2008). Additionally, these variables have been suggested as a useful clinical tool by being very sensitive in response to rehabilitation (Andersen et al., 2009). Andersen et al. (2009) demonstrated a significant improvement in the rapid force capacity after a specific strength protocol suggesting general effects of strength training, pain reduction and mainly neural adaptations as predominant mechanisms.

Although there is a belief that rapid movements exacerbate pain, a multivariate linear regression analyses showed non-significant relationships between pain and pain related fear and functional capacity evaluation in patients with low back pain symptoms (Reneman, Preuper, Kleen, Geertzen, Dijkstra, 2007). Moreover, the neural inhibitory feedback due the pain has a minimal effect on RFD and RER because these variables are measured in a very brief time interval from the onset of contraction to the steepest portion of the torque-time curve (Andersen et al., 2008). Good reliability of MVC for amplitude normalization was suggested for assessing EMG signal of trunk muscles within-days, but sub-MVC showed greater reliability of measurements between different-days. Dankaerts, O'Sullivan, Burnett, Straker, and Danneels (2004) showed good reliability of MVC for amplitude normalization for assessing EMG signal of trunk muscles within-days and greater reliability for sub-MVC between different-days. Additionally, a similar reliability was seen in the healthy control and the low back pain groups supporting the evidence of no influence of pain as the source of measurement error (Dankaerts et al., 2004).

For intra-group comparisons during the trunk flexion task, the CG showed the greatest differences between global muscles and local muscles; in these instances, RA left was higher than IO left for several time intervals. The larger lever arm of global muscles produces a greater level of torque output and greater control of the external forces than do the local muscles (Bergmark, 1989; Hodges, 2003). Thus, a greater RER for global compared to local muscles in asymptomatic women might account for a shorter time to reach RFD peak. However, differences in RER between groups was not sufficient to interfere with the RFD during the trunk flexion task. The present study did not find relevant differences between left and right sides of trunk muscle activity. Oddsson and De Luca (2003) suggested that both asymptomatic and symptomatic subjects presented uncompensated RMS imbalances defined as a global uneven activation even during a symmetrical isometric task (Oddsson & De Luca, 2003).

The reduced RFD and RER mainly during trunk extension in subjects with low back pain might be useful in a clinical setting. For example, the initial phase of an intervention program could focus on high level of muscle activation exercises, and the later phases could include more powerful exercises mainly for the extensor musculature.

Our study has some limitations. The level of disability and pain was not estimated for the LBP group. Considering the heterogeneity of the population with low back pain, this information could be useful to determine the severity of clinical conditions. Furthermore, in this sense, the division of symptomatic group into subgroups could be interesting. Finally, our sample consisted of young women, but low back pain seems to affect older subjects more severely.

5. Conclusion

This study demonstrates that women with chronic low back pain have a deficit in their ability to generate force quickly. Additionally, this deficit was correlated to a reduced capacity of rapid muscle activation, mainly in the trunk extensor musculature. Accordingly, asymptomatic women exhibited a different muscle pattern presenting higher activation for both agonist and antagonist trunk muscles, mainly in the global musculature.

Ethical approval

This study was approved by the Ethics Research Committee of São Paulo State University under the protocol n 084/2011.

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Conflict of interest

None declared.

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