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ORIGINAL REPORT

EFFECT OF PELVIC STABILIZATION AND HIP POSITION ON TRUNK EXTENSOR ACTIVITY DURING BACK EXTENSION EXERCISES ON A ROMAN CHAIR

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Objective: **To assess the effect of pelvic stabilization and hip position on the electromyographic activity of trunk extensors during Roman chair exercise. A secondary objective was to compare genders.**
Design: **Repeated measures.**
Subjects: **Eleven men and 11 women volunteers.**
Methods: **Five trunk flexion-extension cycles for 3 Roman chair conditions: (*i*) pelvis unrestrained; (*ii*) pelvis restrained; and (*iii*) hip at 40° flexion. Electromyographic signals were recorded on the back muscles, as well as on the gluteus maximus and biceps femoris. The percentage of electromyographic amplitude relative to the maximal activity was used to assess the level of muscular activation of each muscle group across the exercises.**
Results: **For both genders, the Roman chair conditions did not influence the activity of the back and gluteus muscles. The hip-at-40°-flexion condition significantly reduced the activity of the biceps femoris (average of 4–18%) relative to the other 2 conditions. Gender differences were observed on the activity of the biceps femoris in all Roman chair conditions.**
Conclusion: **The hip-at-40°-flexion condition would allow the Roman chair exercise to train the targeted back muscles more specifically by overloading them over a longer duration in order to induce physiological changes.**

Key words: electromyography, back muscles, rehabilitation, specificity, gender.

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INTRODUCTION

Prospective studies show that poor back muscle endurance is a predictor of first-time occurrence of low back pain (LBP) (1) as well as a predictor of long-term back-related disability when assessed 4 weeks post-injury (2). In patients with chronic LBP, poor back muscle endurance could be attributed to a higher proportion of type II fatigable fibers and to the atrophy of lumbar muscles (3, 4). Progressive resistance training involving the back muscles has been successful in increasing strength and/or endurance as well as in decreasing pain and/or disability among patients with LBP (5).

One popular exercise to improve back muscle function is the prone back extension exercise using the Roman chair (RC). The level of intensity for this type of exercise is between 40% and 60% of the maximal voluntary contraction (MVC) (6, 7), which should be well suited to improving back endurance. However, this exercise solicits both back and hip extensor muscles (gluteus and hamstrings) and thus may not always specifically train the back muscles. Some studies (8–10) report that hip extensor muscles fatigue faster than back muscles, which could limit the duration of the exercise and consequently impair the endurance training of back muscles. Moffroid et al. (11) brought some further support to this hypothesis since they showed no improvement in any electromyographic (EMG) spectral parameters corresponding to lumbar muscles following a 6-week back endurance training program involving prone back exercises.

Different studies (7, 12–14) have assessed variants of the RC exercise with the purpose of increasing the relative contribution of back muscles and decreasing that of one of the hip extensors. Unfortunately, adding an external load (12, 15) or other variants, such as modifying the hip axial rotation, arm position and lumbar posture (13, 14) were unsuccessful in reducing the contribution of the hip extensors. Dedering et al. (16) proposed flexing the hips at an angle of 40° relative to the horizontal (H40°). This position increases the mechanical advantage (longer lever arms, lengthened muscles) of the hamstrings (17) and consequently appears to increase the endurance time values (295–385 sec) (16) compared with those reported from the traditional RC exercise (109–220 sec) (18). These results might be related to a lower activation level and, consequently, to a slower fatigue increase of the hip extensors during the exercise. However, this remains to be verified.

Another way to increase endurance time values might be to better stabilize the pelvis, as suggested by the results of Novak et al. (19) (4.7 min). Pelvic stabilization is hypothesized to minimize the involvement of hip extensors and to better

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isolate the recruitment of lumbar extensor muscles during trunk extension exercises (20). However, this might only apply in machines (in a sitting posture) and be more difficult to achieve in a RC where the lower limbs are not well stabilized, which would have limited value in influencing the powerful hip extensors. Only one study has evaluated the effect of pelvic stabilization in an RC device (21), but the experimental conditions were not counter-balanced and the EMG of the hip extensors was not recorded. So far, none of these variants of the RC (changing hip position, pelvic stabilization) have been shown to be better than another in maximizing the activity of back muscles while minimizing the activity of hip extensors during an RC exercise (specificity principle). This warranted a more comprehensive EMG investigation of RC exercises. Also of importance, gender differences apparently exist in the activation of back and hip extensor muscles during the traditional RC exercise (22), which calls for the consideration of gender as an independent variable.

The main purpose of the present study was to assess the effect of pelvic stabilization and hip position (H40°) on the EMG activity level of back and hip extensor muscles during a dynamic RC exercise. Considering that hip flexion can engage passive tissues surrounding the leg-pelvis-spine chain (23), the total trunk range of motion was also examined. The second purpose was to compare genders across the exercises. We hypothesized that (*i*) pelvic stabilization would enhance the activation of back muscles, and (*ii*) changing the hip position (H40°) would decrease the contribution of hip extensors. It was further hypothesized that these effects would be observable in both genders.

MATERIALS AND METHODS

Participants

Twenty-two healthy volunteers (11 men and 11 women), age range 20–55 years, with a body mass index (BMI) less than 30 kg/m^2 were recruited (Table I). None of the subjects had a history of LBP in the preceding year. Subjects who had had surgery involving the pelvis or the spine were excluded. The subjects were informed about the experimental protocol and the potential risks of the study and gave written consent prior to their participation. The protocol and consent form had been previously approved by the ethics committee of the Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR).

Table I. *Subject characteristics*

Variable	Men (*n*=11) Mean (SD)	Women (*n*=11) Mean (SD)	*t*-test *p*-values
Age, years	25 (4)	26 (3)	0.710
Height, m	1.77 (5.95)	1.67 (7.41)	**0.002**
Weight, kg	74 (10)	60 (6)	**0.001**
BMI, kg/m^2	23 (3)	21 (2)	0.156
ROM$_{ST}$, °	107 (6)	120 (21)	0.060
ROM$_{S}$, °	30 (7)	32 (11)	0.696
MVC$_{H0°}$, Nm	137 (30)	82 (31)	**0.000**
MVC$_{H40°}$, Nm	269 (41)	184 (48)	**0.000**
MVC$_{BACK}$, Nm	335 (45)	220 (60)	**0.000**

Significant differences ($p<0.05$) are shown in bold.
MVC$_{H0°}$; MVC$_{H40°}$; MVC$_{BACK}$: maximal voluntary contraction, for each muscle group (back and hip muscles), corresponding to the reference positions for the electromyography normalization; ROM$_{ST}$: trunk range of motion from erect standing position; ROM$_{S}$: trunk range of motion from erect sitting position; SD: standard deviation.

Assessments

Two sessions separated by a maximum of one week were required. In the first session, basic anthropometric measures (height, weight) were collected and the subjects were familiarized with the equipment and the different tasks. The second session was used to assess flexibility as well as measures collected across RC exercises (Fig. 1: left-hand pictures, more details below), namely the range of motion (ROM) of the trunk and the EMG activity of the back and hip extensor muscles. We used healthy subjects to obtain a true MVC, instead of LBP participants, in order to avoid confounding factors such as pain-related fear of physical activity and fear of injury, which are known to affect MVC (24) and thus the computation of the Muscular Utilization Ratio (MUR, as detailed below).

Tasks

Lumbar flexibility assessment. The accelerometer was used as an inclinometer to measure lumbar flexibility. Two movements were used to determine the lumbar flexibility of each subject (25). The first movement was from erect standing to maximal lumbar flexion without flexing the legs, while the second movement was extreme toe-touching from the sitting position. Each position was performed once for at least 10 sec to achieve maximal flexion (e.g. Table I, ROM$_{ST}$ from standing and ROM$_{S}$ from sitting). The first movement (from standing) was also used for calibrating the accelerometer at L1 in order to obtain the trunk angle measure during the RC exercises (ROM$_{RC}$) (26).

Maximal voluntary contractions (MVC). To estimate the MUR, which is defined as the percentage of EMG amplitude during RC conditions relative to the maximal EMG obtained from an MVC, the maximal EMG amplitude was determined by isolating each muscle group. In a supine position, 2 static right hip extension MVCs were performed in a Biodex dynamometer using 2 different hip positions relative to the horizontal (Fig. 1, right-hand pictures): (*i*) at an angle of 0° (neutral, MVC$_{H0°}$), and (*ii*) at an angle of 40° (MVC$_{H40°}$). These 2 positions were chosen as reference to normalize the EMG signals, taking into account the length of the hip extensor muscles (neutral hip position vs H40°). The trunk and left leg were firmly strapped against the Biodex chair. A custom-designed stabilization device (2 adjusted pads mounted on a metallic armature) was positioned on the anterior superior iliac spine to prevent motion of the pelvis during maximal hip extension. The knee on the tested side was maintained by an in-house device designed to control the knee position, whereas the axis of the dynamometer was aligned at the greater trochanter, and the resistance pad was fixed at the distal end of the thigh.

For the back muscles (MVC$_{BACK}$), 3 isometric MVCs were performed with the subjects lying prone on an adapted RC device (Fig. 1, middle pictures). The upper body was unsupported at an angle of 20° below the horizontal, and the hands were crossed to the opposite shoulders. The 20° angle was chosen to normalize the EMG activity of the back muscles at approximately the middle position of the ROM of the different RC conditions (ROM$_{RC}$), taking into account the length of the back muscles. The upper border of the iliac crest was aligned with the edge of the pelvic pad. The fixed caudal part of the bench supported the pelvis and the legs, and 3 straps were used to secure the lower limbs (pelvis, knees and ankles) to the bench. A load cell was used to measure the isometric back extension force via a belt positioned over the scapulae.

The MVCs of the back and hip extensors were performed progressively (3 sec to reach the maximal, 1 sec to maintain, and relax), allowing 2 min of rest between contractions. To maximize their performance at each contraction, the extension moment measured by the Biodex (hip

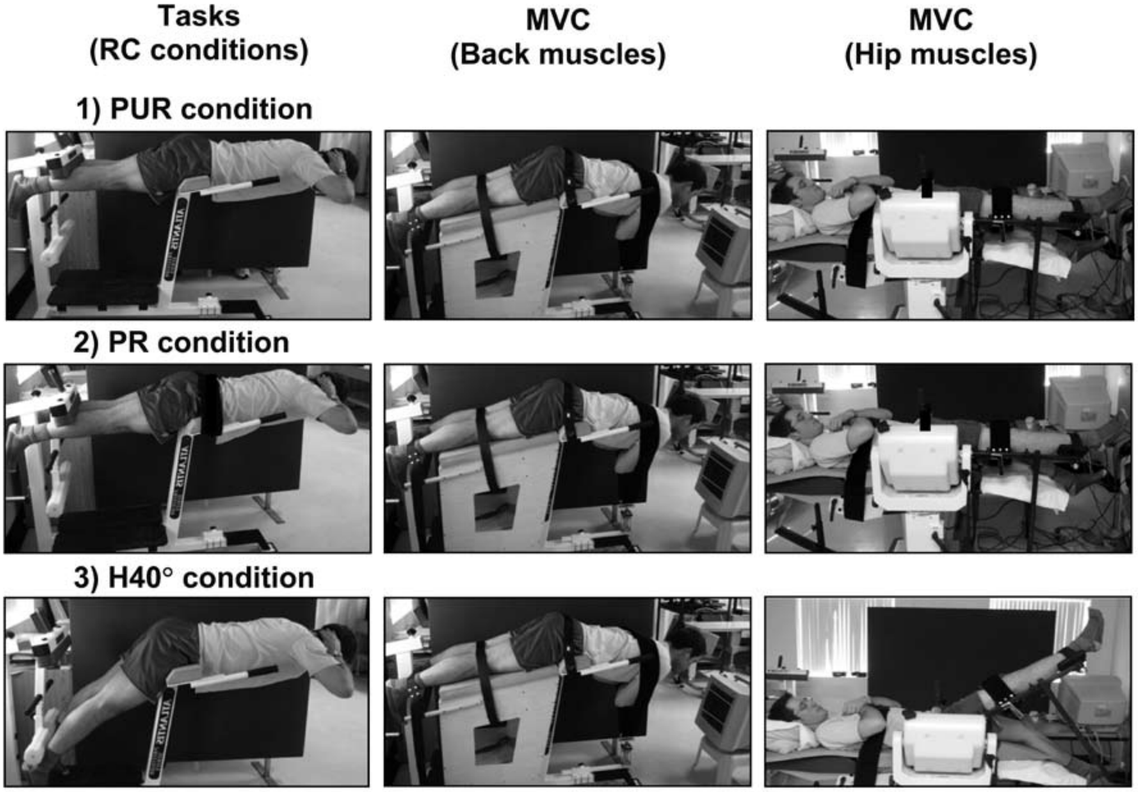

Fig. 1. Roman chair (RC) conditions (left-hand pictures) and corresponding maximal voluntary reference contractions (middle and right-hand pictures) used to normalize the electromyographic (EMG) signals. During the maximal voluntary contractions (MVCs), the positions of the segments were the same (similar muscle lengths) as the position where the EMG was analyzed during the 3 Roman chair conditions: pelvis unrestrained (PUR), pelvis restrained (PR) and hip at 40° flexion (H40°) with the pelvis unrestrained. Note: the left-hand pictures should represent a 20° trunk flexion to represent the posture in which the EMG analyses were done on the back muscles.

extensors) or the perpendicular force measured by the load cell (back muscles) was displayed in real time as visual feedback (on a monitor) and standardized verbal encouragements were given. The largest value of the maximal contractions was retained as the MVC.

RC conditions. Ten minutes after the MVCs, the subjects performed the 3 RC conditions (Fig. 1, left-hand pictures): (*i*) hip at neutral, pelvis unrestrained (PUR; control condition), (*ii*) hip neutral, pelvis restrained (PR), and (*iii*) hip at 40° flexion (H40°) with the pelvis unrestrained. RC conditions were balanced among subjects to control for possible carry-over effects. For all RC conditions, the subjects were placed on the RC with their trunks unsupported along the horizontal so that their anterior superior iliac spines were on the front edge of the pelvic pad. For the PR condition only, the pelvis was firmly stabilized with a broad strap positioned on the sacrum. The participants were asked to tolerate pelvic stabilization with as much pressure as possible but without pain or discomfort during the PR condition. For the H40° condition, the hip was positioned at an angle of 40° relative to the horizontal with the pelvis unrestrained.

The subjects performed one set of 5 dynamic back flexion-extension cycles for each RC condition with their hands placed behind their heads. At least 3 min of rest were allowed between conditions. The subjects started the exercise in a horizontal position (identified by a bar indicator positioned approximately at T4) and were encouraged to execute maximal flexion of the trunk during the exercise. Each flexion/extension cycle lasted 5 sec (1 sec horizontal, 2 sec flexion, and 2 sec extension) and was paced with a metronome (60 beats/min) along with feedback from the investigator.

Measurement techniques (Dynamometry, EMG, Kinematics). All data were recorded via 2 acquisition cards, the first for EMG (sampling rate: 2048 Hz) and the second for dynamometry and kinematics (sampling rate: 128 Hz). The 2 cards were materially synchronized, and trial recording onset was given by a single recording program triggering the 2 cards simultaneously.

Dynamometry. The gravity-corrected strength (in Nm) of the hip extensor muscles was measured with a Biodex dynamometer system (Biodex Medical Systems III, Inc., New York, USA). A load cell system (Model UTC2; Gould Inc., Measurement Systems, Oxnard, CA, USA) was used to measure the force signals from the back muscles. With the subjects lying prone, we measured the lever arm of the perpendicular force generated by the load cell relative to the L5–S1 joint by using a tape to measure the horizontal distance between the vertical projection of the load cell and L5–S1. This procedure was used to determine the peak extension moment at the L5–S1 joint without including the trunk mass moment.

Electromyography. EMG signals were collected from 12 pre-amplified (gain: 1000) active surface electrodes (Model DE-2.3, Delsys Inc., Wellesley, MA, USA). EMG signals from the recording sites were band-pass filtered between 20 and 450 Hz, analog-to-digital converted at a sampling rate of 2048 Hz, and stored on a computer hard disk for later analyses.

After the skin at the electrode sites was shaved and abraded with alcohol, the electrodes were positioned bilaterally on the multifidus at the L4 level (MU-L4-Left and MU-L4-Right), on the iliocostalis lumborum at the L3 level (IL-L3-L and IL-L3-R), on the longissimus at L1 (LO-L1-L and LO-L1-R), and at T10 (LO-T10L and LO-T10-

R) following the recommendations of Defoa et al. (27) with regard to muscle fiber direction (details in (28)). We recognize the difficulty of capturing the multifidus with surface electrodes, and therefore assigned validity of the EMG signal to the landmark location rather than to the multifidus muscle itself. Four additional electrodes were positioned over the belly of the gluteus maximus (GM-L and GM-R) and biceps femoris (BF-L and BF-R) (18). To avoid movement artefacts related to the direct contact of the electrodes on hard surfaces (Biodex chair), we placed pierced circular cushions around the GM and BF electrodes. A reference (ground) silver-silver chloride electrode was positioned over the T8 spinous process.

Kinematics. The angular position of the trunk segment was obtained from one accelerometer (Model ADXL105EM-3, Analog Devices Inc., Norwood, MA, USA) positioned at the L1 level of the spine. This accelerometer measures the angular position as an inclinometer would do, following the calculation and calibration procedures of Hanson et al. (26).

Signal processing. All data processing was performed using MATLAB sub-routines (Version 7.0; The MathWorks Inc., Natick, MA, USA, release 14). Both force signals were low-pass filtered, both ways, with a Butterworth filter using optimal cut-off frequency calculated with residual analysis. Angle signals (inclinometer) were low-pass filtered at 2 Hz, both ways, using a second-order Butterworth filter. A notch-filter was used for the EMG signals, removing frequencies at 60 Hz and their harmonics.

From the EMG signals corresponding to the MVCs, a moving Root Mean Square (RMS) processing method was executed on successive 250-ms (512 points) time-windows. For each muscle, the peak RMS value across all MVC trials represented the maximal EMG activity (RMS_{MAX}). For each RC condition and each flexion/extension cycle (c) [c representing the cycle number], RMS values [$RMS_{DYN}(c)$, where DYN = dynamic] were computed using the EMG signals corresponding to a trunk angle ranging between 30° and 10° to avoid the acceleration and deceleration portions of the concentric contractions (extension phase of movement). RMS processing was also executed on a 1-second time-window to assess the average level of muscle activity [$RMS_{STA}(c)$, where STA = static] during the static phase (i.e. trunk unsupported along the horizontal) of the exercise. Total trunk ROM was computed for each RC condition and each flexion/extension cycle [$ROM_{RC}(c)$]. The $ROM_{RC}(c)$, $RMS_{DYN}(c)$ and $RMS_{STA}(c)$ values were averaged across the 3 middle cycles to give a single value. Finally, the MURs (in %) were computed using the equations below:

$$[MUR_{DYN}\,(\%) = (RMS_{DYN}/RMS_{MAX} \times 100\%)]$$

$$[MUR_{STA}\,(\%) = (RMS_{STA}/RMS_{MAX} \times 100\%)]$$

Statistical analyses. All statistical analyses were performed with NCSS statistical software (version 6.0 for Windows) with an alpha of 0.05 as the level of statistical significance. All variables were normally distributed, as verified with the Wilk-Shapiro test. Student *t*-tests were used to assess between-group (men and women) differences in age, height, weight, BMI, lumbar flexibility (ROM_{ST} and ROM_{S}), and MVC (back and hip extensors). All MURs were averaged bilaterally because no significant differences were observed between the left and right side muscles (ANOVAs, $p \geq 0.05$). Two-way ANOVA (Genders × RC conditions) with repeated measures on the RC conditions factor was used to compare the MUR values of a given muscle and ROM_{RC} across the 3 RC conditions. *Post hoc* analyses were performed, when necessary, using the Tukey test.

Table II. *Muscular Utilisation Ratio (MUR) values of the back and hip extensor muscles during the Roman Chair (RC) conditions. Analysis of variance (ANOVA) results for main effects: both genders and RC conditions. Mean values with standard deviation in parentheses*

			RC conditions			p ANOVA		
Variables	Muscles[1]	Genders	PUR	PR	H40°	Genders	Conditions	Interaction
MUR_{DYN} (dynamic)	MU-L4	M	49 (11)	46 (13)	45 (12)	0.702	0.517	0.620
		W	48 (16)	52 (20)	44 (10)			
	IL-L3	M	40 (18)	37 (16)	39 (17)	0.102	0.634	0.959
		W	49 (18)	43 (14)	46 (15)			
	LO-L1	M	55 (11)	51 (13)	52 (12)	0.356	0.938	0.856
		W	56 (19)	57 (18)	56 (11)			
	LO-T10	M	42 (18)	43 (18)	43 (19)	0.534	0.709	0.801
		W	44 (14)	49 (13)	43 (10)			
	GM	M	22 (19)	25 (20)	15 (7)	0.601	0.677	0.687
		W	23 (16)	23 (15)	23 (14)			
	BF	M	16 (7)	18 (10)	12 (4)	**0.017**	**0.039**	0.570
		W	24 (13)	30 (20)	16 (11)			
MUR_{STA} (static)	MU-L4	M	54 (13)	56 (13)	50 (11)	0.365	0.107	0.799
		W	54 (17)	52 (15)	44 (15)			
	IL-L3	M	43 (11)	40 (10)	38 (12)	0.123	0.139	0.709
		W	52 (18)	41 (12)	43 (18)			
	LO-L1	M	58 (11)	59 (10)	55 (10)	0.434	0.211	0.750
		W	58 (13)	57 (14)	50 (10)			
	LO-T10	M	46 (22)	47 (15)	43 (18)	0.818	0.350	0.889
		W	45 (10)	49 (10)	39 (10)			
	GM	M	29 (24)	26 (23)	15 (10)	0.655	0.364	0.777
		W	28 (20)	26 (17)	23 (17)			
	BF	M	20 (7)	21 (13)	13 (4)	**0.027**	**0.001**	0.193
		W	33 (18)	27 (7)	14 (7)			

Significant differences ($p < 0.05$) are shown in bold.

[1] For abbrevations see Materials and Methods, paragraph Electromyography.

MUR_{DYN} (%): Muscular Utilization Ratio computed from concentric portion in extension (dynamic analyses). MUR_{STA} (%): Muscular Utilization Ratio computed from static portion in extension at horizontal (static analyses); M: men; W: women; PUR: pelvis unrestrained; PR: pelvis restrained using a strap pressing the pelvis against the support pad; H40°: hip at an angle of 40° relative to the horizontal with the pelvis unrestrained.

The activation level of the different muscle groups was not contrasted in order to simplify the interpretation of the ANOVA results and because the activity level does not explain previous results showing more fatigue in the hip extensors (8–10). In fact, the present results indicate, though not assessed statistically, that the activation level is less for the hip extensors than for the back muscles. However, increasing the activity of the back muscles while lowering the activity of the hip extensors would help fatigue the back muscles more specifically, which was tested using the statistical analyses described above.

RESULTS

The demographic characteristics (age, height, weight, BMI) as well as the lumbar flexibility and maximal strength (back and hip extensor muscles) of men and women are presented in Table I. Only height, mass and strength were significantly different between the genders.

The MUR of the back muscles ranged between 37% and 58% across the RC conditions, whereas it ranged between 12% and 33% for the hip extensor muscles (Table II). No significant interaction was found between the genders and RC conditions for both the MUR (Table II) and ROM_{RC} (ANOVA results, $p = 0.930$) variables. In both genders, the RC conditions did not influence the activity of the back and gluteus muscles, either for dynamic or static MUR analyses (Table II). On the other hand, the H40º condition significantly reduced the activity of the BF muscle by an average of 4–18% (across dynamic and static analyses) relative to the other 2 RC conditions (see Table II). This is further illustrated in Fig. 2, for MU-L4, GM and BF results pooled across genders. The H40º condition significantly ($p = 0.031$) reduced the ROM_{RC} relative to the PUR condition (Fig. 3) in both genders. No significant differences between genders were found for the back and GM activities (Table II). In general, women showed significantly higher BF activity than men for the 3 RC conditions, except for the H40° condition from the static MUR analysis. However, when accounting for hip extensor strength in an ANCOVA (results not reported here), the corresponding covariates ($MVC_{H0º}$ and $MVC_{H40º}$ from Table I were tested separately) were statistically significant, and the significant effect of gender on the MUR values disappeared for the 3 RC conditions. In fact, hip strength ($MVC_{H0º}$ or $MVC_{H40º}$) was significantly correlated with the MUR_{DYN} of BF ($r = -0.58$ for PUR, $r = -0.57$ for PR, and $r = -0.57$ for H40°). Other possible confounding factors such as ROM_{ST} and ROM_{S} (2 lumbar flexibility measures) were not significant between genders (*t*-test results, Table I) and consequently were not further considered as possible covariates in an ANCOVA.

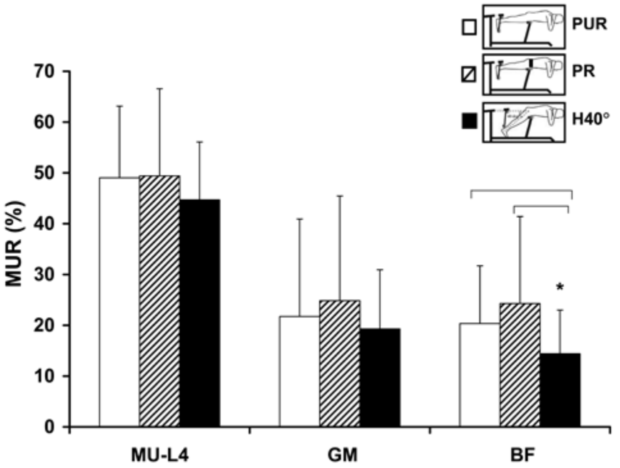

Fig. 2. Muscular Utilization Ratio (MUR) values (error bars correspond to standard deviations) from dynamic analysis, pooled across genders, of the multifidus (MU-L4), gluteus maximus (GM) and biceps femoris (BF) during the 3 Roman chair conditions: pelvis unrestrained (PUR), pelvis restrained (PR) and hip at 40° flexion (H40°) with the pelvis unrestrained. The H40° condition significantly decreased the activity of BF. For more details, see Table II.

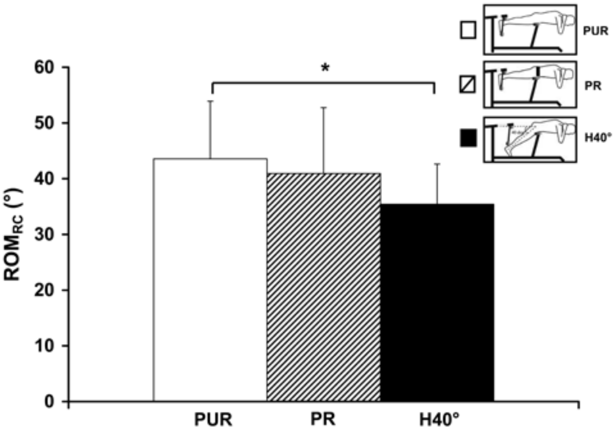

Fig. 3. Trunk range of motion (ROM_{RC}) computed during each Roman chair (RC) condition (pelvis unrestrained (PUR), pelvis restrained (PR) and hip at 40° flexion (H40°)), pooled across genders (error bars correspond to standard deviations). The H40º condition significantly decreased ROM_{RC} relative to the PUR condition.

DISCUSSION

Contrary to our first hypothesis, pelvic stabilization did not enhance the activity of back muscles. On the other hand, flexing the hip decreased the relative activity of BF (one powerful hip extensor) in both genders, which supported our second hypothesis. Gender differences were observed in BF muscle, but disappeared when accounting for hip extensor strength.

Effect of pelvic stabilization. Our results showed, for both genders, that pelvic stabilization did not increase the activity of the back muscles during the RC exercise. As stated earlier, only one study (21) evaluated the effect of pelvic stabilization during lumbar extension in an RC exercise. Although the authors did not balance the RC conditions and did not record the EMG activity of the hip extensors, the back muscles showed comparable activation between the PUR and PR conditions. The hypothesized effects of pelvic stabilization on the recruitment of lumbar extensors and on the reduced contribution of hip extensors (20, 29) may thus only apply in the sitting position. Regarding the hip extensors, these results could be explained by the fact that this muscle group is invariably involved during compound trunk extension movements (30), even when the pelvis was restrained because a well-established motor synergist pattern exists for familiar movements such as lumbar flexion/extension cycles.

The present negative results could also be related to the difficulty stabilizing the pelvis during the RC exercise. Although the pelvis was firmly pressed against the support pad and the participants were asked to tolerate as much pressure as possible without undue pain or discomfort, the use of a strap might not be sufficient. RC is a simple and low-cost exercise, but it does not allow an efficient mechanism for pelvic stabilization compared with exercise machines where the subjects are sitting and well stabilized with more sophisticated pelvic and lower-limb stabilization mechanisms (20, 31). In fact, pelvic stabilization is apparently efficient for strengthening the back muscles (20) as well as for increasing the activation of the lumbar extensor muscles (31) in such machines.

Effect of hip position. In the present study, the H40° condition significantly reduced the activity of one of the hip extensors (BF) relative to the other 2 conditions, for both genders. This supports the longer endurance time values of Dedering et al. (16, 32) and is apparently related to the mechanical advantage of the hip extensor muscles in this position. In this position, the hamstring muscles reach their maximal lever-arms (17) and are also lengthened further so as to increase their strength according to the length-tension relationship. These explanations are further supported by the strength results (Table I). These 2 advantages could have reduced the required relative loading on the BF muscles during the exercise. Even though the GM activation level was reduced in this position, the effect did not reach statistical significance. However, the lever-arm increase of the GM is much smaller than in the BF in this position (17), even though both hip extensors (GM and BF) were lengthened.

The H40º condition significantly reduced the ROM_{RC} relative to the PUR condition (Fig. 3), the magnitude of the effect (8°) being comparable to the 10° difference found elsewhere in similar conditions (33). Hip flexion could have had an effect on the leg-pelvis-spine chain (23) by lengthening the BF muscle, which increases the sacrotuberous ligament tension and thus decreases sacroiliac joint mobility (23).

Effect of gender. One study showed higher lumbar back activity in women relative to men during a dynamic RC exercise, but no difference was observed for GM (22). In the present study, the activity of back muscles was similar in both genders, but women activated more their BF. However, the RC exercise was performed here at a much lower frequency (12 repetitions/min) than in Arokoski's study with 40 repetitions/min (22).

Generally, gender differences exist in the anatomy (34), in flexibility (35) and in muscle strength, as observed for the back (36) or hip (37) extensors. With regard to anatomy, pelvic width is known to differ between genders, which apparently generates different muscle moment arms as observed for the back and hip muscles (17, 34). However, these results were not adjusted to the anthropometry (e.g. height) of the subjects so it is not known if this is only a scaling effect or an intrinsic gender difference. In the present study, gender differences disappeared when accounting for hip extensor strength, which suggests that the relative load induced by the weight of the trunk was different. Women were estimated to support a higher relative load (women = 60% MVC vs men = 48% MVC) during such exercises (15), which could have specifically increased the relative loading on the BF muscle during the RC conditions. Effectively, a significant increase in hip extensor activity (not back muscles) was observed during the RC exercise when the relative load was increased by adding extra load onto the trunk (15, 38). This suggests that the higher relative load induced by the trunk in women would similarly increase the activation of hip extensors relative to men (only for BF here).

Limitations of the study. The overall results of this study cannot necessarily be generalized to patients with LBP. Another limitation of the study is that we did not evaluate the fatigue of the back and hip extensor muscles during the 3 RC conditions. This would have been useful for determining which muscle group (back or hip extensors) is more prone to fatigue during each RC exercise.

In conclusion, our results demonstrate that pelvic stabilization was not effective in increasing the activity of the back muscles during RC exercise. On the other hand, the H40° condition was efficient in decreasing the activity of the BF, a powerful hip extensor, and this in both genders. Consequently, the H40° condition would allow the RC exercise to train more specifically the targeted back muscles so as to induce more physiological adaptations. This has implications for the training of back muscle endurance in patients with LBP.

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