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Original article

Effect of the pelvic compression belt on the hip extensor activation patterns of sacroiliac joint pain patients during one-leg standing: A pilot study☆

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A B S T R A C T

As a means of external stabilization of the sacroiliac joint (SIJ), many clinicians have often advocated the use of the pelvic compression belt (PCB). The objective of this pilot study was to compare the effects of the PCB on hip extensor muscle activation patterns during one-leg standing in subjects with and without sacroiliac joint pain (SIJP).

Sixteen subjects with SIJP and fifteen asymptomatic volunteers participated in this study. Surface electromyography (EMG) data [signal amplitude and premotor reaction time (RT)] were collected from the gluteus maximus and biceps femoris muscles of the supporting leg during one-leg standing with and without the PCB.

Compared to that of the asymptomatic individuals, the EMG amplitude of the biceps femoris was significantly decreased in individuals with SIJP upon the application of the PCB ($p < 0.05$). Furthermore, on using the PCB, in individuals with SIJP, the RT of the gluteus maximus was significantly decreased; however, the RT of the biceps femoris was increased ($p < 0.05$).

Thus, our data support the use of the PCB to modify the activation patterns of the hip extensors among patients with SIJP.

1. Introduction

The sacroiliac joint (SIJ) is a potential source of low back pain (LBP) (Schwarzer et al., 1995; Slipman et al., 2001), and the prevalence of sacroiliac joint pain (SIJP) is reported to be 13–30% in patients with non-specific LBP (Schwarzer et al., 1995; Maigne et al., 1996). The main function of the SIJs has been often described to transfer the load of the upper body weight to the legs, and transmit ground reaction force from the lower limbs to the trunk (Vleeming et al., 1992; Hossain and Nokes, 2005). These functions can differ depending on the patient's anatomical articular stability (form closure) and optimal neuromuscular stability (force closure) during performance of various activities (De Groot et al., 2008). Sturesson et al. (2000) showed that, the form closure and force closure mechanisms provide and control functional stability of the SIJs; the stability was measured using radiostereometric analysis during one-leg standing. Therefore, disruption of these mechanisms has been frequently hypothesized to lead to pain or dysfunction during load transfer through the lumbopelvic region (Snijders et al., 1998; Mens et al., 1999).

Weight bearing on the symptomatic side during standing or walking may aggravate the symptoms of SIJP (Slipman et al., 2001); this probably occurs due to asymmetrical shear loading through the lower extremities or the pelvis (Prather and Hunt, 2004; Zelle et al., 2005). Moreover, one-leg standing on the symptomatic side contributes to the forward rotation of the ilium with resulting flexion at the contralateral hip (Hu et al., 2010), which may be a potential factor to make the SIJ unstable during load transfer (Hungerford et al., 2004).

One-leg stance is a necessary sequence for dynamic transitions of body weight during walking (Rogers and Pai, 1993), and it is often used to assess the capability of the SIJ to maintain lumbopelvic stability during the transmission of load between the lower extremities and the spine (Lee, 2004). Muscular effort is required to stabilize the lumbopelvic region and to control the supporting leg (Hossain and Nokes, 2005). A previous study found that patients with SIJP exhibit altered activation patterns of the biceps femoris and gluteus maximus during one-leg standing (Hungerford et al.,

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2003). Alterations in muscular activation patterns may explain failure of the force closure mechanism and reduced lumbopelvic stability (De Groot et al., 2008). Previous studies have reported that muscle imbalance patterns of the hip extensor muscles have clinical relevance to SIJP (Hungerford et al., 2003; Hossain and Nokes, 2008).

During hip extension in patients with SIJP, the hamstring muscles may be activated before the gluteus maximus (Hossain and Nokes, 2005). This dysfunction pattern, in which the hamstring muscles are activated earlier and the gluteus maximus activated later or to a lesser extent during hip extension, is frequently observed in a clinical setting (Sahrmann, 2002) and is believed to cause lumbopelvic dysfunction (Hungerford et al., 2003). In addition, the strong contraction of muscles that are longitudinally-oriented to the SIJ, such as the iliopsoas and rectus abdominis, may increase the shear load to the SIJ surfaces (Snijders et al., 1998). Therefore, the transversely-oriented lumbopelvic muscles that cross the SIJ possibly provide sustained compression that decreases the shear force at the SIJ during muscle contraction (Snijders et al., 1998; Richardson et al., 2002). Insufficient activity of these muscles may be partially responsible for the substitution of the pelvic motion.

The action of these transversely-oriented muscles can be supported with the pelvic compression belt (PCB) (Prather and Hunt, 2004). The PCB may improve the proprioceptive feedback to the stabilizing muscles of the SIJs (Slipman et al., 2001). The PCB increases the stability of the SIJ and the lumbopelvic region by compressing the articular surfaces of the SIJ (Vleeming et al., 1992; Pel et al., 2008). The use of the PCB also allows women with pelvic girdle pain to perform active straight leg raising (ASLR) with fewer difficulties (Mens et al., 2006). Therefore, it is often recommended that patients suffering from SIJP wear the PCB while walking and standing (Prather and Hunt, 2004), and many clinicians have incorporated the use of the PCB into their routine therapy (Liebenson, 2004; Mens et al., 2006). The mechanical action of the PCB may alter the activation pattern of the lumbopelvic muscles, depending on where the PCB is worn (Pel et al., 2008).

Several researchers have investigated the mechanical advantages of the PCB in both healthy individuals (Damen et al., 2002; Hu et al., 2010) and individuals with pelvic girdle pain (Mens et al., 2006). However, no studies have examined whether the PCB changes the activation patterns of the hip extensor muscles during functional tasks among patients with SIJP. Therefore, the objective of this pilot study was to compare the effects of the PCB on hip extensor muscle activation patterns during one-leg standing in subjects with and without SIJP.

2. Method

2.1. Subjects

Thirty-one women (16 subjects with SIJP and 15 asymptomatic subjects) volunteered to participate in this study. The subjects with SIJP were selected by their orthopedic physicians. The age-matched asymptomatic subjects were recruited with posters placed in and around the hospital. Table 1 depicts the inclusion/exclusion criteria for the study. A detailed description of the study procedures and safety measures was provided to all subjects, and each subject signed an informed consent form approved by the Yonsei University Wonju Campus Human Studies Committee. The demographic data of the participants are presented in Table 2.

Table 1
Inclusion and exclusion criteria for all subjects.

SIJP group	Asymptomatic group
Inclusion criteria Presenting pain: - Unilateral pain for >2 months over the posterior pelvic and SIJ regions without low back discomforts such as pain above the lumbosacral junction (Hungerford et al., 2003) ASLR test: - Heaviness ± pain, which is relieved when performed with manual pelvic compression (Mens et al., 2006) - At least two out of five on the ASLR score was considered positive (Beales et al., 2010) SIJP provocation tests: 1. Compression test 2. Distraction test 3. Gaenslen's test 4. Thigh-thrust test 5. Sacral-thrust test - At least three or more of five provocation tests are positive: (Laslett, 2008)	- No history of low back pain in the previous 12 months - All negative results on the ASLR and 5 provocation tests
Exclusion criteria History of trunk and lower limb surgery; past or present musculoskeletal, neurological, or psychological diseases that could impede the one-leg standing as well as lower limb joint contracture and significant weakness in the lumbopelvic and hip muscles	

Abbreviations: SIJP = sacroiliac joint pain; SIJ = sacroiliac joint.

2.2. Application of the PCB

The PCB (COM-PRESSOR, OPTP, Canada) provides stabilized pressure on the SIJ region and consists of 2 parts, a main body belt and 4 elastic bands (Fig. 1A). The intensity of the compression force can be adjusted by modifying the compression sites, depending on the subject's condition. In the present study, the body belt was positioned just below the anterior superior iliac spine (Damen et al., 2002; Mens et al., 2006), and the elastic compression bands were applied to the body belt with the intention of providing stabilized pressure upon verification of an accurate compression site (Fig. 1B). As suggested by Lee (2004), 4 manual compression tests with various options in compression direction were randomly performed to locate the exact site to apply the elastic compression band, so as to enable the subject to lift the leg easily during ASLR in a supine position (Mens et al., 1999). The order of the tests was randomly performed; for each test, the subject blindly picked one card from an envelope with 4 cards marked 1, 2, 3, or 4. To maintain continuity, the first author performed the compression tests and applied the PCB.

2.3. Procedures

We investigated electromyography (EMG) activation patterns of the hip extensor muscles during one-leg standing in subjects with

Table 2
Demographic data of Subjects($n = 31$).

Parameters	SIJP group ($n = 16$)	Asymptomatic group ($n = 15$)	P-value
Age (years)	26.04 ± 3.42	27.84 ± 2.83	0.391
Weight (kg)	56.65 ± 5.24	57.27 ± 6.92	0.712
Height (cm)	162.13 ± 3.69	160.90 ± 4.28	0.642
ASLR heaviness score (x/5)			
Symptomatic side	3.9 ± 0.5		
Symptomatic side with compression	1.5 ± 0.8		

Abbreviations: SIJP = sacroiliac joint pain. ASLR = active straight leg raise.

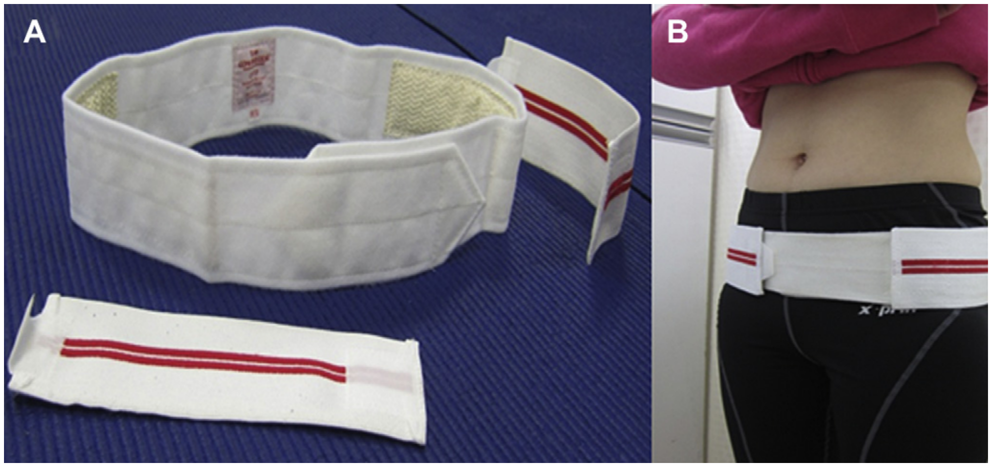

Fig. 1. The pelvic compression belt. (A) Main body belt and two short elastic bands of the pelvic compression belt, and (B) The body belt was positioned just below the anterior superior iliac spine to compress the right anterior pelvis and the left posterior pelvis.

and without SIJP. During the EMG data collection, the patients with SIJP stood on their symptomatic leg and lifted the asymptomatic leg, and the asymptomatic subjects stood on their non-dominant leg and lifted the dominant leg. All subjects participated in 3 practice trials before EMG data collection to ensure they could stand on one leg without any discomfort with 90° of hip and knee flexion in the non-weight-bearing leg. At the beginning of the EMG data collection, subjects were asked to stand upright with their feet at a comfortable distance apart; their hip and knee joints fully extended; and their arms rested at their sides. They were instructed to adopt the one-leg stance as soon as they heard an auditory start signal, which was delivered after a warning signal. To prevent the subjects from anticipating the start signal, the time period between the warning and start signals varied between 1 and 3 s. During one-leg standing, subjects were asked to keep the knee of the lifted leg at the height of a target bar for 5 s, until the end of the auditory stimulus. EMG data were recorded for 3 trials with a 1-min gap between repetitions, and the rest interval between the conditions (with or without the PCB) was 5 min. EMG amplitude [root mean square (RMS) value of EMG] and premotor reaction time (RT) (time between auditory stimulus and onset of EMG activity) were used as dependent variables for statistical analysis.

2.4. EMG recording and data processing

The EMG ZeroWire system (Aurion Ltd., Italy) was used for EMG data collection. After successful skin preparation, two sets of disposable Ag/AgCl bipolar surface electrodes (Norotrode 20TM, Myotronics-Noromed, Inc, WA, USA) were placed on the gluteus maximus and biceps femoris on the symptomatic side of subjects with SIJP and the non-dominant side of asymptomatic subjects. Each pair of electrodes was approximately 2 cm apart in the direction of the underlying muscle fibers. Surface electrodes for the gluteus maximus were placed halfway between the inferior lateral angle of the sacrum and the greater trochanter, and electrodes for the biceps femoris were placed halfway between the gluteal fold and the knee joint (Cram et al., 1998; Leinonen et al., 2000; Hungerford et al., 2003). The EMG signal was amplified with an overall gain of 1785.7 at a sampling rate of 2000 Hz. Band-pass (10–500 Hz) and notch filters (60 Hz) were used.

To normalize the EMG data, we calculated for each muscle the mean RMS of 3 trials of sub-maximal voluntary isometric contractions (sub-MVC), each of which was 3 s in duration. The sub-MVC for the biceps femoris was calculated while subjects performed 30° of knee flexion with a 3-kg sandbag attached to the distal portion of the shank in the prone position. For the gluteus maximus, the sub-MVC was calculated while subjects performed approximately 10° of hip extension with the knee flexed to 90° in the same manner. Subjects then performed one-leg standing, during which surface EMG data were collected from the selected muscles.

All raw EMG signals were digitized with MyoResearch Master Edition 1.06 XP software (Noraxon). To verify the muscle amplitude of the hip extensors, raw EMG signals collected from each muscle were processed into the RMS. EMG data for the medial 3-s of the 5-s duration of one-leg standing were selected for data analysis. The EMG signals collected during one-leg standing were expressed as a percentage of the calculated RMS of the sub-MVC (% sub-MVC). The premotor RT, the time between auditory stimulus and onset of EMG activity of the gluteus maximus and biceps femoris during one-leg standing, was determined as the time point at which the EMG amplitude increased by >2 SD for a minimum of a 500 ms (ms) from baseline (Rogers and Pai, 1993).

2.5. Statistical analysis

Data were analyzed with SPSS version 18.0 (SPSS Inc., Chicago, IL). The data are expressed as mean ± SD. Paired *t*-tests were used for within-group comparisons (with and without the PCB), and independent *t*-tests were used for between-group comparisons (with and without SIJP). A value of $p < 0.05$ was considered statistically significant.

3. Results

The change in the EMG amplitude of the gluteus maximus between with the PCB condition and without the PCB condition did not differ significantly between the subjects with SIJP and the asymptomatic subjects ($p > 0.05$) (Table 3). However, the change in the EMG amplitude of the biceps femoris between with the PCB condition and without the PCB condition was significantly greater in the subjects with SIJP than the asymptomatic subjects ($p < 0.05$) (Table 3). Within each group, the EMG amplitude of the gluteus maximus was significantly greater during the PCB use, and the EMG amplitude of the biceps femoris was lower during the PCB use ($p < 0.05$) (Fig. 2).

The decrease in the RT of the gluteus maximus between with the PCB condition and without the PCB condition was significantly

Table 3
Changes in EMG amplitude (% sub-MVC) and reaction time (ms) of gluteus maximus and bicep femoris muscles during one-leg standing with and without the PCB.

	SIJP group ($n = 16$)				Asymptomatic group ($n = 15$)				p[a]
	Without PCB	With PCB	Change	t	Without PCB	With PCB	Change	t	
EMG amplitude									
Gluteus maximus	6.56 ± 3.32	7.17 ± 3.68	0.62 ± 0.78	−3.17 *	7.10 ± 1.48	7.37 ± 1.69	0.27 ± 0.37	−2.88 *	0.127
Biceps femoris	33.40 ± 15.22	27.44 ± 13.56	−5.96 ± 4.86	4.10 *	10.48 ± 5.25	8.59 ± 3.96	−1.88 ± 1.94	3.76 *	0.005
Reaction time									
Gluteus maximus	570 ± 50	510 ± 50	−60 ± 30	6.98 *	380 ± 10	380 ± 20	−10 ± 20	1.18	0.000
Biceps femoris	270 ± 40	310 ± 50	40 ± 10	−13.30 *	400 ± 30	400 ± 40	0.0 ± 30	−0.21	0.000

*$p < 0.05$.
Change = With the PCB − Without the PCB.
Abbreviation: SIJP = sacroiliac joint pain; PCB = pelvic compression belt; sub-MVC = sub-maximal voluntary isometric contractions.
[a] Comparison between the changes of the SIJP and asymptomatic groups.

greater in the subjects with SIJP than the asymptomatic subjects ($p < 0.05$) (Table 3). Within each group, the RT of the gluteus maximus decreased significantly during the PCB use in the SIJP group only (Table 3) (Fig. 3). The change in RT of the biceps femoris between with the PCB condition and without the PCB condition was significantly different between the subjects with SIJP and the asymptomatic subjects ($p < 0.05$) (Table 3). However, within-group comparisons showed that the biceps femoris RT increased significantly during the PCB use in the SIJP group only (Table 3) (Fig. 3).

4. Discussion

This pilot study examined whether the PCB affects hip extensor muscle activation patterns during one-leg standing in subjects with and without SIJP.

When the PCB was not worn, the subjects with SIJP showed much higher biceps femoris EMG activity during one-leg standing than asymptomatic subjects. This result is consistent with recent findings suggesting that the biceps femoris must relax before initial contact to allow the gluteus maximus a peak loading response (Cappellini et al., 2006; Hossain and Nokes, 2008). During one-leg standing, the pelvis of the supporting leg has a tendency to rotate anteriorly because of a forward torque of the pelvis induced from the sustained contraction of the contralateral hip flexor while raising the leg (Hu et al., 2010). During one-leg standing, pelvic movement is controlled by the hip extensors. Hungerford et al. (2004) reported that in subjects without SIJP, the ilium of the supporting limb could be rotated slightly backwards; however, in subjects with SIJP, the ilium showed slight forward rotation with resulting flexion at the contralateral hip, i.e., supporting leg. In subjects with SIJP, the lack of pelvic control during one-leg standing may reflect reduced muscular effort for pelvic stabilization, which can be related to alteration in the motor control pattern of the hip extensors. This alteration can result in a weak self-bracing effect that aggravates pain in the pelvis during loading.

We also observed that patients with SIJP had a longer RT for the gluteus maximus than asymptomatic subjects, whereas the biceps femoris was activated much earlier with a shorter reaction time. These results are consistent with those of Hungerford et al. (2003), who reported that the biceps femoris is activated before one-leg standing in subjects with SIJP, while the gluteus maximus is activated after the initiation of contralateral leg lifting. Insufficient muscular effort of the gluteus maximus results in earlier activation by the biceps femoris while maintaining lumbopelvic stability during one-leg standing (Hungerford et al., 2003) and walking (Hossain and Nokes, 2008). Although the increased magnitude of contraction and early onset of the biceps femoris might supplement the reduced activity of the gluteus maximus during functional activities (Hungerford et al., 2003), dominant use of the biceps femoris reduces the opportunity to activate the gluteus maximus, and this consequently weakens it. The only muscle tissues that cross the SIJ are the deep sacral fibers of the gluteus maximus; these fibers may be responsible for the stability of the SIJ (Gibbons and Mottram, 2004). Thus, improving the activation pattern of the gluteus maximus should be regarded as an important clinical objective in the treatment of patients with SIJP.

In the present study, the use of the PCB during one-leg standing helped activate the gluteus maximus while inhibiting activation of the biceps femoris in both the SIJP patients and the asymptomatic patients. A previous study found that the use of the PCB increased

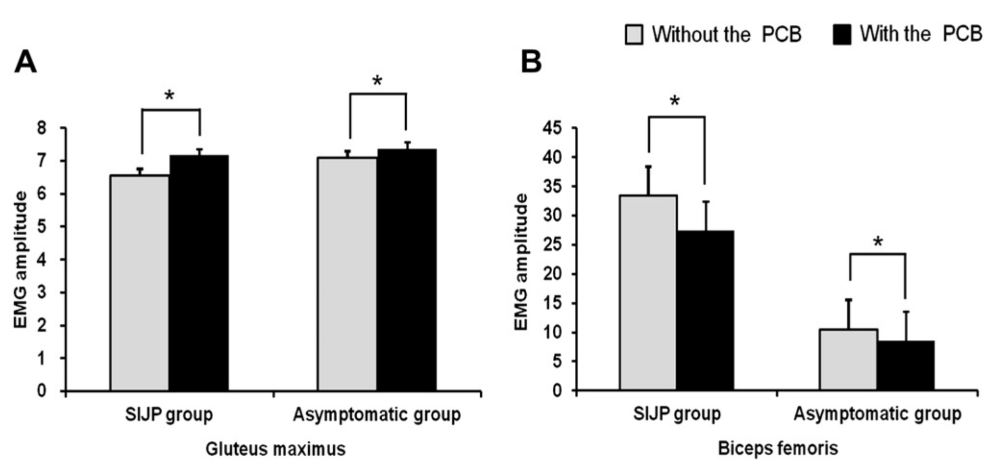

Fig. 2. Changes in EMG amplitude (% of sub-MVC to prone leg-loaded tasks) of gluteus maximus and biceps femoris muscles during one-leg standing.

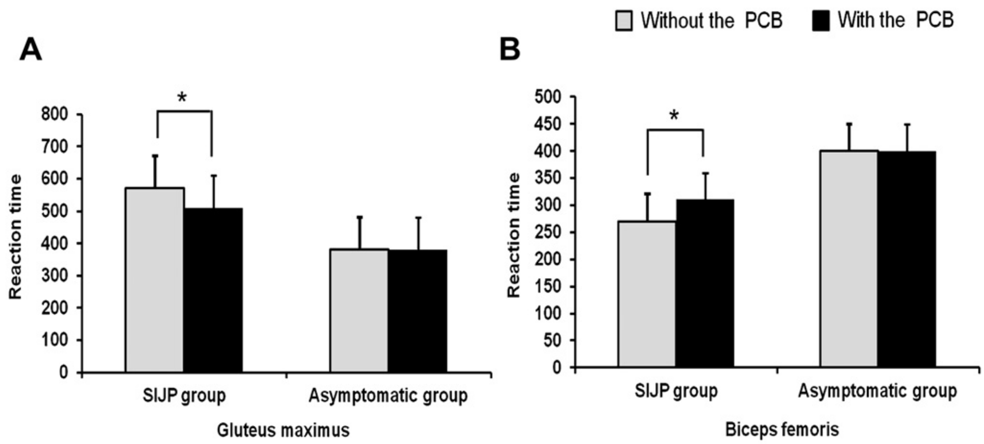

Fig. 3. Changes in reaction time (ms) of gluteus maximus and biceps femoris muscles during one-leg standing.

gluteus maximus activity and decreased biceps femoris activity during walking (Hu et al., 2010). During walking, the initial contact and loading response events require hip extensor muscular effort to maintain SIJ stability, and to transmit weight load and ground reaction force efficiently (Hossain and Nokes, 2008). Therefore, during the loading response, lumbopelvic stability may be necessary for balanced muscle control between the gluteus maximus and the biceps femoris (Hossain and Nokes, 2005).

Because the use of the PCB decreases the laxity of the SIJ (Damen et al., 2002), this may explain why we observed increased gluteus maximus EMG activity and decreased biceps femoris activity during the PCB use among both the patients with SIJP and asymptomatic subjects. The pelvic compression force provided by the PCB increases stiffness in the SIJ. This in turn unloads sensitized ligamentous structures and facilitates activation of the gluteus maximus during one-leg standing. Increased SIJ stiffness also makes it easier for patients to perform the ASLR. A previous study reported a decrease in the ASLR score from 4.1 to 2.5 during the PCB use (Mens et al., 2006). Although our study used a slightly different methodology, we observed a similar decrease in the ASLR score, from 3.9 to 1.5, during manual compression with the patient in the supine position.

In the present study, the PCB significantly reduced the RT of the gluteus maximus and increased the RT of the biceps femoris in the SIJP group, whereas the PCB had no such effect on the hip extensor muscles of asymptomatic subjects. Takasaki et al. (2009) found that a compressive force applied medially across the pelvis can cause early onset of gluteus maximus activity during hip extension in a prone position. In their study, the gluteus maximus became active 263.3 ± 99.5 ms after the semitendinosus muscle when no pelvic compression was applied, but 183.5 ± 77.9 ms after the semitendinosus muscle when 50 N compression was applied. They concluded that a compressive force across the pelvis could be a possible mechanism to establish proper motor control of the hip extensor muscles during functional tasks. Furthermore, a biomechanical modeling study showed that, on application of 100 N compression force, the SIJ compression force increases by 52%, the SIJ vertical shear force decreases by 10%, and the sacrotuberous ligament is unloaded (Pel et al., 2008). Thus, an external compressive force and the PCB might help unload the sacrotuberous ligament and thereby decrease the tension of the biceps femoris. This could produce more normalized motor responses and weaken the assistive action of the biceps femoris during one-leg standing, and it may explain why the PCB is helpful in preventing unwanted substitution of the lumbopelvic region and of the lower limb during one-leg standing. Another possible explanation is that a compressive force on the pelvic ring from the PCB provides the gluteus maximus with proprioceptive feedback (Prather and Hunt, 2004), allowing the gluteus maximus to become even more activated by this additional proprioceptive stimulation.

This study has several limitations. First, we recruited only young women, so it is unknown whether men or older individuals would also benefit from wearing the PCB. Second, we recruited subjects with SIJP using nonprobability sampling through an orthopedic physician's referral so that it would be possible and convenient to find subjects who met the inclusion criteria. Therefore, our sampling procedure might involve some degree of selection bias. In addition, we did not control the patients' pelvic tilt in the coronal, sagittal and transverse planes during one-leg standing; this uncontrolled pelvic position could have influenced the EMG patterns we observed. Finally, we examined only the short-term effect of the PCB on the activation patterns of the hip extensor muscles. Future studies will be needed to assess the long-term effects of the PCB use in a more diverse subject population.

5. Conclusion

We investigated the influence of the PCB on hip extensor muscle activation patterns during one-leg standing in subjects with and without SIJP. Among patients with SIJP, the PCB significantly changed the EMG activity patterns of the hip extensor muscles. Thus, our data support the use of the PCB to modify the activation patterns of the hip extensors among patients with SIJP.

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