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Review Article

Can lumbosacral orthoses cause trunk muscle weakness? A systematic review of literature

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Abstract

BACKGROUND: Wearing lumbosacral orthosis (LSO) is one of the most common treatments prescribed for conservative management of low back pain. Although the results of randomized controlled trials suggest effectiveness of LSO in reducing pain and disability in these patients, there is a concern that prolonged use of LSO may lead to trunk muscle weakness and atrophy.

PURPOSE: The present review aimed to evaluate available evidence in literature to determine whether LSO results in trunk muscle weakness or atrophy.

STUDY DESIGN: This is a systematic review.

METHODS: A systematic search of electronic databases including PubMed, Scopus, ScienceDirect, and Medline (via Ovid) followed by hand search of journals was performed. Prospective studies published in peer-reviewed journals, with full text available in English, investigating the effect of lumbar orthosis on trunk muscle activity, muscle thickness, strength or endurance, spinal force, and intra-abdominal pressure in healthy subjects or in patients with low back pain, were included. Methodological quality of selected studies was assessed by using the modified version of Downs and Black checklist. This research had no funding source, and the authors declare no conflicts of interest-associated biases.

RESULTS: Thirty-five studies fulfilled the eligibility criteria. The mean and standard deviation of the quality score was 64±9.7%. Most studies investigating the effect of lumbar orthosis on electromyographic activity (EMG) of trunk muscles demonstrated a decrease or no change in the EMG parameters. A few studies reported increased muscle activity. Lumbosacral orthosis was found to have no effect on muscle strength in some studies, whereas other studies demonstrated increased muscle strength. Only one study, which included ultrasound assessment of trunk muscle stabilizers, suggested reduced thickness of the abdominal muscles and reduced cross-sectional area of the multifidus muscles. Out of eight studies that investigated spinal compression load, the load was reduced in four studies and unchanged in three studies. One study showed that only elastic belts reduced compression force compared to leather and fabric belts and ascribed this reduction to the elastic property of the lumbar support.

FDA device/drug status: Not applicable.

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CONCLUSION: The present review showed that the changes in outcome measures associated with muscle work demands were inconsistent in their relation to the use of lumbar supports. This review did not find conclusive scientific evidence to suggest that orthosis results in trunk muscle weakness.

Keywords: Compression load; Electromyography; Intra-abdominal pressure; Lumbosacral orthoses; Muscle weakness; Systematic review

Introduction

Lumbosacral orthosis (LSO) is one of the most common modalities prescribed for conservative treatment of low back pain (LBP) and is also used prophylactically to prevent injury to the lower back [1]. There are several different types of LSO based on their material (extensible, non-extensible, or rigid) and application (medical or ergonomic aid), but in this review, the term "LSO" will encompass all types of LSO and applications.

Various hypotheses have been proposed about the mechanism of action of LSO and its possible role in reducing the symptoms of LBP [2]. Some hypotheses have been examined and confirmed in previous studies, including LSO's ability to provide motion restriction [3–6] and passively augment trunk stiffness [7–10]. It is thought that LSO reduces co-contraction of trunk muscles during routine daily activities (sitting, standing, etc.) by increasing the passive trunk stiffness in patients with LBP [11,12]. This reduction in muscle activity may prevent muscle fatigue and subsequent pain in these patients [11] (who already adopt a protective trunk stiffening strategy in an attempt to increase spinal stability [13]). However, a potential disadvantage of orthosis is that it may result in persistent adaptation in motor behavior and lead to the possibility of spine injury following the cessation of its use.

The other possible hypotheses about the mechanism of LSO, such as improved lumbosacral proprioception, are yet to be verified [14–16]. Similarly, there is no consensus regarding the ability of LSO to increase intra-abdominal pressure (IAP) or reduce intradiscal pressure [2].

Although the results of randomized controlled trials suggest effectiveness of LSO in reducing symptoms of pain and disability in patients with LBP [17,18], there is a concern that prolonged use of LSO may result in trunk muscle weakness and atrophy [19–21]. This concern is based on the understanding that LSOs provide considerable trunk extensor moment and thus reduce demand on back muscles [11].

Because orthoses are frequently prescribed, and the concern and controversy regarding their effect on muscle strength continues, the present systematic review aimed to analyze whether the use of LSO was associated with trunk muscle weakness or atrophy. Reduced electromyography activity (EMG) of trunk extensor muscles, muscle strength or endurance, muscle thickness, and cross-section are among the main outcome measures associated with reduced muscle strength and work demand. Other secondary outcome measures, such as increased IAP, reduced spinal compression loading, and spinal shrinkage, can also be indirectly associated with reduced back muscle forces [2]. Thus, this review attempted to examine studies investigating the effect of LSO on the abovementioned outcome measures.

Methods

Search strategy

Literature search was conducted in electronic databases; PubMed, Scopus, ScienceDirect, and Medline (via Ovid) were searched, corresponding to the period from January 1990 to July 2015, by using a combination of keywords associated with the inclusion and exclusion criteria of the study. Details of the search in PubMed were as follows:

("Orthotic Devices"[MeSH] OR Orthotic*[Title/Abstract] OR Orthos*[Title/Abstract] OR Brace* [Title/Abstract] OR Belt*[Title/Abstract]) AND (Torso* OR Trunk* OR Lumbosacral OR Lumbar OR Back OR Spine) AND (Muscle*[Title/Abstract] OR Muscular[Title/Abstract] OR "Muscles"[MeSH] OR (("Intra-abdominal" [Title/Abstract] OR (Intra[Title/Abstract] AND Abdominal[Title/Abstract]) OR ((Spine[Title/Abstract] OR Spinal[Title/Abstract] OR Vertebra* [Title/Abstract]) AND Compress*[Title/Abstract])) AND (Pressure*[Title/Abstract] OR Force*[Title/Abstract])) OR Biomechanic*[Title/Abstract])

To optimize the strategy for each of the other databases, appropriate changes were made in the basic search strategy. In addition, a hand search through a list of references of included studies was carried out to identify other eligible studies.

Inclusion criteria

At the completion of the search, two reviewers (FA and MK) reviewed all titles and abstracts to identify relevant studies. Studies that met the following criteria were included in the final list of studies reviewed:

1. studies published in peer-reviewed journals with full text available in English; results obtained from theses and conference proceedings were excluded
2. studies that employed a prospective design where the same group of people with and without LSO or before and after the use of LSO were evaluated
3. studies in which subjects were either healthy participants or people with LBP
4. studies that included any type of LSO as an independent variable; studies where patients used pelvic belt or thoracic support were excluded

5. studies that included EMG, IAP, spinal shrinkage, spinal force and moment, muscle thickness or cross-section, and muscle strength or endurance as dependent variables

Full text was considered when abstract did not provide sufficient data for inclusion.

Methodological quality assessment

The methodological quality of included studies was assessed by using the modified version of Downs and Black quality checklist [22]. This checklist is reported to have high internal consistency (Kuder-Richardson formula 20 reliability coefficient [KR-20]=0.89), good inter-rater reliability (r=0.75), and high test-retest reliability (r=0.88) [22]. Twelve items were excluded from the original checklist, and 15 items relevant to this review were retained. The included items assessed studies on reporting (items 1, 2, 3, 4, 6, 7, and 10), external validity (items 11 and 12), and internal validity (items 14, 15, 16, 18, 20, and 23). Item 14 was modified to "Were participants blinded to intervention outcomes?", and in studies where a group of patients (conditions with or without orthosis) was tested, item 23 was modified to "Were the order of conditions random?" However, wherever the study design included intervention and control groups, and dependent variables were assessed before and after the use of LSO; item 23 evaluated the random group allocation of participants as in the original checklist (Table 1).

Table 1
Modified version of Downs and Black quality checklist [22]

	Items
1	Is the hypothesis, aim, or objective of the study clearly described?
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section?
3	Are the characteristics of the patients included in the study clearly described?
4	Are the interventions of interest clearly described?
6	Are the main findings of the study clearly described?
7	Does the study provide estimates of the random variability in the data for main outcomes?
10	Have actual probability values been reported (eg, .035 rather than <.05) for the main outcomes except where the probability value is less than .001?
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?
14	Was an attempt made to blind study subjects to the outcome measures?
15	Was an attempt made to blind those measuring the main outcomes of the intervention?
16	If any of the results of the study were based on "data dredging," was this made clear?
18	Were the statistical tests used to assess the main outcomes appropriate?
20	Were the main outcome measures used accurate (valid and reliable)?
23	Were study subjects randomized to intervention groups? Were the order of conditions random?

Scoring guideline: 1=yes, 0=no or unable to determine.

The two reviewers (FA and MK) independently assessed the quality of all included studies and demonstrated almost perfect agreement (Cohen's kappa±asymptotic standard error was 0.89±0.02). The remaining disagreements were resolved during two consensus meetings. The final score was determined in the consensus meeting when the reviewers scored a study differently. The final quality score was reported as a percentage and categorized as high (<75%), moderate (60%–74%), or low (<60%) [23].

Data extraction and analysis

To perform descriptive analyses, data were independently extracted by the two reviewers (FA and MK) from the included studies. The extracted data included the description of study participants (sex, mean age, weight, height, and status of health), description and characteristics of the orthosis used, task and test procedures, outcome measures, and findings.

Meta-analysis was not performed, because the included studies were methodologically different (tests, tasks, procedures, and instrumentation) and lacked homogeneity in terms of the types of LSO used and their outcome measures. Therefore, this review focused only on description and qualitative synthesis of the included studies.

Results

Database search

A total of 1,320 studies were long listed through the electronic database search (Figure). After exclusion of duplicates and review of titles and abstracts, 36 studies were considered eligible for inclusion [7,8,11,12,19–21,24–52]. Two of these were excluded following assessment of full texts (one was a retrospective study [19] and the full text of the other study was unavailable in English [46]). A hand search of references provided in the included studies identified one additional article [53]. Thus, a total of 35 studies were included in this systematic review.

Risk of bias

The quality score of the included studies varied from 40% to 93% (mean±standard deviation, 64±9.7%) (Table 2). According to the classification adopted, two studies were of high quality [32,42], 25 were of moderate quality, and eight were of poor quality. The highest score was achieved in items pertaining to the reporting details, with 11 studies scoring 100% and 15 studies scoring 85.7%. Among the studies scoring 85.7%, five did not report the actual p-value [7,24,25,40,49], two did not provide any estimate of random variability [35,45], seven did not describe the features of LSO used [11,12,36,38,48,51,52], and one did not report the participant characteristics [39]. The lowest score was achieved in items pertaining to external validity. Only two studies identified the population source [42,53], and only one study clearly

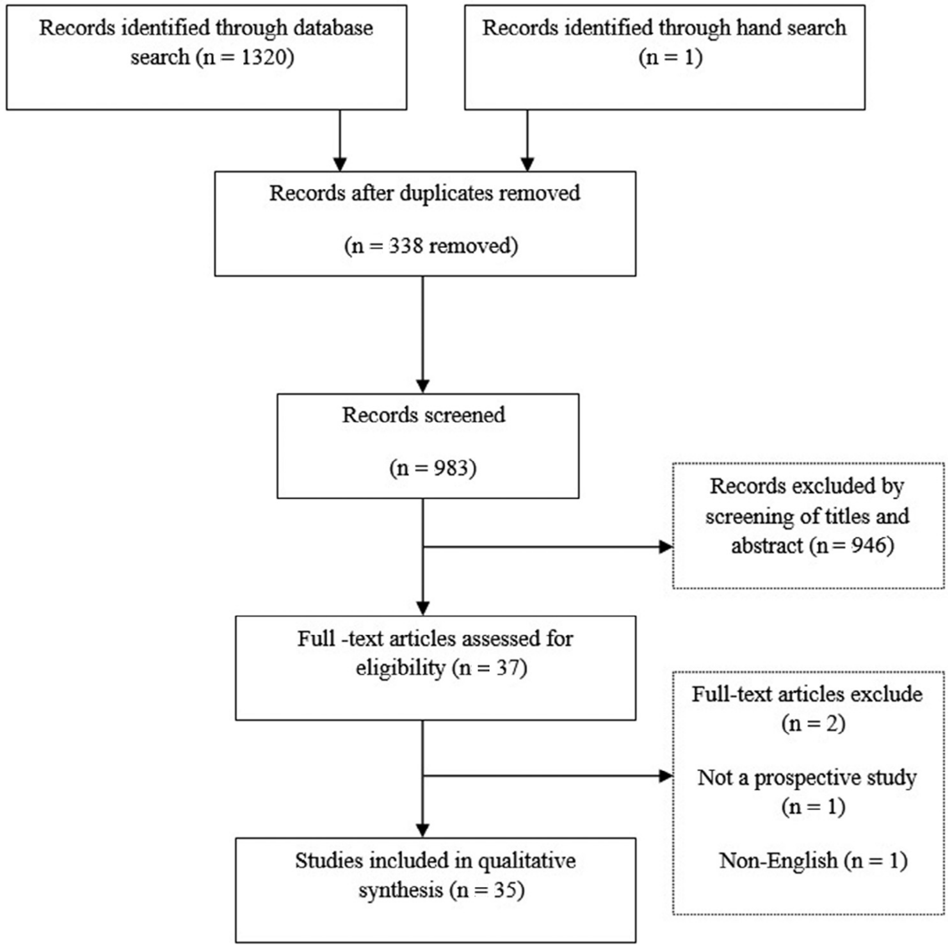

Figure. Flowchart showing search strategy and screening process.

explained that the included participants were representative of the studied population [42]. The internal validity score varied from 33% to 83%, with only one article blinding participants to the outcome measures [32] and two studies blinding the assessor [42,52]. The statistical tests performed in five studies were inappropriate [24,30,33,39,40], and parametric tests were used instead of nonparametric tests. The order of test conditions or the allocation of participants to the experimental and control groups was randomized in 22 studies.

Overview of included studies

The majority of studies included healthy people (Table 3). Both healthy people and patients reporting LBP or history of LBP were included in three studies [21,41,42]. A variety of LSO designs was investigated in the reviewed studies. Four studies used a loose LSO instead of no LSO for comparison with the intervention LSO [8,31,32,34].

Electromyography

Twenty-one studies assessed EMG of muscles while using LSO [7,8,12,25–36,38–40,47,48,51]. The most frequently evaluated muscles included erector spinae (ES), external oblique (EO), and rectus abdominis (RA). The EMG parameters assessed in the majority of the studies were integrated and normalized peak amplitudes. The median power spectrum frequency was reported only in two studies [25,38].

Seven studies reported reduced EMG activity among the trunk extensor muscles [7,12,28,33,34,36,51]. In the study by Granata et al. [26], whereas ES muscle activity was reduced by 4% when wearing an elastic belt, no change in EMG was observed in the ES or latissimus dorsi muscles when leather or fabric belts were worn. Lavender et al. [8] reported a reduction in ES activity on the right side with symmetric loading. Erector spinae activity on the left side and latissimus dorsi activity were increased in male participants. In the study by Thomas et al. [31], whereas the contralateral ES activity decreased by 3.3% on asymmetric loading, the ES activity on the left side increased by 2.9% on symmetric loading. In six of the included studies, no change was observed in the amplitude of back extensor muscle activity [30,32,35,39,40,47]. Orthoses were found to have no effect on median power spectrum frequency and muscular fatigue in the studies by Ciriello and Snook [25], and Majkowski et al. [38].

Table 2
Methodological quality rating of included studies

	Reporting								External validity			Internal validity							Overall quality
Author and year	1	2	3	4	6	7	10	%	11	12	%	14	15	16	18	20	23	%	score (%)
Bourne and Reilly, 1991 [24]	1	1	1	1	1	1	0	85.7%	0	0	0%	0	0	1	0	1	1	50%	60%
Ciriello and Snook, 1995 [25]	1	1	1	1	1	1	0	85.7%	0	0	0%	0	0	1	1	1	0	50%	60%
Granata et al., 1997 [26]	1	1	1	0	1	0	1	71%	0	0	0%	0	0	1	1	1	0	50%	53%
Escamilla et al., 2002 [27]	1	1	0	1	1	1	0	71%	0	0	0%	0	0	1	1	1	1	66.7%	60%
Kingma et al., 2006 [28]	1	1	1	1	1	1	1	100%	0	0	0%	0	0	1	1	1	0	50%	66.7%
Kurustien et al., 2014 [29]	1	1	1	1	1	1	1	100%	0	0	0%	0	0	1	1	0	1	50%	66.7%
Kawchuk et al., 2015 [21]	1	1	1	0	0	1	1	71%	0	0	0%	0	0	1	1	1	0	50%	53%
Lander et al., 1992 [30]	1	1	0	1	1	1	0	71%	0	0	0%	0	0	1	0	1	1	50%	53%
Thomas et al., 1999 [31]	1	1	1	1	1	1	1	100%	0	0	0%	0	0	1	1	1	1	66.7%	73%
Lavender et al., 1998 [32]	1	1	1	1	1	1	1	100%	0	0	0%	1	0	1	1	1	1	83%	80%
Lavender et al., 2000 [8]	1	1	1	1	1	1	1	100%	0	0	0%	0	0	1	1	1	1	66.7%	73%
Lander et al., 1990 [33]	1	1	0	1	1	1	0	71%	0	0	0%	0	0	1	0	1	1	50%	53%
Lee and Kang, 2002 [34]	1	1	1	1	1	1	1	100%	0	0	0%	0	0	1	1	1	1	66.7%	73%
Lee and Chen, 1999 [35]	1	1	1	1	1	0	1	85.7%	0	0	0%	0	0	1	1	1	0	50%	60%
Magnusson et al., 1996 [36]	1	1	1	0	1	1	1	85.7%	0	0	0%	0	0	1	1	1	1	66.7%	66.7%
Majkowski et al., 1998 [38]	1	1	1	0	1	1	1	85.7%	0	0	0%	0	0	1	1	1	0	50%	60%
Marras et al., 2000 [37]	1	1	1	1	1	1	1	100%	0	0	0%	0	0	1	1	1	0	50%	66.7%
McGill et al., 1990 [39]	1	1	0	1	1	1	1	85.7%	0	0	0%	0	0	1	0	1	0	33%	53%
Miyamoto et al., 1999 [40]	1	1	1	1	1	1	0	85.7%	0	0	0%	0	0	1	0	1	0	33%	53%
Holmström and Moritz, 1992 [41]	1	1	1	0	1	1	0	71%	0	0	0%	0	0	1	1	1	0	50%	53%
Walsh and Schwartz, 1990 [42]	1	1	1	1	1	1	1	100%	1	1	100%	0	1	1	1	1	1	83%	93%
Rabinowitz et al., 1998 [43]	1	1	1	0	1	1	0	71%	0	0	0%	0	0	1	1	1	1	66.7%	93%
Reyna et al., 1995 [44]	1	1	1	0	1	0	1	71%	0	0	0%	0	0	1	1	1	1	66.7%	60%
Shah, 1994 [53]	1	0	0	1	1	0	0	42.8%	1	0	50%	0	0	1	1	0	0	33%	40%
Sullivan and Mayhew, 1995 [45]	1	1	1	1	1	0	1	85.7%	0	0	0%	0	0	1	1	1	1	66.7%	66.7%
Zink et al., 2001 [47]	1	1	1	1	1	1	1	100%	0	0	0%	0	0	1	1	1	1	66.7%	73%
Warren et al., 2001 [48]	1	1	1	0	1	1	1	85.7%	0	0	0%	0	0	1	1	1	1	66.7%	66.7%
Woldstad and Sherman, 1998 [49]	1	1	1	1	1	1	0	85.7%	0	0	0%	0	0	1	1	1	0	50%	60%
Woodhouse et al., 1995 [50]	1	1	1	1	1	1	1	100%	0	0	0%	0	0	1	1	1	0	50%	66.7%
Fayolle-Minon and Calmels, 2008 [20]	1	1	1	1	1	1	1	100%	0	0	0%	0	0	1	1	1	1	66.7%	73%
Kawaguchi et al., 2002 [51]	1	1	1	0	1	1	1	85.7%	0	0	0%	0	0	1	1	1	1	66.7%	66.7%
Cholewicki et al., 1999 [7]	1	1	1	1	1	1	0	85.7%	0	0	0%	0	0	1	1	1	1	66.7%	66.7%
Cholewicki et al., 2007 [12]	1	1	1	0	1	1	1	85.7%	0	0	0%	0	0	1	1	1	1	66.7%	66.7%
Cholewicki et al., 2010 [11]	1	1	1	0	1	1	1	85.7%	0	0	0%	0	0	1	1	1	1	66.7%	66.7%
Rostami et al., 2014 [52]	1	1	1	0	1	1	1	85.7%	0	0	0%	0	1	1	1	1	1	83%	73%

Quality rating guidelines: 1=yes, 0=no or unable to determine; high (>75%), moderate (60%–74%), and low (<60%).

Among the studies that analyzed abdominal muscle activity, two reported reduced EO activity with the use of orthoses [33,48]. However, in the study by Warren et al. [48], reduced EO activity was observed in female participants only. Of the six male participants, five had increased EO activity, whereas one had no change in EO activity. Kawaguchi et al. [51] reported a decrease in RA activity. In the study by Escamilla et al. [27], there was a reduction in the EO activity and an increase in RA activity. Kurustien et al. [29] demonstrated a decrease in transversus abdominis-internal oblique (TrA-IO) activity in resting position (quiet stance) and an increase in RA activity during lifting movements. Lee and Kang [34] demonstrated a 4% increase in RA activity and a 3%–5% increase in EO activity. Miyamoto et al. [40] had similar results for RA activity, but failed to demonstrate any change in EO activity. Lander et al. [30], Lavender et al. [32], McGill et al. [39], and Cholewicki et al. [7,12] did not observe any change in EO or RA activities with the use of orthoses. Granata et al. [26] revealed that activity of left IO increased by 3.5% when elastic belt was used for support. However, no change was found in the activity of abdominal muscles when leather or fabric belts were used.

Intra-abdominal pressure

The effect of back support on IAP was investigated in seven studies [28,30,33,39,40,50,53]. Two studies reported no change in IAP [40,50], and five found increased IAP with the use of LSO [28,30,33,39,53]. Miyamoto et al. [40] and Woodhouse et al. [50] found no change in IAP, whereas Kingma et al. [28], Lander et al. [30,33], McGill et al. [39], and Shah [53] reported an increase in IAP with the use of lumbar orthoses. Lander et al. [30] and McGill et al. [39] found no change in activities of ES and EO muscles as a result of increased IAP; however, Kingma et al. [28] and Lander et al., in a later study [33], reported reduced ES activity with increased IAP.

Table 3
Consolidated data from all included studies

Author and year	Subject's characteristics	Description of conditions and orthosis	Task and test procedure	Outcome measures	Findings
Bourne and Reilly (1991) [24]	Eight men, healthy subjects, 24.8±2.3 y, 73.1±5.7 kg, 175.5±7.2 cm	Without belt and with leather weightlifting belt, 15.2 cm wide	Six common weight-training exercises (dead lift, high pull, squat, clean, bent-over rowing, biceps curls), three sets of ten repetitions at 10 RM, in the form of a circuit.	Spinal shrinkage, Pain intensity and discomfort	No significant effect on spinal shrinkage, Significant decrease in discomfort
Ciriello and Snook (1995) [25]	Thirteen men, healthy subjects, 33±10.5 y, 80±22.6 kg, 176.9±10 cm	Without belt and with nylon weightlifting belt, 12.7 cm wide	Lifting and lowering a load from the floor to a 76.2 cm height at the frequency of 4.3 lifts per minute for 4 hours. Fifty repetitions (5 sets of 10 repetitions) maximum isokinetic endurance at the end of the 4 hours of lifting	Maximum isokinetic endurance of the back extensor muscles, Median frequency of the EMG at the L1, L2, and L3 levels	No significant effect on maximum isokinetic endurance and EMG median frequency slope
Granata et al. (1997) [26]	Fifteen men, healthy subjects, 28.3±3.5 y, 178.9±7.4 cm, 77.8±9.1 kg	Without belt and with 3 different belts: nylon elastic belt, leather weightlifting-style belt, and fabric (orthotic) belt with a rigid posterior support	Lifting boxes of 14 kg and 23 kg from a platform at knee height and 10 cm above knee height (symmetric lifting), or at 70 cm height (asymmetric lifting) to an upright posture	Trunk motion, Spine loading, Muscle activity (EMG) of latissimus dorsi, erector spinae, rectus abdominis, external oblique, internal oblique	Elastic belt: significant decrease in spinal compression and shear force, decrease in EMG of the ES (by 4% of MVA); increase in EMG of the left IO (by 3.5% of MVC); decrease in trunk twisting, lateral flexion, and sagittal angles; increase in the pelvic flexion angle, Leather belt: no effect on spinal loads and EMG, decrease in the trunk sagittal angles and lateral flexion, Fabric belt: no effect on spinal loads and EMG, decrease in the lateral flexion
Escamilla et al. (2002) [27]	Thirteen men, (health conditions?), 20.1±1.3 y, 102.8±16.1 kg, 186.6±7.5 cm	Without belt and with leather weightlifting belt, 10 cm wide	Conventional and sumo dead lift at 12-repetition maximum (12 RM), with six knee-angle intervals (90–61°, 60–31°, 30–0°, 0°–30°, 31–60°, and 61–90°)	Normalized EMG of rectus abdominis, external oblique, L3 paraspinalis, T12 paraspinalis	Significant increase in rectus abdominis EMG, significant decrease in external oblique activity
Kingma et al. (2006) [28]	Nine men, healthy subjects, 20.8±5.3 y, 181.1±7.2 cm, 75.5±6.7 kg	Without belt and with leather belt, 15 cm wide	Lifting two different weights (37.5% and 75% of body weight) from two heights (floor and knee height)	IAP, Spinal compression forces, EMG of rectus abdominis, external oblique, internal oblique, iliocostalis thoracic, lumborum, longissimus thoracic, pars lumborum, pars thoracis	Significant decrease in the spine compression force (by 10%), Significant decrease in the EMG of iliocostalis lumborum
Kurustien et al. (2014) [29]	Eighteen subjects, (sex?), healthy subjects, 30.17±6.15 y, 170.5±6.05 cm, 62.08±8.4 kg	Without belt and with elastic belt, 20 cm posterior height, 12 cm anterior height and with 4 semirigid bars aligned on the back	Semi-squat lifting from the mid-shank to knuckle height, and quiet standing	Normalized EMG: transversus abdominis-internal oblique, rectus abdominis, external oblique, erector spinae, multifidus	During resting (quiet stance): significant decrease in the EMG of the T_rA-IO, During lifting: significant increase in the EMG of RA
Kawchuk et al. (2015) [21]	Twenty-eight men, twenty-six women; thirty seven healthy and seventeen patients with LBP, 36.1±13.5 y, 171.6±10.9 cm, 72.4±15.5 kg	Before and after 2 weeks wearing nylon inelastic brace (Quick Draw brace)	Modified Sorensen test (timed test of lumbar extension against gravity)	Lumbar muscle endurance, Spinal stiffness, Oswestry Disability Index (ODI)	Significant increase in muscle endurance, No effect on spinal stiffness, Significant decrease in ODI score
Lander et al. (1992) [30]	Five men, healthy subjects, 23.4 y	Without belt and with leather weight-belts, 10 cm wide	Eight repetition parallel squat exercise at 8 RM	IAP EMG of external oblique, erector spinae, vastus lateralis, biceps femoris	Significant increase in the IAP, No significant effect on the erector spinae and external oblique EMG values, increase in the VL and BF EMG

(*Continued*)

Table 3
(*Continued*)

Author and year	Subject's characteristics	Description of conditions and orthosis	Task and test procedure	Outcome measures	Findings
Thomas et al. (1999) [31]	Ten men and 10 women, healthy subjects, 20–33 y	With 2 different tensioning of belt: very loose or tight elastic lifting belt, 17 cm wide	Suddenly applied load via a cable attached to a thoracic harness, symmetric and asymmetric (45° to the right)	Trunk kinematic, Normalized EMG of longissimus thoracis, erector spinae, external oblique, rectus abdominis	Significant decrease in the EMG of the contralateral erector spinae during asymmetric loading (by 3.3% MVA), Increase in the EMG of left erector spinae during symmetric lifting (by 2.9% MVA), Reduced frontal plane trunk displacement by (0.5°)
Lavender et al. (1998) [32]	Twelve healthy subjects (10 men, 2 women), 29.6 y, 177 cm, 82.7 kg	With very loose or tight lifting belt (mesh/ elastic binder type belt, 10 cm wide)	Phase 1: maximal pulling exertions; four pulling postures: sagittally symmetric, symmetric/asymmetric, asymmetric two-handed, asymmetric one handed, Phase 2: Controlled submaximal pulling exertions, four pulling postures, two different footing condition (slippery or non-slippery surface)	Peak pulling forces, Peak bending moments (for spine, knee, hips), Posture (relative angles between body segments), EMG of erector spinae, latissimus dorsi, external oblique, rectus abdominis	No effect on any of the outcome measures
Lavender et al. (2000) [8]	Eighteen healthy subjects, 10 men, 8 women; 22–47 y, Men: 74.3±10.5 kg, 176±7.2 cm and women: 58.8±7.1 kg, 1.63±0.076 m	Completely slack or tensioned elastic lifting belt, 17 cm wide	Unexpected sudden loading with and without preloading of the box in subject's hand, symmetric or asymmetric	Postural changes in 12 body segments, External moments at L5–S1, knees, hips, EMG of latissimus dorsi, erector spinae, external oblique, rectus abdominis	Significant decrease in ipsilateral (right) erector spinae during symmetric loading, Increase in left erector spinae and latissimus dorsi in men, Decrease in the forward flexion moments (only in men), no effect on lateral bending or twisting moments, decrease in the forward-bending motion and lateral flexion of the spine
Lander et al. (1990) [33]	Six men healthy subjects	Without belt and with 2 different belts: light leather belt, 7 mm thick, 100 mm wide, heavy leather weight belt, 11 mm thick, 100 mm wide	Squat exercise at three load condition (70, 80. 90% 1RM) in increasing order	Spinal force, IAP, EMG of erector spinae, external oblique, lower erector spinae	Significant increase in the IAP, Decrease in the EMG of the erector spinae and external oblique, Decrease in the spinal compression force and back muscle force
Lee and Kang (2002) [34]	Eleven men, healthy subjects 22.8 y, 169±3 cm, 63.7±4.3 kg	Three different belt pressures: (0, 10, and 20 mmHg), elastic belt with four semirigid bars aligned on the back	Squat lifting two different loads (10, 20 kg) from the floor to 0.72 m height, at the frequencies of 1 or 3 lifts per minute, for 5 minutes, with inspire-hold and expire-hold	Ventilation, EMG of right rectus abdominis, external oblique, latissimus dorsi, erector spinae	Significant decrease in EMG of ES (8–11% MVC) and LD (15–21% MVC), Significant increase in EMG of RA (4% MVC) and EO (3–5% MVC), No effect on ventilation variables
Lee and Chen (1999) [35]	Eighteen men, healthy subjects, 22.4±1.4 y, 168.9±3.3 cm, 66.0±5.3 kg	Three conditions: Without belt, With stretchable lumbar belt, 22 cm posterior width, With non stretchable pelvic belt, 7 cm width	Static postures of standing, erect sitting, and slump sitting	Lumbosacral angle (LSA), Pelvic angle, EMG (L3–L4 level)	Non-significant increase in back muscle EMG, Significant increase in LSA (in standing), Lumbar belt: no effect on LSA in erect sitting, Pelvic belt: decrease in LSA in erect sitting
Magnusson et al. (1996) [36]	Twelve healthy subjects; five men; 32.6±12.1 y, 179.5±9.4 cm, 76.6±12.6 kg, seven women: 29±9.1 y, 167.6±4.5 cm, 58.7±10.3 kg	With and without back support	Lifting 10 kg weight from the floor to 72 cm height, twice per minute, for 5 min	Spinal shrinkage (height change), EMG (L3 level)	Significant decrease in the height loss and EMG
Majkowski et al. (1998) [38]	Twenty four healthy subjects (13 men, 11 women), 32±6.5 y, 172±12 cm, 69.4±13 kg	Without belt and with semi-rigid back belt	Dynamic lifting task at frequency of 10 lifts per minute for 20 minutes, static maximal isometric lift on a LIDO lift machine at 0, 10 and 20 minute	Isometric force-generating capacity, EMG median power spectral frequency (MPSF) of erector spinae (muscle fatigue)	No significant effect on MPSF (muscle fatigue) and isometric force production

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Table 3
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Author and year	Subject's characteristics	Description of conditions and orthosis	Task and test procedure	Outcome measures	Findings
Marras et al. (2000) [37]	Twenty men, Healthy subjects, 22.8±1.8 y, 179.0±8.8 cm, 75.6±13.5 kg	Without belt and with nylon elastic back support	Lifting two different weights (13.6 and 22.7 kg) from two different heights (knee and 10 cm above knee height), both symmetrically and 60° asymmetrically	Trunk kinematics (angle, velocity and acceleration), Spinal forces and moments on the L5/S1 intervertebral disc	No significant effect on spinal loading and peak sagittal moment, Increase in the peak hip angle in the sagittal plane, Decrease in trunk position and velocities in both the sagittal and transverse plane
McGill et al. (1990) [39]	Six subjects (sex and health condition ?) 25.7±1.7 y, 177±7 cm, 74.8±8.6 kg	Without belt and with leather lifting belt, 10 cm width	Lifting loads (79.7 to 90.9 kg) on lifting machine, while breath holding and continuously expiring	IAP, Hand force, EMG of rectus abdominis, external oblique, internal oblique, intercostals, erector spinae	No effect on EMG of rectus abdominis and erector spinae, Increase in IAP
Miyamoto et al. (1999) [40]	Seven men, healthy subjects, 24–36 y, 70 kg, 175 cm	Without belt and with leather weightlifting belt, 10 cm width in the back	Experiment 1: Maximum valsalva maneuver for 3 s, Experiment 2: Three types of maximum isometric lifting exertions (arm lift, leg lift and torso lift) for 5 s, using the LIDO lift system	IAP, Intra-muscular pressure in the erector spinae (IMP-ES), EMG of erector spinae, external oblique, rectus abdominis	Experiment 1: No effect on IAP, increase in IMP-ES, no effect on EMG of ES and EO, increase in EMG of RA, Experiment 2: No effect on IAP, increase in IMP-ES, no effect on EMG of ES and EO, increase in EMG of RA (during leg lift)
Holmström and Moritz (1992) [41]	Twelve healthy men: 40±8.2 y, 177.3±7.7 cm, 81.2±10.0 kg, Twenty-four men with low back pain: 36.8±12.2 y, 84.5±13.5 kg, 179.2±6.4 cm	Before and after 2-month use of soft, heat-retaining belt made of neoprene, or leather weightlifter belt	Maximum voluntary isometric contraction of trunk flexors and extensors while standing, Maximum voluntary trunk extensors in prone position (length of time to maintain trunk horizontal position), Maximum voluntary isometric endurance of trunk flexors (length of time to maintain curled-up position)	Trunk muscle strength, Trunk muscle endurance	Soft, heat retaining: No effect on trunk extensor strength or endurance, increase in trunk flexor strength (by 13%), Weightlifter belt: No effect on trunk extensor strength and endurance, significant increase in trunk flexor strength (by 12%) and trunk flexor endurance (by 16%)
Walsh and Schwartz (1990) [42]	Ninety healthy subjects and subjects with previous history of LBP, (Sex?) 29.5 y	Three groups: 1: No intervention, 2: back school, 3: back school and lumbosacral brace with a custom molded lumbar insert and an abdominal binder (6 month)	Abdominal isometric contraction of 6 s using a calibrated cable tensiometer	Abdominal strength, Work injury incidence, Productivity, Cognitive data (knowledge of body mechanics and back problem prevention)	Significant decrease in time lost in group 3, Significant increase in knowledge levels in groups 2 and 3, No effect on productivity, No effect on abdominal strength
Rabinowitz et al. (1998) [43]	Ten men, healthy subjects, 21±0.9 y, 75.1±8.7 kg, 174.7±7.9 cm	Without belt and with body sculpture abdominal belt	Stoop and squat lifting from floor to 75 cm height, 5 times per minute for 15 min	Spinal shrinkage, Heart rate, Perceived exertion, Regional body pain	No effect on spinal shrinkage, No effect on heart rate, No effect on perceived exertion, decrease in back pain during the stoop lift, but non significant
Sullivan and Mayhew (1995) [45]	Sixty healthy subjects (30 women, 30 men), Men: 29.6±7.5 y, 69.4±2.7 inches, 167.6±2 lb, Women: 25.3±5 y, 65.9±2.5 inches, 135±1.5 lb	Three conditions: Without belt, With leather weightlifter's belt, 4 inches width, With synthetic lumbosacral corset with vertical stays, 8 inches width	Isometric simulated lift (static leg lift)	Isometric muscle-force production	Significant increase in force production using the synthetic belt (in males only)
Reyna et al. (1995) [44]	Twenty-two healthy subjects (9 men, 13 women), 27.5 y, 172.47 cm, 71.01 kg	Without belt and with soft, heat-retaining neoprene belt	Lifting and lowering box from floor to knuckle level, from knuckle level to shoulder height, from floor to shoulder height, while weight progressively increased, isolated lumbar muscle strength using MedX machine at 0°, 12°, 24°, 36°, 48°, 60°, 72° lumbar flexion	Isometric lumbar muscle strength, Dynamic lifting capacity	No effect on isometric muscle strength, No effect on functional lifting capacity

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Table 3
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Author and year	Subject's characteristics	Description of conditions and orthosis	Task and test procedure	Outcome measures	Findings
Shah (1994) [53]	Ten men, (health condition?)	Without belt and with patuka (a piece of cloth, 1 m wide, 5 m long)	Twelve common physical activities: standing, forward flexion, backward flexion, left bending, right bending, left rotation, right rotation, walking on horizontal plane, standard wt (10 kg) lift, climbing stairs (without doko), climbing stairs with doko, doko lift (standing, walking on horizontal plane, lowering)	IAP, lumbosacral compression force	Significant increase in IAP during 10 activities, Significant decrease in lumbosacral compression force, during standing with doko and standard lift (10 kg)
Zink et al. (2001) [47]	Fourteen men, Healthy subjects, 28.5±3.3 y, 173.1±9.5 cm, 87.6±10.6 kg	Without belt, with leather weightlifter belt, 10 cm wide	Squat exercise at a self-selected speed with 90% RM	Angular and linear joint kinematic variables, Timing (temporal data), EMG of erector spinae, vastus lateralis, biceps femoris, adductor magnus, gluteus maximus	No effect on EMG of leg or trunk extensor muscle, No significant effect on angular and linear joint kinematics, Increase in the speed of the movement
Warren et al. (2001) [48]	Twenty healthy subjects (14 women, 6 men), 28.9±8.1 y, 180.3±12.2 cm, 91.9±19.9 kg	Without belt and with soft elastic lumbar support	Squat lifting via KIN-COM machine	EMG of abdominal oblique muscle	Significant decrease (by 11.4%) in EMG of abdominal oblique muscles (of the 6 men, in 5 of them, EMG amplitudes increased and in one man did not change, but in all the women (14 women) EMG amplitudes decreased)
Woldstad and Sherman (1998) [49]	Sixteen healthy subjects (8 men and 8 women), Men: 23±4.9 y, 181.5±4.7 cm, 81.7±17.7 kg, Women: 23±4.9 y, 164.6±7.9 cm, 59.6±10.3 kg	Without belt and with double-layered abdominal support belt	Symmetric lift or asymmetric lift 60° to the right, from floor to calf height and standing elbow height	Spinal compressive force at L3–L4, Torso posture, Static lift strength	Decrease in L3–L4 compression force, No effect on flex./ext. and lateral bending, Decrease in axial twist of the torso (by 4°), No effect on static lift strength
Woodhouse et al. (1995) [50]	Nine men, Healthy subjects, 24.7 y, 180 cm, 824 N	No support, Leather weight belt, 12.7 cm width posterior, Leather weight belt with a rigid abdominal pad, Elastic nylon abdominal binder, 22.8 cm wide posteriorly	Squat lift at 90% 1RM	Compression and shear force around L5–S1 joint, Extensor moment around the L5–S1 joint, IAP	No effect on compression force, shear force, extensor moment at the L5–S1 joint, No effect on IAP
Fayolle-Minon and Calmels (2008) [20]	Twenty nine healthy subjects (8 women, 12 men): 21.9±1.77 y, 64.9±10.1 kg, 170.2±8.8 cm	Before and after 21 days wearing soft elastic lumbar orthosis, with 4 rigid dorsal resorts	Isometric test at 30° and 60° of trunk flexion, via Cybex dynamometer with a trunk flex.-ext. module, Isokinetic test at 120°/s, 60°/s, and 180°/s of angular velocity, Endurance test of 10 consecutive flexion-extension movements at 120°/s	Endurance ratio, Maximal isometric force	No effect on trunk flexors and extensors muscle strength, Decrease in trunk extensor endurance
Kawaguchi et al. (2002) [51]	Thirty-one men, Healthy subjects, 27.2 y, 168 cm, 67.3 kg	Without orthosis and with elastic lumbar orthosis	Flexion-extension bending at 120°/s using kinetic measurement system (LIDO back isokinetic system)	Trunk muscle strength, EMG of back muscle at L3 and L5, and rectus abdominis	Significant increase in abdominal and back muscle strength, significant decrease in abdominal and back muscle EMG
Cholewicki et al. (1999) [7]	Ten healthy subjects, (Sex?), 28±4 y, 177±7 cm, 78±14 kg	Without belt and with nylon belt, 10 cm wide	Sudden quick load release, while doing exertion isometric trunk extension, flexion, and lateral bending to the left, in a semi-seated position, at the two IAP levels (0% and 80%)	Trunk stiffness (spinal stability), EMG of rectus abdominis, external and internal oblique, latissimus dorsi, thoracic and lumbar erector spinae	Significant increase in trunk stiffness in all directions (but in extension, this was not significant), no effect on EMG of muscles, with the exception of the thoracic erector spinae in extension and lumbar erector spinae in flexion

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Table 3
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Author and year	Subject's characteristics	Description of conditions and orthosis	Task and test procedure	Outcome measures	Findings
Cholewicki et al. (2007) [12]	Twenty-three healthy subjects (12 men, 11 women), Men: 27.9±9.8 y, 77±4 kg, 179±8 cm, Women: 22.1±2.1 y, 55.6±4.3 kg, 166±7 cm	With and without lumbosacral orthosis (QuikDraw LSO)	Unstable sitting task	Balance performance (average COP velocity), EMG of rectus abdominis, external oblique, thoracic erector spinae, lumbar erector spinae	Significant decrease in EMG of thoracic erector spinae (by 0.7% MVA) and lumbar erector spinae (by 2.2% MVA), No effect on balance performance
Cholewicki et al. (2010) [11]	Fourteen healthy subjects (11 men, 3 women), 26±8 y, 81±14 kg, 180±13 cm	Before and after 3 weeks wearing LSO	Quick force release, in a semi-seated position, while isometric exertions in trunk flex., ext., left lateral bending, right axial rotation, Isometric lift, Unsupported sitting task	Spine compression force, Trunk stiffness and damping, Muscle reflex response (rectus abdominis, external oblique, internal oblique, latissimus dorsi, thoracic erector spinae, lumbar erector spinae)	No effect on spine compression force, Significant increase in the number of agonist muscles switching off, Significant increase in trunk stiffness and trunk damping
Rostami et al. (2014) [52]	Sixty men, Healthy subjects, 22.9±1.47 y	Before and after 8 weeks wearing a nonrigid lumbopelvic belt	Hook-lying position, abdominal drawing-in maneuver (for lateral abdominal muscles), Prone lying, lift up ipsilateral thigh and contralateral upper extremity	Thickness of lateral abdominal muscles (TrA, IO, EO), Cross-sectional area of lumbar multifidus	Significant decrease in the thickness of lateral abdominal muscles and cross-sectional area of lumbar multifidus

BF, biceps femoris; COP, center of pressure; EMG, electromyographic activity; EO, external oblique; ES, erector spinae; IAP, intra-abdominal pressure; IMP, intramuscular pressure; IO, internal oblique; LBP, low back pain; MPSF, median power spectral frequency; MVA, maximum voluntary activation; MVC, maximum voluntary contraction; RA, rectus abdominis; RM, repetition maximum; TrA, transversus abdominis; VL, vastus lateralis.

Spinal loading and shrinkage

Eight studies investigated the effect of orthosis on spinal compression force (via a biomechanical model) [11,26,28,33,37,49,50,53]. Among them, three studies did not find any evidence of change in compression force [11,37,50], whereas four reported a reduction in compression force [28,33,49,53]. Granata et al. [26] reported a reduction of compression force with the use of an elastic belt, but did not detect any change in the compression force when a leather or fabric belt was worn. Woodhouse et al. [50] did not find any effect of orthosis on extensor moment at L5–S1. Sullivan and Mayhew [45] demonstrated an increase in isometric muscle force production, suggesting an increase in trunk extensor moment. Three studies investigated the effect of orthosis on spinal shrinkage [24,36,43], of which two found no change [24,43], and one found evidence of reduced shrinkage [36].

Muscle strength or endurance

The use of LSO did not have any effect on abdominal muscle strength in the study by Walsh and Schwartz [42], and no effect on lumbar muscle strength in the study by Reyna et al. [44]. On the contrary, Kawaguchi et al. [51] found an increase in the strength of trunk flexor and extensor muscles. Holmström and Moritz [41] studied the effect of neoprene orthoses and weightlifting belt and found that these lumbar supports had no effect on lower back extensor muscle strength or endurance. However, flexor muscle strength increased by 13% while using neoprene orthoses. They also demonstrated that the use of a weightlifting belt increased flexor strength by 12% and increased flexor endurance by 16%. In the study by Fayolle-Minon and Calmels [20], although no change was observed in the strength of flexors or extensors, the use of LSO was associated with a reduction in lower back extensor endurance. Whereas Ciriello and Snook [25] found no change in the endurance of extensor muscles, Kawchuk et al. [21] demonstrated an increase in the endurance of lumbar muscles.

Muscle thickness and cross-sectional area

Only one study included ultrasound assessment of trunk muscle stabilizers in its design. The results suggested that the thickness of IO and TrA muscles and the cross-sectional area of multifidus muscles were reduced following the use of orthoses [52].

Discussion

The present review aimed to evaluate the evidence available in literature to determine whether LSO results in trunk muscle weakness. A total of 35 studies that investigated the effect of a variety of LSOs on biomechanical measures such as EMG, IAP, spinal shrinkage, spinal loading and moment, muscle strength or endurance, and muscle thickness and cross-sectional area were identified. Because the included studies were methodologically different in terms of task and test procedures (lifting, pulling, sudden loading, standing, and sitting, among others), and lacked homogeneity in terms of the types of LSO used and their outcome measures, a meta-analysis to reach a definitive conclusion could not be performed.

Quality assessment

The majority of studies included had moderate to poor quality of methodology. Unclear explanations about the population studied and inadequate information about whether the sampled participants were representative of that population reduced the generalizability of the results. Although blinding of participants to the intervention is not possible with orthosis, blinding them to outcome measures or blinding the assessors was possible. However, most of the included studies have not applied such blinding.

Electromyography

There is a concern that prolonged wearing of LSO may lead to weakening of the trunk muscles, as it reduces the activity of the back muscles. The results of this systematic review suggest that the effect of orthoses on back and abdominal muscular activity, as recorded with EMG, is controversial. One possible reason for this inconsistency may be the different types of LSO used in the included studies. Leather weightlifting belts were used as LSO in four out of six studies that did not report any change in back muscle activity [30,39,40,47], and elastic belts were used in the remaining two [32,35]. Of the eight studies that reported reduced back muscle activity, elastic back supports were used in four [26,34,36,51], non-elastic belts in two [7,12], and leather belts in the remaining two [28,33]. Granata et al. [26] compared three different types of LSO and found that only elastic belts were associated with reduced ES activity, whereas the use of leather and fabric belts did not result in any change in muscle activity.

It must be pointed out that weightlifting belts are different from LSOs, which are prescribed for conservative management of LBP. Weightlifting belts are narrower and made of leather; thus, they do not stretch as easily as LSO does [40]. Granata et al. [26], Kawaguchi et al. [51], and Lee and Kang [34] presumed that a significant reduction in back muscular activity may be attributed to the conformity of the elastic belt to the subjects' torso. They also postulated that the extra width of LSO, compared with a weightlifting belt, covers the thorax and iliac crest, making the entire trunk act as a unit. Therefore, such a wide orthosis can reduce muscle activity by transferring the movement from the back to the pelvis [34]. However, in contrast to this hypothesis, the study findings of Cholewicki et al. [54] demonstrated that only non-elastic orthoses were effective in providing passive trunk stiffness. These authors surmised that the central nervous system is able to perceive the additional trunk stiffness provided by orthoses; hence, the central nervous system decreases active trunk stiffness by reducing muscle co-contraction to maintain stiffness at a level that does not compromise the system's performance. Therefore, Cholewicki et al. suggested that non-elastic orthoses may be more effective in reducing muscle activity.

At least part of the observed decrease in back muscular activity can be attributed to kinematic changes resulting from using LSO [34]. Lumbosacral orthosis may reduce the sagittal trunk flexion angle and alter the lifting speed. Modified kinematics, in turn, are expected to result in decreased inertial load and trunk extension moment, ultimately reducing back muscle activity [37]. Lavender et al. [32], Kingma et al. [28], Lander et al. [33], and Granata et al. [26] simultaneously measured the extension moment. In the study by Lavender et al. [32], no changes were observed in the sagittal moment among participants wearing an elastic belt. Granata et al. [26] demonstrated that weightlifting and elastic belts did not affect the moment (an approximately 3.7% increase that was not significant), but an orthotic belt significantly increased lifting moment (10%). However, this type of LSO (orthotic or fabric belt) did not affect the EMG levels of trunk muscles. Kingma et al. [28] and Lander et al. [33] found an increase in trunk extension moment using a leather weightlifting belt. Therefore, it seems that there is no correlation between sagittal moment and back muscle activity among all the studies that simultaneously investigated these variables. In addition, there is contradiction among the results of several researchers.

The tasks used to assess muscle activity among participants using orthoses varied widely in the included studies: lifting, pulling, bending, sudden loading, and sudden load release, to name a few. In studies that used lifting as the principal task, reduction in ES muscle activity was reported as a percentage of maximum voluntary activation, and varied from 0.2% [36] to 11% [34]. Although this amount of reduction in muscle activity may appear significant for postural tasks, it may not be a substantial change while performing heavier activities such as lifting, when muscle activity reaches about 50% of maximum voluntary activation [12]. Further classification of results reporting reduced back muscle activity (according to the type of task performed by participants) provided inconsistent results. Lee and Chen [35] observed increased extensor back muscle activity when lumbar support was used in static standing, upright sitting, and slump sitting postures; however, this increase was not significant. Cholewicki et al. [12] reported reduced activity of lumbar and thoracic ES muscles during an unstable sitting task. Belt tension should also be considered as one of the confounding factors for assessing the results of back muscle activity [34]. Among the studies cited, only Cholewicki et al. [11,12], Lee and Chen [35], and Lee and Kang [34] adjusted the lumbar support with identical tension for all participants.

It is known that the action of abdominal oblique muscles (and to a lesser extent, RA muscles) directly (owing to their line of action) and indirectly (owing to increased back muscle activity to counteract flexor torque created by abdominal muscles) increases the compressive force on the spine [28]. Therefore, in this review, we analyzed the effect of LSO on abdominal muscles.

Miyamoto et al. argue that the RA muscle contracts during lifting in a usual way, and shortens its length, as well as moves slightly forward. Fastening a belt around the abdomen prevents anterior protrusion of the abdominal wall. This indicates that the belt works as a resistance against the contraction of RA muscle; this muscle must therefore contract more than usual to shorten and move anteriorly in the presence of a belt [40]. This mechanism is mentioned as the possible reason for an increase in RA activity and agrees with results obtained in the studies of Escamilla et al. [27], Kurustien et al. [29], and Lee and Kang [34]. However, other studies reported a reduction or no change in the activity of abdominal muscles.

In reporting EMG parameters, researchers are required to observe the standards recommended by the International Society of Electrophysiology and Kinesiology because the quality of EMG signal may be affected by factors such as electrode material, size and shape, electrode location, inter-electrode distance, skin preparation, quality of detection equipment, filter types, sampling frequency, and EMG processing amplitude [55]. Hence, the discrepancy in this review regarding the effect of lumbar support on trunk muscle activity may also be related to the lack of adequate technical standards in studying EMG responses.

Intra-abdominal pressures

Intra-abdominal pressure is thought to cause spinal decompression force through the creation of trunk extension moment, thereby reducing back muscle activity, and thus, spinal load [56]. However, among the abdominal muscles, only TrA muscle together with diaphragmatic contraction can create IAP without simultaneously generating flexion moment [28]. As mentioned previously, abdominal oblique muscles and RA that are active during lifting and generating IAP increase spinal compression load [57]. Hence, there are decades of debate about whether the reduction in spinal compression load, resulting from increased IAP, can outweigh the increased spinal compression load caused by contraction of the abdominal muscles. Nevertheless, we have analyzed studies concerning the effect of LSO on the IAP.

Varying results were reported on the effects of LSO on IAP. Two studies found no effect, and five found increased IAP with the use of LSO. One reason for the difference in results of these studies may be the variety of lifting protocols. In the research conducted by Miyamoto et al. [40], participants performed isometric lifting tasks with maximum exertion, whereas in the studies by McGill et al. [39] and Lander et al. [30,33], isoinertial lifting was accomplished with submaximal exertion. Factors such as lifting speed, lifting posture, and joint motion are confounding factors in dynamic lifting (isoinertial lifting) that complicate direct comparisons of IAP and muscle activities between belt and no-belt conditions. These confounding factors are controlled better in the isometric lifting task [40].

Miyamoto et al. [40] and Lander et al. [30,33] measured intra-rectal pressure rather than IAP. Although the authors have cited the findings reported by Nordin et al. [58] and Rushmer [59] to justify the validity of this variable, it should be noted that in these studies, the IAP was compared with intra-rectal pressure at rest, and in a state of relaxation; hence, these findings may not be generalized to a lifting task. The difference in participants' characteristics is another factor affecting results in these studies. For example, experienced weightlifters participated in the studies by Lander et al. [30,33] and McGill et al. [39], whereas non-weightlifters participated in the study by Miyamoto et al. [40]. According to a survey among weightlifters in Japan, it seems that only people who have experience wearing the abdominal belt during lifting were able to benefit from its positive effects [40].

Spinal force and shrinkage

The effect of LSO on spinal shrinkage was also assessed, because spinal shrinkage indicates a reduction in the height of the intervertebral disc, and is, therefore, considered to be a spinal loading index [24]. Magnusson et al. [36] suggested that wearing a lumbar support resulted in a lesser loss of height of the intervertebral disc. However, changes in stature in this study may be explained by changes in participants' lumbosacral angle, because the findings of Lee and Chen [35] reveal an increase in lumbosacral angle resulting from wearing the LSO.

Regarding the effect of LSO on the estimated spinal compression force, some studies reported no change, whereas others reported a reduction in the compression force, although the clinical significance of a 10% reduction in compression force that was reported in these studies needs to be verified. Validity of the model used to estimate the spinal load is one of the reasons for disagreement about the effect of orthosis on spinal compression load. The models used in the studies by Woodhouse et al. [50] and Lander et al. [33] incorporated IAP without considering muscle activity; however, only the EMG-assisted biomechanical model can accurately estimate the spinal loading [26]. Woldstad and Sherman [49] used postural changes and hand force as inputs for the model and did not measure the IAP or the EMG. Shah [53] has no explanation of the model used to estimate the spinal load.

Granata et al. [26] reported a reduction in spinal compression force following the use of elastic belts, although there were wide variations in the results of their study (an increase of 400 N was observed in some cases). Marras et al. [37] also used elastic belts as back supports, but in contrast to Granata et al. [26], they found no change in the compression force and attributed the difference between the two studies to the nature of the tasks performed for testing. Whereas Marras et al. [37] allowed movement during lifting, Granata et al. [26] ensured that the participants' feet were fixed. Although in the study by Granata et al. [26] a leather weightlifter's belt had no effect on spinal compression load, a decrease in the compression load was found by Kingma et al. [28] and Lander et al. [33]. Various lifting conditions including lifting height and dumbbell weight may be a possible explanation for differences in these findings [28].

Muscle strength

Upon analyzing the effect of LSO on the strength of the back and abdominal muscles, some authors of the studies reported no change, whereas others reported an increase in the strength of flexor or extensor muscles. Studies reported either reduction, increase, or no change in muscle endurance following the use of LSO. A possible reason for the observed variation may be related to the duration of LSO use. Some studies, such as the study by Kawaguchi et al. [51] that assessed the effect of LSO immediately after initiating its use, reported increased strength of trunk flexors and extensors. This could occur owing to the motor control system taking advantage of the increased passive trunk stiffness provided by the LSO.

No change was observed in the strength of trunk flexor and extensor muscles in spite of 21 days of wearing lumbar orthosis in the study by Fayolle-Minon and Calmels [20], and after 6 months of wearing the lumbar support in the studies by Walsh and Schwartz [42]. Holmström and Moritz [41] used soft, heat-retaining belts for 2 months (by healthy people) and weightlifter's belt for subjects with LBP, and found no change in extensor muscle strength. However, flexor muscle strength increased in this study. One factor that may cause discrepancies among these studies is the different methods of assessing muscle strength and endurance. Isometric strength or endurance testing was used in some studies [41,42,44], and its reliability is much lower than that of the isokinetic strength and endurance testing methods [20].

Reduced thickness and cross-sectional area of trunk muscles was reported in the study by Rostami et al. [52]. However, it is difficult to explain these results, because muscle atrophy occurs only when the joint is fully immobilized [60]. Lumbosacral orthosis, on the other hand, does not fully immobilize the lumbar spine, but instead only restricts gross movements [2].

Limitations

Only the studies published in peer-review journals were included in this review and, as in other reviews, a publication bias may have occurred. Additionally, a language bias is possible as only those studies that were available as full text in English were included.

The modified Black and Downs checklist was considered to be the most relevant for quality assessment of included studies, because many of them were laboratory based. A number of items were excluded from the checklist owing to their irrelevance to the design of the included studies, and this may have affected the overall validity of the checklist. Meta-analysis could not be performed because of the wide variations in the methodology of the included studies and the heterogeneity of their outcome measures.

Conclusion

The present review did not find evidence suggesting a consistent association between the use of various lumbar supports and the outcome measures considered representative of diminished muscle structure and function. Thus, this review did not find conclusive scientific evidence to suggest that orthoses result in trunk muscle weakness. Future randomized clinical trials with high-quality methodology and long-term follow-up are warranted to determine the effect of orthopedic or therapeutic type of LSO on the most relevant outcome measures with regard to muscle work demand (eg, EMG of trunk extensor muscles, muscle strength or endurance, and muscle thickness or cross-sectional area). Also, it seems worthwhile to monitor changes in trunk muscle activity and contractile capability during routine daily activities. Moreover, as the current empirical evidence demonstrated that non-extensible LSO leads to superior outcomes in terms of pain and disability and provides more trunk stiffness in comparison with extensible LSO, it seems that further studies are needed to elucidate which LSO design affects muscle function to a greater extent.

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