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TESI DI LAUREA

PHYSIOTHERAPY MANAGEMENT OF LBP IN CHILDREN

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Abstract

Aim of the study

Low back pain is a rising concern among the younger population; the older they get, the higher children show an incidence rate of low back pain similar to adults. Despite this, there is a lack of studies targeted on this population, and treatment is based off on what is known to work on adults. This review aims to discern what are the most common form or treatment among these children, and to offer an overview of their principles and application.

Materials and methods

The search was performed from June 2024 to August 2024, on PubMed, PEDro, EBSCO and Google schoLAR. Selected studies were reviews, systematic reviews, RCT and guidelines focusing on children ages six to twelve years old in English or Italian.

Results

A total of 32 studies of varying quality was selected to be analysed.

Discussion

The most employed treatment modalities are exercise, education and bracing. Of the three, exercise has the highest level of consensus, although what (or if) kind of treatment is the most successful and its dosage are not clear. Exercises for non-specific low back pain recurring along the pool of studies were: stabilization exercises (the most common, based on the principles of spinal stability), McKenzie exercises, Back school and William exercises; exercises common employed for Specific low back pain are SSE (Scoliosis Specific Exercises) and Schroth exercises.

Regarding education, it is not clear wether it works as a form of treatment or as a form of prevention; nonetheless, considering the rinsing concerns for the prevalence and the age at which low back pain appears, researchers are of the idea that an educational program should be included in young children' education, as to lower the chances of new onsets later on.

Finally, bracing seems to be effective on the treatment of mild-to-moderate scoliotic curves (and results improve even more if bracing is paired with exercises or physical activities), but neither the ideal dosage and the more efficient type of brace are clear.

Conclusion

There is a need for more studies with better methodological design focusing on this population.

INTRODUCTION

Low back pain (LBP) describes pain between the lower edge of the 12th rib and the gluteal fold [1, 2, 3].

It can last for a short time (acute), a little longer (sub-acute) or a long time (chronic) [2, 3, 4].

As the leading cause of years lived with disability since 1990, low back pain represents a global health problem [2, 3, 5], and, with an estimated 619 million people affected by LBP worldwide, it is the leading cause of disability worldwide [2, 3].

According to the literature, the lifetime prevalence of LBP in children and adolescents varies from 9% to 69% [6, 7]; even in children and adolescents, pain in the back is a serious health concern [1, 7, 8, 9] with a monthly prevalence of about 20%, increasing with age up to 18 years (and then reaching the same incidence seen in adults [5, 11, 12, 13]) [5, 11, 12, 13, 14, 15, 16], to a lifetime prevalence of approximately 40% depending on the source population and definition of pain [2, 5, 6, 8, 17, 18].

Similarly, back pain occurs in 10–25% of athletes and is more common in football players and gymnasts [1, 2, 10].

It should be noted, however, that these figures and percentages might not coincide with the real data [2. 8, 4, 6]: the majority of studies look at low back pain (LBP), often without defining the term [2, 4]. LBP may be variously defined as low back pain with no apparent clinical cause, non-specific pain or non-organic pain [2].

It is also used as a general descriptive term for any type of back pain [2, 4, 6, 8]. The term mechanical back pain is also confusing as this may refer to pain without a pathological underlying cause, but conversely is also used to describe conditions arising from overuse or trauma such as muscle strain, intervertebral disc prolapse or even spondylolysis [2, 6, 8].

Its prevalence among adolescents has increased over the last two decades [2, 5, 7, 8, 11, 12, 13, 14], and an estimated 10% to 15% of affected children will develop chronic low back pain later in life [6, 7, 8, 14, 16, 18].

Because of that, many authors think it would be worthwhile to start prevention in at an early age, so to lower associated activity limitations, medical costs, work loss, and the incidence of back pain in adulthood [5, 6, 7, 8, 12, 18].

Therefore, proper management at an early stage is essential to improve lifetime trajectories of spinal pain [7, 9, 18]. Management of children's musculoskeletal disorders relies to a large extent on parents' values, preferences and experience [15, 18].
Pain in this age group appears to demonstrate a shift between regions of the spine over time, indicating that there is not independence between pain in the three regions [18].

Up to 94% of children and adolescents with LBP often have a disability [6, 18], the most common one being difficulty in carrying their school bags. Although about 33.6%-56% of adolescents with LBP have limitations for some activities [6, 7], 9 out of every 10 adolescents reporting LBP can be considered healthy, while in a 10% of them LBP can be considered as a symptom of a multidimensional health problem [6, 7]; between 12% and 20% of affected children and adolescents visit a health care professional for their back pain [4, 5, 8, 10] and approximately 30% take pain medication [5].
The burden on the health care system and society is further increased as back pain in adolescence is a risk factor for adult low back pain [3, 5, 7, 9, 11, 14], which is responsible for a considerable amount of work absenteeism in adults [3, 5, 7, 9] and limit participation in sports, activities, and school in children or adolescents [7, 8, 9].
The individual burden in childhood and adolescence includes restrictions in school and leisure activities and poor well-being [3, 5, 7, 9]. Effective evidence-based treatment and prevention is urgently needed for this global health problem [5].
Mostly, in adolescence, there is no specific underlying condition causing the complaint, i.e., the back pain is non-specific (up to 90% of cases) [3, 5]. There are several diagnostic measures (e.g., X-ray, magnetic resonance imaging) and risk factors (e.g., age, sex, with females being more affected [2], psychosocial factors) that help isolate a specific cause of the back pain or assess whether the back pain is non-specific [5]. In the case of non-specific back pain, there are a variety of treatment options, such as massages, manual therapy, acupuncture or medication [5].

While evidence-based guidelines exist for adults [5, 6, 7, 9, 11, 12, 13, 19, 20], focusing on exercise, back school and manual therapy [6], to date, there is not as much research for the treatment of non-specific back pain for children and adolescents [5, 6, 7, 9, 11, 12, 13, 18, 19, 20]. Such studies would be beneficial for health professionals, parents and affected youth to select the best available treatment [5, 6, 9, 12].

Risk factors

Common contributors to low back pain encompass various factors such as older age [6, 7, 8, 9], female sex [6, 7, 8, 9], posture [6, 8], lifestyle factors [4, 6, 7, 18], school-related factors [4, 6], physical factors [4, 6, 10, 18], psychosocial factors [4, 6, 7, 18], underlying health conditions, sleep problems [8], improper lifting techniques, inadequate ergonomics [6], excessive weight and manner of carrying backpacks [15, 17], excessive exercise or physical activity [1, 15, 16, 21], the nature of school furniture [6, 8], overall lifestyle [7] and psychological factors [6, 10], and a history of prior back pain experiences [8, 17].

There is no consensus on the weight of the backpack [8, 17].

Additionally, an observed correlation exists between poor posture (like spending more than two hours per day studying or watching television [8]) and the occurrence of low back pain in children [17].

Diverse approaches, both pharmacological and non-pharmacological, have been employed to mitigate back pain [17]. Non-pharmacological strategies encompass a range of interventions including back care education, exercises, yoga, and acupuncture [17]. While back care education is promoted as a method for managing back pain, ongoing discussions persist about its effectiveness [17].

Red flags

The initial clinical history taking should aim at identifying ‘red flags’ of possible serious spinal pathology [55]. **“**Red flags” are risk factors detected in low back pain patients’ past medical history and symptomatology and are associated with a higher risk of serious disorders causing low back pain compared to patients without these characteristics [55].

If any of these are present, further investigation (according to the suspected underlying pathology) may be required to exclude a serious underlying condition, e.g. infection, inflammatory rheumatic disease or cancer [55].

“Red flags” are signs in addition to low back pain [55].

These include [55]:

- Age of onset less than 20 years or more than 55 years
- Recent history of violent trauma

- Constant progressive, non mechanical pain (no relief with bed rest)
- Thoracic pain
- Past medical history of malignant tumour
- Prolonged use of corticosteroids
- Drug abuse, immunosuppression, HIV
- Systemically unwell
- Unexplained weight loss
- Widespread neurological symptoms (including cauda equina syndrome)
- Structural deformity
- Fever
- Cauda equina syndrome is likely to be present when patients describe bladder dysfunction (usually urinary retention, occasionally overflow incontinence), sphincter disturbance, saddle anaesthesia, global or progressive weakness in the lower limbs, or gait disturbance. This requires urgent referral.

Yellow flags

Psychosocial "Yellow flags" are factors that increase the risk of developing, or perpetuating chronic pain and long-term disability (including) work-loss associated with low back pain [55]. Identification of "Yellow flags" should lead to appropriate cognitive and behavioural management [55].

Examples of ‘yellow flags’ are [16, 55]:

1.Inappropriate attitudes and beliefs about back pain (for example, belief that back pain is harmful or potentially severely disabling or high expectation of passive treatments rather than a belief that active participation will help)

2. Inappropriate pain behaviour (for example, fear-avoidance behaviour and reduced activity levels)

4.Emotional problems (such as depression, anxiety, stress, tendency to low mood and withdrawal from social interaction)

Common Causes

Lumbar muscle strain or spasm

Although published incidence studies are limited, many cases of low back pain in children who present to a primary care setting are attributed to a lumbar muscle strain or spasm [4, 8]. Muscle spasm may be related to growth, resulting in tight hamstrings and quadriceps that cause a posterior pelvic tilt [4, 8].

An association between heavy backpacks and back pain is controversial [8]. In any case, the American Academy of Paediatrics recommends that backpacks not exceed 10% to 20% of the child’s weight [5, 8, 9].

Spondylolysis and spondylolisthesis

Spondylolisthesis occurs when there is a bilateral pars injury with translation of one vertebral body over another [8, 10].

Two types of spondylolisthesis may occur in children: Type I and Type II [10]:

- Type I is also described as dysplastic or congenital: there is a congenital absence of the L5–S1 facet joints with the consequent forward slipping of L5 over S1
- Type II is caused by an isthmic insufficiency and it includes congenital elongation of the pars interarticularis, which is intact, and spondylolysis which can be multi-factorial or the consequence of a pure stress fracture. In most cases, 90% of the slippage has already occurred at the time of diagnosis

Spondylolysis is a stress injury to the pars interarticularis [4, 8, 10].

The amount of the slippage may be calculated as a percentage of the forward slippage of one vertebra over another [4, 8, 10]. Another index of spondylolisthesis severity is the amount of lumbosacral kyphosis measured by the angle formed between the line parallel to the inferior end-plate of L5 and the longitudinal axis of the sacrum on a standing lateral view [4, 8, 10].

Spondylolysis affects up to 6% of all children, but the incidence among athletes is unclear [8]. The primary sites include L5 (71% to 95%) and L4 (5% to 23%), but it can occur at any level [8, 10].

Although spondylolysis is common among athletes whose sports require repetitive lumbar extension (e.g., gymnasts, football linemen, divers, baseball players, weight lifting, diving, soccer and ballet), it can occur in any athlete [1, 2, 4, 8].

Pain tends to be focal, may be associated with tenderness to palpation of the spinous process, and worsens with extension [8]. A positive stork test is concerning for spondylolysis; other associated findings include tight quadriceps and hamstrings [2, 4, 8].

Scheuermann's kyphosis

Scheuermann kyphosis is osteochondrosis that presents as an abnormality of the vertebral epiphyseal growth plates [4, 8, 10].

Criteria include three or more adjacent vertebrae wedged more than 5 degrees and disk space that narrows in the thoracic region [4, 8].

Because there is no diagnostic standard for Scheuermann kyphosis, prevalence rates vary widely [4, 8]. It can be noted in children as young as eight to 12 years with a postural deformity that does not resolve with extension or by lying down [8].

Symptoms include gradual onset of pain without trauma over the deformity [8, 10]. Pain can worsen at the end of the day and is relieved with rest [8]. In this case, the thoracic kyphosis is increased and the lumbar lordosis is reduced [8, 10]. Hamstring tightness is often present [8, 10]. It is most common in male patients who do heavy labour or are engaged in high-level sport activities [8, 10].

Postural disorders

Children going through development can adopt a posture with an exaggerated lumbar lordosis, a prominent abdomen and a compensatory thoracic hyperkyphosis [10], thus developing low back pain [10].

Pre-disposing factors are [10]: ligament laxity, fascial and musculotendinous tightness and muscle weakness. Common causes are [10]: prolonged television watching, improper school furniture and lack of posture awareness or education. As hamstrings grow slower than bones, but faster than the

trunk, they become tight, causing discomfort and altered posture [10]. This often causes a posterior pelvic tilt with flattening of lumbar lordosis and thoracic hyperkyphosis [10].

Back pain radiating to the buttocks and posterior knee pain are the most frequent complaints [10]. Forward flexion of the lumbar spine is limited, as is straight leg raising [10].

Scoliosis

Scoliosis is a broad term that includes a variety of conditions that involve changes in the shape and position of the spine, thorax and trunk [5]. Adolescent idiopathic scoliosis is a lateral curvature of the spine of more than 10 degrees, for which a cause cannot be found [5].

It occurs in 2% to 3% of adolescents [5, 8]. Back pain associated with this condition is linked to increasing age, injuries, and severity of curvature [2, 4, 6, 8]. Another underlying condition is present in 10% to 35% of children with scoliosis and back pain, such as spondylolysis, spondylolisthesis, Scheuermann kyphosis, or disk herniation [8]; therefore, a careful history and physical examination with appropriate imaging should be performed to evaluate for these and other etiologies [8].

Regarding the evaluation and treatment of patients with isolated adolescent idiopathic scoliosis [8], referral to a scoliosis center is indicated if symptoms do not respond to a conservative exercise program [8].

Lumbar disk herniation

Although disk abnormalities on MRI can be common, symptomatic lumbar disk herniations with nerve root impingement are rare [8].

Back pain with or without sciatica is usually the presenting symptom, and the most common vertebrae involved are L4-L5 or L5-S1 [10].

Both MRI and CT scan can be used to diagnose it [10]. Most adolescents with disk herniation (60%) report that an acute event precipitated the pain [8, 10].

Although the straight leg raise and slump tests were developed for adults, these tests have been positively correlated with disk herniation in paediatric populations [4, 8]. The slump test is more sensitive than the straight leg raise test in patients with lumbar disk herniation (84% vs. 52%, respectively) [4, 8].

2. MATERIALS AND METHODS

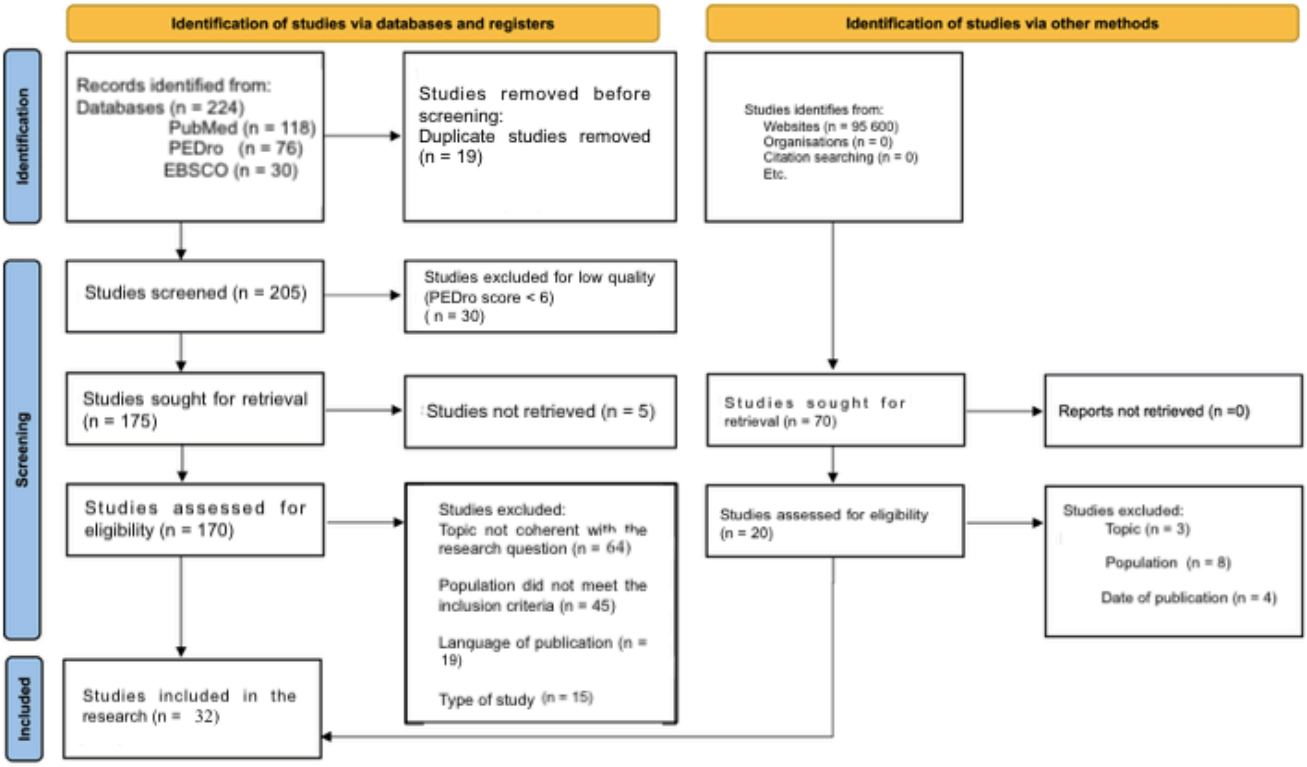

Figure 1. Flow chart of the selection process

Eligibility criteria

Inclusion criteria were: I) Children aged 6 to 13 years old; II) Participants had been diagnosed with acute non-specific or specific low back pain; III) Studies had to have a group design (single case studies were ruled out); IV) When a study involved more than one kind of pathology, low back pain patients had to be represented with a high enough number of participants, in order for the results to be significative; V) The study had to investigate rehabilitation interventions, with no limitations between passive or active modalities; VI) The methods employed had to be non-surgical; VII) Language had to be either English or Italian; VIII) Studies had to have been published from 2000 onward; IX) Studies had to be either guidelines, RCTs, meta-analysis, reviews or systematic reviews; X) RCTs had to have a PEDro score of at least six points (the cutoff for moderate quality).

Search strategy

The search aimed to find the most common methods employed to treat low back pain in children; the search engines were: PubMed, PEDro, EBSCO and Google scholar.

The string of research was modified accordingly to best suite each website.

On PubMed it was:

“Low back pain[Mesh]” AND “Treatment[Mesh]”

Then, the filters added were “Child: 6 to 12 years” and “Article type: Guideline, Practice Guideline, Review, Systematic Review, Meta-analysis”

On PEDro it was:

“Problem: pain” AND “Body Part: lumbar spine, sacro-iliac joint or pelvis” AND Subdiscipline: “Paediatrics”

On EBSCO it was:

“Database: eBook collection (EBSCOhost), SPORTDiscus with Full Text, CINAHL Ultimate, Global health” AND [TI Title]“Low back pain or Lumbar Pain or Lumbar Spine Pain or Non Specific Low Back Pain” AND [TI Title]“Management or Treatment or Intervention Therapy” AND [TI Title]“Children or Adolescents or Youth or Child or Teenager”

On Google Scholar it was:

“Low back pain” AND (“Management” OR “Treatment”) AND “Children”

Quality of evidence

As for the quality of evidence, I decided to use a different tool for each type of study [27]: the GRADE checklist for systematic reviews [22, 23], the SANRA checklist for narrative reviews [24] and the AGREE II checklist for guidelines [25].

The results are shown in tables 1, 2, 3, 4.

The major limitations in this phase were that I was alone, therefore I did not have anyone to counter-grade my assessment or anyone I could settle any dispute with, and the different evaluation tool made it difficult to compare the quality of the various studies.

3. RESULTS

The process of study selection is illustrated in figure 1. The search yielded a total of 142 results, in particular: 37 articles on PubMed, 75 on PEDro, 30 on EBSCO.

I decided to not include the data from Google Scholar as they were 95,600 results and part of the so-called "Grey Literature" (that part of literature that is not affiliated to any kind of international database or repositories commonly used by researchers, scholars, and institutions to search for and access academic and scientific literature; therefore, its quality may be lacking).
As a result, I decided to check the findings on Google scholar as a last resource, to be sure to not have overlooked anything.

Not considering duplicates (n=16), the total number of studies was 126. Of these, 32 were eligible for my research. The reasons because of which a study could not be included in the research were: I) A topic not coherent with the initial clinical question; II) A population that did not met the inclusion criteria; III) The language of publication; IV) The date of publication; V) The type of study. VI) the population diagnosed with low back pain (among other pathologies) was not big enough to influence the results; VII) A PEDro score lower than six.
Treatment modalities are synthesised in Table 4.

	Justification of importance for readership	Statement of aim or formulation of questions	Description of literature search	Referencing	Scientific reasoning	Appropriate presentation of data	Total score	Overall quality of evidence
Achar	0	1	0	1	2	0	4	Low
Alysha	2	2	0	2	1	0	7	Medium
Davis	1	2	0	1	2	0	6	Medium
Geldhof	1	2	1	0	2	1	7	Medium
Habybabady	2	2	1	2	1	0	8	Medium
Harringe	2	2	0	2	1	0	7	Medium
Ippolito	1	2	0	1	1	0	5	Low
Kosseim	1	2	2	1	1	1	8	Medium
Mac Donald	2	2	0	2	2	0	8	Medium
Maher	0	1	2	2	1	2	8	Medium
Ridderbusch	2	2	0	2	2	0	8	Medium

Table 1. Score according to the SANRA checklist for narrative reviews

	Eligibility criteria	Random allocation	Concealed allocation	Baseline comparability	Blind subjects	Blind therapists	Blind assessors	Adequate follow-up	Intention-to-treat analysis	Between-group comparisons	Point estimates and variability	Total score
Cardon	No	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6/10
Dissing	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7/10
Dufvenberg	No	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	7/10
Fanucchi	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6/10
Wang	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8/10

Table 2. Score according to the PEDro score for RCTs

	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Reasons to upgrade evidence	Total score	Overall quality of evidence
Anyachukwu	0	-2	0	-1	-1	0	-4	Low
Calvo-Munoz	0	0	-1	-1	-1	Effect size +1	-2	Medium
Fan	-1	-2	0	-2	-1	Effect size +1	-5	Low
García-Moreno	0	-2	0	0	0	Effect size +1	-2	Medium
Gámiz-Bermúdez	-1	-1	0	-2	-2	Effect size +1	-5	Low
Kamper	0	-2	0	-2	-1	Effect size +1	-4	Low
Kepeng	0	-2	0	-2	-1	0	-5	Low
Kovacs	0	-1	0	-2	-2	0	-5	Low
Michaleff	-1	-1	0	0	0	0	-2	Medium
Steele	-1	-1	0	-1	0	0	-3	Medium
Tsirikos	-2	-1	0	-2	-2	Low levels of dropouts: +1	-6	Low
Vidal	-1	-1	0	-1	-1	Low levels of dropouts: +1	-3	Medium
Yu	-2	-2	0	0	-1	Effect size +1	-4	Low

Table 3. Score according to the GRADE checklist for systematic reviews

	Scope and purpose	Stakeholder involvement	Rigour of development	Clarity of presentation	Applicability	Editorial independence	Overall quality of evidence
Del Prete	75%	42%	57%	72%	3%	73%	High
Frosh	78%	33%	58%	78%	0%	75%	High
Negrini	78%	66%	63%	67%	4%	75%	High

Table 4. Score according to the AGREE II checklist for guidelines

Study characteristics

The included studies were published between 2006 and 2024. Thirteen studies were systematic reviews [6, 7, 12, 13, 16, 17, 20, 26, 28, 29, 30, 31, 32], eleven were narrative reviews [1, 2, 4, 8, 10, 14, 15, 19, 33, 34, 35] five were RCTs [9, 11, 18, 36, 37] and three were clinical guidelines [5, 38, 39].

Five studies were carried out in Spain [6, 12, 16, 28, 32], three in China [26, 29, 37], three in Italy [10, 38, 39], three in Germany [5, 20, 35], three in Australia [7, 30, 34], three in the U.S.A [2, 8, 19], two in Canada [13, 33], two in the UK [4, 31], two in Sweden [1, 36], two in Africa [9, 17], two in Belgium [11, 14], one in Denmark [18] and one in Iran [15].

The majority of the studies were held in schools [9, 11, 14, 15, 16, 17, 18, 32], hospital settings [36, 37], gym centres [1] or it was not specified [2, 4, 5, 6, 7, 8, 10, 12, 13, 19, 20, 26, 28, 29, 30, 31, 33, 34, 35, 38, 39].

The researchers who held the study were professors [1, 2, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 26, 28, 29, 30, 32, 33, 34, 35, 36, 37, 38, 39], physiotherapists [5, 12, 15, 38, 39] or it was not specified [11, 31].

The sample size varied from 45 [20] to 4423 [7], with an age range from 8.7 [12] to 13.0 [20] years old.

Five studies [6, 10, 13, 18, 34] assessed the effectiveness of spinal manipulation as a treatment for low back pain in children, 22 [1, 2, 4, 5, 6, 7, 8, 9, 10 , 12, 13, 18, 19, 20, 26, 28, 29, 31, 33, 34, 35, 36] focused on various modalities of exercise, three [10, 13, 20] focused on passive modalities (like

	Spinal manipulation	Exercise	Passive modalities	Physical activity	Education	Bracing	Rest
Achar		X					X
Alysha		X		X	X	X	X
Anyachukwu					X		
Calvo-Munoz	X	X			X		
Cardon					X		
Davis		X			X	X	
Dissing	X	X			X		
Dufvenberg		X		X		X	
Fan		X					
Fanucchi		X			X		
Frosch		X		X			
Gámiz-Bermúdez		X					
García-Moreno		X		X	X		
Geldhof					X		
Habybabaday					X		
Harringe		X					
Ippolito	X	X	X			X	X
Kamper		X			X		
Kepeng		X					
Kosseim		X					
Kovacs					X		
Mac Donald		X			X	X	X
Maher	X	X		X	X		
Michaleff		X	X	X			
Negrini		X				X	
Ridderbusch		X				X	
Steele					X		
Tsirikos		X				X	X
Vidal					X		
Yu	X	X	X		X	X	

Table 4. Synthesis of treatment modalities

diathermy, laser therapy and TENS [10]), nine [2, 4, 6, 7, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 30, 32, 34] focused on education, eight [2, 4, 10, 13, 19, 31, 35, 36, 39] focused on bracing and five [2, 8, 10, 19, 31] on rest.
Results are synthesised in Table 4.

Excluding narrative reviews (where outcomes were not talked about) [8, 2, 4, 14, 15, 1, 10, 33, 19, 34, 35], differences were present in the outcomes according to the focus of the study (exercise, education, bracing etc.); the most common were: pain levels [TUTTI], back care behaviour [11, 12, 13, 14, 15, 16, 17, 20, 30, 32], back care knowledge [11, 12, 20, 30], quality of life [6, 11, 12, 13, 14, 17, 20, 26, 28,36, 37], disability [6, 7, 12, 13, 20], spinal deformity [26, 28, 36, 37].

Risk of Bias

The studies were of moderate [1, 2, 4, 6, 9, 11, 12, 14, 15, 18, 19, 20, 30, 33, 34, 35, 36, 37] or low quality [7, 8, 10, 13, 16, 17, 26, 28, 29, 31]; three studies were of high quality [5, 38, 39]. The reasons for such scores are: a medium or low risk of bias (e.g. the researchers did not randomise the participants; the assessors, researchers and patients were not blinded) and inconsistency in the results (data not reported; low p value, substantial heterogeneity, large or in any case substantial I^2 value).

4. DISCUSSION

As a result, the treatment modalities I expanded upon were: exercise, education, braces and spinal manipulation.

Exercise

NS-LBP

The term “Exercise” includes approaches that follow exercise physiology principles, traditional mind-body exercises (eg, Tai Chi, yoga [34]), styles that emphasise precise control of movement and bodily awareness (eg, pilates, motor control exercise, Alexander technique [34]), and approaches that incorporate psychological principles (eg, graded exposure, graded activity [34]) [34].

It seems to be a viable method to employ to treat non-specific low back pain in children [1, 4, 5, 6, 7, 8, 9, 10, 12, 13, 19, 20, 34] and to lower its prevalence up to the three following months [9, 13]. The level of evidence quality is moderate [1, 4, 6, 9, 12, 13, 19, 20, 34].

The same buoyancy can be observed when pairing exercise with other treatment modalities, like manual therapy [6, 13], or if the training regimen can be progressive [10, 12].

On this note, Cardon et al. (in five out of the nine studies they analysed) found no significative improvement when pairing exercise and education [11]; they reckoned that children who were enrolled in both programs had less time and efforts to spend on the integration and repetition of the back care principles [11]. The level of evidence quality is moderate, due to the great heterogeneity and presence of risk of bias (lack of concealed allocation, blinding of both subjects and assessors, lack of intention-to-treat analysis) [11].

Regarding compliance, children have been shown to enjoy class exercise, not only because it helps diminish the pain, but also because they enjoyed the physical activity, felt that the exercises helped to make them feel better and to make their backs stronger [9, 20].

These motivations may be linked to the fact that exercise during childhood and adolescence may modify the sensory perception of peripheral pain at the level of the central nervous system, which will result in fewer pain syndromes in adolescence and adulthood [9, 20]; it is important, also in light of the fact that the age range from 6 to 12 years old is a difficult time for children, as they go through hormonal, physical, and emotional changes [9].

Conversely, exercise does not seem to improve other psychological aspects, like the sense of well-being [9], and is thought to be a risk factor for the onset of low back pain if practiced in excessive

	Outcomes	Outcome measures
Achar	X	X
Alysha	X	X
Anyachukwu	Pain intensity **Knowledge** **Back care behavior** Back pain prevalence Postural habits Back pack carriage Physical activity Fear-avoidance Beliefs Use of locker or alternate means Minimum weight of back packs Skills Self-efficacy	Visual analogue scale (VAS) Questionnaires 5point scale, questionnaires, observation Questionnaires Back pain and body posture evaluation instrument Questionnaires Accelerometer Questionnaires 6point scale Questionnaires Questionnaires Checklist 4point scale
Calvo-Munoz	Pain, disability, flexibility, endurance, mental health	Self-reports, and clinician assessments
Cardon	**Back care behaviour**; back care knowledge Fear-avoidance beliefs and 1-week prevalence of back pain P.A. levels	Observation Questionnaire Accelerometer
Davis	X	X
Dissing	**Number of LBP recurrences** Average duration of spinal pain Total duration of complaint time Changes in pain intensity after two weeks	Questions through SMS; VAS
Dufvonberg	Adherence, motivation, and capability Physical activity levels Angle of Trunk Rotation Health-Related Quality of Life	Self report IPAQ-SF Cobb angle SRS-22r, EQ-5D-Y.

Table 5. Outcomes and outcome measure (primary outcomes are in bold)

	Outcomes	Outcome measures
Fan	**Curve regression** Trunk asymmetry Quality of life	**Cobb angle** ATR SRS-22r. SRS-23r
Fanucchi	**Pain intensity** Muscle length, lumbar stability, Neural mobility, Proprioception 3 months-prevalence	**VAS** ASLR, PSLR Questionnaire
Frosh	X	X
Gámiz-Bermúdez	**Spinal deformity** **Quality of life**	**Cobb angle** **SRS-22**
García-Moreno	Back care behaviour, back care knowledge, trunk flexion endurance, trunk extension endurance, hamstrings flexibility, posture, lower limb power, awareness, sitting time, standing time, stepping, step counts, sit-to-stand counts, upper limbs muscular endurance, cardiovascular endurance, lumbar motor control, skills, self-efficacy, and beliefs.	Questionnaires and measurements
Geldhof	Back posture knowledge Prevalence of back and neck pain within the last week Fear-avoiding beliefs	Questionnaire
Habybabady	Back care knowledge	Questionnaire
Harringe	Back pain prevalence Pain intensity	Questionnaire Borg scale
Ippolito	X	X
Kamper	LBP related outcome measures, onset of LBP. pain disability, global perceived effect or participation in daily activities.	X
Kepeng	**Spinal deformity**	**Cobb angle**
Kosseim	X	X
Kovacs	Back care knowledge	Questionnaire
Macdonald	X	X
Maher	X	X
Michaeleff	Pain Fear avoidance beliefs Disability Back care behaviour/knowledge P.A.levels Physical measures	Questionnaires Questionnaires Questionnaires Questionnaires and observations Accelerometer Flexibility and resistance test
Negrini	X	X
Ridderbusch	X	X
Smith	X	X
Steele	Spine/spinal care knowledge Spinal care behaviours Spinal pain prevalence	Practical tests

Table 5. (continued)

Tsiricos	X	X
Vidal	Back care knowledge	Questionnaire
Wang	Spinal curvature magnitude Balance and postural stability Quality of life	Cobb angle, ATR Coronal and sagittal balance index SRS-22
Yu	Body functions (pain intensity, frequency, duration; range of motion, depression, anxiety) Activities and participation (disability, communication, mobility, interpersonal interactions, self care, learning, applying knowledge, return to activities/school)	NRS, VAS. Faces pain scale. Goniometer. Child Anxiety and Depression scale Modified Oswestry Low Back Pain Disability Questionnaire. Pediatric quality of life inventory. KIDSCREEN-52

Table 5. (continued)

amounts [1, 21].

Specific types of exercises the researchers talked about were: stabilisation exercises [1, 9, 12, 13, 21], back school [5, 19, 26, 28], McKenzie Exercises [2, 10, 33], Williams exercises [4, 34].

Stabilisation exercises

Stabilisation exercises focus on the stabilisation of the lumbar spine [1] and on improving the stabilizing capacity of lumbar muscles, that are deemed to be of importance in reducing low back pain [9]. Several groups of muscles are targeted, particularly the transversus abdominis (TrA), lumbar multifidi, and other paraspinal, abdominal, diaphragmatic, and pelvic musculature [1].

It is tailored to the patient and to the probable mechanical cause of low back pain (following Panjabi's model from 1989 that links low back pain to a deficiency of the passive system, active system or the neuromuscular control system [40]) [41].

This approach is aimed at improving the neuromuscular control, strength, and endurance of muscles central to maintaining dynamic spinal and trunk stability [41]: a well-functioning stabilizing system in children can better protect the body against the repetitive loads placed on it during normal physical activity and activities of daily living [9].

What can vary is [41]:

- The type of muscle contraction
- The body position
- The level of resistance or load
- The number of repetitions
- The method of progression

The type of muscular contraction is decided based on the functional characteristics of the targeted muscle [41]: the global muscles span the lumbar area and they shorten or lengthen eccentrically as they produce the torque to move the trunk [41]; on the other hand, the local muscles attach from vertebra to vertebra and are responsible for maintaining the position of the lumbar segments during functional trunk movement [41].
Thus, isometric exercise in these cases seem to be the most effective, at least at the beginning of the rehabilitation program. This is also due to the fact that stabilizing muscles are at the beginning stiff also due to disuse and reflex inhibition [41].
When taking into account the progression of exercises, co-contraction of back and abdominal muscles, isotonic exercises and exercises that involve other parts of the body can be added [41].

At the beginning of the training regime it is not necessary to add any kind of external resistance (like weights or elastic bands) [41]; the difficulty is instead increased thanks to the patient's body weight itself [41].
To do so, the exercise will be performed in four point kneeling or prone lying [41].
In addition, heavy weights and positions that increase external loading are not suitable to increase muscle stiffness and joint stabilization [41].
On the other hand, some added weight is ideal when rehabilitating the local muscles for lumbar spine stabilization [41].

Progression during training can be achieved, at beginning, by increasing the holding time of the isometric co-contraction as well as the number of repetitions [41]. Patients also have to maintain their lumbar spine in a neutral position throughout the exercise [41].

To avoid wrong postural adjustment or wrong muscle activation, strategies including specific palpation, careful observation of changes in body shape and the use of various kind of feedback can be used [41].

If the patient is still unable to perform the correct movement, other commonly employed strategies are [41]:

- Visualising the correct muscle action, also trough anatomical illustrations. E.g.: "The local muscles form a corset like structure which acts to tighten around the waist"
- Using instructions which cue the correct action. E.g. "Draw your lower abdomen up and in" or "Pull your navel up towards your spine"
- Focusing on precision. The patient has to concentrate and focus on the precise muscle action to be achieved, while the others stay relaxed
- Facilitation techniques, like manual pressure

The four point kneeling position and the prone position allow the contraction of the deep local back muscles (simultaneously inhibiting the others) and facilitates the stretch of the deep abdominal muscles, while keeping the normal curves of the spine [41].

Patients should also keep a regular breathing pattern [41].

The prone position facilitates the evaluation of the patient's ability of co-contracting the deep muscles [41].

The upright position is essential for postural and functional retraining [41]; once the patient reaches a pre-seated arbitrary goal (e.g., performing an exercise 10 times by 10 second holds in succession without fatiguing), the load and the functional demands can be progressively increased [41].

Contraindications to stabilisation exercises are: spinal or medical conditions that preclude exercise for the trunk musculature such as acutely unstable spine injuries, significant acute neurologic compromise, or an unstable medical presentation [41].

Stabilization exercises are not used in acute settings, at the very least not before the condition has been stabilised; the same can be said for patients with significant medical conditions or for those with various structural lesions the can be badly affected by this kind of treatment [41].

By performing similar regimens, children were showed to reduce both the length period and the intensity of low back pain [1, 9, 12, 13, 21].

Back school

Swedish back school

The first back school vas founded in 1969 by Mariane Zachrisson Forssell (physiotherapist for the Danderyd Hospital in Stockholm) in Sweden [42]; however, the basis for her work have to be sought in Alf L. Nachemson study on intervertebral lumbar disk pressure during daily life and physical activities from 1960 [42]. From this research it was possible to understand that [42]:

- excessive pressure on the intervertebral discs can lead to the onset of low back pain;
- while sitting the pressure on the discs is higher than when standing;
- lifting weights incorrectly produces very high pressure on the spine.

The same studies have highlighted that in the supine position with the lower limbs bent, the pressure is minimal because the ileopsoas muscle is relaxed [42].

The Swedish Back School Program consisted of four 45-minute lessons, which took place over a 2-week period [42]. The lessons were led by a physiotherapist [42].

In the first lesson the fundamental notions of anatomy and physiology of the spine were given and the psoas position was taught [42].

In the subsequent lessons, exercises for the development of the abdominal muscles (Crunch) were proposed [42], indications were given to reduce pressure on the discs in daily postures and movements and regular physical activity was recommended [42].

California Back School

It was founded in 1976 in California [42]. The course was divided into four lessons of an hour and a half each and took place over two weeks; it was led by a physiotherapist [42].

Like the Swedish school, it began with the notions of anatomy and physiology of the spine and prescribed exercises for the abdominal muscles (Crunch) [42].

Since the increase in lumbar lordosis was considered a cause of low back pain, retroversion of the pelvis was taught to reduce this curve and flexion exercises of the lumbar spine were proposed [42].

A peculiar characteristic of the California Back School is the fact that it gave space to relaxation exercises, as anxiety and excessive tension were thought to cause vertebral pain [42]. The program began with the identification of patients' stress causes, in order to focus on them and attempt to remove or at least reduce them [42].

Canadian Back School

The Canadian Back School, like the American one, was articulated in four 90-minute lessons [42]; lessons were held by four different specialists [42]: an orthopedist for teaching the anatomy and physiology of the spine, a physiotherapist for testing correct exercises and postures, a psychiatrist who underlined the role of emotional factors in the onset of pain and finally a psychologist who taught relaxation exercises [42].

In 1983 Hall [42], in a review of 6418 participants, published the results, finding that 80% of low back pain patients showed significant improvement and 97% of participants found the back education program very useful [42].

Back School in New Zealand

The New Zealander back school was founded by Robert McKenzie, the creator of the name that still today takes his name [42].

McKenzie's intuitions and method have made it possible to set up the exercise program for patients suffering from low back and neck pain, adapting it to the patient's needs [42].

McKenzie pointed out that in most working positions and movements, lumbar lordosis is reduced or even reverses into lumbar kyphosis [42]: if patients are offered flexion exercises, all they would do is renew the same posture and movements that caused them low back pain [42]. To rebalance the structures of the spine, to prevent and treat pain, they need postures and movements that promote extension [42].

This intuition is confirmed by the fact that patients who normally work sitting have an increase in pain when sitting and a decrease in pain when walking [42].

On the contrary, those who work in extension, that is, assume positions or perform movements that accentuate lumbar lordosis, benefit from flexion exercises, i.e. from the program proposed by Williams [42].

Back School in Japan

The Japanese Back School uses a multidisciplinary team approach, which begins with the functional evaluation of the spine and then proposes the notions of anatomy and physiology of the spine and therapeutic exercises [42].

Back School in Nigeria

The Nigerian Back School program consists of two 45-minute lessons that include [42]: structure and functions of the spine, epidemiology and causes of back pain, correct postures and specific exercises to prevent and relieve back pain [42].

McKenzie exercises

The McKenzie method uses history-taking and symptomatic and mechanical responses to spinal loading strategies (e.g. centralization, or changes in range of motion, or both [43]) to classify people into one of three McKenzie syndromes (derangement, dysfunction, or postural syndrome [43]) and to determine the ideal management for each person with NS-LBP [43; 44].

After the classification, patients follow a customised treatment, including specific exercises that resemble the loading strategies used during assessment, postural advice and education [43].
The core of the "education" part of the treatment is self management [43, 46]. Since independence is important, patient generated forces are used as a first resource; if they are insufficient, they are assisted by other methods, such as mobilization [46].

Each syndrome (derangement, dysfunction, or postural syndrome) follows a different treatment regime [45]:

- "If the classification is Derangement Syndrome the patient would be given an exercise that moves them into their Directional Preference" [45]
- "If the classification is Contractile Dysfunction the patient would be guided to load the tissue in a graduated way to stimulate recovery" [45]
- "If the classification is Chronic pain Syndrome the patient would work through an individualised, graded, progressive and paced plan to regain confidence in movement for greater function" [45]

The McKenzie exercise program is made up of seven exercises: four in extension, three in flexion. Their aim is to reduce pain, gain range of movement and restore normal function [47].
In addition, patients should correct and maintain throughout their life a good posture, even when not affected anymore by low back pain [47].

When performing the exercises, it is normal to experience pain [47]; however, during the session, it should diminish over the following sessions and centralization should occur [47].

Should this not happen, e.g., the pain spreads instead of receding, it is mandatory to stop and seek advice [47].

Back exercise #1: Lying face-down

To perform the first back exercise the patient should [47]:

- Lie face-down on a flat, sturdy surface
- Keep the arms straight and relaxed by the side of the body
- Turn the head to one side
- Make a conscious effort to remove all tension from the low back, hip, and legs – the exercise will not be beneficial without keeping the body in a completely relaxed state
- Take a few deep breaths in and out, and then relax for 2-3 minutes

This exercise prepares the body for the second exercise [47].

Back exercise #2: Lying face-down in extension

The second exercise is done only after completing the first exercise [47].

To perform the first back exercise the patient should [47]:

- Start in the lying-down position as in exercise 1
- Place both elbows under the shoulders and push the upper body up, leaning on the forearms
- Keep the hips steady on the ground
    - If this exercise is painful the elbows should move farther away from the body to lower the top half of the body to a tolerable point
    - Alternatively, the patient should place a pillow under your chest to support the upper body
- Similar to exercise 1, a conscious effort must be made to remove all tension from the low back, hip, and legs
- Patients should maintain this position for 2 to 3 minutes with controlled, deep breathing.

This exercise is performed only once per session, and the sessions must be evenly spread 3 to 4 times a day [47].

Exercises 1 and 2 prepare the body for the third exercise [47].

Back exercise #3: Extension in lying

The third exercise is done only after completing the first and second exercises, and it should be attempted only if leg pain has not worsened in the previous positions [47].

To perform the first back exercise the patient should [47]:

- Start in a face-down position with the head forward rather than to the side
- Place both the hands under the shoulders
- Gently push up and straighten the elbows
- Keep the hips on the ground and only push up as far as tolerable
- Keep the lower body in a completely relaxed position.
- Allow the pelvis and legs to sag or sink into the ground
- Hold this position for 1 to 2 seconds and return to the lying-down position

10 repetitions of this exercise should be performed every 2 hours during the day [47].

With each repetition, patients should aim to push their body higher than before [47].

Back exercise #4: Extension in standing

For some individuals, exercise 3 might be uncomfortable or challenging, or their spine may lack the flexibility needed to perform the extension movement correctly [47].

In such cases, extension in standing offers an excellent alternative [47].

To perform this exercise the patient should [47]:

- Stand upright with feet slightly apart
- Place the hands in the small of the back (the curved area in the low back)
- Using the hands as a fulcrum, bend the upper body backward at the waist as far as possible without pain
- Hold this position for 1 to 2 seconds and return to the starting position [47].

Perform 10 repetitions of this exercise should be performed every 2 hours during the day [47].

With each repetition, the patients should try to bend farther than before, if possible [47].

If it is challenging for the patients to remain balanced while performing this exercise or discomfort starts setting in the shoulders, an alternative is to stand with the lower back against a countertop and use the countertop as a fulcrum to bend backward [47].

Back exercise #5: Flexion in lying

To perform this exercise the patient should [47]:

- Lie on your back with your knees bent and feet flat on the floor
- Slowly lift both feet and bring the knees close to the chest
- Wrap both hands around your knees and pull the knees as close to the chest as possible
- Hold this position for 1 to 2 seconds

While performing this exercise the patient should [47]:

- Avoid raining their head
- Avoid at any point straightening their legs

10 repetitions of this exercise should be performed every 2 hours during the day [47].

Back exercise #6: Flexion in sitting

This exercise is recommended only after doing exercise 5 consistently for at least 1 week, and it should be attempted only if leg pain has not worsened in the previous positions [47].

To perform this exercise the patient should [47]:

- Sit on the edge of a chair with knees and feet apart and both hands on the thighs
- Bend forward at the waist and hold the ankles or touch the floor
- Return to the starting position immediately

10 repetitions of this exercise should be performed every 2 hours during the day [47].

With each repetition, the patient should try to bend farther than before, if possible [47].

Back exercise #7: Flexion in standing

This exercise is recommended only after doing exercise 6 consistently for at least 2 weeks [47].

To perform this exercise the patient should [47]:

- Stand upright with feet apart and arms by the side of the body
- Slowly fold down at the waist and move the hand along the leg as far as possible without pain
- Return to the starting position immediately

10 repetitions of this exercise should be performed every 2 hours during the day [48].

With each repetition, the patient should try to bend farther than before, if possible [48].

The 7 back exercises are performed in phases depending on the severity of symptoms and duration of pain [48].

Following the recommended number of repetitions and sessions provides the full benefit of the exercises [48].

Exercises 1 through 4 are not suitable during pregnancy [48].

When in acute, constant pain, patients should perform exercises 1 and 2, and move on to exercise 3 [48].

If exercise 3 cannot be performed due to acute pain in a lying-down position, patients should perform exercise 4 after exercise 2 [48].

Exercises 1 through 4 should be performed for the first few days until the acute pain subsides [48].

When the acute pain has reduced, the patient should continue exercises 1 through 4 and slowly introduce exercise 5 [48].

After at least 1 week of performing exercise 5, exercise 6 may be introduced into the workout sessions [48].

When exercise 5 becomes tolerable and improves flexibility in the low back, it can be stopped and exercise 6 may be started [48].

When exercise 6 becomes tolerable, it may be stopped and exercise 7 can be started [48].

Exercises 5, 6, and 7 must always be followed by exercise 3 and a short period of rest thereafter with the lumbar roll [48].

When there is no pain or stiffness [48], the patient should perform exercise 3 every morning and evening to prevent a recurrence or flare-up of back pain, exercise 4 before and after heavy lifting and at regular intervals during sitting to keep the back conditioned and exercise 7 once or twice a week to maintain flexibility in the low back [48].

Williams' Back Exercises

Williams' back exercises, or Williams' flexion exercises are back exercises developed for mild-to-moderate back pain patients (originally men younger than 50 years of age and women younger than age 40 who had moderate to severe lumbar lordosis and whose plain radiological films revealed diminished disc space between the lumbar segments L1-S1 [49]); while other, more recent, modalities have been proved to be effective, these exercises are still used, as they seem to be effective and can be performed at home as well [49].

Comparatively to the McKenzie method (both born in 1930, but the former focuses instead on lumbar extension) [49], Williams exercises favour back flexion; their aim is to reduce pain, improve the stability of the lower pelvis, the range of motion and function, and help prevent future injuries as well as chronic pain [49].

These exercises can be performed in the supine position on any flat surface [49]. For starters, patients should grab the legs and pull the knees to the chest and hold them for several seconds [49]; this is thought to help the intervertebral foramen, stretched the ligaments, and distracted the apophyseal joints [49]. The theory was that when pressure is placed on the posterior aspect of the lumbar vertebral with extension, disc herniation can occur [49]. In theory, this is due to increased lumbar lordosis; lumbar lordosis would decrease by limiting the pressure placed on the posterior aspect of the lumbar vertebra [49]. The decrease in pressure would improve by improving the flexion of the vertebral disc, leading to decreased disc herniation, thus reducing the incidence of chronic low back pain [49].

The recommended duration and repetition of these exercises are 10 to 20 minutes, every day. Williams' exercises include [49]:

1) Posterior pelvic tilt; with the patient lying on their back with their hands at their side and their knees bent. The patient is then told to tighten the muscles of their abdomen, as well as their buttock muscles, flattening their back against the floor
2) Single knee to chest; lying on a table or bed, patients are instructed to let a leg fall off the table or bed, bend their other leg and wrap their hands around the bent knee, and pull the bent leg toward their chest
3) Double knee to chest; patients are instructed to bring both their knees, one at a time, to their chest. With their hands held together, they pull their knees towards their chest and curls their head forward. While performing the motion, patients are instructed to keep their knees together and to have their shoulders flat on the floor. Then, they lower one leg at a time
4) Partial sit-up; patients are instructed to use their abdominal muscles to raise their upper back off the floor while exhaling. They are supposed to rise only enough to get their shoulder blades off the floor, and are not supposed to thrust themselves off the floor or to lift their heads with their arms. While performing this motion, patients are supposed to keep their knees bent and their feet flat on the floor, in order to feel the muscle contraction only in their abdominal muscles. Alternatively, this exercise can be performed diagonally, with one shoulder higher than the other

5) Hamstring stretch, with one knee bent and the other straight, patients are asked to pull the foot of the straight leg toward themselves. Then, they raise the leg until they feel the stretch in the hamstrings
6) Hip flexor stretch; lying on their back with their hands at their sides and their knees bent. The patient is then instructed to rotate their knees towards the direction of pain
7) Squatting; patients should send their hips back and bend the knees to lower themselves while keeping their chest raised

S-LBP

Mechanical causes

Alongside other forms of treatment like education or orthotic devices (soles), exercise for strengthening the core and back muscles is also indicated [2, 4, 9, 10, 12] in case of postural problems, pelvic tilt caused by leg length discrepancy, or any other kind of asymmetrical weight bearing (occurrences most common during growth spurts [9] and some of the primary underlying causes of low back pain in childhood [9, 12]; the difference seems even more true when talking about adolescents and not about children [12] or adults [20]. The quality of evidence is moderate [12, 20].

This is because, during growth spurs, spinal structures are more likely to get damaged or go through injuries, sprains or strains, since they cannot withstand the forces placed upon them [9. 20]; exercise would hence promote optimal spinal alignment, dynamics and loading, as well as enhance back function, minimise injury, make children learn to be responsible for their health and developing healthy exercise habits during the growth spurt [9, 11].

Lumbar disk herniation

When pain subsides, alongside other treatment modalities (mobilisation, laser therapy or diathermy [10]), strengthening and mobilisation exercises (the former should focus only lastly and gradually on core muscles [10], and the latter only after the stitches have been removed [10]) can be incorporated in the rehabilitation program [8, 10]; depending on the patient, passive and even active straight leg-raising exercises in bed must be started to avoid adhesions between the nerve root and the operated disk space [10].

Patients should also be encouraged to gradually start walking [8, 10].

Spondylolisthesis

After a period of rest [4, 8, 10, 19], alongside a brace [10], strengthening exercise and stretching for tight hamstrings, fascia lata, lumbosacral fascia and hip capsule are indicated [4, 10, 19]; the aim is to improve the core muscles, glutei, spine erector and ileopsoas and improve spinal mobility [4, 10, 19].

Scheuermann's disease

Exercises to improve strength and correct bad posture seem to be effective in the rehabilitation post intervention for Scheuermann's disease [10, 31]. The goal of the rehabilitation program is to recover normal lumbar lordosis and thoracic kyphosis by postural and muscle strengthening exercises [10, 31].

Scoliosis

The Schroth method consists of scoliosis-specific sensorimotor, postural and breathing exercises [26].

The patient's ability to reduce the spinal deformity through active postural alignment of the spine (known as auto-correction) is a fundamental component of the method [39]. This auto-correction is achieved through self-elongation and postural corrections that are specific for each curve pattern and will eventually be integrated in daily activities [5].

SSE exercise (core muscle training [26], posture education [26], and traditional exercise therapy [26]) are useful to reduce Cobb angles beyond the measurement error of 5° [26, 31, 39]; SEAS (Scientific Exercises Approach to Scoliosis) allows a reduction of the curve and of the ATR (Angle of Trunk Rotation), but a slight increase once the patient has reached skeletal maturity [26].

Generally speaking, these types of exercise are more effective in patients older than 13 years and with Risser stage 0 (where skeletal maturity has not been reached yet) [26, 31] and with mild curves [26, 28]; this would be promising (as curves <30° are unlikely to progress after skeletal maturity [26]), but the quality of evidence is low [26, 28, 31].

SSE can be paired with other typologies of exercises (like breathing exercises) [26], but the results show no clinically important difference [26]. The quality of evidence is moderate [26]. The opposite is true for SSE paired with bracing, as both modalities combined are more effective on mild

scoliosis than what they would be if considered alone [26, 28, 31]. The quality of evidence is moderate [26, 28, 31]. The quality of evidence is low [26, 28, 31].

Furthermore, SSE does not seem to be superior than either bracing or core muscle exercises in improving mild scoliotic deformity [26]; the same can be said for SEAS and bracing [26]. The quality of evidence is low [26].

Existing studies seem to report a moderate to high level of adherence, motivation and capability regarding the treatment of scoliosis through exercise [36]; their levels are also higher than adherence to bracing treatment [36], but are reduced if treatments start being complex and self-managed [9, 36, 50]. Thus, it is essential for those who administer the treatment to facilitate the patient and their caregiver as much as possible in following the instructions [36].

High patient adherence had a significant positive association with patient capability and motivation [36]. Hence, the importance of the HCP strategies in the delivery of the treatment plans [36]. This not only serves to facilitate and maintain patient capabilities, but also to improve motivation, which may be important for long-term adherence to interventions [36].

In any case, it should be kept in mind that adherence is not a "Black and white" phenomenon (meaning, patients either follow the treatment perfectly or not at all), but a nuanced one, where some recommendations are followed and others not, or they are all followed to different degrees [36].

Conversely, exercises for scoliosis seem not to be useful to improve quality of life in patients [26, 28] as defined by the Scoliosis Research Society 22 measurement (SRS-22) score [28]; despite this, corrective exercise-based therapy seems to show a medium or large effect on pain, self-image and mental health but not on function [28]. The quality of evidence is low [28].

Schroth exercises

The Schroth technique was developed by Katharina Schroth, a German physiotherapist, in the early 20th century [51].

The spine is addressed in all three anatomical planes: sagittal, frontal, and transverse [51]; the purpose of the method is to create spinal balance and stability by improving body mechanics and spinal stabilization to prevent further curve progression [51].

The treatment is made up by four components [51]:

1. Assessment and Evaluation

- Initial Assessment: A thorough evaluation is conducted to assess the patient's spinal curvature and overall posture. This includes physical examination and potentially imaging studies like X-rays.
- Curve Classification: The therapist categorises the type and severity of scoliosis, often using classifications such as the Cobb angle to determine treatment direction.

2. Individualised Exercise Programs
   - Curve-Specific Exercises: Each exercise program is tailored to the individual's unique spinal curvature. Common exercises may target the thoracic or lumbar regions, focusing on:
     - Rotational Exercises: These help counteract the rotation associated with scoliosis, promoting spinal alignment.
     - Side-Bending and Stretching: Targeting muscles on the convex side of the curve to improve flexibility and balance.
     - Strengthening Exercises: Focusing on the muscles that support the spine, particularly the core, to enhance stability.

3. Breathing Techniques
   - Diaphragmatic Breathing: Emphasises breathing into the ribcage, promoting lung expansion and helping mobilise the spine. This aspect is crucial as it encourages optimal posture and supports spinal decompression.

4. Functional Integration
   - Daily Activities: Patients learn how to apply the principles from their exercises to everyday movements, such as sitting, standing, and walking. This helps maintain proper posture throughout daily life.

Schroth exercises although different from person to person include three important components:

1. Muscular symmetry
2. Rotational angular breathing
3. Awareness of posture

Education

Education is part of the non-pharmacological approaches for the prevention and treatment of low back pain [5, 6, 7, 10, 11, 12, 13, 15, 16, 17, 20, 30, 31, 32, 33, 34, 52]. It can be either only theoretical [14, 30] or both theoretical and practical [6, 11, 12, 13, 16, 17, 32, 33]. Authors seem to agree that the latter modality best underlines the complementarity of the two components [5, 7, 11, 12, 17, 52].

While the majority of the programs is destined to adults, many are starting to advocate the need to move the age range from adulthood to childhood [5, 11, 12, 14, 15, 16, 17, 32, 52]:

- There are more information about the risk factors, that are more preventible if education starts at an earlier age
- This would allow to reduce the costs of intervention for the treatment of low back pain and medical consumption
- Loads and postural habits start impacting on the spine early in life, therefore it is essential to start prevention at an early age
- Children have a "younger" brain and learn new information more easily than adults
- To let researchers have a one period of time to receive feedbacks
- As a preventive measure, as pain levels in growing children are rising
- A possible decrease in fear-avoidance beliefs, especially if practical or mixed modalities are employed
- To hinder the decrease of physical activity levels from childhood to adulthood
- To wane misconceptions regarding low back pain (that are common in adults and cause long-term disability)
- Enhancing students' understanding of low back pain mechanism
- Having adequate knowledge about back care can give children and adolescents the ability to change their lifestyles on their own

Conversely, other researchers argued that, due to its multi-factorial nature in adults, it seem necessary to rely on the positive effects on adult risk factor and on the existing guidelines [11, 14, 53], and that early interventions support fear-avoidance beliefs and reinforce a passive behaviour [11, 14].

Children are at an age where they are much more susceptible compared to adults to learning and changing attitudes (if properly stimulated) [6, 11, 30, 52]; however, interventions need to last some time, as they need time to learn what was taught and how put those skills into action [30, 52].

Programs involving reading materials or indirect modalities (like focusing only on the activities the back is involved into, e.g. backpack carrying and backpack weight, sitting and standing postures, weights lifting [12]) have been shown to be less effective than active learning or programs involving both education and physical exercise [11, 12, 17].
Nonetheless, the results seem to be maintainable for at least some months after the end of the programs (17, 16 and Vidal et al.: 3 months) [17, 30, 32], and the percentage of low back pack in adults in less in those who took part in educational programs compared to those who did not [5, 11, 15].

Regarding the retention of the results, it seems that both gender and age influence learning, health-related attitudes, and behavioural changes [15, 30]; this is also supposed by the work of Habybabady et al., where children were able to retain the knowledge they acquired up to two years after the end of the study [15]. Results are likely to be influenced by factors such as previous history of spinal pain and presence of parental spinal pain [15, 30, 52].
Therefore, these factors should be considered when researching this topic, especially in settings like schools or with children in general [15, 30, 52].

Interestingly, while teachers (rightly so) do not seem to have the background necessary to hold lessons about LBP education [11, 12, 17], they make up for it by being motivated [11] and by enabling them to retain the results [11].
This is even more true if one thinks that, across two school years, many things could happen: a child could change school, teachers, miss or repeat the year; despite this, result tends still to be positive [11].
Hence, positive results count for its capability of improving knowledge and behaviour, and diminishing back pain intensity [17].

The contents and duration of the sessions vary, but their goal is common: to diminish back pain by educating patients on proper back care [17, 52], and to promote physical activity and optimum spinal load (since physical activity levels in youths are lower than what would be ideal, and those same levels further drop when reaching adulthood) [11]; while the modalities have been changed and updated [17], the aim remains unchanged [17].

An example of a program is [52]:

1. Learning back care with the help of an instructor (in this case, a school teacher) and of some provided materials. The program was defined with the help of various healthcare professionals (like orthopaedics and psychologists) and teachers. They focused on anatomical knowledge of the back and spine, good and bad posture while sitting (e.g. dynamic sitting, plus the need to minimise sitting time), healthy backpack habits, healthy lifting and carrying (e.g. through bending the knees for the consistent distribution of weight), and back-friendly sports (e.g. swimming and skating) and nutrition
2. Posture awareness training and improvement. Three posters put up in the classroom showed alternative sitting variations to promote dynamic sitting, strengthening exercises for the core muscles and mobilization/stretching exercises to improve muscular tensions and shortenings. All the exercises were doable at the student's own desk
3. Mandatory back and abdominal exercises at the beginning of each lesson and at another time of the day to reduce muscular imbalance. Each teacher was given a list and a description of the valid static and dynamic exercises. Examples of the exercises involved: plank, crunch, hip lifts, flexion of the back muscles, and ball-exercises

Cardon et al., while not identical, reported similar programs and modalities [11, 14].

Many feel that back care education should be integrated into school curricula for a variety of reasons [11, 12, 14, 17, 32]:

- Teachers would be able to monitor the program (thus reinforcing the desired behaviour)
- Teachers are a role figure for children and spend a lot of time with them, and would therefore be more effective than other healthcare professionals in imparting their knowledge
- Schools seem to expose children to loading factors, such as prolonged sitting postures
- Moreover, health education seems easier to organise in elementary school, which has a more flexible system than secondary school; this is especially for last grades

However, the education should continue outside of school as wells, as families and cultural lifestyles affect how children would adapt to and continue the taught behaviour [11, 15, 17]. For example, in the study by Habybabady et al., Iranian children whose parents lacked knowledge about the risk factors of musculoskeletal disorders either at baseline or at follow up scored less than children whose parents' knowledge was greater [15].

Conversely, school curricula are already packed full, there is little time to go through everything properly [11, 32], there are many practical limitations (a lecture-based education system [15],

limited space allocated to each child in school [15], mismatched school furniture with children body size [15], limited time for physical activities [15], inadequate sports facilities at school [15], spending long time commuting to school [15], inappropriate furniture at home while studying and watching TV [15], and the teachers themselves admit their own lack of knowledge [11]). Additionally, lack of media coverage and governmental structured programmes do not help sensitise parents, children and educators [11, 15].

The use of concrete educational materials (like books or pamphlets) is more indicated when compared to other modalities, as the children have to read information by themselves (and the process is not imposed on them by a teacher or an instructor) and the information are more likely to be retained [14, 16, 17].

Reading material would also help with their development (improving their vocabulary and concentration) [17]. For example, Kovacs et al. reported the use of a very short booklet in a comic book format with messages consistent with those in the *Comic Book of the Back*, (a short book on low back pain popular in Spain) [16].

Its main content included the following [16]: back pain is usually not due to any serious injury; physical activity and exercise have a positive effect on back pain for both prevention and treatment; and if back pain occurs, bed rest should be avoided and the highest possible degree of activity should be maintained.

In addition, the comic book recommended that backpacks should not surpass 10% of body weight and that children involved in competitive sports follow the advice of their coaches and physicians strictly [16].

On the other hand, this approach could be less exciting and interesting for children, and reading require a lot of concentration and time, especially at an early age [17].

Another modality is practice and motivating strategies through environmental and behavioural influence [14]; in order to avoid prolonged static sitting short movement breaks between the lessons were introduced, and teachers were asked to teach following an activating approach (distribution of handouts systematically through children, variable work organisations, use of sitting alternatives [14]) and to change structural class organisations (decentralised storing places for educational tools, textbooks, and schoolbags [14]).

This has been showed to work better than the simple transmission of information [14].

Braces

Braces are a common approach in the treatment of low back pain in children, in particular with pathologies like Adolescent Idiopathic Scoliosis (AIS, the most common), Scheuermann's kyphosis, Spondylolysis and Spondylolisthesis [2, 4, 8, 10, 19, 29, 35, 36, 37, 38, 39]; while bracing has not been proven to speed up healing, it can help control pain (if other modalities are not useful or available) [4, 8].

A brace's efficacy is based on its ability to apply external forces, thus redistributing mechanical stresses and promoting vertebral remodelling [26, 29, 31, 37].
This way, the progression of the pathological curve can be stopped or slowed down [38]. This effect is inversely proportional to the patient's skeletal age [35, 38] and proportional to the amount of time the brace was worn [27, 29, 36, 37, 38, 39, 54.]. This dose-effect response is also known as "Concertina effect" [39. 39].

The aim of the braces is morphological (stop the progression of the curve, generally speaking no further than 45° Cobb, for aesthetics or to provide support for the spine) or functional (prevent respiratory disfunction, treat pain symptoms and preserve quality of life) [29, 31, 35, 37, 38, 39].

The final goal should be to avoid surgery [38, 39]; in children (especially very young ones), conversely, the aim is to reduce the curve by 50%: bracing should follow the principles of Mehta (wearing braces as soon as two years old, in order to reduce the deformity and lower the probability of having to undergo surgery) [35, 57] for children with a Cobb angle >20 degrees; this is due to the fact that children have soft horizontally aligned ribs, and inadequate bracing could exert the wrong pressure and cause thoracic deformities [35]. The earlier a patient is presented, the greater is the chance that there will not be the need for surgical intervention [2, 4, 8, 10, 26, 31].
However, the majority of the patients is presented too late [38, 39], and bracing simply delay the need for surgery [38].

Overall, braces are used on skeletally immature patients with a curve of less than 50° Cobb, for greater curves where it is not possible for the patient to undergo surgery or for limitations on flexibility and mobility [26, 28, 31, 36, 37].
Indications on the amount of time a brace should be worn are [36, 39, 54]:

- Night Time Rigid Bracing (8–12 h per day) (NTRB): wearing a brace mainly in bed

- Part Time Rigid Bracing (12–20 h per day) (PTRB): wearing a rigid brace mainly outside school and in bed
- Full Time Rigid Bracing (20–24 h per day) or cast (FTRB): wearing a rigid brace all the time (at school, at home, in bed, etc.)

This type of treatment seem to be effective in haltering the progression of mild-to-medium curves, while it does nothing on more important curves (Weinstein et al. reported inefficacy on curves greater than 50° [38]).

In case of curves of 60° Cobb or more, CETIK et al. and Bezalel et al. suggest wearing a brace for at least 20 hours per day [35, 38, 39].

For curves greater than 50°, there is a lack of studies supporting the efficacy of part-time or night-time braces, and all the successful studies focus on full-time wear [5, 35, 38, 39].

Therefore, patients need to be compliant [38. 39] and receive a throughly education on the matter [35], since effectiveness is proportional to the number of hours spent wearing the brace [38, 39], and that the majority of the patients tend to overestimate that time [36, 38, 39].

Skeletal maturity, in-brace correction, curve magnitude, flexibility and compliance with brace wearing are significant factors influencing the outcomes of brace treatment [26]. In addition, bracing can be stressful for patients, induce a flatter back, and negatively affect quality of life (QoL) [26, 29].

Moreover, most braces are uncomfortable to wear, resulting in poor brace-wearing compliance [26]; patients may also report weakness of trunk muscles [2, 29] or neurological effects on muscles near the lumbar spine [2].

Children and, especially, adolescents tend to report a negative effect on the perceptions of their body appearance, a reduction in quality of life, and a lack of symptoms improvement [28, 36, 37]: rigid braces, although effective, have been described as uncomfortable, bulky, and aesthetically unappealing, leading to issues with compliance and psychological stress [38].

Because of that, youth reported in the majority of cases a fear of stigmatisation, restriction of mobility, discomfort and lack of acceptance by their peers [26, 38]. This explains why nighttime wear seem to be more accepted than daytime [39].

In order to solve these shortcomings, more sophisticated orthoses are starting to be researched on [38].

Bracing can also be paired with other treatment modalities (like SSE [2, 8, 26, 28, 29, 36, 38, 39], body awareness exercises [26], core exercises [26], 3D insoles [37]) and, generally speaking, to continue being active and doing sports (aside from those involving jumping, marked stress, and functional overuse of the back, a lot of back extension, like basket or gymnastics) [38]. However, results are unclear [26, 28, 36].

In particular, pairing bracing and SSE is thought to lesser the former's side effects (flat back, muscle atrophy, low QoL) [26, 29, 37]; insoles help with the conditions associated with LBP [37]: obliquity of the pelvis and imbalance in lower extremity biomechanics, such as flat foot and leg inequality [37].

Types of braces provided by the Italian SSN

The types of braces provided for free by the Italian SSN are [38, 39]:

- The standard rigid brace, that follows the principle of three point pressure (a force is applied on the point of correction, while other two counter forces acting in the opposite direction are placed above and below the first point)

  The aim is traction, lateral deflection, and de-rotation. The specifics depend on the location and rigidity of the curves, the age, and specific patient preferences
- The Milwaukee brace is not used on patients close to skeletal maturity. It consists of a neck ring and a pelvic mold that fix and extend the spine, inducing constant self-elongation. An axillary sling and thoracic and lumbar pads apply transverse corrective forces to the curves, resulting in a consequent correction of the deformity [31, 56].

  The three point pressure is of minor importance, as its aim is to stimulate the trunk muscles and to change the direction of spinal growth. This type of brace is used on mild and moderate curves (up to 40°-45°) [31, 56]; on patients going through skeletal growth [31, 56].

  According to Misterska et al. and Razeghinezhad et al., the success rate of this brace in the treatment of scoliosis varies from 43% to 53.33% [38, 39]; the percentage might be linked to its psychological impact (because of its neck ring) and to its induction of a flat back [38, 39].

  In the present times, it has been replaced by thoraco-lumbo-sacral orthoses (TLSOs, like the Boston and Cheneau brace, which show a higher success rate compared to the Milwaukee brace) [36, 38].
- The Boston brace is prefabricated, open in the back and customisable by the patient. Its structure allows the de-rotation of vertebral bodies, so to correct their lateral deviation and rotation, in order to Bring the trunk in axis with the sacrum.

It is used on scolioses where the spine presents a curve between 20° and 50° Cobb, or cases where the patient cannot undergo surgery. Kaelin et al. found in their study in 2018 that the brace did not have [38, 39], and Emans et al. found in their study in 1986 that 32 (11%) out of 295 patients treated with this brace had to undergo surgery [38, 39]

- The Chêneau brace is lightweight and has an anterior velcro opening. It is used for patients of all degrees of severity and maturity, in cases with an apex lower than T5 [56] and it can be worn for all the day

  Its aim is to allow a correction of the scoliotic curve in all the three directions, while mobilising the flat parts (like the back), reducing humps and leaving respiratory movements free.

  Maruyama et al. and Feng et al. reported a success rate (the curve did not progress more than 50°) of 76,81,81% [38, 39]. A study by Minsk et al. from 2017 comparing the Boston and Chêneau braces reported that the latter is less effective than the former [38, 39]; however, the different characteristics of the studies make it difficult to compare them [38, 39].
- The Lyon brace is a rigid brace. It is used in lumbar or low thoracolumbar scoliosis between 30° and 50° Cobb; greater curves if there is skeletal immaturity or no indication for surgery; for the 3 to 6 months after surgery.

  It follows the principle of the three-point pressure, one at the apex of the curve and the other two on two neutral vertebrae. The overall efficacy of the Lyon brace is 95%. However, it drops to 87% for thoracic curves and to 80% in patients with Risser sign 0 [38, 39].
- The SPoRT (symmetrical, patient-oriented, rigid, three-dimensional, active) brace is a very rigid and customised type of brace [56]. The Sibilla and Sforzesco braces are deviated from its concept [39], and are customisable as well [56]. The Sforzesco brace envelopes the trunk and connect posteriorly through a metal rod positioned longitudinally in the middle [39, 56].

  Their action is based on the mechanism of elongation, derogation and flection of the spinal curve [56]. According to Negrini [39] this kind of brace is more effective than the Lyon brace and the Risser cast; patients wearing it did not worsen beyond 45° Cobb, and they also reported better results from a psychological point of view [39, 56]

As for the type of braces, hard ones are more effective than soft ones [38] and, among those provided for free by the Italian SSN, the Boston and Chêneau ones seem to be the most effective [38]. The quality of evidence is high [38].

On the other hand, Negrini et al. deemed the Milwaukee brace the most effective [39]. The quality of evidence is high [39].

Ridderbusch et al. found that the most effective types are the Charleston and Boston ones [35]. The quality of evidence is moderate [35].
Janicki et al. obtained the best results with the Providence night-time orthosis over a TLSO [38, 39], Gammon et al. reported equal results with a rigid TLSO and SpineCor [38, 39], and Coillard 2014 reported better results with rigid brace than SpineCor [38, 39]. The quality of evidence is high [38, 39].
Negrini proved with the support of radiological findings that the Sforzesco brace was more effective than the Lyon brace [39]. The quality of evidence is high [39].

Therefore, here as well there is little consensus on the most effective type of brace [38, 39]: studies comparing them are few, with varying quality and characteristics, different types of pathologies treated and small patient samples.
Because of this, in 2012 the same authors that published the SOSORT guidelines published the Brace Thematic Series [39, 54], so as to allow for an easier comparison and a better understanding of the characteristics of each type of brace [54].

New trends have also been emerging: new designs are trying to supersede the old ones, in order to avoid their shortcomings (like their bulky, invasive and at times unaesthetic appearance [39]): night time bending braces or SpineCor over TLSOs over Milwaukee, Sforzesco brace over casting. Meanwhile, old designs can be progressively refined and improved (like the Chêneau or the Boston braces) [39].

5. CONCLUSION

To summarise, exercises, education and braces are the most employed types of treatment in the management of low back pain in children aged six to twelve.

While the majority of the researchers tends to agree on the buoyancy of exercises as a treatment for low back pain in children, the same cannot be said for education and bracing: the former surely works as a preventive measure against the new onset of low back pain, but the same certainty is not present when discussing it as a treatment modality, unless it is paired with active treatments like physical activity or exercises; the latter seems to work, but only on mild curves and there is no consensus on the dosage and the type of brace to prescribe, as well as wether it should be paired with active management modalities (like exercises, physical activity or SSE).

It would be interesting to investigate the most common shortcomings of these modalities (like the lack of compliance, the worsening of quality of life), and find their solution, or at the very least lessening them.

Limitations

Common limitations of the studies were: lack of data (like the type of bace used [26]) [5, 6, 16, 20, 26, 29, 32, 37, 52], short length of the studies [1, 26, 29, 30], presence of confounding factors (like patients undergoing bracing treatment and a exercise program at the same time [26] or, as bracing is a time-dependant treatment, wrong results is the short run [11, 13, 20, 26, 28, 29, 37]), great heterogeneity at the beginning [1, 12, 26, 30], small samples [1, 6, 7, 12, 13, 20, 28, 29, 32, 38, 39], various unexpected practical problems [14, 15, 16, 17, 32], short follow up periods [39] (or lack thereof [1, 16, 30, 32]), parents' refusal of the randomisation process [39]**,** low level of compliance observed [26, 38, 39], lack of methodological quality [1, 4, 5, 6, 7, 8, 9, 10, 12, 13, 19, 20, 34] or high RoB [1, 9, 12, 13, 20, 26, 28, 30] and the impossibility of the generalisation of results (thus leaving them to be specific for certain countries [9, 36], categories [1, 20] or settings [1, 20]) [1, 9, 11, 20, 26, 28, 36].

To summarise, more studies with bigger samples and better data collection are needed.

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