



# Review of rehabilitation and orthopedic conservative approach to sagittal plane diseases during growth: hyperkyphosis, junctional kyphosis, and Scheuermann disease

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**An increase of the physiological kyphosis during growth is defined hyperkyphosis (HK) and, according to the level where the apex of the curve can be retrieved, we can distinguish a thoracic HK and a thoraco-lumbar one, also called junctional kyphosis. Since these conditions can cause pain and esthetics impairments, lead in adulthood to an higher incidence of spinal and shoulder pain, and evolve during growth, it is important to manage this deformity. The aim of this paper was to present the state of the art about HK and its treatment. Scheuermann Disease (SCHK) is the better known cause of HK; other causes can be idiopathic or postural, trunk extensor muscles weakness or neurological problems. Despite etiology a specific treatment can be required during growth to prevent evolution and reach a better spinal alignment in adulthood. It is at the base of treatment and allow monitoring. There are some validated methods that can be used in a comprehensive rehabilitation approach. Evidence in this field is scanty, even if there is quite a consensus on possible treatments. They aim at improving posture and esthetics, and abolishing pain; they include: exercises, used mainly in mobile postural/idiopathic HK, and in SCHK without HK; braces (plus exercises, in this case aimed at reducing brace impairments), that in rigid HK and in most of SCHK patients also allow a better vertebral growth; surgery could be used in worst cases, even if it should be carefully considered, because it requires fusion and loss of spinal function.**

**KEY WORDS:** Kyphosis - Scheuermann disease - Spine, therapy.

The thoracic anterior concave spinal curvature is defined kyphosis. This is a physiologic conformation of the spine that, together with lumbar and cer-

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vical lordosis, which are the posterior concave curvatures, makes it more balanced and allows to face gravity force. An increase of the physiological kyphosis is defined hyperkyphosis (HK) and, according to the level where the apex of the curve can be retrieved, we can distinguish a thoracic hyperkyphosis (THK) and a thoraco-lumbar one, also called junctional kyphosis (JK).<sup>1, 2</sup>

During fetal life and immediately after birth, the spine is characterized by a global kyphotic curvature. Later, from the 6th-9th month, when the child begins to crawl, the spine change its conformation into a global lordosis, that is almost maintained during the learning of walking. In the following years, kyphosis gradually develops, thus defining also the cervical and the lumbar lordosis. Thus, the whole developing age and most of all adolescence represents the critical period of final spinal maturation, when pathologic events can lead to develop an HK.

Esthetic impact is the most immediate problem related to HK,<sup>3</sup> but sometimes this condition is associated with back pain, and this latter can be quite frequent during adulthood as well as shoulder pain;<sup>4</sup> the forward flexed position is also quite unfavorable because, when it is important, it limits autonomy and movements in everyday activities.

We have no data about the prevalence of HK during adolescence. Some studies report a prevalence

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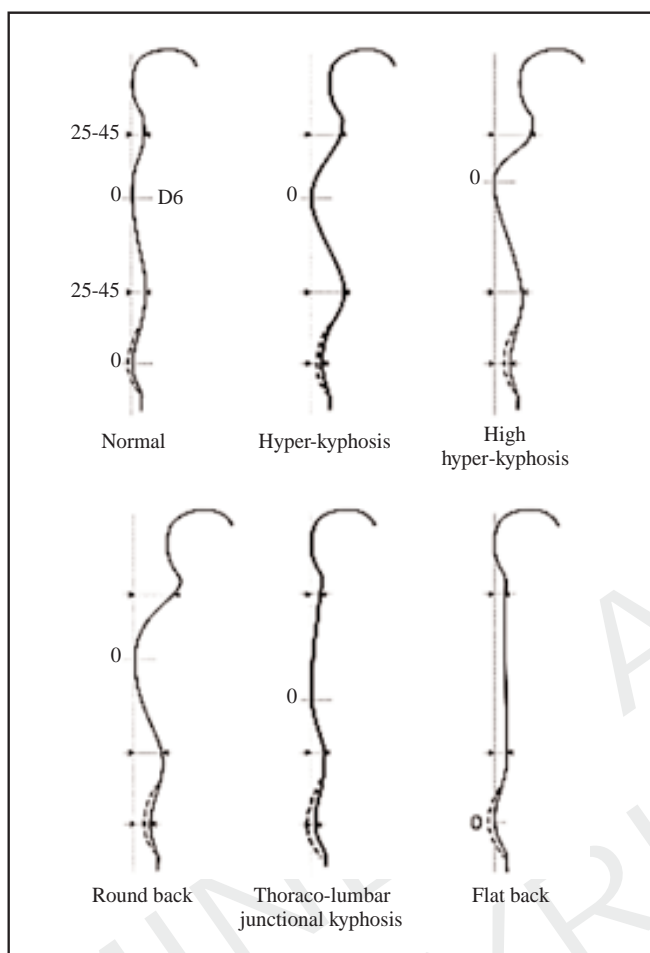


Figure 1.—Spinal sagittal deformities occur within the physiological curves of the spine, that can be excessively increased (thoracic hyper-kyphosis or round back, lumbar hyper-lordosis), reduced (flat back, hollow back, hypo-lordosis, lumbar kyphosis) or modified in their normal distribution (kyphosis of the thoraco-lumbar junction, cervico-thoracic kyphosis).<sup>1, 2</sup>

of 1-8% HK secondary to Scheuermann disease (SCHK),<sup>5, 6</sup> but this is not the only cause; so, the general incidence is not known. Moreover, this prevalence can change during developing age, with an higher prevalence in adolescence with respect to juvenile age. So the number of HK patients can be really relevant, and many parents seek for a medical evaluation and treatment since they notice an attitude to a forward flexed position of their children.

This is a neglected area of research among spinal deformities during growth (in 2008, one paper in PubMed using “kyphosis” MESH term every ten using

“scoliosis”). Consequently, there is neither strong evidence on evaluation nor on treatment.

The aim of the present paper is to present the actual knowledge about HK during growth, its causes and treatment coming from our long-term experience and prevalent dedication to these pathologies.

### Theoretical basis of sagittal plane deformities treatment

Spinal sagittal deformities are posterior (kyphosis) or anterior (lordosis) pathological deviations, irreducible to a variable extent, being caused by structural disco-ligamentous modifications and vertebral bone changes of different aetiologies.<sup>7</sup> Because these deviations occur within the physiological curvatures of the spine, the latter can be excessively increased (THK or round back, lumbar hyper-lordosis), reduced (flat back, hollow back, hypo-lordosis, lumbar kyphosis) or modified in their normal distribution (JK, cervico-thoracic kyphosis).<sup>1, 2</sup>

Considering the Cobb angle measured on the lateral X-ray of the spine during stance, the values considered physiological during developing age for kyphosis are between 20-25° and 40-45°. For less than 20-25° we define a “flat back”, while for more than 40-45° we define THK.<sup>9</sup> Reference values for the lumbar spine are not well defined: the normality range can be considered between 20-25° and 50-65°. Lumbar lordosis can become more straight and eventually revert (lumbar kyphosis) or increase (Figure 1).

During growth, we can distinguish between structural and functional HK, the latter being of minor clinical importance, and entirely corrigible (round back, or postural HK). The kyphotic attitudes during the juvenile age could be attributed principally to a reduced strength of back extensor muscles, to which follows an increase of the physiologic thoracic curve. A certain degree of neuromotor control deficit superimpose to the muscular component, accompanied very often by a psychological introversion attitude. All adult kyphoses are structural, being characterised by rigidity of the curve, which cannot be totally reverted. The maturation of the spine causes, at the end of adolescence (Risser stages 3 to 5) a progressive stiffening of kyphosis. With this normal mechanism, a pathological but still functional HK can become a structural HK.<sup>1</sup> In some cases, rigidity can also be found in children, while on radiographs vertebral

bodies have normal size profiles and show no sign of wedging or endplate irregularity. In this case, too, there is a structural HK.

SCHK is the most frequent form of HK, having a mean estimated incidence of 18% in the population.<sup>5, 6</sup> This disorder is essentially caused by smaller height growth in the anterior region of vertebral bodies (wedge-shaped deformity) due to a transient histopathological modification of fertile cartilages (classified among osteocondrosis), with a consequent irregularity of endplate profiles and an inhibition of somato-vertebral growth correlating to secondary mechanical factors.<sup>10-12</sup> In its classic form, three or more continuous vertebral bodies, usually in the middle thoracic region, show at X-ray an anterior wedge deformity of 5° or more; nevertheless, sometimes only one or two vertebrae are wedged for more than 5°. The typical endplate alterations (thickening, undulance, Schmorl herniations, alterations of ringapophysis), can be seen also in not wedged vertebrae, despite eventually not present in wedged vertebrae. This deformity is often accompanied by a thoracic backache related to movement and posture (mechanical thoracic pain), which sometimes is the symptom that first brings the patient to the physician.<sup>13</sup> Generally, SCHK is considered mild when inferior to 50°, moderate between 50° and 70°, and serious when superior to 70-75°; nevertheless, when the deformity is localized outside the physiologic kyphosis should always be considered pathological. In these cases we can define the Atypical Lumbar SCHK or Type II SCHK.<sup>14</sup> This condition, relatively unknown, can be found at the thoraco-lumbar junction or at lumbar level, eventually as an angular kyphosis, usually not so evident for the involvement of just one or two vertebrae; it can frequently generate back pain, especially after intense mechanical solicitations.

JK is a so-called "long" kyphosis because it descends below T12, *i.e.*, it also includes L1 and L2 in the kyphotic tract (and sometimes other lumbar vertebrae). It can have a postural origin: muscle hyposthenia and poor back control drive the patient to "sit" on his/her back, with an inversion of physiological lordosis in the upper part.<sup>1, 2</sup> Otherwise, it can be caused by an osteochondrosis localisation at the cranial lumbar vertebrae (type II SCHK). Kyphosis is pathological solely on the basis of its positioning and the seriousness of somato-vertebral modifications, not for its angular value, which is generally limited to a few degrees. This condition predisposes the patient to

backaches as soon as early adolescence and even more in adulthood, given the degenerative nature of long-term outcomes. That is why it must be treated regardless of the angular value.

Lumbar lordosis rarely requires treatment. It is indeed a totally mobile spinal region, inserted between two stiff tracts (sacral and thoracic kyphosis), that is shaped according to postural needs due to fixed points: pelvic orientation and horizontality of the eyes. Therefore, a hyper-lordosis in upright posture is generally due to an increase of thoracic kyphosis and/or a pelvic antiversión.

### Hyperkyphosis clinical evaluation

The first general evaluation begins when the patient enters the examination room observing him/her.<sup>15</sup> It is possible to notice eventual rough deficits from gait, speech and undressing. A global observation and evaluation of the patient is required in order to assess the most affected somatic areas and posture alterations.<sup>15</sup> The patient should be evaluated in standing position, preferably while positioned on a podoscope, with straight legs and habitual posture. It is possible to evaluate the antiversión/retroversión of the pelvis, the abdominal prominence, the anteposition or retroposition of the trunk and the anteposition of the head.<sup>15</sup> Frontally it is possible to evaluate eventual rib cage abnormalities such as pectus excavatum or carinatum; from the back one can evaluate the symmetry of the shoulders, scapulae, thorax, waist, and finally the head.

The plumbline is used to assess the sagittal and frontal profiles of the spine, normally C7 and the intergluteal line. The frontal decompensation is set along the median sacral crest, and the discrepancy from the plumbline is measured at C7. The intraobserver repeatability is of 1 cm, so that 1.5 cm is the minimum to be considered significant when recorded in two different visits.<sup>16</sup>

Considering the sagittal profile, which is the most relevant in these patients, the distance from the plumbline is measured at the spinous processes of C7, T12 and L3 with respect to the most prominent points of the dorsal kyphosis (Figure 2). The intraobserver repeatability is 1.0 cm (2.0 for interobserver), so 1.5 cm is the minimum to be considered significant when recorded in two different visits of the same operator. It is also possible to measure the

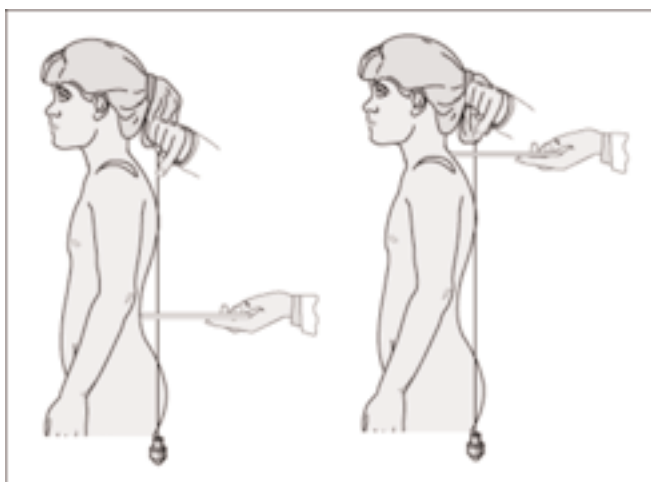


Figure 2.—Plumbline sagittal profile assessment.

trunk forward and backward decompensations by comparing the data to S1 instead of the apex of the dorsal spine.<sup>16</sup>

Other tools can be used to assess the sagittal profile: the Arcometer<sup>16</sup> and the Inclined, whose measurement error has been calculated (7° and 6°, respectively) give a measure quite similar to the one of the X-ray.<sup>17, 18</sup>

Since we are evaluating a growing patient, it is useful to verify the presence of scoliosis through a surface trunk analysis using a dedicated instrument called a Scoliometer: the patient is asked to forward bend with arms dangling and palms pressed together. The Scoliometer is placed on the back and used to measure the most leaning point of each hump.

Some electronic instruments are also available to complete the clinical evaluation. The Formetric is one of the most used instruments, that showed also a high sensitivity and precision and it is one of the most used tool and whose measurements showed to be quite similar to the one of X-ray.<sup>19</sup> Other instruments include Spinal Mouse, ISIS, Quantec, AUSCAN and others,<sup>20-26</sup> but up to date the lateral X-ray is still considered as the gold standard. The X-ray allows to verify the eventual presence of spinal deformities, the stage of maturation of the vertebrae and the measurement of the Cobb Angle relative to Kyphosis and Lordosis. The Kyphosis Cobb angle is generally measured by drawing perpendicular to the upper plate of the 4<sup>th</sup> thoracic vertebra and lower plate of the 12<sup>th</sup>. One of the limits of the X-ray evaluation relies in its

invasiveness, so many authors prefer after having verified the vertebrae morphology to use surface topography, that showed a good correlation to X-ray.<sup>19</sup> Moreover, a standard position for arms during X-ray acquisition is missing, and this introduces an error in our measure.<sup>27</sup>

### *Therapeutic approach*

The possible treatment for HK are: specific exercises, rigid brace accompanied by specific exercises, a plaster cast and eventually surgery.

Specific exercises can be effective when the thoracic spine has not developed a relevant stiffness and when the sagittal curve is not too high: considering kyphosis Cobb Angles, they are usually proposed from 45°±5° to 55°±5°,<sup>2</sup> while when considering the plumbline distance from C7 to the apex of kyphosis from 50 mm to 60-65 mm. Their aim is to reinforce the strength of back muscle and educate the children to reach and maintain a correct sagittal alignment. In some cases it is necessary to improve the mobility of the spine while we proceed with the strengthening.<sup>28</sup>

A rigid brace should be used when HK Cobb Angle is 55°±5° to 65°±5°,<sup>2</sup> or the plumb line over 70±5 mm. Initially, the hours of wearing should be at least 18 up to 23, according to the rigidity and the degree of vertebral deformity. During brace wearing, specific exercises should be performed in order to improve the efficacy of the brace pushes and to reduce the spinal stiffness.<sup>28</sup> After the achievement of the necessary correction, the brace should be gradually removed, increasing progressively the daily number of hours free from brace, thus accustoming the trunk to self sustain. During brace weaning, the relative role of exercises grows up progressively, since they determine the efficiency of trunk extensor muscles. When the HK is more relevant, more than 65°±5° up to 75°±5°, there is indication for a plaster cast,<sup>2</sup> that will be later replaced by plastic braces whose timing will be progressively reduced. Some authors<sup>5</sup> suggest that for HK more relevant, over 75°±5°, there is an indication for a surgical treatment, but there is no shared consensus about this indication.

In our experience, we can report pretty good results with rigid braces and a good exercise program even in really serious HK, thus progressively reducing the need for plaster casts.



Figure 3.—Braces for hyperkyphosis. A) Milwaukee brace. B) Boston brace. C) Lyon brace. D) Maguelone brace. E) Lapadula-Sibilla brace.

#### BRACES FOR ADOLESCENT HYPERKYPHOSIS

*Indications and goals.*—Literature about adolescent HK bracing is very few and the available studies on efficacy of brace treatment are only retrospective studies, with different inclusion criteria, and without control groups. Majority studies are about SCHK and, perhaps due to incomplete understanding of the natural history of this pathology, the indication for brace treatment are not well defined and differ between these papers. According to our knowledge and those of most of authors, bracing are used in the case of structural HK or JK that is no longer reversible through exercises because it is too stiff or because exercises have already proved insufficient; and in all cases of SCHK with pathological curvature.

According to the literature, the “classic” prerequisites for brace treatment of SCHK include patients that have at least a 45°-curve up to 65°.29, 30 Curves greater than 74° have been associated with a higher failure rate,<sup>9</sup> and thus this magnitude of deformity has been declared by some as an indication for surgery.<sup>5</sup> Candidates for bracing need to have some flexibility in the curve and must be skeletally immature (at least one remaining year of growth).

The authors from ISICO observed that the “timing” of start is decisive in obtaining the final outcome:<sup>31</sup> it is important not to arrive at an excessive degree of stiffness that would endanger the achievement of an adequate correction even if, in the first instance, it is nearly always better to implement exercise treatment, which is less invasive and thus a preferable as first approach.

In the case of sagittal plane deformities, brace therapeutic goal is a full correction.<sup>2</sup> If the patient shows an adequate compliance, correction is complete for HK, very good for a thoracic SCHK (mainly on the overall sagittal shape of the spine, and much less on the deformity of the single metamers (which in part can recover) and good to moderate for a JK.

*Most common type of braces.*—The most common brace presented in studies retrieved is the modified Milwaukee brace (Figure 3A), that has posterior pads (attached to the posterior bars) pushing anteriorly on the kyphosis, with both the neck and pelvis controlled by the upper and lower segment of the brace. The brace is adjusted monthly, and ideally is worn 23 hours a day for 1 to 2 years.

Gutowski and Renshaw<sup>30</sup> have reported on the use of the Boston lumbar brace (Figure 3B) and they recommended it for flexible curves below 70° in magnitude with an apex at or below T7. These braces work under the assumption that flattening the excessive compensatory lumbar lordosis will result in the patient hyperextending the thoracic spine to stand erect.

A classic principle with which are made common braces for HK is the three point concept, utilized in the Lyon Brace for HK (Figure 3C): this is a bivalve rigid brace with a posterior shell usually T7-S3 and an anterior shell with a manubrial thrust reinforced by a metallic bar. Similarly some used also a bivalved overlapped brace sometimes with a cervical collar named Spitzzi collar.

The authors from ISICO use two main type of braces

in which the mechanical efficacy is based on a direct push on the kyphosis apex, which is the actual stiff zone to be corrected. Thrusts in other regions of the spine must be avoided, so as not to cause an excessive straightening in unaffected areas. The anterior thrust to the spine is obtained by directly acting on the clavicles in order to have an effective posterior push of the spine, in a place that is not highly sensitive and where dresses can succeed in masking the brace. This is a crucial point, to increase compliance and achieve better results according to our principles of bracing.<sup>28, 32</sup> Consequently, we do not use sternal pushes, which mostly cause a closure of the shoulders that drives towards kyphosis. Neither do we use acromial pushes, because they usually cause pain and excessively (and uselessly) limit the mobility of the shoulders. We teach the patient to escape from the clavicle pushes all day long in order to learn a new posture, strengthen useful muscles and progressively mobilize the rigid tract of the spine against the posterior apical push. This is much better achieved through specific in-brace exercises, as well as through a stabilizing one during the weaning period. The brace we used according to this principles is called Maguelone (Figure 3D), and is a custom-made, two-valve TLSO with posterior thoracic and sacral thrusts interconnected by three metal bars and one anterior plastic abdomen moulded in hypolordosis and connected with two stiff metal clavicle pushes. The name "Maguelone" is due to its origin from the HK corrective principles described by Perdrille, but it has been developed by Sibilla *et al.*<sup>31</sup> This brace is highly effective and very dedicated to the most frequent pure THK with apex from T5-6 to T8-9. However, because its structure is not very versatile it should not be used in other kyphoses, nor should it be used if there is an associated important scoliosis.

The authors from ISICO also use a different braces for HK other than TK, and for all combined pathologies (*i.e.*, including scoliosis and/or spondilolisthesis). The Lapidula-Sibilla brace (Figure 3E) is a one-valve, custom-made plastic LSO with a median frontal clasp that enwraps the chest from the submammary line to the groin, and posteriorly from T5 to the buttocks. This brace, originally created for lumbar and thoraco-lumbar scoliosis, is versatile and allows the control of all situations in which HK is not the typical thoracic one with a T8 apex. This is because it can also protect the frontal and horizontal planes while following the entire course of sagittal curvatures. Pushes

are obtained through pads that are properly moulded and positioned, in symmetrical or asymmetrical ways, at the metameric level demanded by the specific clinical situation, as well as the escapes, which are usually obtained through posteriorly openable windows in the body of the brace. Maguelone clavicle pushes can be applied to the Lapidula-Sibilla brace as well, but their use must be avoided in lumbar and thoraco-lumbar diseases to avoid an improper straightening of the upper thoracic spine.

*Results of braces.*—An initial report on Milwaukee brace treatment of SCHK was published in 1974 by Bradford *et al.* who documented in 75 patients a 40% decrease in mean THK and a 35% decrease in mean lumbar lordosis after an average 34 months of brace wear.<sup>29</sup> In a later study from the same centre<sup>30</sup> observed in 120 patients an initial correction of approximately 50% of the HK followed by loss of correction. The average time of brace wear was 14 months fulltime and 18 months part-time. At average five-year follow-up, consistent brace wearers had an improvement in the HK in 76 patients, worsening in 24 and no change in 10.

Bradford *et al.* found that the amount of flexibility of the HK on an initial hyperextension radiograph did not correlate with the final correction.<sup>29</sup> Sachs *et al.* concluded that an initial HK >74° was associated with a higher percentage of poor results, yet their data show that 9 of 14 patients in this group had some improvement of their kyphosis.<sup>9</sup>

Montgomery and Erwin reviewed 39 patients with SCHK treated with a modified Milwaukee Brace for an average of 18 months.<sup>33</sup> The HK before treatment averaged 62° and at the completion of brace treatment averaged 41°. Follow-up of more than 18 months after completion of brace wear showed an average of 15° loss of correction, resulting in an average overall correction of 6°. Wedging of the vertebral bodies improved from 7.9° to 6.8° with brace treatment. They found that brace treatment was successful in improving HK greater than 75° in several cases.

Gutowski and Renshaw reported on the use of Boston lumbar and modified Milwaukee orthoses for SCHK and abnormal juvenile round-back with an average 26-month follow-up.<sup>30</sup> Of 75 patients in their study group, 31% completely rejected the orthosis within four months. Compliant patients had an average improvement in HK of 27% in the Boston group and 35% in the Milwaukee group, despite use of the

Milwaukee brace for older patients who had greater curves. Authors reported “surprisingly effective” results with the use of a modified Milwaukee orthosis in their patients with HK of 75° or greater.

Riddle presented a study with a newly designed brace, the DuPont kyphosis brace, in a group of 22 children with SCHK.<sup>34</sup> Of these 22 children, 9 demonstrated an improvement, 7 remained unchanged, and 6 demonstrated progression of the HK. It was recommended that the brace be worn until skeletal maturity, which in this series was at least 16 months. Flexible deformities seemed to predict successful brace treatment. The authors found that the DuPont brace results were comparable to those with the Milwaukee brace with additional advantage of concealment under clothes.

With use of Maguelone brace the authors from ISICO observed retrospectively 15 patients (5 of them with a diagnosis of HK and 10 with a SCHK) arrived at the end of treatment to assess efficacy of brace treatment on clinical parameters (plumbline distances). We observed a significant change of C7 and L3 distances in both groups. We evaluated also the number of patients for which there was a significant change for C7 and L3 according to a previous study,<sup>35</sup> where we considered clinically significant a change of at least 10 mm for C7 and 15 mm for L3. About C7 we reported in the SCHK group 70% improved and 30% unchanged and all patients improved in the idiopathic one; about L3 60% improved in the SCHK group while 90% of them improved in the HK group.

All of these brace studies were retrospective case series, or Level IV evidence, that are presented in two papers that tried to analyse SCHK from the etiology to the treatment.<sup>36, 37</sup> Even if we have not strong methodological studies, observation demonstrate that brace are effective in the treatment of adolescent HK both idiopathic and SCHK, with a permanent correction of vertebral deformity.<sup>16</sup>

## Exercises for hyperkyphosis

### *Patient's physiotherapeutic evaluation*

The patient's evaluation allows us to achieve two essential goals: to adapt therapeutic modalities and evaluate treatment results. The examination regards the body as a whole. Therefore, it is necessary to have a global view of the subject, bare-chested, in an upright

posture; and in the frontal, lateral and back views. In the static examination, we must highlight the following: feet equilibrium, lower limb alignment, sagittal and frontal pelvic balance, hip asymmetry, the abdomen, the spine as a whole, every possible morphological disharmony of the chest, and finally the shoulders and bearing of the head.

Sagittal posture is measured through the distances from the plumb line in order to highlight the different forms of deviation and their magnitude (Figure 2). The evaluation of joint mobility in general and of the spine in particular, through axial auto-stretching, allows us to highlight stiff regions within the curvatures. You should be particularly careful during the evaluation of musculo-articular retraction, particularly in regard to the stretching of certain muscular groups (pectoral muscles, upper recti, psoas, ischio-crural retraction) that have a negative influence on sagittal curves. To complete the evaluation, you will proceed to the analysis of the moving subject given that the observation of coordination and balance can influence therapeutic choices. Equally important is the need to record possible aggravating factors such as visual disorders, excessive shyness, psychological disorders and so on, which can sometimes require the intervention of an expert in such problems.

### *Exercises*

Only a few studies among those published into indexed literature deal with exercise efficacy in adolescence HK treatment. The main part of the articles in fact deal with the effect of exercises in reducing the fracture risk in adults with HK<sup>38</sup> an fall risk in elder.<sup>39</sup> Even without scientific evidence of efficacy, in many patients specific exercise represent a therapeutic tool commonly used for HK. Exercise are used both in case HK and SCHK, an according to the severity can be performed alone or used to accompany a brace treatment.<sup>35, 40</sup> Generally speaking, the objectives of the exercise treatment are not shared among experts, especially for the lack of data about aetiopathogenesis. Recently, the international scientific Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) ([www.sosort.onet](http://www.sosort.onet)) performed a Consensus on HK treatment that will soon be published in the journal *Scoliosis* ([www.scoliosisjournal.com](http://www.scoliosisjournal.com)).<sup>3</sup> Some authors believe HK to be secondary to muscular retractions, so the treatment they propose is based on the recover of the proper length of involved muscles.<sup>41</sup>

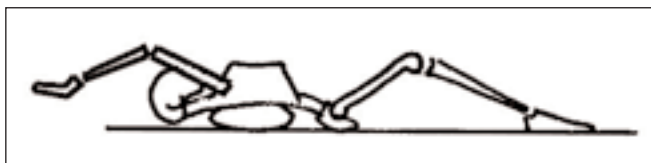


Figure 8.—Example of an exercise to increase mobility at the apex of kyphosis.

Other authors believe some pelvic balance alterations to be the origin of the sagittal alterations, and plan consequently the treatment.<sup>42, 43</sup>

Some evidence of the efficacy of physical exercise for the sagittal profile derives from studies performed on young athletes during which it was observed that an intense sport activity correlates with an increment of the sagittal curves.<sup>44, 45</sup> Consequently, we can assume that exercise able to correctly orientate pressure and forces on the spine can improve HK and we can cite some studies that showed a reduction of new vertebral fracture risk in patients who underwent a vertebroplastic intervention with a specific and intense programs of trunk extensor muscles reinforce.<sup>46</sup>

According to our clinical experience, treatment objectives are:

1. increase of mobility and elasticity of the thoracic spine in the direction of the extension;
2. reinforce of the endurance capability of trunk extensor muscles;
3. recover of muscular retractions when present;
4. learning of correct posture to be adopted in everyday life activities;

The first objective is to improve the capability of thoracic spinal extension, because frequently these patients show an abnormal stiffness, especially near the curve apex. It is advisable the use of supports on which the patients can hang to strongly deflect toward straightening (Figure 8) or with the help of an external operator to apply a proper pressure with the aim of improving the elastic properties of the spine.

The second objective of treatment is to reinforce endurance capability of trunk extensor muscles, to give the patient “tools” to help him/her to contrast the postural trend toward a forward bending. The exercises will be performed through an isometric contraction to stress resistance. Some loads or decompenstate postures can be used to help this action (Figure 9).

Beside the seek for retracted muscular chains balance



Figure 9.—Example of an exercise to strengthen back muscles isometrically in extension with forward unbalance in hyperkyphosis patients.

and elasticity, the final objective of treatment is the progressive education of the patient at maintenance over time of a correct posture with a correct spinal alignment, especially while sitting, the moment when the postural trend will show an increased forward flexion. This postural re-education is the main step of treatment because exercises devoted to improvement of spinal mobility and muscular endurance in spinal support are only tools to be used to achieve a good sagittal posture. Even a strong and elastic spine can unconsciously collapse forward for the gravity force that attempt at flex it, if the patient is not enough trained to actively face this posturale trend.

## Conclusions

HK during growth remain quite a neglected area of research. Treatments aims at reducing esthetic impairments and pain during growth and, while allowing a proper sagittal development of the spine, aims also at reducing disturbances in adulthood like pain and progressive flexion with time. Even if traditionally these approaches have been made mainly by orthopedic surgeons, the treatment tools used for the so-called “conservative management” (we prefer rehabilitation approach) are mainly in the Physical and Rehabilitation Medicine speciality domain, including braces and exercises.<sup>47</sup>



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