

Sagittal Imbalance

A patient guide

In brief: Sagittal imbalance is the loss of the normal front-to-back alignment of the spine, so that the trunk and head come to be carried forward of the pelvis and feet, producing a stooped, forward-tilted posture that is tiring to hold upright. It is best understood not as a single curve but as a whole-spine and pelvis problem: a summary of how the neck, chest and lower back curves, together with the position of the pelvis, succeed or fail in keeping the head balanced over the hips. This makes sagittal imbalance the broad, umbrella condition of which several more specific problems, such as flat back syndrome and proximal junctional kyphosis, are particular causes. It is one of the most important ideas in modern spinal deformity, because of all the ways a spine can be misshapen, it is forward imbalance in this sagittal plane that correlates most strongly with pain and disability.

What sagittal imbalance is (and why it is the broad, whole-spine concept)

Viewed from the side, a healthy spine is not straight. It forms a series of gentle, reciprocal curves: a forward curve in the neck, a backward curve in the chest, and a forward curve in the lower back, all sitting on a pelvis tilted to a particular angle. The purpose of this arrangement, often called the chain of balance, is to carry the head directly over the pelvis and the hips with as little muscular effort as possible, so that standing upright feels almost effortless. The term sagittal simply refers to this side-on, front-to-back plane, as distinct from the side-to-side plane in which scoliosis is measured.

Sagittal imbalance describes the state in which this side-on alignment is lost and the upper body comes to sit in front of the pelvis rather than over it. The key idea, and the one that sets this condition apart from its neighbours, is that sagittal imbalance is a global, whole-spine measurement rather than a single regional curve. A surgeon assessing it does not look at one part of the spine in isolation; the whole column, from the head down to the pelvis, is measured against gravity to see whether the head finishes up balanced over the hips or pitched forward of them.

This is why sagittal imbalance is described as the broad concept of which other conditions are particular causes. A loss of the forward curve in the lower back, known as flat back syndrome, is one specific way of producing sagittal imbalance. A kyphotic collapse at the top of a previous spinal fusion, known as proximal junctional kyphosis, is another. A wedged osteoporotic fracture, or a stiff degenerative spine that has lost its lordosis with age, can do the same. In each case the underlying mechanisms differ, but the final common picture, the forward-tilted trunk, is the state of sagittal imbalance. Understanding it therefore means understanding both the global alignment and the various regional faults that can produce it.

The spinopelvic parameters: the language of alignment

Because sagittal imbalance is a question of whole-spine geometry, it is described using a set of measurements taken from a side-on, full-length standing X-ray. These spinopelvic parameters form the language in which the condition is discussed, and a brief account of them makes the rest of the picture intelligible.

Pelvic incidence is the most fundamental of them. It is a fixed, individual measurement of the shape of the pelvis that does not change with posture once growth is complete. Its importance is that it sets how much forward curve, or lordosis, the lower back *needs* in order to be balanced: a person with a high pelvic incidence requires a deep lumbar curve, while a person with a low pelvic incidence needs only a shallow one. Pelvic incidence is therefore the master variable against which everything else is judged.

Lumbar lordosis is the depth of the forward curve in the lower back. The crucial comparison is between pelvic incidence and lumbar lordosis, the so-called **PI-LL mismatch**. When the lordosis fails to match what

the pelvis demands, a mismatch develops, and a difference greater than about ten degrees is a recognised marker of abnormal sagittal alignment.

****The sagittal vertical axis**** is the most directly meaningful measurement of imbalance. It is the horizontal distance by which a plumb line dropped from the base of the neck falls in front of the back of the sacrum. The further forward this line falls, the more the trunk is pitched ahead of the pelvis. A value beyond about fifty millimetres is regarded as positive sagittal malalignment, and it is this measurement that correlates most consistently with pain and disability.

****Pelvic tilt**** measures how far the pelvis has rotated backwards in an attempt to compensate, and ****T1 pelvic angle**** is a more modern measurement that captures both the forward lean of the trunk and the backward rotation of the pelvis in a single number, with the advantage that it is not disguised by the body's own compensation. Together these parameters allow a spine to be described precisely and compared against age-appropriate norms.

The compensation cascade and why it fatigues

One of the most important features of sagittal imbalance is that the body fights hard to conceal it. When a regional curve is lost, most often the forward curve of the lower back, the spine does not simply tip forward straight away. Instead it recruits a stereotyped, ordered sequence of compensatory manoeuvres, all aimed at keeping the eyes level and the head over the pelvis for as long as possible.

The first and most powerful of these is backward rotation of the pelvis, known as pelvic retroversion, which swings the base of the spine back underneath the trunk and shows up as a rise in pelvic tilt. When that reserve begins to run out, the chest curve flattens to bring the upper trunk back, and the neck extends to keep the gaze horizontal. Finally, when the spine and pelvis have done all they can, the knees bend and the ankles flex, dropping and shifting the whole body backwards to keep it from falling forward.

This cascade explains the central distinction between a **compensated** and a **decompensated** spine. A spine may be regionally abnormal, with a flattened lower back, yet still hold the head over the hips by means of a retroverted pelvis and slightly bent knees. Such a spine is compensated, and the forward imbalance is hidden. Only when these reserves are exhausted does the trunk visibly pitch forward, the sagittal vertical axis climb, and the deformity become decompensated and obvious. The same underlying fault can therefore be silent or striking depending on how much compensation remains.

The reason compensation fatigues is that none of it is free. Holding the pelvis retroverted and the knees bent against gravity is continuous, active muscular work, performed by the buttock, thigh and back muscles, in place of the near-effortless ligamentous balance of a normal spine. This raises the energy cost of simply standing. It produces the characteristic pattern reported in the literature, in which discomfort and exhaustion build through the day and on walking or standing, and ease on sitting or lying down. The hips and knees, pressed into service as accessory balancers, may themselves become painful. The forward-stooped posture of decompensated sagittal imbalance is, in essence, the visible sign that this exhausting compensatory effort has finally been overwhelmed.

How it differs from its neighbours

Because the spine can be misshapen in several planes at once, it is worth setting out plainly how sagittal imbalance differs from the conditions with which it is most often confused.

****Coronal scoliosis**** is a side-to-side curvature with rotation, measured in the frontal plane. Sagittal imbalance, by contrast, is a front-to-back alignment problem measured in the side-on plane. The two frequently coexist, particularly in degenerative scoliosis of later life, but they are distinct measurements, and the published evidence is consistent that it is the **sagittal** component, not the size of the side-to-side curve, that correlates best with disability.

Isolated kyphosis, such as a Scheuermann curve in the chest, a post-traumatic angulation, or an osteoporotic wedge fracture, is a **regional** increase in forward curvature. It only amounts to sagittal imbalance once the rest of the spine and the pelvis can no longer compensate for it and the head moves forward of the hips. In other words, a regional kyphosis is a possible cause of sagittal imbalance, not the same thing as it.

Flat back syndrome is the most specific cause to distinguish. It refers to loss of the forward curve of the lower back, classically described after older spinal fusions that flattened the lumbar spine, and also arising through degeneration. It is therefore one particular regional mechanism that produces global sagittal imbalance, rather than a synonym for it.

Proximal junctional kyphosis is a focal kyphotic failure at the upper end of a previous fusion construct. It is described in the literature as a recognised cause and complication that can secondarily tip a previously balanced spine into forward imbalance. Once again, it is a specific local fault sitting beneath the broad umbrella of sagittal imbalance. Holding these distinctions in mind, the global versus regional, the sagittal versus coronal, and the compensated versus decompensated, is the key to understanding where any individual problem fits.

How it is classified (SRS-Schwab and the GAP score)

To bring order to this complexity, two classification frameworks are widely used in the literature, and both are worth describing because they shape how the condition is discussed.

The **Scoliosis Research Society–Schwab classification**, validated in 2012, gives adult spinal deformity a common language. Alongside a description of any coronal curve, it grades three sagittal modifiers, each as normal, moderate or marked: the PI–LL mismatch, the sagittal vertical axis, and the pelvic tilt. The value of this system, demonstrated in a large prospective cohort, is that progressively worse grades of these sagittal modifiers were associated with progressively poorer quality of life and a greater likelihood of needing major surgery. In other words, the classification does not merely describe the deformity; the sagittal grades track how much the deformity matters to the person living with it.

The **Global Alignment and Proportion score**, published in 2017, takes a subtly different and influential approach. Rather than measuring the spine against universal target numbers, it assesses whether the correction is **proportionate** to the individual's own pelvis, using pelvic-incidence-based proportional measurements together with the person's age. The score sorts spines into proportioned, moderately disproportioned and severely disproportioned categories, and was developed to predict mechanical complications after deformity surgery, such as kyphosis above a fusion or breakage of the metal rods. Its central insight, that what matters is the proportion of correction relative to a person's own anatomy rather than hitting one fixed value, has been important, although later validation studies have found its predictive power to be more variable than the original work suggested. This nuance is itself part of an honest account of the evidence.

Age-adjusted alignment targets

A development of considerable practical importance has been the recognition that the ideal alignment for a spine is not the same at every age. For many years, a single set of targets, such as a sagittal vertical axis under fifty millimetres and a small PI–LL mismatch, was applied to everyone. Careful study of how alignment relates to disability across age groups showed that this was too rigid.

The work on age-adjusted alignment targets demonstrated that the ideal values for the sagittal vertical axis, the pelvic tilt and the PI–LL mismatch all increase with age. Put plainly, an older person can carry a somewhat more forward-set spine and still function well, whereas a younger person needs a more upright correction. The practical consequence reported in the literature is that correcting an older spine too aggressively, to make it resemble that of a young adult, is associated with a higher rate of kyphotic failure at the top of a fusion. Matching the goal to the person's age, rather than to a single universal ideal, has been shown to reduce that complication without sacrificing the improvement in quality of life. This principle of an age-appropriate, individualised target now runs through the modern understanding of the condition.

The relationship between imbalance and disability

The reason sagittal imbalance occupies such a central place in spinal deformity is the strength of its relationship with how people actually feel and function. A landmark study of several hundred adults with spinal deformity found that, of all the radiographic measurements considered, it was positive sagittal balance, the forward offset of the trunk measured by the sagittal vertical axis, that correlated most strongly with poorer scores on validated measures of pain, function and quality of life. The relationship was graded, meaning that the further forward the trunk had drifted, the worse the reported disability, and it held whether or not the spine had previously been fused.

This finding reframed the whole field. It established that the sagittal plane, rather than the coronal curve that the eye notices first, is where the burden of adult deformity largely lies, and that restoring front-to-back balance is a central goal of treatment when treatment is undertaken. Later work confirmed that pelvic tilt and the forward inclination of the trunk add further information about disability beyond the sagittal vertical axis alone. The consistent message of this body of evidence is that sagittal imbalance is not merely a matter of appearance; it is the deformity parameter most tightly linked to suffering and loss of function, which is precisely why it is measured, classified and, in selected cases, corrected with such care.

What the evidence shows about management (conservative vs realignment surgery) — impersonal

It should be said clearly at the outset that the evidence base for managing sagittal imbalance rests largely on prospective and retrospective cohort studies, radiographic-outcome correlations and classification work, rather than on randomised trials, which are scarce in adult spinal deformity. The account that follows is therefore a description of what the literature reports, not guidance for any individual, and decisions in practice are individualised.

****Conservative, non-surgical management**** is the starting point for many people, particularly where the imbalance is mild, well compensated, or where general health makes major surgery unwise. The reported approach centres on pain relief, physiotherapy directed at the strength of the hip and trunk muscles that share the work of balance, posture and activity modification, walking aids where helpful, and attention to bone health. Bone health carries particular weight here, because thin bone both contributes to the deformity, through compression fractures, and can threaten the fixation if surgery is later undertaken. Non-surgical care tends to stabilise symptoms and support function rather than to correct the underlying structural malalignment, and the literature describes it as a substantial and legitimate pathway in its own right.

****Surgical realignment**** is described for more severe, decompensated or progressive deformity, and its goal is to restore proportionate lower-back curve, matched to the individual's pelvic shape, and to bring the global alignment

back into an age-appropriate range, then to stabilise it. Where the spine is still mobile, this may be achieved with releases and interbody techniques; where it is stiff or already fused, a wedge of bone is removed to swing the spine back upright, a procedure known as an osteotomy, of which the pedicle subtraction osteotomy is the best known for correcting fixed imbalance. The literature is candid that this is major surgery carrying a significant burden of complications, including kyphosis above the fusion, breakage of the metal work and failure of bony union, which is precisely why the age-adjusted targets and the proportion-based scoring described above were developed, to temper the correction and avoid over-doing it. Comparative cohort data suggest that, in carefully selected patients, surgery produces larger improvements in function than non-surgical care, but at the cost of these higher complication rates. The balance between the two pathways is therefore an individual judgement made with the treating team rather than a fixed rule.

Outlook

The outlook in sagittal imbalance varies as widely as its causes. Where the imbalance is mild and well compensated, many people remain comfortable and active for long periods with conservative measures, and the principal task is monitoring for any progression and supporting the muscles that share the work of balance. Where the spine has decompensated and the trunk is fixed in a forward stoop, the burden, in terms of fatigue, pain and difficulty with everyday upright tasks, can be considerable, which is the very reason the condition is taken so seriously.

For those who undergo realignment surgery, the published cohorts report meaningful gains in pain and function when balance is restored to an age-appropriate target, set against a real risk of mechanical complications that may require further surgery. The consistent themes across the whole field are that the sagittal plane is where most of the disability of adult deformity resides, that correction should be proportionate to the individual and their age rather than aimed at a single universal ideal, and that recovery and outlook are best understood as individual matters shaped by the particular cause, the degree of compensation remaining and the person's general health. Any individual outlook is a matter for assessment by the treating team rather than something that can be read from a category alone.