ERGONOMICS
RETHINKING CLASSROOM SEATING

FIRA International Limited
www.fira-international.com
Registered office: 3rd Floor, Davidson Building, 5 Southampton Street, London, United Kingdom, WC2E 7HA. Registration Number: 03181481.

This Report relies on the information and conclusions contained in the referenced documents at the end of the report and has been prepared by a team of ergonomic experts employed or formerly employed by FIRA International Limited, including:

- Claire Clark, head of Ergonomics at FIRA International, MSc Ergonomics & Human Factors. Claire is a registered member of Chartered Institute of Ergonomics and Human Factors. She has 13 years of experience working in human factors/ergonomics roles. She is a committee member for the European Committee for Standardisation's (CEN) committee on educational furniture.
- Levent Caglar, head of Consultancy and Chief Ergonomist at FIRA International, MSc Ergonomics, University College, London. Levent has over 30 years of experience in ergonomics and human factors. He is the chair of CEN's committee on educational furniture.
- Hellen Davies, ergonomist, MSc Human Factors for Inclusive Design, BSc (Hons) Psychology. Hellen has three years of experience working as an ergonomist.

1. INTRODUCTION

In this report FIRA International has drawn on research from fields of study including education, child development, anatomy and biomechanics, ergonomics, and neuroscience to help understand important factors in learning environments that contribute to children's physical and mental well-being, and cognition. This paper will discuss the effect that the current education system, educational environments, and recent developments in society are having on children's outcomes both in terms of health and academic success. It will also highlight how changes in the way education is delivered and small changes to the classroom environment could help to combat some of the challenges faced by children and educators today. It is intended to be a resource for therapists and educational decision-makers. This resource evaluates conventional seating in early years settings and suggests that alternative seating options would improve children's health, success, and well-being.

2. OVERVIEW

This paper will discuss how movement is critical to children's development, both physical and cognitive. It will explore the challenges posed by traditional classroom seating and the impact on the human body, how this affects cognition and what research advocates to help overcome these challenges. Whilst this paper is relevant to the whole of the education system, the focus is on how early years settings can help children to develop necessary motor skills and good postural habits to help them succeed when they reach school. It is hoped that along with improvements in early childhood settings, the educational system at large will adapt to meet the needs of children as they grow, providing school environments that nurture their health, wellbeing, and academic success.

3. IMPORTANCE OF MOVEMENT

3.1 Impact of Education System on Children's Physical Activity

Humans are not designed to be static. Young children have lots of energy and move all the time; however, children tend to become more sedentary after entering the education system due to several factors related to the structure and demands of school environments. Once children start school, they spend a significant portion of their day sitting. An Australian study tracking students with wearable devices revealed that class time is the largest contributor to sedentary behavior, with students sitting for up to 75% of the time (Arundell et at, 2019). Another meta-analysis review (Kruzik et al, 2022) stated that "Evidence indicates that children spend most of their school day sedentary, with one meta-analysis estimating that on average 63% of the school day is spent sedentary for children and adolescents in the United States," referencing the following paper (Egan et al, 2019).

Many schools have reduced or eliminated break times (recess) and physical education (PE) classes to focus more on academics. As a result, students have fewer opportunities to engage in physical activity during the school day. Even when break time is provided, it is often too short to counteract the long periods of sitting. Researchers have suggested that a decrease in opportunities for children to move in school will result in lower academic achievements (Center for Public Education, 2008). This could be due to reduced brain activity when the body is inactive (Breithecker, 2006).

A sedentary school day may also be followed by sedentary activities at home, such as doing homework and engaging in screen-time activities like watching TV or playing video games. The effects of this are discussed later in this paper. Sedentary lifestyles can negatively impact academic performance and cognitive development. Physical activity, on the other hand, has been shown to improve academic achievement, retention, and focus.

Decreased opportunities for children to move in school and at home is a concern, as sedentary behavior has been linked to various negative health outcomes. The World Health Organization (WHO) has published guidelines on physical activity and sedentary behavior (World Health Organization, 2020), and within these guidelines a section detailing sedentary behavior guidelines for children and adolescents (aged 5–17 years) states that "In children and adolescents, higher amounts of sedentary behavior are associated with the following poor health outcomes: increased adiposity; poorer cardiometabolic health, fitness, behavioral conduct/pro-social behavior; and reduced sleep duration." In its 2019 guidelines for children 5 years old and younger, WHO states that adequate physical activity "is associated with better motor and cognitive development, psychosocial (emotional regulation) and cardiometabolic health, bone and skeletal health and reduced risk of injuries." In addition, the organization states that "time spent restrained should be limited" for this age group.

3.2 Other Factors Affecting Child Development

3.2.1 Technology Use

Increased use of technology can impact motor skill development, which is crucial during early childhood. Children spending significant time looking at screens are likely to engage in less physical play, which is essential for the development of both gross and fine motor skills. Activities like running, jumping, and playing with physical toys help children develop coordination, balance, and strength. While some screen-based activities can help with fine motor skills (e.g., using a touchscreen), they do not replace the broad range of fine motor activities that are crucial during early years, such as drawing, cutting with scissors, or building with blocks. A study in Jama Paediatrics highlighted that children with longer screen time exposure had delays in the development of fine motor skills (Takahashi et al, 2023).

In addition to longer screen time being associated with delays in the development of fine motor skills, a study by researchers at Drexel's College of Medicine (Heffler et al, 2024) found that babies and toddlers exposed to early digital media experiences may be more likely to exhibit atypical sensory behaviors, such as being disengaged and disinterested in activities, seeking more intense stimulation in an environment, or being overwhelmed by sensations like loud sounds or bright lights.

Sensory processing refers to the way a person's nervous system receives sensory messages and turns them into responses allowing a person the ability to register, discriminate, adapt and respond appropriately, both physically and emotionally to sensory input from our bodies and the environment. These senses include sight, sound, touch, taste, body position, and movement. When normal sensory processing is disrupted, it can have various undesirable consequences for a child's ability to navigate their environment from a sensory perspective. Therefore, this study linking screen time with atypical sensory behaviors is important to note given the findings of this study suggest that:

- At 12 months, any screen exposure compared to no screen viewing was associated with a twofold increased risk of exhibiting behaviors related to low registration at 33 months, meaning they may require lots of stimulation or a more intense sensory stimulus in order to respond than children displaying typical sensory behaviors.
- At 18 months, greater screen exposure was associated with increased risk of high sensation avoiding, and low registration. High sensation avoiding is characterized by an oversensitivity to certain sensory inputs.
- At 24 months, greater screen exposure was associated with increased risk of high sensation seeking, sensory sensitivity, and sensation avoiding.

Sensory issues can exist on their own but are sometimes seen with conditions like attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD). Hefler et al's paper also references research that indicates early screen exposure is associated with other suboptimal developmental outcomes, including language delay, lower cognitive development, behavioral problems, emotional dysregulation, and sleep problems. Given what we are coming to understand about the negative effects of increased screen time on young children, it is important to acknowledge these and consider how educational settings might help to mitigate these negative effects.

3.2.2 COVID-19 Pandemic

The COVID-19 pandemic offered a unique opportunity to study what happens to children when they are placed in environments that limit movement, freedom to play outside, and opportunities to socialize outside of their family unit. As health experts suggest that future lockdowns are more than likely, it's worth considering how to mitigate the detrimental impacts of these events on children in the learning environment.

During COVID-19, reduced opportunities for physical activity and structured play notably impacted children's motor skills development. Many affected children have missed key developmental milestones due to reduced social interaction and physical activity during lockdowns. One study found an association between the experience of COVID-19 and a higher risk of neurodevelopmental delay in the fine motor and communication domains in 1-year-old children (Huang et al, 2021).

Another study conducted in the Netherlands found that the lockdowns resulted in significant delays in the development of fundamental motor skills among children aged 6-7. This longitudinal study used the 4-Skills Test to measure components such as jumping force, bouncing a ball, and standing still, and found that children who experienced lockdowns performed worse than those who did not (den Uil, et al, 2023).

Research focusing on Taiwanese preschoolers indicated that the frequency, time, and intensity of physical activities were significantly reduced during the pandemic. This decrease led to poorer performance in stability, locomotor, and manipulative movement skills (Cheng, et al, 2023).

In 2022 the Nuffield Foundation published a report on the implications of COVID for early childhood education and care (ECEC) in England (la Valle et al, 2022), part of their study included qualitative case studies to explore views of parents, ECEC providers, and local authority early years staff; the perceptions of the participants in these case studies revealed the following implications of disruptions in ECEC arrangements:

- Speech and language delays were reported across all age groups as children had fewer opportunities to develop their communication skills at home.
- Children struggled to adapt to new situations and missed out on opportunities to socialize and develop self-regulation skills resulting in increased social, emotional, and mental health needs.
- Children's physical development, including their motor skills, were negatively affected by not being in a setting, as they spent less time outdoors and more time in sedentary activities.

The COVID-19 experience highlighted just how important play and movement are for children's development. Whilst COVID-19 is behind us, babies born in 2020 are just entering the education system, meaning that there may be many more children requiring extra support to meet missed development milestones, adapt to educational environments, and reach their full potential. Additionally, we can expect to be faced with similar challenges in the future, as experts anticipate more lockdown events.

3.3 Impact of Sedentary Behavior

Research highlights that prolonged seated postures in children during school hours have significant negative effects on various aspects of health, including physical, respiratory, and cognitive functions. These impacts manifest both in the short and long term.

3.3.1 Physical Health Effects

Research into traditional seating suggests it could affect the development of children by causing musculoskeletal disorders, bad posture, neck and back pain, as well as other kinds of health concerns (Harvey & Kenyon, 2013). Over time, these issues can lead to chronic pain and postural disorders that persist into adulthood. In addition, poor sitting posture often involves a slouched position, which compresses the lungs and diaphragm. This reduces lung capacity and impairs efficient breathing. Over time, reduced respiratory function can impact overall fitness levels and the ability to engage in physical activities. Prolonged sitting can also compress internal organs, affecting digestion and potentially lead to gastrointestinal issues. A slouched posture can compress the abdomen, slowing down digestion and causing discomfort. Extended periods of sitting, especially in non-ergonomic furniture, increase the risk of health impacts on children.

3.3.2 *Cognitive and Psychological Effects*

There is evidence that sitting posture can directly influence cognitive processes. Poor posture can lead to decreased concentration and cognitive performance. This is partly because discomfort and pain from poor posture can be distracting and partly because a slouched posture can affect mood and energy levels, further impacting cognitive abilities (Kounter, 2019). Children with poor posture often experience negative psychological effects such as lower self-esteem and increased feelings of anxiety and depression. These emotional states can be exacerbated by physical discomfort and pain associated with poor posture (Kounter, 2019).

3.3.3 *Short-Term Effects*

In the short term, poor sitting posture can lead to immediate physical discomfort, reduced academic performance, and lower participation in physical activities. This can create a cycle of inactivity and further exacerbate health issues.

3.3.4 *Long-Term Effects*

The long-term effects of poor sitting posture established during childhood can extend into adulthood, leading to chronic musculoskeletal problems, persistent poor posture, and associated health issues such as chronic back pain and an increased risk of cardiovascular diseases due to prolonged sedentary behavior.

3.4 Movement and Neurodiversity/Impact on Attention and Focus

Movement can enhance thinking and learning by triggering physiological changes in the body, such as increased blood flow to the brain, changes in brain chemicals (such as dopamine and noradrenaline), structural changes in the central nervous system, and variations in arousal levels. These changes help explain the link between physical activity and cognitive functions, such as thinking and learning (Sibley and Etnier, 2003).

The vestibular system provides sensory information about movement and balance to the central nervous system and is essential for maintaining balance (Blythe, 2004). It senses changes in head position and movement, allowing a person to stay upright and steady. Similarly, the cerebellum plays a key role in controlling posture and movement (Leppo, 2000). By coordinating muscle actions, the cerebellum helps maintain balance, enabling smooth movements and proper body positioning. Together, the vestibular system and cerebellum ensure stability during activities like sitting or performing everyday tasks.

Balance and stability are important for learning; higher cognitive skills require spatial and directional awareness, which is aided by knowing one’s own position in space.

Using a stool or seat that requires the child to use their core muscles to stabilize themselves allows for continued development of the vestibular and proprioceptive senses in children—important systems for the sense of motion and body awareness. Unlike restrictive seating, this option allows children to develop their sense of balance and awareness of their body in space as they move on and off a stool. Posture provides stability and, in turn, has a positive impact on learning (Blythe, 2004). Good posture has been linked to improved memory performance and better communication between important brain areas, such as the hippocampus and the medial prefrontal cortex (Tao et al., 2016). In contrast, poor posture, like slouching, has been associated with worse performance on memory tasks, specifically those involving recalling past events (Cohen et al., 2016). Maintaining good posture has been linked to improved mood, which can enhance performance on tasks involving verbal and spatial working memory (Storbeck & Manswood, 2016). Therefore, posture can indirectly support cognitive functions by positively influencing mood (Muller, 2022).

Additionally, maintaining physical stability through good posture supports essential movement skills, including non-locomotor movements, which involve staying in one place while still moving the body (David and Gbenga, 2014). Examples of non-locomotor movements are bending, stretching, twisting, and lifting, many of which can be performed while seated. Movement is thought to increase dopamine and noradrenergic activity, thereby improving focus and alertness (Hartano, et al, 2016). It has been found that restrictive seating made it harder for some neurodivergent students to focus (Collins, 2024). Offering less restrictive seating options that allow freedom of movement and give children more control over their posture can be particularly beneficial for those with ADHD, but all children are likely to benefit. While all neurodivergent learners are unique and some may benefit from other solutions, this is one important tool to try.

3.4.1 Importance for Early Years Settings

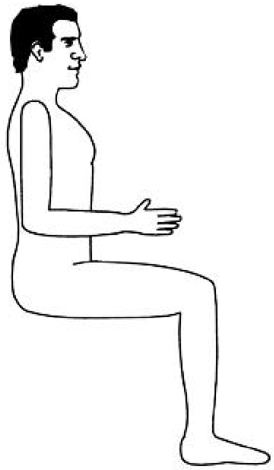
Early years settings help children to develop behaviors and habits which they will take with them and develop as they enter the education system. Addressing some of the challenges facing children in these early years and helping them to build their core strength and motor skills will help them to succeed as they grow. Gross motor skills are critical for children's overall development, affecting their ability to perform everyday activities, engage in physical play, and develop fine motor skills. Large muscles typically develop before smaller muscles, but children need to coordinate both types of muscles for more advanced motor skills.

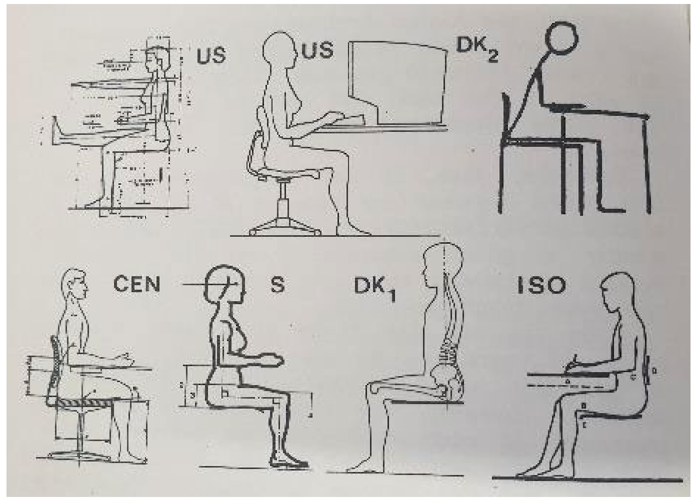
Therefore, gross motor skills form the foundation for more complex movements and are essential for healthy growth ensuring children develop strong muscles, bones and joints. Gross motor skills involve the large muscles of the body that enable movements such as walking, running, jumping, climbing, and playing. These skills are crucial for children's overall development, help children build muscle strength and endurance, improve their balance and coordination, and enhance their overall physical fitness. They serve as the foundation for more complex movements and fine motor skills by providing the foundational strength and stability needed for tasks requiring precision and control, such as writing, using scissors, and buttoning clothes. Developing gross motor skills is essential for healthy growth, as it impacts a child's physical, cognitive, and social-emotional development. Central to the development of gross motor skills is core strength.

Beyond physical development, learning experiences and classroom seating that take into consideration the developmental needs of children will contribute to their overall relationship to school, and support a lifelong joy in learning.

4. THE SCIENCE OF SITTING: CONVENTIONAL SEATED POSTURES

When using conventional classroom furniture, children are asked to assume upright static seated postures with their hips, ankles, and knees at right angles. It has been suggested a child cannot maintain this posture for longer than one to two minutes (Castellucci et al., 2017, Mandal, 1981). This upright static posture can cause children biomechanical problems changing the lumbar curve from lordosis (standing) to kyphosis (sitting). Kyphosis lumbar posture could accelerate the degenerative process, which leads to dysfunction and spine pain in children due to higher spinal loads and torso muscle strength (Bruno et al., 2012 and Briggs et al., 2007). To explain why this is the standard seated posture, it is necessary to look further into the origin of the "reference posture," a commonly cited image of "correct" seated posture. The reference posture was developed to standardize taking body measurements and provide data for designers to use when designing and assessing products, to verify that they fit the intended user populations. Below are drawings of the reference posture from anthropometric standards.

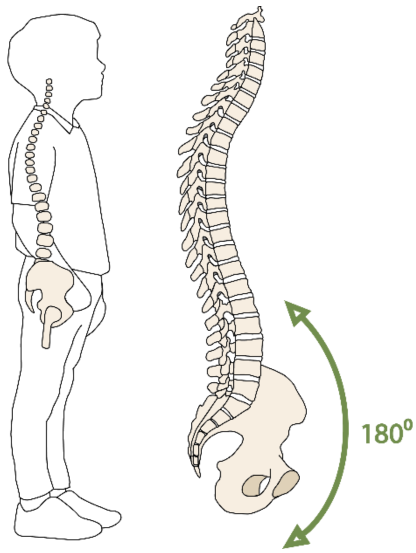




The reference posture was never intended to be promoted as the optimum or ideal posture, but to be used as a universal way to measure people. This position is very difficult to maintain and leads to muscle fatigue.

Dr. A.C. Mandal, who promoted dynamic seating since the 1970s, said about the reference posture: "Nobody wants to explain where the idea for the drawings came from, perhaps they were divinely inspired in ancient times. At least no connection with scientific thinking has ever been established" (1985).

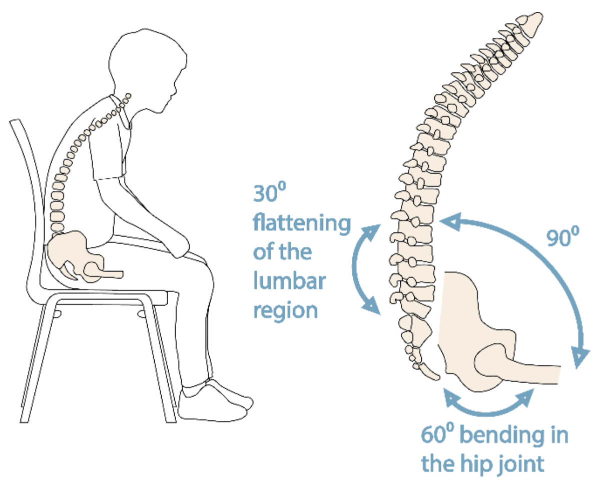
From childhood people are told to sit up straight in their chairs, but sitting up straight in right-angled chairs is difficult. The human body is not designed to be static. Humans move all the time, even when asleep. The human spine is more suited to standing or crawling postures than sitting upright in chairs. Not so long ago, humans used to squat or sit on low seats on the floor. But as lifestyles and working practices changed, so has the way people sit and the length of time they spend seated has lengthened. In schools, children are required to sit for longer and longer periods as the demands of the curriculum increase, and as they get older and enter employment, office workers are required to adopt static upright postures for extended time periods while working at their computers. However, the evolution of the spine has not kept up with these changes in sitting habits or seating design.



When in a standing posture, the spine has a natural “S” shape, with the lumbar region curved slightly inward (lordosis). The image above shows how, when standing, the pelvis is 180 degrees to the spine. This posture takes minimal effort to maintain.

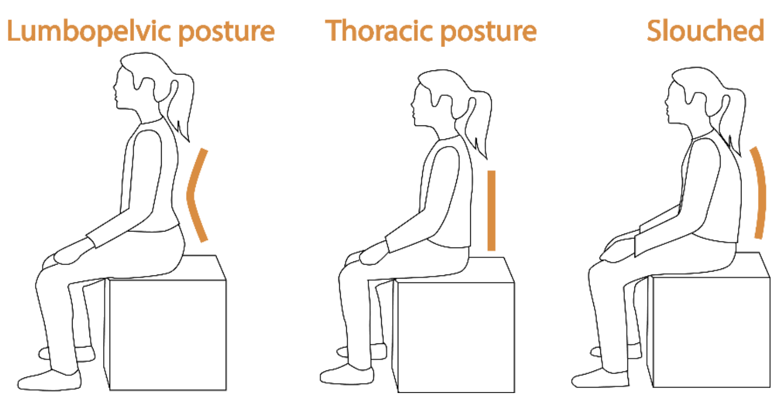
However, the modern way of sitting on right angle seating forces the pelvis to rotate backwards. This automatically flattens the curve of our lower back from its natural healthy s-shape, causing a slouched posture (kyphosis).

This rotation of the pelvis is caused by tension in the muscles connecting the pelvis to the legs (hamstring and hip flexors);to correct this, significant muscle exertion is required to maintain an upright posture whilst seated, especially in a bolt upright position. Understanding this helps to explain why maintaining an upright posture, the “reference posture,” is only possible for a few minutes before returning to a slouched posture, it is a consequence of human anatomy and is very difficult to overcome.

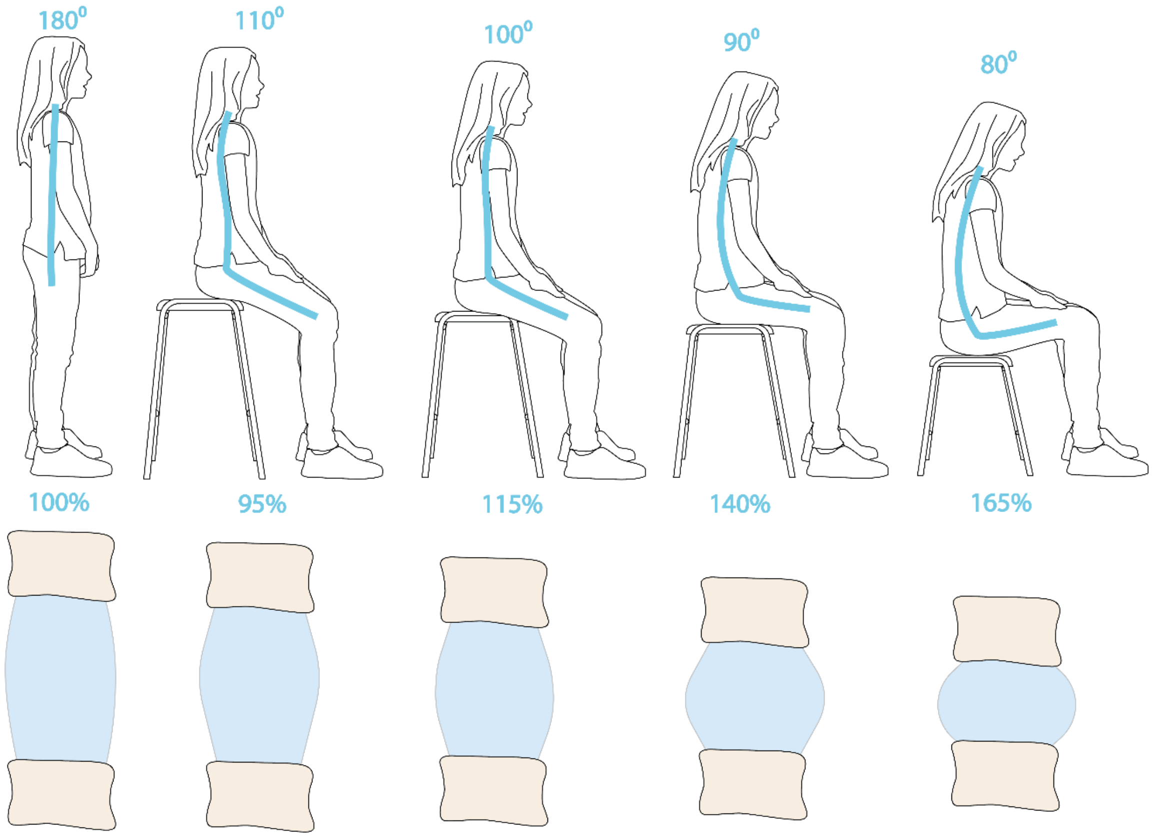


In addition, the right-angled "reference posture" does not provide whole-body balance. In trying to find balance, the feet will eventually position themselves below the head, or the head will position itself above the feet. Often this will then result in the head being propped up by the hand(s) with arms resting on the table.

Head and neck position is very important when sitting as the smallest vertebrae in the spine are in the neck, therefore they are more susceptible to damage. The average human head weighs between 5 and 11 pounds. When the head is in a neutral position, it is in balance with the spine and is supported by the neck with around 20 muscles and seven vertebrae. However, tilting the head forward (neck flexion) can significantly increase the force on the discs between the vertebrae in the neck. Prolonged neck flexion can cause muscle fatigue and pain as well as other damage to the spinal discs and nerves. A study published in the *Manual Therapy Journal* in 2010 (Caneiro et al, 2010) found that different sitting postures affect head/ neck posture and cervico-thoracic muscle activity. The study investigated three different sitting postures to determine the effect on the head/neck posture (Lumbopelvic posture, Thoracic posture, and Slouched). There were significant differences in lumbar and thoracic curvatures in the three different sitting postures. Slouched sitting (the posture that is often observed among children in classrooms) was associated with greater head/neck flexion, forward head posture and increased muscle activity of cervical erector spinae (a set of muscles that straighten and rotate the back) compared to thoracic and lumbo-pelvic sitting.



Uneven pressure on the spinal discs is also a significant factor that influences discomfort and fatigue in seated postures. Slouched postures increase the pressure in the spinal discs as can be seen in the figure below. When a person is slouched over their desk, the pressure on their spinal discs is nearly double that of when they are standing (Nachemson & Elfström, 1970).



These high pressures over a long time can cause degeneration of spinal discs resulting in back pain, by the time back pain occurs, the damage is often done. This is why it is important to address poor posture before it starts to become a problem, starting with how children in education are expected to sit. The figure above shows the extent to which pressure increases as the angle between the torso and thigh decreases.

A further difficulty faced by school children is the inevitable mismatch between their body dimensions and the classroom furniture they are using. In an ideal world, all furniture in schools would be adjustable to accommodate the wide size variation that occurs in school children, (Parcells et al. 1999, Panagiotopoulou et al. 2004); data has shown that there is substantial variability in student's bodily dimensions making it unlikely that furniture with fixed dimensions is able to accommodate the majority of students. This is in line with the findings of Chung and Wong (2007) who found that almost none of the 214 subjects in their study had a chair in school with an appropriate seat height. The traditional design of a school chair, with its negative sloping seat angle and rigid construction, does not allow much flexibility for children to adapt their posture in order to overcome any mismatch in the dimensions of the chair and their body. Even to have a chance of obtaining a remotely comfortable posture, the child is reliant on their popliteal height (the vertical distance from the floor to the underside of the knee) being the same as the seat height so they can sit with their feet firmly on the ground. If a child's popliteal height is less than the seat height, their feet will dangle in the air unless the child sits forward with their thighs tilted down. If they do this, they will not be able to make use of the backrest. If a child's popliteal height is larger than the seat height, there will be increased weight on the ischial tuberosities, and the position of the knees will result in a more closed angle between the torso and the thighs.

5. ALTERNATIVE SITTING SOLUTIONS

By the time people reach the age of 30 to 40, their backs have become much less flexible, and the healthy lumbar curvature of the spine becomes much less prominent. The concave curve of the back at the lumbar region is essential to maintain an upright posture. In 1948 Åkerblom was able to show how the pelvis rotates backwards, and the lumbar curve disappears when sitting upright on a typical chair with a horizontal or slightly sloping backwards seat pad (Åkerblom, 1949).

As discussed in the previous section, this places very high loads on the lumbar vertebra where chronic back pain typically occurs. Keegan (1953) argued that even for people with healthy backs, a flattening of the lumbar curve of around 30 degrees creates the maximum load the lower back can maintain. Keegan further argued that the natural resting position of the hip joints are when there is an angle of about 135 degrees between our torsos and the thighs, where muscles at the back and front of the thighs are in a relaxed balanced state, and the back has a concave backward lumbar spine very similar to the one in standing. Following Åkerblom and Keegan's findings, and Mandal's own work, in 1974 Mandal argued that, in theory a sitting position where the angle at the hip joints was about 45 degrees (i.e., an angle of 135 degrees between the torso and the thighs) would be ideal as at this position muscles at the back and front of the body are in balance. He referred to this as a balanced position, which is very similar to the one Keegan called normal. Mandal then postulated that this position is very similar to the way a rider sits on a horse and maintains the natural concave curve at the lumbar region of their back. One of the reasons why a horse rider can sit up straight and maintain the lordosis at the lumbar region is due to the angle between the thigh and the torso being 120 to 130 degrees. At this balanced posture the center of gravity remains vertically above the seat bone (ischial tuberosities), hence the term "balanced posture." Mandal stated that this is a much better and healthier sitting posture where the back is straight with the concave curve around the lumbar and the body in balance.

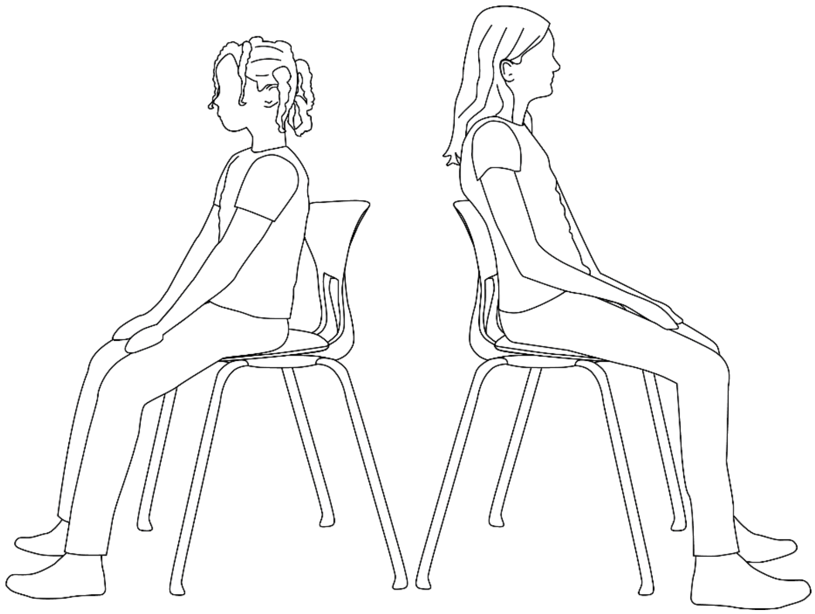
Mandal expanded that such a sitting posture is dynamic, allowing the person to adopt different postures very easily. The most comfortable position being the next position. He points out that organists, potters, and weavers often sit on forward-sloping seats (or saddle-like seats) to keep a balanced position while bending forward and moving around. He also pointed out that in the old horse cabbies, the driver's seat is sloped forward like a saddle, keeping the driver balanced even when the carriage goes around a tight bend.

Mandal then proposed a higher seat with a forward-sloping seat pad and a higher table with a tilting tabletop, not only for school children but also office workers. A Danish company has produced a Mandal type of seating whereby the seat pad has the rear half sloping backwards and front half sloping forwards. This enables the sitter to sit at the rear part of the seat and rest their feet on a footrest on the chair or table for listening or relaxing. Or they may sit/perch at the front half of the seat pad with their feet on the floor to enable to work on the table. In the UK, through discussions with Mandal, Anthony Hill, a British designer and academic, designed and manufactured Mandal-type chairs and tables.

The European educational furniture standard EN 1729-1 includes this type of chair and table design to allow for alternative classroom furniture solutions. Currently the furniture market has numerous saddle-like stools and perches with a large height adjustment range, mainly for the commercial market.

For children, maintaining a balanced, comfortable posture while seated for longer periods is incredibly important for long-term postural health, and to help prevent degradation of the spinal discs, and therefore the development of back pain. However, it is also important for immediate well-being and cognitive reasons. When a person sits in an open, balanced posture as described by Keegan and Mandal, they are not compressing their internal organs, including their lungs and digestive system, meaning they are able to breathe deeper allowing more oxygen to enter their bloodstream and feed their brain, and also allow their digestive system to work unobstructed. This posture also has the added benefit that the child is less restricted in their seat; they are poised to move between a seated and standing posture easily, to twist and turn to follow the teacher as they move around the classroom.

When the seat is positioned higher than a normal seat height and the thighs are allowed to fall away from the torso, the exact height of the seat surface becomes less crucial as it accommodates a far larger range of sizes of children as each individual can adopt a perched position whereby shorter users perch with straighter legs and less of a bend at the knee, and taller users have more of a bend at the knee, as illustrated in the image below.



A seat that allows users to rotate their pelvis in an anterior direction, opening up the angle between the torso and thighs and allowing the legs to fall away, e.g. a saddle-like seat, has the added bonus that even short people can sit without having their thighs compressed by the front edge of the seat, and still have their feet flat on the floor. There is no front edge digging into the upper leg, and the buttocks and leg muscles are free of contact pressure. The veins and arteries that carry blood to and from the legs are in their most open position. With the angles between upper and lower legs being much wider than usual, the user's legs can be more active, accelerating the metabolism.

When sitting on a saddle-type stool, the hips are abducted and the legs are spread apart. This stabilizes the pelvis in an upright orientation. The position of the feet in a wide stance helps to maintain balance and allow non-locomotor movements (as discussed in Section 3.4) allowing a person to be more active while sitting. This is particularly important in schools where children are required to sit and focus for long periods of time. Seating that allows them to move without being disruptive is crucial. It may even address the age-old problem of children dangerously rocking back in their chairs (which is clearly a desperate attempt to gain some relief from the uncomfortable, static postures they are being asked to maintain). If the root cause of particular disruptive behavior is addressed (discomfort leading to inattentiveness), maybe teachers would see a reduction in it.

6. CONCLUSION

Today's children are growing up in a world that poses many challenges to their development. The detrimental impact of factors such as increased technology use and sedentary lifestyles can already be seen on children's physical and mental health. While comprehensive solutions are needed, improvements to seating in early childhood educational settings will be an important step to help children develop in an ideal fashion. Seating that is tailored to the developmental needs of young children helps build core strength, develop motor skills, and set healthy postural habits for the years to come. Providing opportunities for movement rather than restricting children to unnecessarily static and sedentary positions in the classroom helps to counteract the many other environmental factors challenging children's ability to thrive.

7. REFERENCES

Akerblom, B. (1949). Standing and Sitting Posture, with Special Reference to the Construction of Chairs. Physical Therapy Review, 29(10), 486. https://doi.org/10.1093/ptj/29.10.486c

Arundell, L., Salmon, J., Koorts, H., Contardo Ayala, A. M., & Timperio, A. (2019). Exploring when and how adolescents sit: Cross-sectional analysis of activPAL-measured patterns of daily sitting time, bouts and breaks. BMC Public Health, 19, 653. https://doi.org/10.1186/s12889-019-6960-5

Blythe, S. G. (2004). The Well Balanced Child: Movement and early learning. https://openlibrary.org/books/OL8768276M/The-Well-Balanced-Child

Breithecker, D. (2006, November). Beware of the Sitting Trap in Learning and Schooling. DesignShare. http://www.designshare.com/index.php/articles/sitting-trap/

Briggs, A. M., van Dieën, H. J., Wrigley, T. V., Greig, A. M., Phillips, B., Lo, S. K., & Bennell, K. L. (2007). Thoracic Kyphosis Affects Spinal Loads and Trunk Muscle Force. Physical Therapy, 87(5), 595–607. https://doi.org/10.2522/ptj.20060116

Bruno, A. G., Anderson, D. E., D'Agostino, J., & Bouxsein, M. L. (2012). The Effect of Thoracic Kyphosis and Sagittal Plane Alignment on Vertebral Compressive Loading. Journal of Bone and Mineral Research, 27(10), 2144–2151. https://doi.org/10.1002/jbmr.1658

Caneiro, P., O'Sullivan, P., Burnett, A., Barach, A., O'Neil, D., Tveit, O., & Olafsdottir, K. (2010). The influence of different sitting postures on head/neck posture and muscle activity. Manual Therapy, 15(1), 54–60. https://www.sciencedirect.com/science/article/abs/pii/S1356689X09001052

Castellucci, H. I., Arezes, P. M., Molenbroek, J. F. M., de Bruin, R., & Viviani, C. (2017). The influence of school furniture on students' performance and physical responses: Results of a systematic review. Ergonomics, 60(1), 93–110.

Center for Public Education. (2008). Time out: Is recess in danger? http://www.centerforpubliceducation.org/Main-Menu/Organizing-a-school/Time-out-Is-recess-in-danger/default.asp

Cheng, S.-Y., Tai, H.-L., & Wang, T.-T. (2023). Impact of COVID-19 Pandemic on Children's Fundamental Motor Skills: A study for the Taiwanese preschoolers teachers. International Journal of Environmental Research and Public Health, 20, 6764. https://doi.org/10.3390/ijerph20186764

Chung, J. W. Y., & Wong, T. K. S. (2007). Anthropometric Evolution for Primary School Furniture Design. Ergonomics, 50, 323–334.

Collins, B. (2024). Exploring the Impact of Classroom Seating on the Educational Wellbeing for Students with Diverse Bodies (Doctoral dissertation, The Ohio State University).

Cohen, R. G., Vasavada, A. N., Wiest, M. M., & Schmitter-Edgecombe, M. (2016). Mobility and Upright Posture Are Associated with Different Aspects of Cognition in Older Adults. Frontiers in Aging Neuroscience, 8, 257.

David, B., & Gbenga, J. (2014). Role of Physical Activity and Motor Learning in Child Development. Journal of Nigeria Association of Sports Science and Medicine, 15(1), 239–247.

den Uil, A. R., van Doorn, H., Schweitzer, M., et al. (2023). The Effects of the COVID-19 Lockdowns on Motor Skill Development of 6- and 7-year-old Children in the Netherlands: A longitudinal study. BMC Public Health, 23, 1871. https://doi.org/10.1186/s12889-023-16733-1

Egan, C. A., Webster, C. A., Beets, M. W., Weaver, R. G., Russ, L., Michael, D., et al. (2019). Sedentary time and behavior during school: A systematic review and meta-analysis. American Journal of Health Education, 50(5), 283–290.

Hartanto, A., Lewis, S., & Schweitzer, J. (2016). Don't Stop the Movement! [PDF]. https://d393uh8gb46l22.cloudfront.net/wp-content/uploads/2018/06/ATTN 02 16 DontStopTheMovement.pdf (Accessed: September 20, 2024)

Harvey, E. J., & Kenyon, M. C. (2013). Classroom Seating Considerations for 21st Century Students and Faculty. Journal of Learning Spaces, 2(1). https://libjournal.uncg.edu/jls/article/view/563

Heffler, K. F., Acharya, B., Subedi, K., & Bennett, D. S. (2024). Early-Life Digital Media Experiences and Development of Atypical Sensory Processing. JAMA Pediatrics, 178(3), 266–273. https://doi.org/10.1001/jamapediatrics.2023.5923

Huang, P., Zhou, F., Guo, Y., Yuan, S., Lin, S., Lu, J., Tu, S., Lu, M., Shen, S., Guedeney, A., Xia, H., & Qiu, X. (2021). Association Between the COVID-19 Pandemic and Infant Neurodevelopment: A comparison before and during COVID-19. Frontiers in Pediatrics, 9, 662165. https://doi.org/10.3389/fped.2021.662165

Keegan, J. J. (1953). Alterations of the Lumbar Curve Related to Posture and Seating. Journal of Bone and Joint Surgery–American Volume, 35-A(3), 589–603. https://doi.org/10.2106/00004623-195335030-00017

Kounter, T. (2019). The Prevalence and Consequences of Poor Posture in Children and Adolescents (Senior Honors Thesis, Liberty University). https://digitalcommons.liberty.edu/honors/903 (Accessed: October 18, 2024)

Kuzik, N., da Costa, B. G. G., Hwang, Y., et al. (2022). School-related sedentary behaviours and indicators of health and well-being among children and youth: A systematic review. International Journal of Behavioral Nutrition and Physical Activity, 19, 40. https://doi.org/10.1186/s12966-022-01258-4

La Valle, I., Lewis, J., Crawford, C., Paull, G., Lloyd, E., Ott, E., Mann, G., Drayton, E., Cattoretti, G., Hall, A., & Willis, E. (2022). Implications of COVID for Early Childhood Education and Care in England. Centre for Evidence and Implementation. https://www.nuffieldfoundation.org/wp-content/uploads/2022/06/Implications-of-Covid-for-ECEC-in-England-June-2022-.pdf

Leppo, M. L., Davis, D., & Crim, B. (2000). The Basics of Exercising the Mind and Body. Childhood Education, 76(3), 142–147.

Mandal, A. (1982). The Correct Height of School Furniture. Human Factors: The Journal of the Human Factors and Ergonomics Society, 24(3), 257–269.

Muller, S. J. (2022). The Effects of Posture on Health Information Recall: A Randomised Trial (Doctoral dissertation, ResearchSpace@ Auckland).

Nachemson, A., & Elfström, G. (1970). Intravital Dynamic Pressure Measurements in Lumbar Discs: A study of common movements, maneuvers and exercises. Scandinavian Journal of Rehabilitation Medicine Supplement, 1, 1–40.

Panagiotopoulou, G., Christoulas, K., Papanckolaou, A., & Mandroukas, K. (2004). Classroom Furniture Dimensions and Anthropometric Measures in Primary School. Applied Ergonomics, 35(2), 121–128.

Parcells, C., Stommel, M., & Hubbard, R. P. (1999). Mismatch of Classroom Furniture and Student Body Dimensions. Journal of Adolescent Health, 24, 265–273.

Sibley, B. A., & Etnier, J. L. (2003). The Relationship Between Physical Activity and Cognition in Children: A Meta-Analysis. Pediatric Exercise Science, 15(3), 243–256.

Storbeck, J., & Maswood, R. (2016). Happiness Increases Verbal and Spatial Working Memory Capacity Where Sadness Does Not: Emotion, Working Memory and Executive Control. Cognition and Emotion, 30(5), 925–938.

Tao, J., Liu, J., Egorova, N., Chen, X., Sun, S., Xue, X., ... & Kong, J. (2016). Increased Hippocampus–medial Prefrontal Cortex Resting-state Functional Connectivity and Memory Function After Tai Chi Chuan Practice in Elder Adults. Frontiers in Aging Neuroscience, 8, 25. https://doi.org/10.3389/fnagi.2016.00025

Takahashi, I., Obara, T., Ishikuro, M., et al. (2023). Screen Time at Age 1 year and Communication and Problem-Solving Developmental Delay at 2 and 4 years. JAMA Pediatrics, 177(10), 1039–1046. https://doi.org/10.1001/jamapediatrics.2023.3057

World Health Organization. (2020). WHO guidelines on physical activity and sedentary behaviour. https://www.who.int/publications/i/item/9789240015128 (Accessed: October 18, 2024)