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SPINE SAGITTAL PARAMETER ASSESSMENT IN
ADOLESCENT STUDENTS – AN ONLINE STUDY TOOL

Degree Programme in Physiotherapy

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Satakunta University of Applied Sciences

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The trend of decrease in active lifestyle observed in the pediatric population nowadays raises concern considering the severe consequences this change can have on the developing body's musculoskeletal, neurological, and cardiovascular health. Assessing and addressing postural changes stemming from the sedentary lifestyle can diminish the negative effects. Therefore, it is very important for physiotherapists to learn to distinguish postural fluctuations as early as possible.

The purpose of the thesis was to build an online study platform covering the assessment of adolescent pupils' posture to be used by physiotherapy students at Satakunta University of Applied Sciences as individual study material in Basic movement classes.

The theoretical material for the study tool was collected based on the available scientific literature and a student survey on the necessity of such content. The presented information consisted of four sections: the basics of posture and the posture control mechanism, the role of spine and muscle anatomy and function in the biomechanics of posture, changes in the spine's sagittal posture occurring prior and during the growth spurt period, and sagittal parameters and their implementation into postural analysis.

The objective of the thesis was to create a tool that presents information on posture assessment and inferences regarding adolescent posture evaluation in a comprehensive way. Thus, the theoretical material combined with questions and tasks for the readers was presented in an online platform with a discussion section which could be used by the university's teachers and students.

CONTENTS

1 INTRODUCTION

Assessing posture is extremely important in the age of adolescence as the body is developing and one goes through biological and psychological changes. Postural faults may cause greater musculoskeletal issues later in life and, since the occurrence of postural deviations is more and earlier occurrent nowadays, it is essential to address the issue as soon as possible. (Straker, Maslen, Burgess-Limerick & Pollock 2007.)

The increasing trend in the instance of children with incorrect posture is correlated with the ever-growing body mass index amongst pupils as well as inactive lifestyle. Studies have shown that the majority of children with excessive body mass express postural deviations. (Smith, O'Sullivan, Beales, Klerk & Straker 2011; Ku, Osman, Yusof & Wan Abas 2012; Maciałczyk-Paprocka et al. 2017.) What is more, the decrease in active lifestyle and exposition to prolonged periods of sitting in classes or spending leisure time in front of screens only adds to the increased body mass index and postural faults incidence (Brink & Louw 2013; Ruivo, Pezarat-Correia & Carita 2014; Maciałczyk-Paprocka et al. 2017; Araújo, Martins, Alegrete, Howe & Lucas 2017).

Postural failures among 13-18-year-old adolescents are discussed to be associated with puberty. Due to the increased body height, fat gain along with change in chest and shoulder dimensions (and in part the associated psychological effects), some pupils tend to slouch while others express an increase in the lordotic curve or forward position of the head. (Ku, Osman, Yusof & Wan Abas 2012.) Noticing and addressing these changes early can prevent issues that are associated with untreated faulty body posture in children and adolescent such as reduced cardio-respiratory efficiency and vital lung capacity, pains in the lower back, bone degeneration as well as internal organ displacement (Maciałczyk-Paprocka et al., 2017).

2 AIM AND OBJECTIVE OF THE THESIS

The purpose of this thesis is to create an online study tool for Satakunta University of Applied Sciences physiotherapy students that would serve as a part of individual study material in the subject of Basic movement to improve physiotherapy students' knowledge and clinical reasoning skills in the assessment of teenage pupils' posture.

The objective is to create a web-based platform that would provide comprehensive information on posture assessment and specific implications when evaluating adolescent subjects.

3 UPRIGHT POSTURE AND STABILITY

3.1 Definition of posture

Posture could be defined as the alignment of the body by the relationship between the segments of the body and the line of gravity. However, this should not be limited to only the torso's vertical alignment but also take into consideration the shoulders, lower limbs, feet. (Maciałczyk-Paprocka, 2017.) The body employs various systems to achieve "the state of muscular and skeletal balance which protects the supporting structures of the body against injury or progressive deformity irrespective of the attitude (erect, lying, squatting, or stooping) in which these structures are working or resting" and where optimal body stability that requires minimum muscular effort is provided (Website of American Posture Institute 2016).

3.2 Functions of posture

The unique alignment of the human posture serves various important functions. Active postural control is essential for the body to maintain upright position and perform movements (Penha, Joao, Casarotto, Amino & Penteado 2005, 9; Horak 2006). This quality allows for standing on uneven or unstable surfaces, walking, or reaching to be

performed. What is more, posture alignment protects body structures against injury or progressive deformity. If the alignment is compromised by any pathology, the equilibrium and its compensatory mechanisms are distorted and that in turn influences body's tissue healing efficiency and neurological function, while changed loading distribution on spine vertebrae may lead to degenerative disc disease. (Troyanovich, Harrison & Harrison 1998; Harrison, Cailliet, Harrison, Troyanovich & Harrison 1999a; Harrison, Cailliet, Harrison, Troyanovich & Harrison 1999b; Harrison, Cailliet, Harrison, Troyanovich & Harrison 1999c; Roussouly & Pinheiro-Franco 2011b; Diebo, Varghese, Lafage, Schwab & Lafage 2015.) Moreover, by particularly distributing the body mass, postural alignment ensures more efficient muscle work. The abdominal and thoracic organs are organized in relation to base of support, gravity, internal cues and environment and, for instance, if spinal curves become more exaggerated, passive structural support must exert more effort to maintain the posture in turn affecting one's participation in daily activities. (Winter 1995; Cardia & Masculo 2001, 364; Kendal, McCreary, Provance, Rodgers & Romani 2005; Kisner & Colby 2012, 424.)

Maintaining erect posture is a complex skill that depends on the interaction of dynamic sensorimotor processes and is comprised of two different components – postural orientation and postural equilibrium. Postural orientation, also referred as body posture, involves the active alignment of the head and the torso regarding gravity, base of support, visual fields and internal references. (Horak 2006, ii8.) Postural equilibrium, or balance, on the other hand, aims to maintain the centre of body mass within in the base of support by coordinating movement strategies (Westcott, Lowes & Richardson 1997, 630; Roggia, Filha, Correa & Rossi 2015, 396). This is done through cooperation between the central nervous system and the three sensory systems: (1) vision – applied by planning ahead to avoid obstacles, (2) somatosensory system – sensing body segments' position and velocity, contact with external objects, and (3) vestibular system – which detects linear and angular accelerations (Winter 1995, 194). Sensory information from somatosensory, vestibular and visual systems is used to determine spatial orientation which is used in order to make needed adjustments on both postural orientation and postural equilibrium by activating different neuromuscular synergies (Nashner 1976; Fitzpatrick, Burke & Gandevia 1994; Gatev, Thomas, Kepple & Hallett 1999; Horak 2006).

To sustain postural stability, postural orientation serves by maintaining body's static state, and postural equilibrium acts in providing the dynamic aspect to the control mechanism that is essential in cases of both externally triggered and self-initiated oscillations (Westcott, Lowes & Richardson 1997, 630).

3.3 Spine stability

Stability is important in terms of spine function: it allows the spine to bear loads and move without injury and pain (Reeves, Narendra & Cholewicki 2007). Spine stability analysis can provide valuable information on the probable injury under light loading, or the requirement for trunk muscle stiffness to sustain spine stability and the necessity for coordinated muscle employment as these components are associated with injury (Bergmark, 1989; Crisco & Panjabi 1990; Crisco & Panjabi 1991; Cholewicki and McGill 1996).

Stability of any system can be tested by imposing small perturbation. If the new observed behaviour is almost the same as the old one, the system can be deemed stable. And vice versa, if the new behaviour differs meaningfully – the system is unstable. This is a general description that can be applicable to any arrangement. (Reeves & Cholewicki 2013.) However, the views on spinal segment stability are conflicting – the debate on spine (in)stability can be less than enlightening or worse, confusing. Stability is dependent on the context and it is important to emphasize that the system discussed is dynamic and therefore cannot through static analyses. (Nachemson 1985.)

To avoid confusion, stability is suggested to be analysed in the context of the task that is being performed and the overall system. For instance, if one of the tasks is to maintain a standing position and due to perturbations, the stepping strategy was used, this can be perceived as stability maintenance failure. However, if another task (with a different goal) is to be investigated, e.g. placing an object on a shelf, and a step to do so would be required, the conclusion would be successful stability maintenance as the overall goal of the task is different. Same viewpoint can be applied when discussing completing tasks without pain. (Reeves, Narendra & Cholewicki 2007.)

3.4 Posture control mechanism

Research on posture motor control has been extensively analysed and scholars have used different approaches towards the issue. Reductionists focused on dissecting the mechanism into separate, simplified parts. However, noticing that some of the information is lost if the interactions between different body systems are not considered, in the beginning of the twentieth century, researchers began applying the systems approach to explain complex processes observed in nature and the human body emphasizing the necessity to discuss the role of biomechanical, neurophysiological and psychological points of view simultaneously as they interact to provide feedback control. (Reeves & Cholewicki 2013, 7.)

The control of the spine and pelvis involves passive, active and neural systems (Kisner & Colby 2012, 415). The first one, passive subsystem, involves the inert structures – bones and ligaments in the body. By common definition, these structures provide minimal passive resistance when positioned in the neutral range, but once the segments move to the elastic range they present passive restraint. Thus, stability to the direction of movement is created. In addition, feedback encouraged by the receptors in the joints to the central nervous system influences neural control system to limit the motion. (Penjabi 1992a; Penjabi 1992b.) The second subsystem contains active structures – the muscles. Trunk muscles help maintaining the spine in an upright position. The global muscles respond to shift in the centre of mass caused by external loads through compressive loading – not to individual vertebral segments. (Hodges & Richardson 1997; Hodges, Cresswell & Thorstensson 1999.) Deep/segmental muscles that attach directly to the spinal segments support and maintain each segment in a stable position for not to stress the inert structures (Moseley, Hodges & Gandevia 2002). The third subsystem responsible for postural control is the neural control system. It reacts to both anticipated or unforeseen forces and provides feedforward control by regulating the stiffness and movement to match the imposed oscillations (Hodges, Cresswell & Thorstensson 1999; Ebenbichler, Oddsson, Kollmitzer & Erim 2001; Barr, Griggs & Cadby 2005). This is a complex task since, when innervating trunk muscles, the nervous system must also take into account movements of the limbs and determine the right time and the amount of modulation (Hodges & Richardson 1997; Hodges, Cresswell & Thorstensson 1999; Moseley, Hodges & Gandevia 2002). All in all, precise interaction

between stabilization structures – passive, active and neural – is essential to maintain the stability of spinal segments and the structure as a whole (Kisner & Colby 2012, 415).

3.4.1 Biomechanical approach

In terms of biomechanics, postural control aims to position the body's centre of mass within the base of support in an upright position, which is inherently an unstable position, often likened to an inverted pendulum. A torque produced by gravity results in the centre of mass accelerating away from the upright position in case of spontaneous sway in quiet stance. To respond, the system is stabilized through feedback control, i.e. counteractive torque is generated through corrective strategies. (Winter 1995; Sousa, Silva & Tavares 2012, 134.)

Reeves, Narendra & Cholewicki (2011) use the example of balancing a stick on a hand to illustrate the feedback control of the spine: while the feedback control is quite more complex, the experiments allow for insight into how the central nervous system monitors and corrects (maintains) the stable position of the spine. The feedback control mechanism uses muscle spindle of the paraspinal trunk muscles to monitor the situation (Picture 1) and the velocity of spine movement (Picture 2). In addition, the architecture of trunk muscles plays an important role in controlling individual vertebrae while the sensory receptors aid in forming neural models to forecast the state of the system and generate feedback. (Houk, Rymer & Crago 1981; Nitz & Peck 1986.)
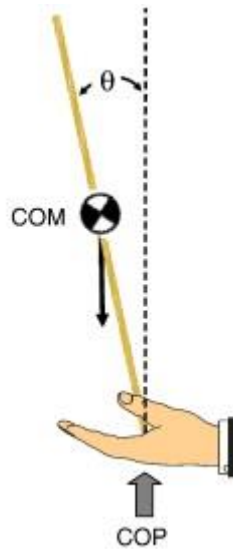
Picture 1. The feedback control mechanism uses sensory input to determine positional deviations of the stick (spine) (Reeves, Narendra & Cholewicki 2011).
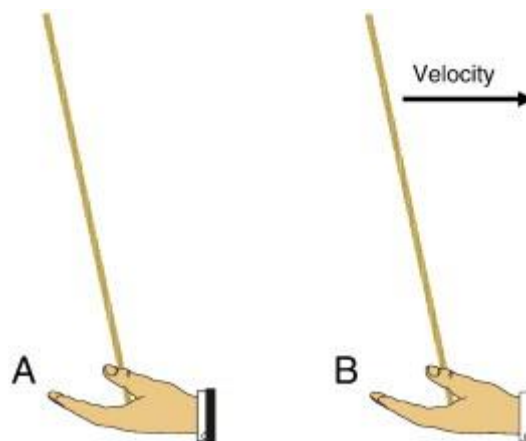
Picture 2. Sensory input is used to evaluate the velocity of the change in position (Reeves, Narendra & Cholewicki 2011).

Based on goal of the task, the strategy of control is chosen by the central nervous system. The corrective strategies, if needed, work separately and are activated depending on the position of standing. For example, when standing with feet side by side, ankle strategy is dominant in anteroposterior direction, while hip strategy is leading in mediolateral direction. (Gatev, Thomas, Kapple & Hallett 1999; Winter 1995, 212.) To determine which strategy is to be employed, the central nervous system analyses information on the area of support, degrees of freedom, musculoskeletal characteristics, sensory input and task constrains (Amiridis, Hatzitaki & Arabatzi 2003, 137;

Fujisawa et al. 2005, 107). The pathways that are inappropriate for the task are inhibited (Nashner 1976, 71; Fitzpatrick, Burke & Gandevia 1994, 371).

The ankle strategy is primarily used in case of minimal internal or external disturbance, wide base of support and small angle of inclination (Fujisawa 2005, 108). Alternatively, hip strategy is applied when ankle strategy is not adequate: base of support is not big enough or a forceful external disturbance is applied to segments of the body (Fujisawa 2005, 122). However, it is still unclear to what extent active feedback control mechanisms participate in the maintenance of upright posture in quiet environment (Sousa, Silva & Tavares 2012, 144).

The stabilization mechanisms are constantly acting to maintain the position of centre of mass within the base of support – maintain the equilibrium of the inverted pendulum (Horak 2006). This can be observed due to presence of body sway in quiet standing. Gatev, Thomas, Kapple & Hallett (1999) investigated muscle activation in this phase and reported gastrocnemius muscle activity anticipating the loading pattern and thus, ankle strategy manner in quiet stance. According to other studies, the body uses the feedback of velocity frequency to anticipate changes and adjust body position by treating the body as an inverted pendulum in body sway of lower than 0.5 Hz frequency and as a double inverted pendulum at the hip joint in higher frequencies (Nashner, Shupert, Horak & Black 1989; McCollum & Leen 1989; Yang, Winter & Wells 1990). Impairment in feedback control may stem from poor proprioception, longer delays and decreased resolution in muscle force regulation or faulty control logic and lead to pain or degenerative changes in the body (Reeves & Cholewicki 2013, 12).

3.4.2 Physiological approach

The sensory systems with their afferent pathways in the CNS partake the control of upright posture. Proprioception, the vestibular system and vision contribute to the continuously updated internal representation of body's posture by providing multisensory feedback that is in turn used to control the position of body in space. (Sousa, Silva & Tavares 2012, 133.) The central nervous system constantly reweighs parameters such as center of mass, bodily acceleration, internal and external conditions. These

adjustments cause both the immediate changes stemming from the input information and those that are developed over a long time (due to aging, learning, etc.). (Chiba, Takakusaki, Ota, Yozu & Nobuhiko 2015; Reeves, Narendra & Cholewicki 2007.)

3.4.3 Psychosocial approach

A correlation between posture and psychosocial factors should also be considered when discussing postural control in adolescents. The beginning of puberty and challenges that accompany (e.g. increased demands at school, social pressure and relationships with parents and peers) can influence one's psyche and performance sequentially having effects on posture. Internal aspects, such as lower self-esteem, higher fear, poorer mood, fewer positive emotions, are observed among slumped subjects compared to the upright group. (Nair, Sagar, Sollers, Consedine & Broadbent, 2015.) Moreover, external aspects causing a change in emotion can too affect muscle stimulation. For example, stress while typing can influence one's sitting position, thus resulting in excessive upper body muscle tension for a period of time and these effects might persist if adequate rest is neglected. (Lundberg 2003; Chou, Chen & Chiou 2011.) Factors such as socioeconomic status, social exclusion, stress, depression and psychosomatic symptoms may have long term influence on child's posture (Wilder 1963; Scheflen 1964; Mehrabian 1969, Prins, Crous & Louw 2008).

4 POSTURAL ALIGNMENT AND BIOMECHANICAL INFLUENCES

4.1 Spinal anatomy in relation to posture

The distinct organization of the spine is essential in maintaining erect, vertical, bipedal position. Spine has four distinct curves – cervical lordosis (C1-C7), thoracic kyphosis (T1-T12), lumbar lordosis (L1-L5), and sacral kyphosis (sacrum) – with differing morphology in vertebrae of each curve, which is developing as one ages and is fixed only at the termination of the skeleton growth. (Kisner & Colby 2012, 414.) While the limits

of thoracic and lumbar spinal curvatures are usually defined by the anatomical properties of the vertebra, Roussouly & Pinheiro-Franco (2011a) suggest that there is a great variability of the length of lumbar lordosis and propose the method of functional segmentation of the spine instead of anatomical (Picture 3). Since the morphology of vertebrae within spine is not identical, it leads to propositions of determining curve bounds by the points where the curves' orientation changes (Roussouly 2003; Bethonnaud, Dimnet, Roussouly & Labelle, 2005). These curves are significant in enduring the effects of gravity and other external forces as well as maximizing energy efficiency (Kisner & Colby 2012, 414; Diebo, Varghese, Lafage, Schwab & Lafage 2015).
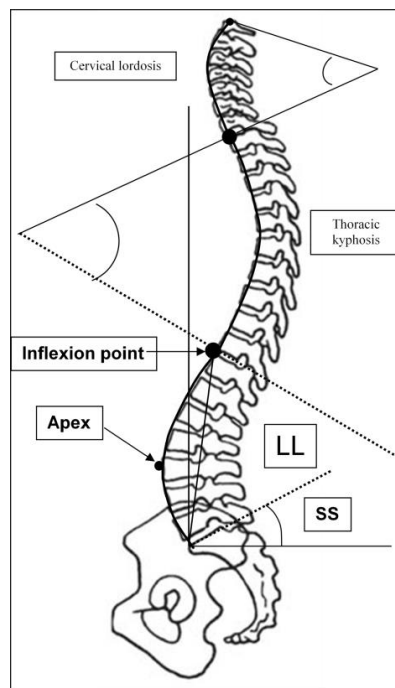
Picture 3. Sagittal spine division by function: limits of spinal curves are determined by the inflexion points (Roussouly & Pinheiro-Franco 2011a).

4.1.1 Vertebrae morphology and arthrokinematics

Vertebrae of each region of the spine have different morphological properties that allow for varied motions and function throughout the cervical, thoracic, and lumbar spine. The movement of two spinal column segments generally occurs at the two zygapophyseal facet joints and the intervertebral disc (the structure altogether is represented as functional unit). Thoracic and cervical spine facets have relatively flat articular surfaces, whereas the superior facets of lumbar spine tend to concave and

articulate with the contiguous inferior convex facets. (Kisner & Colby 2012, 411.) The functional units and the spinal curves are closely related as change in one can imply altered loading to the other. For example, decreased lumbar lordosis is associated with increased lumbar loads. These changes in the loading characteristics can lead to tissue degeneration and additional stress to the muscles. What is more, compromising sagittal balance can present intervertebral discs with additional sustained loading that could cause hydrostatic mechanism failure. (Keller, Colloca, Harrison, Harrison & Janik 2005, 304-306.)

4.1.2 Gravity line

Gravity impacts the structures of the trunk and lower extremities, thus challenging the task of maintaining body's upright position (Kisner & Colby 2012, 414). Bipedalism allows for upper limb liberty leaving feet as the single ground contact point. Nevertheless, humans are able to run and carry loads while maintaining a vertical position and a fixed unstable horizontal sight line, that is essential for balance control. (Le Huec, Saddiki, Franke, Rigal & Aunoble 2011.) Global sagittal alignment is created by translating vertebra and combining angular orientations in relation to the gravity line (Cil et al. 2005, 96).

According to Le Huec, Saddiki, Franke, Rigal & Aunoble (2011), "the line of gravity is a result of a reaction between the ground and an ideal dynamic chain between the trunk, pelvis and lower limbs." The position of the gravity line varies among healthy subjects but always falls within the base of support (Keller, Colloca, Harrison, Harrison & Janik 2005). Frontally, this line is perpendicular to the ground and passes through the middle of sacrum. Laterally, the line is located slightly posteriorly to the femoral heads in quiet stance. (Schwab, Lafage, Boyce, Skalli & Farcy 2006; Roussouly, Gollogly, Noseda, Berthonnaud & Dimnet 2006.)

In pathological cases, the discrepancy of the gravity line causes ergonomic changes to the chain of balance. If the gravity line surpasses the base of support posteriorly, increased thoracic kyphosis is induced. On the contrary, if the line is positioned too far anteriorly, several strategies can be employed: posterior spinal muscle contraction,

pelvis anterior tilt around the femoral heads, hyperextension at the hip joint or excessive flexion at the knees. (Le Huec, Saddiki, Franke, Rigal & Aunoble 2011.) The variation in relation to axial skeleton is reported to be not related to race or gender (Jackson & McManus 1994; Vedantam, Lenke, Keeney & Bridwell 1998; Janik, Harrison, Cailliet, Troyanovich & Harrison 1998; Korovessis, Stamatakis & Baikousis 1998; Chen 1999). In addition, some studies indicate weak age dependency. For instance, in adolescent individuals, the sagittal balance when standing is increased posteriorly. (Vedantam, Lenke, Keeney & Bridwell 1998.) Contrary, in elderly, the sagittal balance shifts anteriorly and thoracic kyphosis increase (Hammerberg & Wood 2003; Hasegawa et al. 2017). Therefore, understanding the attributes of the erect posture regarding the gravity line is important to understand the underlying causes of said alterations (Roussouly & Pinheiro-Franco 2011b).

4.1.3 Role of muscles in posture

To maintain posture, balanced and regular skeletal component arrangement is required. Muscles of the trunk act as spine stabilizers. The superficial trunk muscles (m. rectus abdominis, m. quadratus lumborum, m. erector spinae, m. iliopsoas, external and internal oblique muscles) cross several vertebral segments and provide large guy wire function to the spine through compressive loading. (Kisner & Colby 2012, 417.) Coactivation of trunk flexors and extensors is present even in neutral spine position for mechanical stability (Cholewicki, Panjabi & Khachatryan 1976). The segmental (deep) muscles (m. transversus abdominis, m. multifidus, m. quadratus lumborum (deep portion) and deep rotators) attach directly to each vertebra and preserve inert structures at the limits of motion by controlling each segment's stability (Kisner & Colby 2012, 417). The transversus abdominis plays a key role in the stabilization of the spine as it is shown to be active in both trunk isometric flexion and extension (Cresswell, Grundstrom & Thorstensson 1992). In addition, it activates in the anticipation of limb movements and coordinate respiration during limb activity (De Troyer 1983; Hodges & Richardson 1997).

Muscles located distally from the spine play nonetheless a significant role in posture control. Anterior and posterior muscle structures allocate the load in order to minimize

stress and fatigue to the mechanical systems, including the spine, by providing static (dorsal muscles) and dynamic (ventral muscles) support. Alterations in muscle length tend to stem from one's habits and have an influence on the gravity center: anterior balance is associated with shortened hamstrings and hip flexors, and is more common among subjects sitting long hours at a desk, whereas posterior balance is associated with shortness in gastrocnemius that is frequent in women who wear high-heeled shoes. (Zagyapan, Cihan, Kurkcuoglu, Pelin & Tekindal 2011.) What is more, carrying a high loading backpack (more than 20% of the subject's body weight) results in decreased posture balance control (Grimmer, Williams & Gill 1999; Al-Khabbaz, Shimada & Hasegawa 2008). The imbalance instigated by changes in muscle length could lead to increased muscle fatigue and pain over time (Duval-Beaupère, Schmidt & Cosson 1992; Zagyapan, Cihan, Kurkcuoglu, Pelin & Tekindal 2011).

## 4.2 Parameters of sagittal alignment

Since deviations in the line of gravity can cause significant compensatory mechanisms, placing body structures in positions that are not ergonomically efficient, parameters to analyze sagittal alignment should be defined. For the pelvis these can be the incidence angle, pelvis tilt and the sacral slope, the spino-sacral angle (general analysis); for the spine: the point of inflexion, thoracic flexion angle, the apex of lumbar lordosis, craniovertebral angle. (During, Goudfrooji, Keessen, Beeker & Crowe 1985; Roussouly, Gollogly, Bertthonnaud & Dimnet 2005; Schwab, Lafage, Patel & Farcy 2009; Le Huec, Saddiki, Franke, Rigal & Aunoble 2011; Singla, Veqar & Hussain 2017.) Understanding how these parameters relate to each other can open possibilities for early diagnostics, various treatment possibilities and methods of prevention. However, the correlations provided should not be evaluated in isolation but rather in context of individual as a whole (Boulay et al. 2006; Le Huec, Saddiki, Franke, Rigal & Aunoble 2011; Roussouly & Pinheiro-Franco 2011b).

4.2.1 The pelvis

Pelvis is an essential structure in the maintenance of the upright position. Being the junction point between the lower limbs and the spine, it dictates the position of the

entire vertebral column. In addition, broad iliac wings provide insertion sites for long muscles with a significant lever outcome. On the other hand, this property, combined with the upward tilting of pelvis, requires additional effort from the gluteal muscles to ensure stabilization when standing or walking. (Duval-Beaupère., Schmidt & Cosson 1992; Le Huec, Saddiki, Franke, Rigal & Aunoble 2011.)

Three parameters – pelvic incidence, pelvic tilt and sacral slope – are used to describe pelvic biomechanical properties (Picture 4). (1) Pelvic incidence is used to define the relation between the sacral plate and the femoral heads. This parameter is morphological and specific with each person. (2) Pelvic tilt describes the rotation of pelvis around the femoral heads – a compensation mechanism to counteract spinal malalignment. (Roussouly & Pinheiro-Franco 2011b.) However, depending on the position of the lower limbs and the angle of knee flexion, the femoro-pelvic system fluctuates thus influencing the tilt – greater knee flexion results in greater tilting. Therefore, the measurement should be done in full knee extension. (Vaz, Roussouly, Berthonnaud & Dimnet 2002, 86.) (3) The sacral slope provides the base for the lumbar curve and is positively associated with the angle of lumbar lordosis (Diebo, Varghese, Lafage, Schwab & Lafage 2015, 297). These parameters are interrelated (Picture 5) and have been shown to have correlation to the type of lumbar lordosis representing differing spino-pelvic morphological complex among individuals (Roussouly, Berthonnaud & Dimnet 2003).
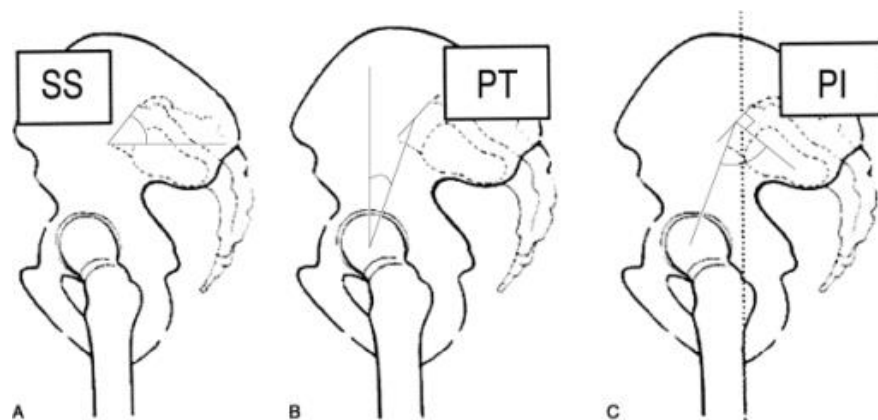
Picture 4. Parameters of the pelvis: sacral slope (SS), pelvic tilt (PT), and pelvic incidence (PI) (Oh, Chung & Lee 2009).
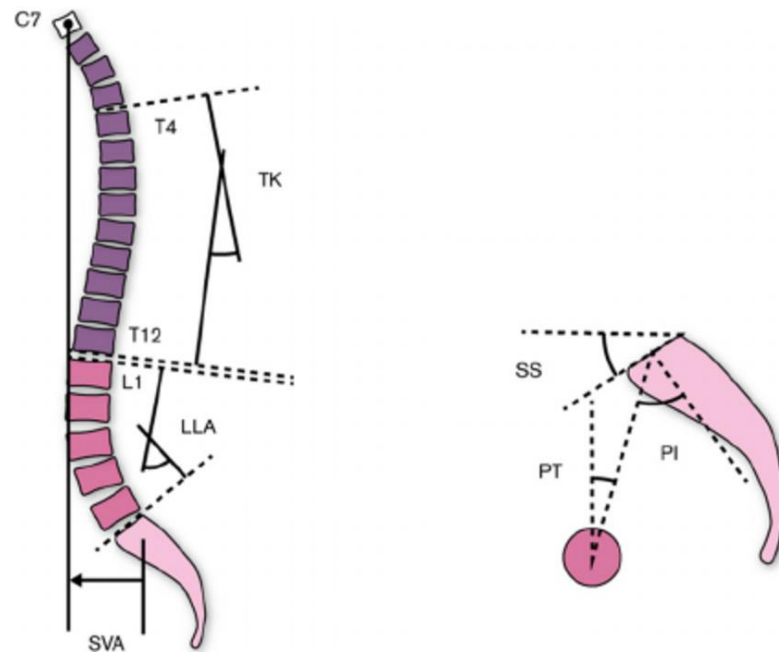
Picture 5. Relation between the spinal (TK - thoracic kyphosis angle, LLA - lumbar lordosis angle, SVA – sagittal vertical axis) and pelvic parameters (SS - sacral slope, PT – pelvic tilt, PI – pelvic incidence) (Todd et al. 2015).

4.2.2 The spine

Several studies determined a strong correlation between the sacral slope angle and the lumbar lordosis (Stanagra et al. 1982; Roussouly, Berthonnaud & Dimnet, 2003; Russouly & Pinheiro-Franco, 2011a). Therefore, the inferior arc of lumbar lordosis has a significant influence on lordosis in the lumbar spine: higher sacral slope angle results in increased values of the spine's inferior arc (Diebo, Varghese, Lafage, Schwab & Lafage 2015, 298). Analysis of the geometrical properties of the spine curves also shows correlation between thoracic kyphosis and lumbar lordosis. Thus, the angle of lumbar lordosis is dependent on both factors (thoracic kyphosis and the inferior angle lumbar lordosis). (Vaz, Roussouly, Berthonnaud & Dimnet 2002.)

4.2.3 Global sagittal balance

Several points have been proposed to evaluate the alignment of the spine over the pelvis and the femoral heads. Since the weight that each vertebra must support varies depending on the changes in spinal curves and pelvic slope, the study by Duval-

Beaupere, Schmidt & Cosson (1992) suggests that "there is a tendency to maintain the body in the most economical position in terms of muscle fatigue and vertebral strain" and designates the T9 tilt (the angle between the vertical axis crossing the midpoint of the femoral head and the line connecting the centers of femoral head and T9 vertebra body) as the spine balance indicator at the level of body mass center. However, C7 plumb line is noted to be the most common measure of the global balance and can be used as a reliable and steady index. The C7 plumb line is projected vertically from the center of the C7 vertebral body and the horizontal distance is measured in regard to the posterior superior corner of S1. (Kuntz, Levin, Ondra, Shaffrey & Morgan 2007.) Measurements from other anatomical landmarks to C7 plumb line can also be used. Commonly, it is the spino-sacral angle – an intrinsic factor used to quantify global kyphosis. Moreover, several studies identify strong correlation between the sacral slope, lumbar lordosis and the spino-sacral angle. (Jackson, Peterson, McManus & Hales 1998; Gardocki, Watkins & Williams 2002; Roussouly, Gollogly, Noseda, Berthonnaud & Dimbet 2006.)

4.3 Classification of sagittal alignment

As suggested by Kisner & Colby (2012) faulty postures are commonly characterised into four main types: lordotic, swayback (slouched), flat back and kyphotic with forward head. These postures are common among adolescent demographic are associated with back pain (Smith, O'Sullivan & Straker 2008).

The lordotic posture is defined by an increased lumbosacral angle and thus an increase in lumbar lordosis curve, anterior pelvic tilt and flexion at the hips. Such posture is usually associated with weak abdominal muscles. (Kisner & Colby 2012, 425-426.)

Swayback posture is defined by hip extension though anterior pelvis shift and flexion of the superior lumbar spine through posterior shift of the thoracic segment. Prolonged maintenance of slouched posture may result in impaired abdominal muscle mobility or impaired lower abdominal, thoracic extensor and hip flexor muscle performance. (Kisner & Colby 2012, 426.)

The main characteristic of the flatback posture is decreased lumbosacral angle, lumbar lordosis, hip extension and pelvis posterior tilt. Decreased mobility in trunk flexors and hip extensors as well as impaired lumbar extensor and hip flexor activity are caused by this position. (Kisner & Colby 2012, 426.)

The round back posture type is expressed by the increase in thoracic curve along If this trait presents in combination with forward head translation, head and scapulae protraction that might lead to impaired mobility of the intercostal and upper thoracic muscles as well as inadequate muscle activity in inferior cervical and superior thoracic region erector spinae, scapular retractors and head flexors. On the other hand, if the neck is in increased occiput flexion, mobility of the anterior neck, thoracic erector spinae and scapular retractor muscles might suffer. In addition, impairment in protractors of scapula and intercostal muscle activity can be observed. (Kisner & Colby 2012, 426-427.)

5 DEVELOPMENT OF POSTURE CONTROL

The postural stability in children improves with age. Until the age of seven, the proprioceptive reflex loop does not yet function, thus resulting in struggles when maintaining balance. Due to fluctuations in neurohomones, posture weakens at puberty but eventually, physiological spinal curvatures and normal muscle tension develops, while the function of balance system mitigates. (Stanek, Truszczynska, Drzal-Grabiec & Tarnowski 2015, 135.)

Sagittal spinal alignment is evolving, and spinal curvature is changing during childhood. As illustrated in Picture 6, thoracic kyphosis (beginning at T1-T2 segment, progressively increasing until the high point at T7-T8 and steadily decreasing to T10-L2) is of greater angle in infants compared to older subjects. At the ages of 8 and 14-16 the kyphosis is more significantly expressed whereas during the growth spurt, spine anterior vertebral growth starts surpassing posterior growth, thus diminishing thoracic kyphosis. Lordosis (from L1 to S1) is reported to gradually increase throughout pre-

growth spurt period and decrease in magnitude only at around age 13-15. (Willner &
Johnson 1983; Nissinen 1995; Cil et al. 2005, 99; Poussa et al. 2005.)
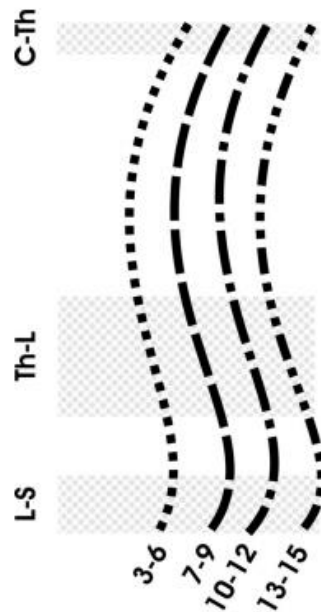
Picture 6. Spine curvature changes from childhood to adolescence (Cil et al. 2005,
99).

According to Dede, Büyükdogan, Demirkıran, Akpınar & Yazıcı (2016), spine sagittal
alignment changes occurring throughout childhood and adolescence are more likely
linked to the maintenance of sagittal balance and not the profiles of separate vertebrae.
Even though the spinopelvic parameters in this age differ compared to the adult meas-
urements, the correlations are shown to be similar (Mac-Thiong, Labelle, Berthon-
naud, Bertz & Roussouly 2007). With age, the increasing pelvic tilt and lumbar lordo-
sis match the morphological and physiological changes that are present in children's
development and prevent the anterior centre of gravity shift (Mac-Thiong, Berthon-
naud, Dimar, Bertz & Labelle 2004).

Some significant differences in the sagittal spinal alignment between genders are also
reported. Various studies described changes in thoracic kyphosis and lumbar lordosis
related to adolescent growth spurt (Mellin & Poussa 1992; Widhe 2001; Cil et al.
2005). General tendency in gravity line position in prepubescent subjects is gender-
specific, thus suggesting that the variances in lever arms and loading distribution are
related to gender and some even imply that these differences are specific across posture
categories. Boys with neutral and sway-back posture present "more forward inclina-
tion of the trunk, more thoracic kyphosis and more pelvis back tilt compared with

girls", whereas girls with leaning-forward posture showed lumbar segmental hyperextensions as well as "more forward trunk lean, less thoracic kyphosis and more pelvic anteversion". (Dolphens, Cagnie, Vleeming, Vanderstaeten & Danneels 2013.) These changes seemed to positively correlate with growth velocity but while thoracic kyphosis was more prominent among males and lumbar lordosis among females, after the phase of peak growth, continuation of increasing thoracic kyphosis is observed only in male subjects (Willner & Johnson 1983; Poussa et al. 2005). Additionally, research on some developmental spinal disorders (adolescent idiopathic scoliosis, spondylolisthesis, and spondylitis) show prevalence ratios linking to gender (Masi, Dorsch & Cholewicki 2003; Lonstein 2006; Tsirikos & Garrido 2010; Schlosser et al. 2015). Generally, the described postural changes occur at different ages in different genders and this is linked to the difference in the beginning of adolescent growth spurt (Cil et al. 2005, 99).

6 POSTURE ANALYSIS METHODS

6.1 X-ray analysis

Even though there is no standard procedure for posture analysis and postural assessment methods still lack scientific precision, they can provide physiotherapists some information about deviations from the norm. While X-ray analysis is able to provide definite reference points and is thus considered the "golden standard" in literature, it exposes the subject to radiation and is usually not applicable in physiotherapy on a regular basis. (Hazar, Karabicak & Tifiticki 2015, 2123; Singla, Veqar & Hussain 2017.)

6.2 Photographic analysis

Photography of a subject in standing position is a method that can be used in posture screening due to the "reasonable correlation between radiographic measurements and

the placement of markers" (Rosario 2013). When using this method, it is very important to correctly define the locations of anatomical markers as measurements of angles and small distances can be easily skewed if the markers have not been used correctly. C7 is easy to locate and can be applied for spine, head and shoulder measurements while other spinous processes are marked together and used to measure spinal curvatures. (Niekerk, Louw, Vaughan, Grimmer-Somers & Schreve 2008; Rosario 2013; Ruivo, Pezarat-Correia & Carita 2014.)

The photographic analysis method is considered to be accurate and objective and thus is often found in scientific literature, but other similar methods such as using the line of gravity and palpation should not be neglected when analyzing subjects posture, especially in heavier-weight subjects when some anatomical landmarks may be more difficult to locate (Rosario 2013, 60).

7 ONLINE STUDY TOOL

7.1 Blended learning

Blended learning methods incorporating contact lessons with electronic resources (that do not entirely replace face-to-face interactions) are used quite often in the modern classrooms. They seem to provide the benefits of both ends of the spectrum. While the traditional face-to-face learning allows for creating a learning community and providing instant response to questions or discussions, it does present the requirement for a specific participation schedule. On the other hand, tools based online and aimed at individual studying offer flexibility and convenience both in terms of location and time. (Welker & Barardino 2005.) One can access any needed information at their fingertips and discuss with others around the globe and the teacher can ensure effective student feedback and program supervision (Tang & Byrne 2007). Using online tools is often chosen due to its cost-effectiveness and the ability to consider individual differences and varied study pace (Arkorful & Abaidoo 2015, 34).

Unfortunately, such immense electronic studying tool flexibility may present some challenges. The issue of having technology to access the information is rarely of concern in the age of computers and smartphones, but these devices are also used for entertainment and communication. Constant distractions disturb students' focus and can interfere with the process resulting in longer time to complete the task (but not the comprehension of the information). Such outcome naturally eliminates the advantage of effective individual scheduling and can decrease one's motivation to use online tools in studying. (Fox, Rosen & Crawford 2009.)

Moreover, online discussion can be indicated as ineffective due to decreased social interaction and decreased responsiveness that might cause confusion and require motivating less autonomous students. This issue might require more effort to be put by both students and teachers and decrease the motivation to use the resources online. (Heinze & Procter 2004; Welker & Berardino 2005.) However, this additional time can promote cognitive thinking skills and thorough information processing. Not only that, online discussion also helps to level and promote learner participation as well as assist collaborative learning (e.g. sharing different perspectives and information). (Chen & Looi 2007.) In-class discussions are chosen among students, if given a choice, but discussing online too results in positive response (Tiene 2000).

7.2 Learning and motivation

Pintrich & Schunk (2002, 5) define motivation as "the process whereby goal-directed activity is instigated and sustained". When considering what could increase one's motivation to use an online study tool, individual differences and rewards have a significant role. Focusing on intrinsic goals to achieve the goal is indicated to be more motivating and requiring less effort. (Simons, Dewitte & Lens 2004; Website of American Psychologist Association 2017.) Pupils connecting their performance to external rewards (such as grades, instructor approval, etc.) and failing to see the use for the learned information show significantly lower motivation than their peers with the opposite type of instrumentality (Simons, Dewitte & Lens 2004).

7.3 Questionnaire

To better understand what kind of learning tool would enhance students' interest and motivation, a short thesis introduction with a questionnaire was sent out to the first-year student class at SAMK as well as two third-year students. The questions were intentionally open-ended, and encouraged to share their thoughts on the Basic movement classes they have had so far ("Were there any part of the course you wished you had more information on/more extra reading? Any part(s) you feel were explained enough/had too much emphasis and there is no need in repeating that?"). The reasoning to choose these questions was to understand how the students feel after finishing this basic course and what are their interests/weak points they would like to develop. The second part focused on the learning style that the students find most effective ("How do you prefer to study: make your own notes/mind maps/drawings etc. or having bullet points at the end of the reading material to revise after you're done reading?"). The intent to inquire information on preferred learning techniques was related to efficient presentation of information and tasks in the study tool. To account for individual differences, the students were not limited to only these questions could also submit any other notes related to the subject.

Answers were received from three first-year students and one third-year student. The younger students reported sometimes feeling lack of knowledge, especially in practical tasks and "contradicting" and overwhelmingly vast amount of information online. The third-year student reported that the course was well-structured, and one would not feel topics being repetitive. "The information did not go too deep in certain topics, since we were only learning anatomy at the same time."

As expected, some differences in recording learned information were described, too. Some students stated that they preferred having short bullet points with the essential information, while others said they remember better when making their own notes. In addition, visual data recording, such as drawings and mind maps, was noted positively.

7.4 The online platform

The studying tool was created based on the information gathered and in consideration to the answers given by SAMK's students. In order to make the information easily accessible, a website link was created.

The contents of the tool are divided into four parts: Posture control, Biomechanical influences, Development, and Posture analysis. Information is presented as a summary of the concepts the students learn in their classes (e.g. the anatomy of the spine, systems involved in the control of posture) and simplified introduction to biomechanical concepts (such as gravity line, inverted pendulum) and their effects on the body. As the information is introduced, it is sometimes interrupted by a quick question to consider, that would hopefully, allow for better understanding or deviations deeper into the topic.

The tool aims at providing comprehensive and easily accessible information that can be referred to later. However, only passive presentation was avoided, and student involvement is encouraged. This is done through small tasks (e.g. filling the ICF framework for posture and adding to it as one reads further or drawing a scheme of spinal changes in children through age) that serve as additional notes on the subject and incorporate the visual elements that are easy to remember.

When creating the tool, the audience was kept in mind thus more advanced details were avoided when possible. However, articles exploring sagittal spinal alignment were in some cases involved as a button for additional reading that is not compulsory but can provide a clearer view through mathematical explanations and thorough illustrations.

Last subsection of *Posture analysis* invites the students for a case examination. The students ought to think of interview questions and role-play the situation with a friend who decides on the answers. Such method intends to create different cases and encourage the student to think of the possible evaluation scenarios. Next, the student has to decide on the markers s/he'd be analysing and practice locating those on their peers.

While the tool or its parts might create an impression of lack of instructions at times, it has to be emphasized that it is proposed to be used as a blended learning tool, i.e. not as a completely independent project but rather as an additional tool to combine theory and practice and as a catalyst for discussion on the topic.

8 DISCUSSION

Balanced and efficient postural control is important to both the functions of internal systems and movement without pain or risk of injury. The intention to choose adolescent posture analysis stemmed from observing the decline in active lifestyle and increasing sedentary habits in pupils and how important the role of physiotherapy is in registering and addressing the critical fluctuations as soon as possible.

Physiotherapists should be educated on inherent and acquired changes and how to implement therapy (or refer to a different health care professional) in different cases. Understanding the arrangement of bodily systems and how they react to the environment is also important to enhance critical thinking and clinical reasoning together with patient education skills. In terms of thesis, this area seemed as an opportunity to explore the current scientific literature and share the knowledge with fellow physiotherapy students.

Nevertheless, posture is a wide subject, and even narrowing it to adolescent age group and focusing on only sagittal alignment of the spine proved to be of wider scope than anticipated. Given the intention of covering posture arrangement on various levels, the subject had to be narrowed to standing posture which only partially addresses the issues of the nowadays lifestyles mentioned above. Moreover, the focus was shifted to static posture as this analysis is common in clinical practice. However, analysing dynamic posture would be equally beneficial as it would take the practice from the clinical to everyday application.

The theoretical background for the final product was being collected for a rather long period of time (from February to November 2017). One of the reasons for this was the vast amount of information available about posture. Not only the subject is complex and covers different concepts such as static and dynamic posture, balance, development, biomechanics and physiology, but it is a topic that has been researched for a long time and thus providing extensive information.

That being said, research on spine stability and spine biomechanics in the past few decades showed detailed and consistent analysis of the processes in question, in turn providing a comprehensive overview and allowing for a better understanding that could be implemented in posture analysis, pathology and corrective surgery. The research on children posture development is, similarly, consistent. However, the papers tend to review posture development throughout the span of toddler- to adult-age thus making it a little more difficult to extract the information needed for the adolescent age group that was analysed in this thesis.

After the theoretical material was collected, a questionnaire was sent out to assess the shape and content needed in the online tool. Unfortunately, when conducting the questionnaire, only a small number of students delivered their answers therefore providing insufficient representation. The material for the online tool was compiled using their answers and the theory gathered on motivation and online learning techniques but a greater participation would have given a better idea on what the students would enjoy and benefit from the most. On the other hand, the answers submitted were extremely valuable. As simple as it sounds, the answers emphasized the audience of this project and prevented from delving into too much detail that would diminish motivation to learn or comprehension of the information presented.

Initially, a pilot of the project, followed by participants' feedback was also planned. However, currently, no volunteers have responded thus leaving this part of the project unfulfilled, but this could be a subject for future thesis studies. What is more, the project could grow to provide information on different posture types, adding to what is already there. Alternatively, different posture failure coping strategies could be explored as part of thesis thus enriching the existent content of the product.

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