SEMMELWEIS UNIVERSITY BUDAPEST
DOCTORAL SCHOOL

RISK FACTORS OF PROLONGED SITTING AND LACK OF PHYSICAL ACTIVITY IN RELATE TO POSTURAL DEFORMITIES, MUSCLES TENSION AND BACKACHE AMONG ISRAELI CHILDREN. A CLINICAL CROSS SECTIONAL RESEARCH

Written by: Ben-Zion Adar

Academic research consultants: Prof. Róbert Frenkl

The Scientific Committe:
Dr. János Mészáros Ph.D., president
Dr. Anikó Barabás Ph.D. secretary
Dr. István Berkes Ph.D.

Dr. Éva Martos CSc. opponent
Dr. Tamás Szabó CSc. opponent

BUDAPEST, 2004

Table of Contents

List of Figures

List of Tables

Appendices

Preface

During childhood and adolescent growth, the development of bones and muscles should be coordinated, because muscular forces influence the growth and function of bones and joints. The alignment and posture of the spine is related to the length and balance of muscles attached to the spine and pelvis (Toppenberg and Bullock, 1986). Its misalignment is considered as a cause of back pain (Milgrom et al 1993, Christie et al 1995, Adams and Hutton 1985). Despite great care dedicated to proper motor function in children, shortness of muscles is common among them (Katz 1992, Reimers 1993). This may be due to a modern lifestyle related epidemic of inactivity- e.g. the time spent in front of TV and computers – which is one of the factors related to the increasing of back pain among children (Balague et al 1994, Gunzburg 1999). The trend of changes in the spinal curvatures during childhood growth period is not well known, in particular its relationship to the changing length of the ilio-psoas and hamstring muscles during this period, especially with regard to sitting habbits and the amount of physical activity of young children.

The purpose of the present study was to assess the changes in length and flexibility of muscles in the lower extremity around the knee and the hip among Israeli school children, and their relationship to the curvatures of the lumbar and thoracic spine and the prevalence of back pain, according to various of sitting parameters and physical activity parameters.

I wish to thank Prof. Robert Frenkl, Prof. Haim Weinberg and Dr. Victor Roth for their invaluable assistance in reviewing this work throughout its preparation.

Ben-Zion Adar, Jerusalem, Israel, 2004

1. INTRODUCTION

1.1 Posture

The term posture is not easily defined, and even today no consensus exists with regard to its definition. The definitions proposed do not usually gain acceptance by researchers, due to their unilateral tendencies. There are also further difficulties, such as: individual variation in posture properties, the influence of extrinsic factors that change over time, and the close relation between the physiologic and psychic aspects of posture. Furthermore, we do not have at our disposal any uniform gauge or standards for posture that can provide us an overall description of the phenomenon over its various aspects. This also holds from a medical viewpoint, as the effort made in many studies on this subject has hitherto failed to assist in the clarification of the posture problem (Gilad, 1982).

The definition of posture according to the American Orthopedic Association, made in 1947, only goes to demonstrate its own shortcomings in clarity: "Good posture is a state of equilibrium of muscles and skeleton that protect the body's supporting structures from damage or deformation in any state of rest or work. Bad posture is a relation of body parts that causes increasing effort on the supporting structures, wherein there is a less efficient body-base equilibrium."

The human posture excels mainly in the interdependence between various body parts. The major difference between man and quadrupeds is that the axis of the human body is parallel to the vertical line. This exemplifies the importance of coordinated functioning between various body systems. Posture here means a situation upholding an optimal equilibrium between the skeleton and the forces developing within muscles. The advocates of the physiological approach diagnose normal posture as one in which the consumption of energy is minimal, with no overloading of connective ligaments or strain or deformation in the positions of a various sections of the locomotive system. (Gilad, 1982). However, it cannot be established that there is a uniform posture that is good for everybody. Wiles states that the demands for good posture among healthy people are sufficient muscular strength and sound reflexes. The muscular strength required for maintaining correct posture is low, meaning that muscle weakness alone is not likely to lead to postural defects. He claims that in many cases the reason for such defects lies in postural reflexes, and that this factor must be given the most attention (Wiles, 1937).

Raskin describes sound posture as a situation identified with a decent appearance and good health. An upright posture and a supple gait are a universal symbol of a pleasant, esthetic appearance, and there is a high correlation between these expressions of posture and appearance with feelings and states of health. (Raskin, 1990). Kendall et al. Also described the amount of deviation of the various points of reference from the vertical line (plumb line) as revealing the extent to which an individual's alignment was faulty. They provided extensive examples of different variations in human posture and contrasted these to the ideal standard posture.
(Kendall et al.1993).

The prevalent definition to be found in professional literature describes ideal posture as an upright posture upon standing, in which the center of gravity runs, on the lateral plane, on a vertical line from the center of the vertex, crosses the lordotic arch of the cervical vertebrae, runs through the chord of the kyphotic arch through the front edge of the shoulder, crosses the lordotic arch of the lumbar vertebrae, goes through the head of the femur at the hip joint, through the plane of the hip to the knee, continuing to reach slightly anterior to the ankle. The center of gravity of these parts falls as close as possible to this line. In the saggital plane, a vertical line descends from the center of the vertex through the spinal column, bisecting the body at its center, runs between the legs to reach the middle point between the feet. (Feldenkrais, 1966; Kendall, 1971; Wiles, 1937; Asmussen, 1985; Clarkson & Gilewich, 1989; Raskin, 1990 and others). The muscles in this position generate equal tension on both sides of the body. This is a natural muscle tone without intentional, voluntary effort.

A defective posture is manifest in a change of the body's position in standing relative to the vertical line running through the saggital and frontal planes described above (figure 1).

Figure 1: Ideal posture **(Kendall et al.1993)**

Kendall et al state that due to posture being dynamic and variable in nature, it must meet the following criteria:

a. Minimal tension and stress on the weight bearing structures (pelvis, lower limbs).
b. Balanced distribution of stress and weight between joints – to prevent pain or deformation.
c. Maintenance of equilibrium.
d. Dynamicity – an ability to alter position and activities easily, rapidly and efficiently.

e. Optimal function of the various body systems, especially the respiratory system.
f. Horizontal ocular plane.
g. Esthetic posture.

(Kendall, 1971).
In fact, good posture is a compromise between the criteria listed above.

<u>1.1.1 Postural ‘types’</u>

An early and apparently influential classification of postural types was firstly made by Staffel in 1889. (Raine & Twomey, 1994). Staffel qualitatively categorized different types of posture (Figure 2) in standing when viewing from the side according to the labels of ‘normal’, ‘roundback’, ‘flat back’, ‘lordotic back’ and ‘kypholordotic back’.

Figure 2. postural types by Staffel . (Raine & Twomey, 1994)

Wiles described the lumbar lordosis, sway back, flat back and round back posture types, four types into which he considered the majority of cases of postural variation could be classified (Figure 3). Such postural variations were referred to as ‘deformities’ and they were defined on the basis of two principal components, variation of pelvic inclination and the presence of a dorsolumbar kyphosis.
In a person demonstrating a lordotic posture, the pelvis was described as titled anteriorly and the lumbar curve was exaggerated, whereas the thoracic curve was increased slightly , having the appearance of an exaggerated kyphosis due to the exaggeration of the spinal curves above and below. A sway back in contrast, was demonstrated when the pelvis was tilted forward with a concomitant dorsolumbar

kyphosis, often merely a flattening of the upper part of the lumbar curve. A flat back posture was described when the pelvis was tilted backward and as the result the curvature of the lumbr spine was flattened . The round back posture, as described by Wiles, occurred in individuals with reduced pelvic inclination and an associated dorsolumbar kyphosis (Raine & Twomey, 1994).

Figure 3. Classification of the types of ‘ postural deformity’ by Wiles
(Wiles, 1937)

1.2 Postural deformities:

1.2.1 Lordosis

Lumbar lordosis is a state wherein the lumbar spinal column tilts anteriorly due to an overextension of the lumbar vertebrae. The pelvis tilts anteriorly, with the hip joint flexed. The knees are overextended, the Ilio-psoas muscles are very short and can rotate the pelvis anteriorly, thus increasing the lumbar recess. Furthermore, the abdominal muscles are very weak, and may cause the waist to move forwards, thus increasing the lumbar recess. Kendall, in addition to these reasons, states that the

imbalance of body parts due to this muscular status may be detrimental to the relations of body organs, thus increasing lumbar lordosis (Kendall et al, 1993).

In the case of increased lumbar recess, the abdominal muscles are weak and long. The hamstrings can also be long and weak, or short. Short, strong muscles are those of the lower back and the thigh flexors (Kendall et al, 1993).

1.2.2 Dorsal kyphosis:

This postural defect is manifested in an increase in the convexity of the dorsal arch. The position of the body organs in dorsal kyphosis is as follows:The head is turned anteriorly, with the cervical vertebrae extended anteriorly. The scapulae may be abducted. Long, weak muscles, in this state are the neck flexors and upper erector spinae. The middle and lower trapezius muscles are weak in the case of abducted scapulae.

1.2.3 Sway back.

In this postural deformity, there is a transfer of the pelvis and hip joint anteriorly, beyond the center of gravity line. The lumbar curve flattens out. The pelvic position may be normal or inclined posteriorly. The hip and knee joints are overextended. Long and weak muscles in this state are: one of the thigh flexors, the external oblique abdominal muscles, the upper back extensors, and neck flexors. Short, strong muscles are the hamstrings and the internal oblique muscles, and the lower back muscles are strong but not short. With the posterior incline of the pelvis, there is a flattening of the lumbar spinal column and upper back. The thorax is positioned posteriorly. This is not a state of lumbar lordosis. (Kendall et al, 1993).

1.2.4 Flat back.

In this postural feature, the lumbar curve is flat, with a posterior incline of the pelvis. The hip and knee joints are overextended. The head is canted anteriorly, with an increase of the convexity of the dorsal spinal column.One of the thigh flexor muscles is long and weak. The hamstrings are strong and short. The abdominal muscles may also be strong, with long back muscles.(Norris, 1995; Kandell et al, 1993).

1.3 Children's posture patterns:

Changes in body proportion occurring during the years of growth are essential to the adaptation and adjustment of the body to gravity. The pelvis may tilt downwards

by 25-30 degrees. The knees are usually slightly bent, and overextension of the knees is not essential for maintaining equilibrium between the upper and lower body. The lower limbs gain stability and can bear the body weight of the growing child. From the age of 6, in the primary school period, there is a growth spurt of the lower limbs. At the age of 10 for girls, and 11½ for boys, there is a decrease in the speed of the growth of the upper limbs (Asher, 1975).

a. Age 7.5: 40 degree pelvic tilt.
b. Age 8: 35 degree pelvic tilt.
c. Age 9 : 42 degree pelvic tilt.
d. Age 12.5: 36 degree pelvic tilt.

Asher states that the determination of posture patterns during the childhood years is made according to the following indices: state of head, neck and shoulders, scapulae, protrusion of abdomen, lordosis, kyphosis, pelvic tilt and knee posture. Asher further states that this posture, despite the variations in pelvic tilt, is normal for girls at primary school age with a mesomorphic build. The forward pelvic tilt angle decreases with the increase in age, and reaches a difference of 6 degrees between 7 and 12½ year old girls. This posture is characterized by a stance with the pelvis rotated anteriorly downwards. This may be associated with lumbar lordosis or an anterior protrusion of the abdomen. In order to achieve balance, the knees are overextended, and scapulae retruded backwards. Furthermore, lumbar lordosis may be very large. In comparison with primary school age girls with an ectomorphic build, there are postural characteristics that differ from the mesomorphic build.

a. Age 6 – 58 degree pelvic tilt.
b. Age 7 – 40 degree pelvic tilt.
c. Age 10½ - 38 degree pelvic tilt.

The pelvic anterior tilt angle decreases with the increase in age, and is between 38 and 58 degrees. There is a marked decrease of 18 degrees from age 6 to 8. From age 8 to 10, the decrease in pelvic tilt is only 2 degrees. This posture pattern is characteristic of tall children. This posture is more passive than that of the mesomorphic build, due to the little effort involved in countering gravity. The pelvis is tilted anteriorly, and the abdomen protrudes slightly. The knees are overextended. There is a slight lumbar lordosis. The spinal column leans slightly posteriorly. The scapulae are winged, the

neck leans anteriorly, and there may be a slight kyphosis. Asher describes this postural pattern as swayback. This pattern, he states, has been found to be common among primary school pupils, and is very rare among adults. (Asher,1975).

The postural characteristics of primary school age boys indicate a protruding abdomen, lumbar lordosis and overextended knees, with pelvic tilt between 34 degrees at 7 years old and 39 degrees at 12 years of age.

a. Age 7 – 34 degree pelvic tilt.
b. Age 8 – 35 degree pelvic tilt.
c. Age 12 – 39 degree pelvic tilt.

There is an increase in the pelvic tilt angle from 34 degrees at age 7 to 39 degrees at age 12. On the other hand, among girls with mesomorphic build, the trend for change with age is decreased. Seven-year old girls with a 40 degree pelvic tilt reach a tilt of 36 degrees at the age of 12. (Asher, 1975). In contrast with Asher, who states that there are changes in the characterization of postural indices with age and build-dependent, Asmussen, in his article about the structure and function of developing children's spinal columns, states that the variations in the spinal curvatures change very little relative to the increase in height over age (figure 4). In this study, the deviations

Figure 4. Deviation of Lordosis and kyphosis angles by child height.
(Asmussen, 1982).

of angle with growth in height were measured at the following points:

a. The line between the tragus and C7.
b. The line between C7 and the kyphotic peak point.
c. The line between the kyphotic peak point and the deepest point of the lumbar lordosis.
d. The line between the deepest point of lordisis and the end point of the lumbar lordosis.

These angles were measured for 200 Danish children, in comparison with height (Asmussen, 1982).

Apparently, the proportions of body sections change very little with the increase in age. The proportions for girls were almost identical to those of boys. Asmussen did not find significant differences for either boys or girls, in the relative changes in lordosis and kyphosis between the ages of 8 and 16, as expressed with relation to height (figure 4).

Figure 5. Kyphosis and lordosis for boys and girls, by child height.

(Asmussen, 1982).

The lumbar lordosis and dorsal kyphosis curvatures in the figure 5 were calculated according to the degree of deviation of these curvatures from the straight vertical line of the back. Apparently, there is a greater tendency for variations among girls than boys (not significant), but variations relative to growth in height are almost

identical for boys and girls. Lumbar lordosis, apart from the slightly high values for girls, is apparently barely influenced or increases only slightly with increase in height. In contrast, dorsal kyphosis for both sexes increases with increased age for the age group sampled. In Asmussen's opinion, the spinal curvatures, lordosis and kyphosis, according to the series of measurements made, featured slight variations during the growth period between 8 and 16 years of age (Asmussen, 1982).

Mellin et al. found that girls had less thoracic kyphosis than boys. The most significant sex difference (8.2^0, $p<0.01$) occurring at 13-14 years of age (Mellin & Poussa, 1992). This gender difference was smaller in the a study by Willner et al. who found the least kyphosis among both boys and girls at the age of 10-12 years, and an increase at the ages of 8 and 14-16. They also reported that the lumbar lordosis was more pronounced among girls, and that there was a small continuos increase of lordosis in both sexes between 8 and 16 years of age (Willner & Johnson. 1983) .

1.4 The spinal column:

The spinal column is the main part of the osseo-cartilaginous system, and has many functions. On the one part it contains the spinal cord – the central nervous system, serves as a bearing for other essential systems and in fact bears all the systems of the body, and on the other part is serves as a fulcrum for the body's movements, with the body's upright posture dependent on it. These functions are provided for by the special, complex structure made up of the continuity of vertebrae and vertebral disks. All these components work together as an integral system, but are vulnerable
both as a system and as units thereof, (Gilad, 1983).

There are 33 vertebrae forming the spinal column: 24 individual ones, the sacrum (5 fused vertebrae) and the coccyx (4 fused vertebrae) (Anderson, 1983).

7 Cervical vertebrae, designated C1 to C7. These vertebrae form the cervical lordotic arch. 12 thoracic vertebrae, designated T12 to T12. These vertebrae form the dorsal kyphotic arch. 5 lumbar vertebrae, designated L1 to L5. These vertebrae form the lumbar lordotic arch. 5 sacral vertebrae, designated S1-S5, and fused to form the sacrum. 4 coccygeal vertebrae, fused to form the coccyx, (Anderson, 1983). From an anterior view of the 33 vertebrae constituting the spinal column, one may see that their bodies gradually increase in size downwards. Between their bodies, the intervertebral disks serve to separate them. From the posterior view one

may track the flat transverse processes of the cervical area changing to large processes at the upper back, whereas for the two lowest dorsal vertebrae, these processes are barely visible. In contrast, in the lumbar area large and well-developed transverse processes appear again. This has an influence on the mobility of the spinal column in different areas. The variations in the spinal processes are also marked. The cervical vertebrae processes are short and ramified These are replaced by long, narrow processes pointed sharply downwards in the back. In the lumbar area, short and very solid processes appear, which face posteriorly in a straight line. From a lateral view the curvature of the spinal column is apparent. In the neck area, the arch is concave posteriorly- cervical lordosis . In the lumbar area, the arch is once again concave posteriorly - lumbar lordosis, whereas in the dorsal and sacral areas the arch is convex posteriorly - thoracic kyphosis (Gilad, 1983). While standing, the line of gravity passes between these curves, so there is a need to use the erector spinae muscles in order to maintain equilibrium. The functional unit of the spinal column is comprised of two vertebrae and the soft tissues surrounding them. From an anterior view, the unit resembles two cylinders (the vertebral bodies) adapted to one another, for holding and supporting pressure loads from above downwards. These two bodies are separated by a hydraulic system (the intervertebral disk) and are connected by longitudinal ligaments. The intervertebral disk provides internal support, while ligaments and muscles surrounding the vertebrae provide external support for the spinal column. From a posterior view, one can identify two arches, two transverse processes and one central body. The transverse processes have two articular surfaces, one inferior and the other superior, called "facets". These protuberances are insertions for the erector spinae muscles. In addition, there are a number of posterior ligaments that take part in the stabilization of the vertebrae from behind.

The facets are synovial joints at the posterior part of the vertebral bodies. The direction of possible movement for each section of the spinal cord (cervical, thoracic and lumbar) is limited by the direction of these joints. Apart from two cervical vertebrae (C2-C3), the facets in the cervical region are directed 45 degrees to the horizontal, and are parallel to the frontal plane, which allows for flexion and extension, lateral flexion and rotation. In the thoracic area, the facets are 60 degrees from the

horizontal plane and 20 from the frontal, allowing for movement including lateral flexion, rotation, and slight flexion and extension. In the lumbar area, the articular facets are directed perpendicular to the horizontal and 45 degrees in the frontal plane, allowing for flexion and extension and lateral flexion without any possibility for rotation, (White & Panjabi, 1978). In the past, it was thought that the main role of the facets was the direction of movement, and that they had only a secondary role in load distribution. However, contemporary studies (El-Bohy & King, 1986) have shown that load distribution between the facets is associated with the position of the spinal column, and that the facets can support 30% of the load applied to the spinal column. These loads are especially large when the body is overextended or flexed forward combined with rotation. The vertebral arches have an important role in resisting loads. The erector spinae muscles insert into the transverse processes in these arches. This is where the movement of the spinal column begins.

The erector spinae muscles provide external stability to the spinal column structure. In contrast the ligaments surrounding the spinal column provide internal stability. The ligaments contain collagen fibers providing them an ability to resist tension. The ligamentum flavum connects the two arches of adjacent vertebrae. This ligament is an exception to the other spinal ligaments as it contains a large amount of elastic, providing it with an active role in the support and stabilization of the vertebral bodies. The ligamentum flavum spans between two vertebrae and contributes to the forming of intervertebral pressure for the disk (Nachemson & Evans, 1968; Rolander, 1966). The effort exerted on the ligaments depends on the type and direction of movement performed with the spinal column. For example when flexing the torso, the interspinous ligament is the one subjected to the greatest effort, with the capsular ligament and ligamentum flavum bearing less. In extending the torso, on the other hand, the anterior longitudinal ligament is the one to bear most of the load (Adams & Hutton, 1980).

The intervertebral disk is made of soft collagenous material, containing fluids. The fluid content is greater in younger than in older people. This composition allows the disk to absorb various loads mechanically. The superior and inferior surfaces of the disk are connected to the vertebral bodies. The disk is built up of rings known as the annulus fibrosus. The core, the nucleus pulposus, is within the center of the concentric

rings. Exceptions to this rule are the lumbar disks, whose nuclei are situated somewhat posteriorly. The nucleus pulposus contains some 88% fluid, and pressure applied to the nucleus is transferred to the outer rings. The rings are made up of collagenous fibers arranged in cross-linked bundles. This cross-linking allows the rings to resist flexion and stretching (White & Panjabi, 1978).

1.4.1 Spinal column mobility:

Movements in daily life are complex, including various regions of the spinal column, and are made in three planes. Movements combine other organs, such as the pelvis, in order to achieve a large range of movement or to conserve energy. When one part is fixed and cannot move, another adapts itself to make the movement in mind.

Within the vertebral system of the spinal column, each vertebra is connected to the adjacent one by an intervertebral disk between the vertebral bodies, and by articular facets between the articular processes of the posterior part of each vertebra.

Each movement made by the spinal column is a combination of small movements made between the individual vertebrae. Some movements may be restricted by body parts, such as the thorax, that limits the spinal column to flexion, or the pelvis, that accompanies the spinal column's movement by rotation (tilting). The measurement of ranges of movement in given sections of the spinal column is a complex and complicated task, mainly because of the many components involved in movement. A further difficulty is the great difference between individuals. The ranges of movement are associated mainly with age. Young people's spinal columns have a much wide degree of movement than those of older people. The disks allow for the angular movement required for flexion in such a way that the articular facets slide over one another, despite the movement being a wide range flexion. The greatest freedom of movement is in the cervical area, where the articular facets are horizontal. This allows for anterior and posterior flexion and rotation. The first two joints, between the cranium and the atlas and between the atlas and the axis, each allow for 15 degrees of flexion (Anderson, 1983).

Normally, the flexing ability of the spinal column is more than that of extension. Some 75% of flexion is provided for by the lumbosacral joint (between L5 and S1). Remaining flexion is distributed among the other vertebrae. The flexing mechanism for lifting an object from the floor, for example, is provided for by the coordination of the

flexing of the spinal column and anterior rotation of the pelvis. When flexing the spinal column, the first 50-60 degrees of movement occur mainly in the lumbar region. The anterior rotation of the pelvis adding range to flexion after the first 50 degrees is apparent (Farfan, 1975).

In flexing the spinal column, the movement is initiated by contracting the abdominal muscles and the vertebral part of the psoas major muscles. Gravity adds to the increase of action thereafter, while the erector muscles limiting the action as antagonists. In addition, the posterior thigh muscles act against the anterior rotation of the pelvis, (Carlsoo, 1961). With maximum flexion, the erector spinae muscles are stretched out and become less active. The spinal column thus held up by the erector muscles, which are stretched and inactive, and the posterior ligaments, which were flaccid at the onset of the movement. In lifting (extension) movements, the muscles rotating the pelvis posteriorly are the main ones active, working in unison with the erector spinae. When the pelvis is rotated, they are the major actors, with vertebral movement support provided by the posterior ligaments. In this state, the lumbar spinal column flattens out, with very high intervertebral pressure building up (Nachemson, 1963). Correct, coordinated lifting may prevent a great part of these pressures (Farfan, 1975). Lateral flexion occurs mainly in the thoracic region of the spinal column. This movement is mainly restricted by the articular facets. The muscles acting on the spinal column are the spinotransversals and the transversospinals of the erector spinae, with

the contralateral sides working as antagonists. Horizontal rotation of the spinal column occurs mainly in the thoracic and lumbar regions. Less rotational movement occurs in the lumbar region, due to the direction of the articular facets. The movement occurs through the erector spinae and abdominal muscles acting together, with antagonism from the contralateral side.

In the dorsal area, the shape of the articular processes allows some freedom of movement, but the presence of the more solid ribs and intervertebral disks allows for only limited movement. The long spinal processes in this area restrict posterior flexion significantly. Despite the size and shape of the lumbar vertebrae, a great degree of movement is permitted in this area. The thick intervertebral disks in this area contribute to this freedom. The articular facets in this area are vertical, and face one another to allow for anterior and posterior flexion, and only limited rotation. The tendons and

ligaments have elastic properties, and tend to return the back to its state of origin. In this way they contribute to stability during locomotion and flexion. However, they tend to restrict provisions for movement.

Anterior flexion is restricted by the posterior longitudinal ligament, whereas posterior flexion is restricted by the anterior longitudinal ligament and by the spinal ligaments.

<u>1.4.2 Biomechanical aspects of the spinal mobility:</u>

From an anatomic point of view, upright posture is dependent on the osseous system, the ligamentous system and muscular system. From a biomechanical viewpoint, these three systems form a complex system of stresses, in which tension, pressure and shearing complement one another and ensure an upright posture. Posture is mainly determined by the spinal column, as in contrast with the backbone of quadrupeds, it has an additional function in humans as the bearer of weight above the pelvis, and articular moment generated in rest and movement are applied to it, in addition to the pressure applied by the body's weight itself, in order to preserve static and dynamic equilibrium. Static mechanical equilibrium is defined as the sum of moment and forces applied on a given point, an axis of rotation or point of gravity, which must be zero all the time. Dynamic equilibrium is defined similarly, but it holds at every place and time (Gilad, 1982).

Bipedal locomotion has lead to a fundamental change in the location of the postural center of gravity. For quadrupeds, the body's load is distributed over an area running between shoulders and thighs, leading to a stable equilibrium. This equilibrium is similar to that of a suspension bridge, which is a flexible structure with an ability for limited self-imposed movement (Gilad, 1982). Gilad claims that according to Slijper's bowstring principle, the kyphotic spinal column of quadripeds acts as an arch that tends to flatten out under the body's weight. This tendency is balanced out by the longitudinal tension enacted by the rectus abdominis and oblique abdominal muscles, which tend to flex the arch. The spinal column acts as a bow, whereas the tense system of abdominal muscles acts as a "bowstring". This structure provides for special flexibility of the entire system. In Gilad's opinion, the same principle may be applied to the description of the upright human's backbone. The bow principle is applied, first of all, to the cervical section of the spinal column. Differing from quadrupeds, whose

spinal column is dorsally convex at the back, this section is dorsally concave in man owing to the backbone's cervical lordosis. The neck muscles and ligaments are located dorsally. The same state holds also for the lumbar section of the spinal column. The cervical and lumbar sections of the spinal column have developed as a special mechanism leading to mobility along with the existing bowstring system – the transversus abdominis and rectus abdominis muscles, intercostals and neck muscles, which act as a bowstring, whereas the spinal column as a whole, including the pelvis, acts as the bow.

The integration of these systems leads to the excellent mobility of the upright spinal column, and ensures its ability to function under loading and as a stabilizing organ (Gilad, 1982). From a biomechanical viewpoint, the pelvis has become the base of the upright spinal column. It must absorb the forces and moments of the upper body during erect posture. The forces and moments must be absorbed and balanced out within the pelvis, which works as a base. This is possible owing to the strong muscular system that has developed surrounding the lumbar joints. The pelvis has become the axis of rotation for the gluteus maximus and ileo-psoas muscles. The system of forces applied by these muscles fix the pelvis in upright posture.

MacNab, in the context of atrophy of the intervertebral disks, states that strong lumbar muscles are the most important factor against recurrent attacks of disk atrophy. The spinal column is not a self-supporting structure. If the abdominal and lumbar muscles were neutralized, the backbone would collapse. The spinal column is supported by muscular activity, just as the mast of a ship is supported by ropes, anteriorly and posteriorly, by back and abdominal muscles. In addition, the abdominal cavity acts as a hydraulic pump, distributing the loads caused by pressure upwards towards the diaphragm, and downwards towards the pelvic floor, to reduce the load borne by the vertebrae. For this reason, the tone and strength of the abdominal muscles are of vital importance to the protection of the vertebrae during the lifting of heavy loads and during tensile exertion (MacNab, 1990).

The three curves in the sagittal plane (thoracic kyphosis, and cervical and lumbar lordosis) contribute: a) to the spinal column's ability to bear large loads, and b) to the maintenance of an upright back during equilibrium. Studies assessing the spinal column's in vitro resistance to vertical forces have shown that fracturing occurs at loads of 20 Newton (Nachemson, 1981). However, at this point other factors come into play, such as muscles, so that the spinal column is capable of withstanding greater forces.

In standing, the line of gravity runs slightly anterior to the fourth lumbar vertebra. This means that the body tends to fall forward. To balance this out, the erector spinae muscles act, together with the abdominal muscles, to stabilize this forward movement. Such synergistic action occurs constantly, with the aim of maintaining an upright posture under equilibrium. The degree of activity of this system depends on the angles of kyphosis and lordosis.(Basmajian, 1958; Nachemson, 1966).

The pelvis also plays a role in maintaining equilibrium. In figure 7, the sacrum is depicted at the normal upright angle (30^{o} anteriorly). During posterior rotation of the pelvis, while standing, the sacral angle is reduced, along with that of lumbar lordosis. In this state, kyphosis is synergistically reduced in order to prevent too large a deviation of the line of gravity. Similarly, when the pelvic angle increases, lordosis and kyphosis also increase. In other words, the pelvic movement affects the curves and static loads on the spinal column (Floyd & Silver, 1955).

Figure 7. Effect of pelvic rotation and sacral angles.
(Floyd & Silver, 1955)

Another factor influencing the loads in the spinal column (apart from the lordotic and kyphotic angles) is the posture one assumes. Postural changes cause reflex changes in the spinal column's angles. During relaxed standing, the relative load

applied to the intervertebral (see figure 8), (Anderson et al, 1974). As anterior flexion increases, the loads also increase, causing increased pressure within the intervertebral disk. In figure 8, one can see that the intervertebral pressure during lying is the lowest, whereas the upright pressure is lower than that of any seated postures. In addition, figure 8 shows that out of all the sitting positions, straight sitting with lordosis maintained and sitting with the upper limbs supported are the positions with the lowest intervertebral pressures. Kyphotic sitting with an anterior tilt of the body is associated with the highest pressures. The factors increasing the intervertebral pressure during kyphotic sitting as opposed to standing are as follows:

During kyphotic sitting the pelvis is rotated posteriorly, straightening out the lordosis, with an anterior shift of the line of gravity, leading to a lever whose fulcrum is within the disk, and maintenance of equilibrium achieved by using the erector spinae muscles (Lindh, 1980). During standing, some of the load is supported by the joint facets. (Adams & Hutton, 1980). Some state that 16 percent of the total load is supported by these facets. In addition, these researchers state, that in kyphotic sitting, the joint facets do not share in loading. Anderson (1974) maintains that during kyphotic sitting, intervertebral pressure is increased because of posterior pressure, as opposed to standing, where the pressure is normal (evenly distributed across the entire disk area).

Figure 8. The relative loads on L3 in various body positions
(Anderson & Orengren, 1974; Nachemson & Elfstorm, 1970)

The action of the iliopsoas muscle in sitting also increases the load on the spinal column. During upright sitting with an anterior rotation of the pelvis, the loads are reduced somewhat, but they still fail to reach standing levels. Anterior rotation of the pelvis is possible when the knees and thighs are extended. Sitting with posterior support is associated with lower loads than sitting without such support. In this situation, some of the body's weight is supported by the back-rest. The back-rest serves to reduce the loads when supporting the lumbar part of the back at an optimal incline angle of 100º (figure 9). however, when the back-rest supports the thoracic portion only, the lumbar region tends to move posteriorly, and flatten thus bearing an increased load (Anderson & Orengren, 1974).

In another study conducted by Anderson & Orengren (1974), the electrical activity of the erector spinae, and the intervertebral pressure in the lumbar spine, were assessed. The researcher placed electrodes on the subjects' backs, and inserted a pressure-sensitive needle between vertebrae L3 and L4. The measurements were made in states of standing, unsupported and supported sitting and with the back-rest adjusted at a number of angles. The results of this study were: a) the greatest intervertebral pressure occurred in unsupported sitting. When subjects sat with back support, the

Figure 9. Effect of back-rest angle and lumbar support on L3 intervertebral disk pressure. (Anderson & Orengren 1974).

intervertebral pressure subsided with increased inclination of the back-rest. b) The electrical activity of the erector spinae muscles was similar in standing and upright sitting without support. c) Positive correlation was found between the two measurements (intervertebral pressure and electrical muscle activity. Also found that back, shoulder and neck muscles were less active during sitting with a slight incline than for sitting upright.

Klausen (1986) assessed the relation between the electrical activity of the erector spinae ,the abdominal muscles and the standing spinal column angle. Men, with an average age of 22 years, took part in this study. The researcher found that the standing kyphotic angle was more emphasized in the subjects whose abdominal muscle electrical activity was greater than that of the erector spinae muscles. Zacharow (1987) suggested that the flexed position can be associated with shortened abdominal muscles and increase kyphosis.

Ochipinti & Colombini, (1985) examined the degree of physical stress applied to the lumbar spine during sitting, with the upper limbs supported by a table. They concluded that in situations with the body inclined forwards at an angle of 30 degrees, the arms support between 10-15% of the body weight and the strain on the lumbar region decreased. Furthermore, a high positive correlation was found between EMG-measured contraction intensity of the erector spinae muscles and the torso flexion angle. A significant difference was also found between the erector spinae contraction intensity and the bending angles, with the lumbar portion of the spinal column being flattened i.e. tending to kyphosis.

Bridger & Wilkinson, (1989) conducted a study with the aim of examining the ergonomic characteristics of sitting on a chair with the seat inclined at various angles. Based on a comparison between angles at various positions, the researcher reached the conclusion that lordosis straightens out following sitting, especially with the thigh angle being 90 degrees to the pelvis, with a horizontal seat. It was also found that the kyphotic angle is less influenced in the seated position. In addition, no statistically significant interaction was found between the kyphotic and lordotic angles and the gender of the subjects.

In another study conducted by Bridge et al. (1989), evaluating the motile ability of the pelvis and the angles of the spinal column during standing and various seated postures, 25 women were examined. The correlations between the spinal column angles and anthropometric variables (weight, height and ratio thereof) were calculated. No statistically significant relations were found, and according to this researcher, there is no connection between body build (endomorphic or ectomorphic) and the spinal curves. However, statistically significant correlations were found between the lordotic and kyphotic angles, together with a statistically significant relationship between these angles and pelvic motility. In other words, the angles were more emphasized (small, in this case) when the pelvis was less mobile. For subjects with limited pelvic movement, the lordosis underwent greater changes when the subjects moved from standing to sitting. From this it was concluded that the lack of flexibility of the muscles limiting pelvic movement may prevent straightening of lordosis during sitting.

Toppenberg & Bullock (1986) examined the connection between the spinal curves and the length of various muscle groups in adolescent girls. He used the inclinometrical method for measuring spinal curves, and found a significant negative relation between the erector spinae length and the lordosis angle. He also found a significant positive correlation between the length of the abdominal muscles and lordotic angles, a significant negative relationship between hamstring length and lordotic angles, and a significant negative connection between abdominal muscle length and kyphotic angles. In the literature, conflicting approaches can be found with regard to sitting recommendations. One, presented by Corlett & Bishop (1976), states that sitting must be with a slight bend of the body, with thighs lifted towards the pelvis. The supporters of this approach include Adams and Hutton (1985), who reviewed the influence of various sitting positions over the spinal column. In this review they outlined the advantages and disadvantages of the "bent" compared to the "straight" position. (The "bent" back position is associated with the disappearance of the natural angle of lordosis (figure 10).

Figure 10. Lordotic angle in bent and standing positions, and anatomic sitting.
(Adams and Hutton, 1985)

The authors noted reduction of posterior vertebral joint pressure, reduction in pressure on the posterior part of the intervertebral disk, improvement of metabolite transport to the disk, and increased resistance to pressure. On the other hand, the disadvantages of the bent position included: increased pressure on the anterior part of the disk and hydrostatic pressure on the nucleus pulposus. Their conclusion was that the disadvantages were not significant to cause damage to the spinal column, whereas the mechanical and nutritious

advantages (for the disk) were more significant, contributing to the health of the spinal column. Mandal (1982) and McKenzie (1981), on the other hand, state that lumbar lordosis during sitting must be similar to that of standing, which
may be achieved by increasing the thigh angle. Keats & Morgese (1969) found that an angle of 135 degrees between the thigh and pelvis, lumbar lordosis is maintained similar to that of standing. Anderson (1974) and Nachemson (1975), some of whose studies are mentioned above, support this approach. They proved that the loads measured in the interbertebral space during standing (with normal lumbar lordosis) were smaller than those of sitting.

1.5 Postural evaluation and measurement

1.5.1 Problems in evaluating and measuring posture:

The evaluation of posture for growing children is no easy task. There are still no valid tests for measuring various parameters of body mobility, normal muscle length, muscular force and body mobility. (Hanne, 1982). Furthermore, postural changes during growth years and differences in postural characteristics related to gender and body build lead to difficulties in establishing a consensus for postural standards. (Dauer, 1983).

In the evaluation and measurement of posture, we must be well aware of the problems associated with this task, including:

a. Difficulty in forming standards of posture that take individual variation into account.
b. Subjects tend to stand in unnatural poses due to their being aware of the postural examination they are subject to.
c. In repeat measurements of posture, subjects find it difficult to reconstruct the exact position they were previously in.
d. Administratively, postural evaluation usually entails a lot of time, and measuring instruments may be costly.
e. The use of photographs previously required a high degree of skill in the fields of lighting and lens adjustment, in order to achieve clear, well-defined pictures. Recent improvements in photography equipment, such as automatic adjustment and zoom, have abolished this problem to a significant degree.
f. The subjective evaluation of posture is usually controlled, due to the low validity and fidelity of postural evaluation procedures.
g. Due to the manifold variables associated with posture, doubts always rise with regard to the accuracy of measurement, and questions always arise with regard to the true significance of the measurements (Johnson & Nelson, 1986).

1.5.2 Methods and means for postural evaluation and measuring:

1.5.2.1 Physical examination:

Physical examination provides a great deal of information concerning the location of body sections, but is not considered scientific. This examination is undertaken with the subject standing barefoot wearing only short underclothing. The examination is performed from an anterior view, reviewing such major parameters as the symmetry of the iliac crest, anterior superior iliac spine, greater trochanters, overall contour lines, nipple height, waist symmetry and clavicular symmetry. The posterior view examination includes: cervical lordosis, shoulder height symmetry, inferior scapular angle height symmetry, winged scapulae, spinal curvature and scoliosis. The lateral view examination includes: locked knee, spinal curvature, rounded shoulders and cervical lordosis. The examiner must assure that the feet remain in a uniform state during the examination. The heels must be a constant distance from one another. Physical examinations must be undertaken systematically, from head to toe. (Hines, 1980).

1.5.2.2 New York state postural evaluation test

This postural evaluation includes 13 different areas of the body. On the evaluation sheet, three pictures are depicted, indicating each of the positions for the first stance. The subject stands facing forward towards the examiner. For each of the

positions measured, the examiner gives a grade of 1 to 5. “Correct position” (5 points), “slight deviation” (3 points), “significant deviation” (1 point). The highest grade that the subject can receive is 65 points.

The postural evaluation is undertaken using two observation points. The first stance is undertaken with the subject standing facing a screen, so that the vertical line bisects the back of the head, leading downwards along the spine, passing between the legs and feet. From this position lateral deviation is evaluated. The second postural evaluation position is performed with the subject standing with his side along the vertical line, with a line passing through the tragus, shoulder, thigh, knee and foot. The malleolar point must be on the vertical line. From the results of examining children, it has been found that the correlation coefficient range for test validity is between 0.93 and 0.93. In this test, measurement norms were established for boys and girls from 4^{th} to 12^{th} grades (Johnson & Nelson, 1986).

1.5.2.3 Spinograph – Wellesley posture test (MacEwan and Howe 1935)

This instrument uses a pointer that plots the subject’s spinal column. The drawing of the curvatures is made on a sheet of paper alongside the pointer (figure 11). In this

Figure 11. Spinograph

(Johnson & Nelson, 1986).

way of measuring spinal curvatures, various body sections such as arms, thorax, back muscles and protruding scapulae, do not conceal the true spinal column line, as stated as a shortcoming of measuring methods based on silhouettes and photographs. Postural measurement is determined according to the weighing of 3 spinographic measurements (Johnson & Nelson, 1986).

1.5.2.4 Symmetrigraph:

This instrument serves for evaluating posture from lateral and frontal view. Postural examination with this instrument is simple and rapid. A normal range of the subject's posture does not necessitate further processing of postural evaluation. Postural evaluation against a line board increases the fidelity of this evaluation significantly as opposed to evaluation without a symmetrigraf board. (Dauer, 1983).

1.5.3 Methods for measuring angles of the spinal column :

A number of studies have measured the posture of the erect spine. In common with one another, they examined the surface curvatures of the thoracic and lumbar spines in the sagittal plane, employing a variety of different methods.

Some researchers consider the measuring of spinal column angles as a factor that may define functionally healthy (ergonomic) positions in daily use. Other researchers have placed importance on the determination of the normal angles of the spinal column in the sagittal plane as part of the clinical diagnosis of structural spinal pathologies. (Bernhardt & Bridwell, 1989).

Measurement of the spinal column, while standing or sitting, requires use of more complex methods. To this end, methods, such as that used in Cobb's protocol, were developed, along with measurement using an inclinometer (Bridger et al, 1989) or a pantograph (Willner, 1981).

In their study of the curves of the spinal column, Bernhardt & Bridwell (1989), measured the angles between the thoracic kyphosis and lumbar lordosis. Measurements were made on 55 females and 45 males, including children (age range was 4.6 to 28.6 years, mean age = 12.8 years). The data was accomplished using lateral radiograms taken with the subjects standing in the anatomic position, and the calculation of the two angles was performed using Cobb's principle. Cobb's protocol establishes the measurement of the kyphosis angle by drawing lines parallel to the superior end plate of T3 and the inferior end plate of T12. The angle is measured at the intersection of the perpendiculi of both these lines. The lordosis angle is measured in the same way from a line parallel to the superior part of T12 and a line parallel to the inferior part of L5. (Figure 12).

Figure 12. Cobb's lordosis and kyphosis angle in the sagittal plane.

Bernhardt & Bridwell, 1989

The results indicated that the mean average in the thoracic area is 36 degrees, with a standard deviation of 10 degrees (range 9-53 degrees). The mean angle in the lumbar area was 44 degrees with a standard deviation of 14 degrees (range 14-69 degrees). The researchers reported that there were no statistically significant differences between age and sex in this age range. The mean location of the peak of kyphosis was between T6 and T7 (sd = 1.5 vertebrae), and for the peak of lordosis this was between L3 and L4 (sd = 0.5 vertebrae). A similar study was carried by Flint (1963) using lateral Photographs (figure 13). The lumbar lordosis angle was determined from the perpendiculi dropped between the T12 and L5 tangents and the angle of their intersection was recorded. Thoracic kyphosis was similarly determined using a modification of this method for C7 and T12. The validity of this technique has been documented by Flint and the correlation between X-rays and this method was found to be significant (p = 0.01) for the lumbar curve between L2 and L5/S1 (Heather 1995).

Figure 13. Measurement of Lumbar lordosis (L) and Thoracic Kyphosis (T)
(adapted from the method described by Flint, 1963)

The Statometry (Molhave method)method is based on a technique of calculating angles of spinal curvature based on photographs of the subject from a lateral view, by designating points in various areas of the subject's body using markers. The subject stands laterally, parallel with the vertical, with markers applied to his body on the following sites: tragus, spinal process of C7 (vertebra prominens), peak of kyphosis, maximum lordosis point (deepest point of lumbar recess), superior posterior iliac spine, major trochanter, turbeculum pubicum, lateral epicondyle and lateral malleolus. The method whereby spinal curvatures and pelvic incline angles are measured was based on the analysis of line angles between the various points (Asmussen, 1982).

Bridger et al, (1989), performed a study in which the angles of the spinal column were measured in the saggital plane during standing and sitting, (25 men and 25 women with an average age of 28.4 and 22.4 respectively). The measurements were performed using an inclinometer, an instrument composed of a ruler placed on the subject's back, with its end in continuation with the end plate of the vertebral body, allowing for measurement of the angle between this line and the line of gravity perpendicular to the ground. The inclinometer was placed in three places: a) between L5 and S1; b) between T12 and L1; c) between T1 and T2. Based on this data, the spinal curvature angles could be calculated using a mathematical formula. According to the researcher, this inclinometry method is accurate, and the correlation between it and methods for measuring angles using radiograms is high. The kyphosis and lordosis angles were measured in the anatomical standing postion and in 4 other positions of sitting. The anglular results measured in anatomical standing were: For men: 33.6 (±10.9) degrees of lordosis and 55.8 (±7.9) degrees of kyphosis; For women: 34.8 (±9.9) degrees of lordosis and 53.7 degrees (±7.8) degrees of kyphosis.

In another study conducted by Bridger and others (1989), to examine the mobility of the pelvis and the spinal angles while standing and in sitting positions, 25 women were examined. This study also used inclinometry for measuring the spinal angles . In addition, the range of movement of the pelvis was measured by measuring the length of the muscles restricting its movement (hamstrings and iliopsoas). The mean angle for lumbar lordosis in standing was 32.6 (±10.72) degrees, and for dorsal kyphosis 30.9 (±11.0) degrees.

Carr et al. (1991) used the ISIS method for examining the spinal curvatures in 271 children (aged 10-16 years), and 72 adults (aged 21-59). This method of measuring spinal angles is based on photography using multiple camera instrumentation and analysis of the pictures was performed automatically by the equipment.

Only healthy subjects without signs of scoliosis were chosen. The results of the study indicated that there were no statistically significant differences between boys and girls of different ages. In contrast, statistically significant differences were found between the kyphotic angles of adults and those of children, for both male and female subjects. The mean kyphosis angle for 10 year old boys (N=20) was 36.7 (±7) degrees, and for girls (N=18) this angle was 34.9 (±7.3) degrees. The angle of lordosis for 10 year old boys was 31.1 (±6) degrees and for girls 38.3 (±9.7) degrees.

Another method of measuring spinal angles was used by Willner (1981). The method implemented the use of a pantograph, an instrument to copy profiles on paper at a smaller scale than the original. After the profile is plotted onto paper, the tangents were drawn on the spinal curves and the angles were calculated. Using the pantograph, back curvatures in the sagittal plane were measured for 30 subjects. In addition, radiographs were made of the subjects in order to measure the angles using Cobb's protocol. The aim of the study was to examine the validity of pantography. The results indicated a correlation of R= 0.91 between the angles derived from the two methods. The kyphosis angle was 39.7 (±12.2) degrees, and that of lordosis was 38.9 (±11) degrees.

Article	N	Sex	Age	Lordosis (SD) deg.	Kyphosis (SD) deg.
Bernhardt & Bridwell (1989)	100	M+F	X=12.8	44.0 (14)	36.0 (10)
Bridger (1989)(a)	25	M	X=28.4	33.6 (10.9)	55.8 (7.9)
Bridger (1989)(b)	25	F	X=28.4	34.8 (9.9)	53.7 (7.8)
Bridger (1989)(c)	25	F		32.6 (10.72)	30.9 (11.0)
Carr (1992)	20	M	10	31.1 (6)	36.7 (7)
Carr (1992)	18	F	10	38.3 (9.7)	34.9 (7.3)
Willner (1981)	30	M-F		38.9 (11)	39.7 (12.2)

Table 1: Summary of kyphosis and lordosis angles in anatomical position, measured in various studies using various methods.

1.6 Anatomic review of the muscles action:

1.6.1 The hamstring muscles:

The hamstrings are the muscle group including the biceps femoralis, semitendinosus and semimembranosus muscles, whose origin is in the ischial tuberosity and insertion is in the tibia and fibula (Anderson, 1983). The three muscles, the semimembranosus, semitendinosus and biceps femoris act together to flex the knee, extend the hip joint and adduct the thigh. The biceps femoris, through its ischial fibers, can also serve as a weak lateral rotator of the thigh. With bent knees and free legs, the biceps femoris is the main lateral rotator of the leg. When the leg and foot are fixed, this activity causes a medial rotation of the femur. The femoral part participates in both these actions.

The semitendinosus and semimembranosus muscles are medial rotators of the thigh and medial rotators of the leg then the knee is bent. The hamstrings, being biarticular muscles, have exclusive functional relations with the their antagonist, the rectus femoris, the only biarticular muscle of the anterior part of the limb. When the knee and thigh are to be flexed, the hamstrings act distally to flex the knee, while the rectus femoris acts proximally to flex the knee, but it cannot extend the leg due to the hamstrings' action. During the extension of the thigh and knee, the hamstrings and rectus femoris change roles. This action with the rectus femoris is essential for preserving the muscle at optimal length and maximal tone. The amplitude of the muscle's action is in direct relation to the length of its parallel fibers. A straight-fibered muscle can contract by up to 50% of its maximal length. The semitendinosus muscle, being straight-fibered, has a greater amplitude than that of the semimembranosus. The semimembranosus muscle, owing to its large cross-section, can develop greater tone. The biceps femoris muscle is straight-fibered, but it is limited in action due to its insertion into the femur. The overall cross-section of its two heads is greater than that of the other two muscles. (Anderson, 1983).

According to Bauman, these physiological anatomic differences between the muscles explain functional differences. The semitendinosus and the short head of the biceps act mainly during the swing stage of locomotion, which requires great amplitude of muscular action. The seminmembranosus and the long head of the biceps femoris act mainly during the stance stage, which involves a building up of tension within the muscle. (Baumann, 1980).

1.6.2 The iliopsoas muscles:

The iliopsoas muscle group include three muscle group includes three muscles: the psoas major, psoas minor and iliacus . The psoas major muscle flexes the thigh, with a slight lateral rotation. When the thigh is fixed, it rotates the pelvis medially and increases lordosis by pulling on the lumbar vertebrae. It serves as an active ligament of the hip joint. In opposed movement it flexes the waist towards the lower limbs, thus increasing lordosis. The action of the iliacus muscle is identical to that of the psoas major. It flexes the thigh, and rotates the pelvis medially, increasing lordosis, when the thigh is fixed.

The two muscles stated above are important for posture. They stabilize the hip joint and prevent the anterior shift of the pelvis. The action of the psoas minor muscle manifests in the stabilization of the pelvis with relation to the lumbar ligaments. It also flexes the torso towards the pelvis. (Carmeli, 1993; Anthony & Kolthoff, 1975; Anderson, 1983).

1.7 Muscle length measuring tests:

The tests undertaken for measuring the length of muscles are aimed at establishing whether the muscles' range of movement is normal, limited or excessive. Muscles that are too long are usually weak or lead to short antagonists. Muscles that are too short are usually strong, with long antagonists. A muscle length examination test is composed of movements that increase the distance between the muscle's origin and insertion and extend the muscle in the direction opposing its direction of action. (Kendall et al, 1993).

1.7.1 Tests for measuring hamstring length:

1.7.1.1 Straight leg raising test (SLR):

This test is passive, i.e. conducted by the examiner, with the subject being passive. The SLR test has three variables: the lower back, hip joint and knee joint. The knee joint is controlled by its insertion during extension, with the knee locked. The lower back and pelvis positions are controlled by the maintaining of the pelvis and sacrum flat on the measuring table (Kendall et al, 1993).

Initial position: Lying supine, with legs extended and lower back and sacrum flat on the measuring table, this is an essential position for standardizing the test requirement. The knee must be extended, without flexion, and the lower back lies on the table without any lordotic arch, in order to control the variance resulting from the anterior or posterior pelvic incline. If the lumbar lordotic arch cannot be abolished. It is recommended to place a cushion under the knees, until knee flexion eliminates the lumbar arch. With lower back and sacrum flattened out, the examiner holds the contralateral thigh with slight passive pressure on the thigh's flexors, in order to prevent excessive forward inclination of the pelvis prior to the initial raising of the second leg as part of the SLR test (Figure 14).

Figure 14. SLR test

Kendall et al, 1993

Test movement: Lying supine, with lower back and sacrum against the table. One lower limb is held down by the thigh and the other is lifted slowly, with extended, unflexed knee, and relaxed foot. The relaxation of the foot is intended to prevent the gastrocnemius acting on the knee. When this muscle is taught, it causes a flexion of the

knee if the foot of the lower limb examined is flexed. This may cause an intervention in the hamstring test. During the raising of the limb, if the knee bends slightly, we must lower the limb slowly, extend the knee and raise the limb again, until resistance is felt or the subject feels slightly uncomfortable. The angle between the table and raised lower limb is the degree of hamstring movement. According to Kendall et al, 1993, the normal range of movement of the hamstrings is at least 80 degrees, or greater. A range of movement of 50 degrees is considered to indicate a shortened muscle. An angle exceeding 90 degrees indicates an excessively long hamstring muscle group . There is a modification of the SLR test, when the thigh flexors are short. When the waist is overly extended, the pelvis inclines anteriorly, and the hip joint is already flexed. If the test is performed from this position, hamstrings of normal length will be found to be short. (Kendall et al, 1993).

1.7.1.2 Toe touch test for measuring hamstring length:

This is an active test performed by the subject himself. The length of the hamstrings is measured by the range of movement of the hip, with extended knees. In the SLR test there is a flexion of the thigh only through the movement of the thigh towards the pelvis. In the toe touch test the pelvis moves towards the thigh (Figure 15). In the SLR test, the angle between the thigh and table (horizontal) is measured,

Figure 15. Toe-touch test

Kendall et al, 1993

whereas in the toe touch test the angle between the sacrum and table is measured. In both cases, the total movement of the hip joint allowed by the hamstrings is measured. When there is no difference in the length of the left and right hamstrings, the toe touch test is a practical, accurate tool. When there is such a difference, the SLR test is to be performed. Initial position: the subject sits down, with flexed thighs, straight knees and relaxed feet, without plantiflexion. Keeping the knees straight ensures that the hamstrings stay long and straight above the knee joint. Preventing plantiflexion of feet serves to prevent the gastrocnemius from flexing the knees as a result of its tension. From this position, the subject performs a sit-up, with hands stretched anteriorly, attempting to touch his toes. In this state the subject tilts the pelvis anteriorly towards the thighs, flexing the hip joint until reaching the angle the hamstrings allow him to.
The measuring angle is between the sacrum and table at the end of the toe-touch. The normal range of movement from the state of the pelvis flexed anteriorly towards the

thighs is at a point where the angle between the sacrum and table is at least 80 degrees. (Kendall et al, 1993). This test, according to Kendall et al, also examines the flexibility of the back muscles, but here the distance between fingertips and toes is measured.
As shown in figure 16, one’s ability to reach one’s toes with one’s fingers can be considered normal for young children and adults. But many children aged 11 to 14 who do not have short muscles or stiff joints cannot complete the maneuver.

Figure 16. The toe-touch normal degree of flexibility by age.
Kendall et al, 1993

The reason for changes in the ability to flex the hip joint at different ages apparently lies in the fact that the limbs in picture D, of 11 to 14 year old children, are long relative to the waist, in comparison with other age groups (Kendall et al, 1993).

1.7.2 Thomas' method:

This test examines the length of the iliopsoas muscle (figure 17). The subject lies prone with hand under chin. Throughout the test the pelvis remains close to the bed. The examiner slowly lifts the lower limb until a moderate resistance was encountered (Ahlback & Lindahl, 1964). The examiner holds the subject's limb above the knee, with the limb completely straight without any flexion in the knee. The examiner's right hand presses the subject's waist in order to fix the pelvis to the table. The test angle is between the line running of the greater trochanter and lateral malleolus and the horizontal. Daniels state that a 30 degree range of movement is considered to be a sound range with regard to suppleness of the muscle (Daniels, 1972).

Figure 17. Hip extension test.
Ahlback & Lindahl, 1964

1.8 The relation between hamstring and iliopsoas length, pelvic position angle, and spinal curves

The stabilizing systems of the spinal column curves include an active mechanism provided by the muscles. The muscles provide motion control that is essential to the normal functioning of the spinal column. Sound movement is not dependent only on the mobility of the passive joint, but also on the active stabilization provided by the muscles. Therefore it is important emphasizing the components of muscle length and power, and the movements influencing the spinal curves. The quality of movement, more than just its power, is important for the process of balancing muscle groups. (Norris, 1995).

During childhood years, the body muscles and tendons must develop proportionally to the dimensions of the child, because of the muscles' influence over bone growth, posture and body joint functioning. Reimers believes that the imbalance of muscle systems due to shortened muscles has not been given sufficient attention during the many years of ensuring the proper motor functioning of children. (Reimers, 1993).

In a study held in Israel between normal 1-10 year old children, it was found that the popliteal angle value, constituting an index for the length of the hamstrings, was greater that what was conventionally thought. (Katz, 1992). In a similar study performed in Denmark on children aged 3-17, it was found that 75% of the boys and 40% of the girls had shortened hamstrings. (Reimers, 1993). Katz relate the increase in hamstring muscle tone from age 4 to the gradual increase of the lumbar curve and the anterior incline of the pelvis that starts from age 3. The anterior incline of the pelvis, they state, is counterbalanced by hamstring tone, which is manifested in an increased popliteal angle result. The wide range of movement of the popliteal angle among older children is a result of differing angles of anterior pelvic incline. (Katz, 1992). Kendall, in contrast, states that contraction of the medial and lateral hamstrings causes a flexion of the knee, and a very strong contraction leads to a posterior tilting of the pelvis and a flattening of the lumbar spine. Muscle contraction allows for straight standing, but such a posture would be characterized by a posterior tilt of the pelvis and a flattening of the lumbar lordosis. Short iliopsoas muscles will lead to an anterior tilting of the pelvis, and an increase of lumbar lordosis (Kendall, 1971). The opposite assumption, allegedly, raised by Katz from the findings that Kendall raises in his book with regard to the hamstrings, is based on the existence of compensatory changes occurring due to a shortening of the hamstrings prior to the increase of dorsal kyphosis, thus leading to an increased apparent lordosis.

In describing the muscle groups in a state of lumbar lordosis, Norris mentions the "pelvic crossed syndrome" raised by Janda. There is an imbalance of muscles in the lumbar area surrounding the pelvis that causes an anterior pelvic tilt and lumbar lordosis. This occurs combined with tension in the thigh flexors and erector spinae muscles, and a weakness of the abdominal and gluteal muscles (figure 18). In this syndrome, the pelvic tilt increases. This tilt is usually countered by a shortening of the hamstrings, which attempt to tilt the pelvis in the opposite direction (Norris, 1995).

Figure 18. Pelvic crossed syndrome

Norris, 1995

In Toppenberg's research concerning the relations between the spinal curvatures, pelvic incline and muscle length, a significant negative correlation ($R=-0.213$, $P<0.05$) between the length of the hamstrings and the lumbar recess. Shorter hamstrings have been associated with a greater degree of lumbar spine curvature. Toppenberg states

that this finding is surprising, as the customary opinion is that shortened hamstrings lead to a posterior pelvic tilt, thus leading to a flattening of lordosis. He claims that these findings raise questions concerning the correctness of the traditional view of the connection between pelvic tilt, lumbar lordosis and hamstrings. (Toppenberg & Bullock, 1986).

In the study conducted by Gajdosik et al, concerning the influence of the hamstring length over lordosis and dorsal kyphosis among 3 groups of people with differing hamstring length, similar findings were raised. He claims that the hamstring length may be associated with a given posture of the pelvis and waist. Shortened hamstrings have been found to be associated with a decrease in the range of movement of pelvic angle and lumbar angle flexion. This means that the increase of the lumbar recess and the anterior tilt of the pelvis would be associated with shortened hamstrings, and an increase in the degree of flexion movement of the dorsal kyphotic arch. (Gajdosik et al, 1994).

Stokes & Abery, in their study concerning the influence of the hamstrings over the lumbar spine during sitting, finds that tight hamstrings cause a smaller lumbar lordosis when the knees straighten out from 90 to 45 degrees during flexing (Stokes & Abery, 1980).

With regard to the relation between hamstring length and dorsal kyphosis, Asher states that dorsal kyphosis usually occurs after the age of 11, and reaches its maximum incidents close to the age of 16. Body build has importance: ectomorphic children, especially girls, have been found to have increased kyphosis, beyond the normal curvature for their age. The dorsal kyphosis problem was first described by Scheuermann in 1920, and was observed among children at 9-18 years of age. One of the causes of increased kyphosis, according to Asher, is excessive tone of the hamstrings (Asher, 1975). Reimers also raises this speculation, adding further influences: growing pains in the lower limbs have been found to be more common among the group with high hamstring tone (30-40 degree extension). Short hamstrings cause difficulties in lifting the foot from the ground during walking and running during the swing phase. Furthermore, short hamstrings cause heel ache as a result of heel tap during running. Strides shorten. Patellar pains have been found to be more common among people with shortened hamstrings. Posture while seating in a regular chair has been found to be bad, because the normal situation of 90 degree thigh flexion causes the spinal column to be compressed posteriorly into kyphosis (Reimers, 1993).

1.9 Back problems:

Back problems currently constitute a serious health problem throughout the western world. Paterson states that 80% of the total population and more will suffer from back pain at least once in their life. Back pain has been found to be in second place in the contemporary western world as a reason for absence from work. (Olsen, 1982; Paterson, 1990).

Morbidity and disability as a result of lower back pain has increased in the United States by 2,500% over the last two decades, and by 4,000% in Sweden in the last three decades.

The conclusion raised by Nachemson for this epidemic is sudden lifestyle and work changes with a high risk for leading to back problems (Nachemson, 1992). The economic aspect of back pain constitutes a problem of first degree financial importance, leading to the loss of many working day and expenditures on medical care and compensation. In an international review of back problems in developed countries, the following data have been presented: in the United States, 217 million working days were lost as a result of back pain. In Britain there was a loss of 46 million working days. Contemporary estimates talk about losses of more than $50 billion per year. From 1983 to 1988, there was a sharp increase of 74% in people suffering from spondylosis. Disk problems have increased by 28%, sprains and strains have increased by 26% over five years (Paterson, 1990).

The causes of back problems are varied, and may be classified into major groups of psychological, neurological, physiological and behavioral factors associated with the cumulative influence of lifting loads, static positions without moving for a long time, incorrect posture and characteristic occupational problems suffered by typists, drivers, porters and others (MacNab, 1990).

<u>19.1 Lower back pain and hamstring length:</u>

The relationship between lower back pain and straight leg raising is insufficiently clear, and there is no consensus between researchers on this issue. In a study held to assess the connection between lower back pain and straight leg raising among children aged 6-13 and adolescents aged 14-18, a greater significant finding of
lower back pain history and low SLR average was found among high school pupils as opposed to primary school pupils.

Furthermore, a significant relationship between lower back pain and lower SLR average was found within the adolescent boy group (14-18 years of age). Within the adolescent girl group (14-18 years of age) and the children group of both sexes (6-13 years) no such relationship was found. (Mierau, 1989).

Million found that the SLR test had low correlation with back pain patients. (Million, 1982). On the contrary, Biering Sorensen found that the hamstring muscle length was of prognostic value for women's back pain. Women with low SLR values were characterized by recurrent back pain. (Biering Sorensen, 1984). Furthermore, low hamstring tone was found within known orthopedic symptoms in adolescents, associated with lower back pain. (Fisk & Baigent 1981; Bell, 1988). Fisk states that a difference of at least 10 degrees between the left and right foot in the SLR test may constitute a significant difference for people with lower back problems. The difference in SLR results was found, according to him, to be at least 10% for his patients suffering from lower back pain. (Fisk & Baigent, 1981).

1.10 Physical activity as a risk factor in relation to back pain and posture problems:

Physical inactivity contributes to the manifestation of back pain, whereas engagement in regular physical activity contributes to the reduction of such cases. Experts and researchers all agree with regard to this issue, namely that there is a need to maintain correct and regular physical activity. Over-engagement in physical activity can be dangerous, and may cause no less damage than the lack of physical activity. The situation in Israel, today points to the fact that the vast majority of population are not engaged in regular physical activity outside their work and that their only source of physical exertion is dictated by their work. Those people who spend most of their time sitting and as a result, have undergone a gradual process of deterioration of the muscular, vascular and other systems in their bodies, will be more prone to injuries. This does not apply to those who maintain regular physical activity outside work. Those people engaged in arduous physical activity during their work, may cause excessive joints degeneration. This holds true for professional sportsmen, in particular to athletes exposed to grueling physical exertion for long periods of time. Joint cartilage and ligaments making up the softer constituents of joints are composed of a fibers that may become roughened as a result of excessive, continuous friction, even though these are vital, regenerating tissues in which dead cells can be replaced by new ones. The tissue may not withstand the high rate of abrasion due to frequent effort. The result is cumulative damage to joints. In the majority of cases, controlled physical activity can contribute to the strengthening of muscles and an improvement in cardiopulmonary effort which allows a person to go about their daily activities in safety. Controlled physical activity may also contribute to a reduction of fatigue which may be an important factor in causing back problems.

Research findings indicate that 80% of cases of low back pain are associated with inactivity. Furthermore, a close relation has been found between weak abdominal muscles, low back problems and stiffness of the spinal column. Physical activity which strengthens the abdominal muscles and improves flexibility of the dorsal and cervical vertebrae, by stretching the back ligaments, helps in improving overall physical fitness which can markedly reduce the frequency of back problems (Gilad, 1982). Controlled physical activity plays an important role in the therapy of people with back injuries. According to Nachemson, this is the most popular prescription for treating back problems. Physical activity is intended to provide the skeletal system as a whole, and the spinal column in particular, with flexibility, in addition to maintaining its strength. Increase in flexibility and reinforcement of muscles helps back injury patients to return to activity and avoid recurrences, provided they keep to the regimen of physical exercises prescribed. In the case of back pain resulting from muscular fatigue, the strengthening of such muscles will assist in the prevention of recurrent back pain. In cases of severe, permanent back injury in a particular muscle group, an improvement in mobility in the area affected will often help to relieve pain. Sometimes certain muscle groups within the back may be developed as a substitute for the injured muscles, or, if a particular spinal disk is affected, resulting in increased intra-discal pressure, training specific muscle groups, by means of regular exercises, can help to reduce the pressure on the affected disk. Nachemson recommends isometric strengthening exercises for the abdominal muscles by lifting the legs, in the supine position, and strengthening the quadriceps muscles, which have been proven to be the main weight bearing muscles when lifting loads correctly. (Nachemson, 1975).

Nachemson's article, concerning the influence of physical activity on back pain, reviews in detail the multi-dimensional influence of activity related to back pains. The beneficial effects of physical activity on ligaments, tendons and spinal joints, comes about by an increase of collagenous tissues and a reinforcement of the connective tissues. In a study involving dogs running varying distances, it was shown that increased perfusion of vertebral disks was markedly achieved as a result of exertion lasting 30 minutes a day in comparison to less activity, or inactivity. High-frequency activity at higher loads did not increase perfusion nor lead to greater flow of fluid into, and out of, the disks (Nahemson, 1990).

Other studies have shown similar results, despite the fact that disk metabolism has been shown to be genetically determined. Increased perfusion has been demonstrated to positiely influence other cellular tissues. According to Nachemson, there is clear, unequivocal proof, that immobilization has a detrimental influence on disks, joints, tendons, ligaments and muscles. This is also true of bones, especially for the trabecullar bones of the lumbar vertebrae. Today, scientific evidence supports the beneficial effect of activity on tissues that may cause back pain. As mentioned above, there is ample proof that these tissues become mechanically stronger as a result of physical exercise. This is true for inter-vertebral disks too. The minimal amount of mobility required for preserving and increasing the strength, or healing ability, of various tissues associated with lower back pain is not known. From studies concerning the connection between physical fitness, injuries and lower back pain, it may be stated that 30 minutes of running per day is beneficial for disks and cartilages. For the cardio-vascular system , the same amount of physical activity does not have the similar positive effects. It seems logical that for disks, which have no direct blood supply, exercises that improve the overall circulation around them are more important than the development of very strong muscles (Nachemson, 1990). In a follow-up study conducted by Cady over ten years, concerning firefighters in Los Angeles, a clear correlation was found between the level of physical fitness and back pain. The group with low physical fitness had a ten-times higher frequency of back pain than the group with good physical fitness. (Cady , 1979). A highly significant relationship has been found in the combination of the three factors: body weight, smoking and infrequent physical activity, with reference to low back pain.

In another prospective study Nachemson discusses cardiovascular fitness as a risk factor for back pain among industrial workers. No absolute connection between cardiovascular fitness and back pain incidence was proven following three years of following up involving 2,400 subjects that underwent tread-mill testing. The study showed that cardiovascular fitness alone does not reduce the danger of back pain for workers who are required to undertake a wide array of tasks. On the other hand, those workers who developed chronic back pain were clearly of a lower physical fitness level than those of the control group (Nachemson, 1990).

There is no definite proof that physical fitness prevents back pain. However, it is clear that physical activity in a large group of muscles reduces the frequency of back pains. Furthermore, low stamina of large muscle groups, especially the extensor spinae muscles, increases the risk of back pain with time. The advantages of physical activity and mobility may be attained at a number of levels. At the tissue level, the inter-vertebral disks have an improved nutrition level as a result of mobility. The general oxidation process apparently takes part as a filling effect at the level of the disk alone. The pain level is controlled by endorphins that are influenced by the activity of large muscle groups, and the psychological perception of pain may be altered through activity (Nachemson, 1990).

1.10.1. Anterior flexion and lifting as a cause of back problems.

The studies conducted by Chaffin et al. indicate that anterior flexion during standing, and lifting an object from this position, is the number one cause of back pain. This study, and others, indicate that it is the uncoordinated movement, mainly during lifting, which causes damage. To illustrate this statement, the human skeleton is likened to a crane, in which the spinal column serves as the beam, and the back muscles are equivalent to the cables supporting it. Changes in the beam angle require full coordination with the cable length.

A slight deviation in these changes may place the load of the entire beam onto a single cable, which of course is not sufficiently strong to bear the weight. This phenomenon, known as 'postural fatigue', may occur in people lifting loads, or where there is lack of coordination resulting from insufficient care, illness or incorrect posture, all of which are known to cause back pain. Recurrent loading of the spinal column, as a result of frequent lifting, leads to a cumulative effect on the vertebral disks and accelerates their deterioration (Gilad,1982). One of the most damaging factors is lifting loads, especially from a seated position, when bent forward. Figure 37 shows a comparison between two classic lifting methods: lifting with knees straight and back bent, and lifting with a straight back and bent knees (Gilad, 1982).

The results point, unequivocally, towards the necessity of lifting with a straight back and flexed knees, with regard to intradiscal pressure.
Andersson relates the disk pressure to the physical moment when lifting the weight (figure 19). He believes that intradiscal pressure is equal whether the lifting is performed by back or legs, for as long as the moment, with regard to the load lifted, is equal (Andersson, 1990).

Figure 19. Moment with relation to load lifted
Andersson, 1990

The importance of moment is that where the weight is closer to the body, the pressure on intervertebral disks will be lower than for a weight held further away from the body with a larger physical moment. (Andersson, 1990).

Prolonged postural positions create a "positional load" – these are forces and moments acting on the disks and vertebrae, as a result of balancing gravitational forces against the body's muscles. Gilad states that "positional load" increases when sitting as opposed to standing, and increases yet further when bent forwards while sitting. Too large a load may cause a disk hernia, especially dangerous among adults and old people whose intervertebral disks anuli have deteriorated, partially calcified and lost resilience. A static postural position also damages the body's muscular systems. Muscles function by acting rhythmically, through contraction and relaxation, thereby receiving a regular blood supply providing oxygen and removing waste products secreted from the active muscle. This is different for groups of muscles that are contracted uniformly during a long static period. In this state, contraction leads to the occlusion of blood vessels and prevents blood supply and waste product removal. This may result in temporary painful muscle cramps, This pain makes one cease assuming one's static position and renew the blood supply to the contracted muscle.

A static position repeated day after day, year after year, by children whose activities compel them to assume such a position, may cause cumulative damage to muscle tissue. The cumulative "fossilization" phenomenon, caused by repeated prolonged static positions, is well known. We experience this, for example, when we try to straighten out after being bent forwards in a static position. This phenomenon is caused by prolonged pressure on neurons causing their temporary paralysis. A cumulative effect of this phenomenon may cause irreversible damage to the nervous system.
In a study conducted on hockey players, the intravertebral pressure of the spinal column was assessed during movement. As known, the posture of hockey players is slightly bent forwards while dribbling the puck. The results indicated that 53% of the subjects were

suffering from lower back problems because of the forward bending position and the rapid movements required in this position. Furthermore, it was found that the contraction of the spinal column in this position equals 0.4 mm/min. This contraction is larger than that of other daily activities examined. The conclusion of the study is that the bent position required for hockey players causes physiological tension and a burden on the spinal column (Reilly, 1990).

1.11 Sitting at school:

As mentioned above, the "sitting culture" develops from a very young age and especially after children enter school. Their bodies have to cope, for many hours, with positions dictated by the physical structure of the tables, desks, and classroom layout in addition to the nature of each activity (reading and writing, listening to teacher, etc.) conducted mainly in the sitting position. As part of physical development, and in accordance with available possibilities and stimuli, children's bodies will gain a definitive postural structure. Logan (1970) calls this the "SAID principle" (**S**pecific **A**daptations to **I**mposed **D**emands) whereby the body adapts itself to the mechanical demands of its surroundings. Embrey et al, (1983), indicates that good posture and muscle tone for school children constitute a basis for proper sitting throughout life.

From the beginning of the century, importance has been placed on the position in which children sit at school. For example, in the survey conducted by Bennett (1994) concerning the posture of primary school children, children's sitting positions were observed during the school day. The positions were divided into slumped and upright categories. The results showed that 59% of positions were slumped, of which 65% were during reading and writing. One of the problems in sitting at school is that most activities require a position in which the torso, head and shoulders are inclined anteriorly. Some of these positions are associated with placing the upper limbs on a table. Salminen (1984) examined the posture of 370 Finnish children (aged 11-17 years).

Figure 20. Lateral view of kyphotic sitting with anterior incline of torso. (Zacharow, 1987)

He observed the characteristic positions of children while standing and sitting, and found postural defects in the sagittal plane for 29.5 percent of them. Of the defects, half were "round-backed", defined by the researcher as a position in which kyphosis is emphasized, lordosis is straightened, abdomen protruded and the head and neck region of the spine are flexed anteriorly (figure 20).

Zacharow (1987), in his book about sitting posture, states that prolonged sitting at a horizontal table (that is not inclined forwards by any angle) causes an habitual rounding of the upper back, and when lifting the head forwards, excessive cervical lordosis results (figure 21). In addition he states that when the thorax is approximated to the pelvis, i.e. there is excessive kyphosis, increased loading on the thoracic and thoracolumbar areas of the spinal column results.

Figure 21. Kyphotic sitting with an increase of cervical lordosis.
(Zacharow, 1987)

Milne & Mierau (1979) measured and compared the stretching ability of the hamstrings in 3-5 year old children, primary school and high school children. The researchers found that this ability decreased with age. They explained part of this decline by the children's prolonged sitting attitudes once starting school.
In an study undertaken in Israel on 180 school children in grades 2, 4 and 6, it was noted that tight hamstrings was the 'normal' state of these children. The Mean SLR was 68^{o} which is well below the expected norm, according to Janda and Kendal, who consider 85-90^{o} as normal.

Coe (1983) states that while seated the pelvis is not as stable as in standing, the reason for this, in his opinion, being that while standing, the thigh is fully extended, and the iliofemoral ligaments firmly hold the pelvis. In contrast, while sitting, this mechanism of passive locking is not available (due to the flexion of the thigh), and muscular action is required to stabilize the pelvis.

A number of surveys have discussed the subject of back pain in school children. Mierau (1989) reported that 22.8% of school children (aged 6 to 12 years) suffer from back pain, and that the presence of back pain increased to 33.3% for children aged 12-17 years. In another study, Salminen (1984) found that 19.7% of children (aged 11 to 17 years) reported symptoms of neck pain and headache, and that 58.9% of these pupils stated that the pain resulted from sitting in classrooms.

1.11.1 School furniture – ergonomic aspects of child posture

Zacharow (1987) wrote that the building of a chair-desk set adapted for children does not ensure healthy posture, because an unsuitable setup , with regard to chair and desk height, constitutes a stimulus for bad posture. Relating to chair-desk distances, he recommended a negative distance between the end of the chair and the closest end of the desk in order to prevent excessive flexing of the torso during work. In addition, he stated that too low, or too high, a table could cause the positions depicted in figure 22.

Figure 22. Characteristic sitting forms of school children
(Zacharow, 1987)

Bendix and Hagberg (1984) recommend inclining the desktop by 45 degrees. They state that this desktop angle straightens out the cervical and lumbar areas when reading. In addition, the researchers believe that these positions reduce fatigue and discomfort.

Special attention to the subject of school furnishing, and the use thereof by children , was paid by Floyd & Ward (1976). In their article, anthropometric and physiological aspects of school and office sitting were discussed. Their aim was to examine the behavior of school children while seated. They maintained that providing correct ”motor skills” at a young age, especially those skills associated with sitting, may provide maximal benefit for children’s lifestyle. The article was written following the publication of recommendations by the British Standards Institute, which emphasized the need for building furniture at school, based on the anthropometric and physiological needs of the children. In the first part, Floyd and Ward observed children sitting, reported that children only used their back-rests a mean 50% of their time. They noted that the reason for this failure i.e. to lean, with a forward inclination of body, was due to writing. In addition, no differences were found in the sitting habits of boys and girls. The second part of the study included a follow-up of the motor behavior of 84 high school pupils. This follow-up was made during language, geography, history and mathematics lessons, as these lessons did not require special equipment that would entail special activities by pupils (such as those of nature or biology lessons). The follow-up included observing and noting the activities conducted by children: listening, following text , reading, looking forward, writing, talking, preparation and arrangement activities, moving objects, getting up and sitting down, and absence from the classroom. Concurrently, motor behavior was noted, including standing, position of torso, use of back-rest, position of upper limbs. The results indicated that listening was the most common activity, conducted 30-35% of the time. Writing occurred for 30% of the time, and the rest of the time was devoted to other activities. The motor behavior follow-up results are interesting, since, most of the time, the pupils sat without back support, or sat with their torso inclined forwards and hands on the table (80% of the time). The main conclusion the researchers drew was that writing activity was not the single cause of children’s sitting posture. In addition, in the third part of Floyd and Ward’s article, they describe a study in which the electrical

activity of the erector spinae muscles of 42 school pupils was measured. The results of this study show that when children sit “under supervision”, the electrical activity was similar on both sides of the back, and increased activity was observed for the lumbar area muscles in upright, unsupported sitting. However, when the pupils sat without supervision, in a slumped manner, the electrical signals were no longer symmetrical.

Oxford’s article (1976), an anthropometric survey performed on Australian children in 1965, the height and body dimensions of 4-20 year olds were measured, while standing and sitting. The aim of the survey was the recommendation of a chair-desk set suitable for school children. The survey results were compared to those of prior reporting made by the Ministry of Education in Australia in 1908. It was found that there was an increased trend in the children’s overall heights between the surveys. The difference between the two surveys was 4-8 cm (in 1965, children were higher). In addition, it appears that girls attained 65% of their maximal height at an age of 4 and

95% at an age of 13. In contrast, boys attained 60% of their maximal height at the age of 4 and 95% at an age of 15. In accordance with these survey results, the researchers recommended six chair-desk sets with chair height between 254 and 457mm, and desk height between 457 and 700mm. In order to recommend a set tailored for each individual child, the researcher undertook another survey in which children were asked to choose the chair-desk set most comfortable for them. The survey findings showed that children preferred sitting on chairs whose height was equal to their leg length, or at the most 5 cm higher. When the children was asked "whether they sat at the end of the chair or used the back-rest", 555 responded that they sat at the end, while 45% said that they used the back-rest. 48% of the pupils answered that they sat at the end of the chair while reading. When they were asked about the "distance from the paper during writing", 60% reported of a distance between 15 and 30cm, and 30% reported a distance in excess of 30cm. 64% of the pupils preferred a desk with an incline rather than a horizontal one. The researchers believed that greater attention must be given to the comfort of pupils while sitting, in order or help them concentrate on their studies.
The author added that, in his opinion, proper postural habits could not be imparted to children by the use of a uniform height chair-desk set. However, the presence of good chairs and desks in different sizes at school is insufficient, and children should be encouraged and educated towards proper postural habits.

Zacharow (1987) wrote that the ratio between chair and desk sizes was critical for school children. Sitting on a low chair at a high desk causes an elevation of the shoulder girdle. Sitting at a desk too distant from the chair causes an excessive flexion of the torso. In this case, children must slope the desk or chair in order to bring them closer. Mandal (1982) examined the most suitable height of furniture for school children. He emphasized the importance of lumbar support, a forward inclination of the chair seat and an elevation of the chair. Sitting on this chair, he said, would increase the thigh angle and rotate the pelvis forward (in comparison to sitting on a standard chair). This posture, with regard to the lordosis angle, is similar to that of standing. Mandal also recommended an increase in the desk height in order to prevent flexion of the torso. Practically, the researcher's conclusion was that the desk height should be half the height of the pupil, and the chair height one third of the height. This recommendation emphasized the need for individual adaptation of the chair-desk set. In addition, it proposes that the chair angle should be 10-15^o forward, with an elevated desk angle of 10-15^o.
Levy (1986) examined the suitability of the chair-desk set to elbow height, for 657 8^{th} and 9^{th} grade pupils. She states that the elbow height, when sitting, should normally be 5cm higher than the desk height. She did not find any pupils fitting this criterion.

1.11.2 . Intradiscal pressure for various physical activities and sitting.

The term "physical activity", in relation to posture and back pains, includes the system of movements and attitudes which one assumes while sitting, during study, work, home-life and sports, and, in fact, refers to any physical posture that causes large or small pressure on the vertebrae and interverterbral disks. It is important to emphasize that the measuring of pressures within the intervertebral disk is not a method for measuring back pain, but is one that indirectly measures loads on the spinal column. This information may be of great assistance from an ergonomic viewpoint, for improving work measures and various physical activities, and for learning the mechanical influence of various therapy modalities (Andersson, 1990).
According to Andersson, the measurement of intradiscal pressure is the most direct and accurate method for evaluating loads on the spinal column, in real time. The disadvantage of this method is the invasiveness of the procedure and that it is restricted to the laboratory (Andersson 1990).

In vivo measurements were first undertaken by Nachemson (1963). Volunteers for the trial had a barometer-equipped needle inserted into the disk betweeen L3-L4, and they were asked to make various movements and assume various positions, during which the pressure was measured in the disks. From the data shown in the table below (figure 23), the intradiscal pressure while sitting is 30% higher than in standing without support, and pressures while lying are 50% lower than during sitting (Andersson, 1990).
As shown in Fig. 23 the forward leaning position creates the highest intradiscal pressure. The posture is typical of children while sitting in the classroom.
Nachemson & Elfstorm, (1970), measured the intradascal pressures during bending forwards in different positions. From these studies it was clear that the pressure increased proportionally to the angle of flexion.

Figure 24. Loads on the lumbar spine measured by disk pressure
Andersson, 1990

An increase in disk pressure, according to Gilad, is associated with a risk of back pains, but this function remains unclear. It may be a result of mechanical loading causing tears in the disks' membranous casing, with the fluid compressed out of the disk and chemically irritating nerve endings. In addition, it is clear that an increase in

intervertebral disk pressure leads to an accelerated attrition and deterioration of the intervertebral disk (Gilad, 1982).

Table 2 describes the pressures within disk L3/4 in various subject positions. The pressure is indicated as a relative percentage, with pressure being 100% during upright standing (Gilad, 1982).
The lowest disk pressure was noted when the subject was supine.

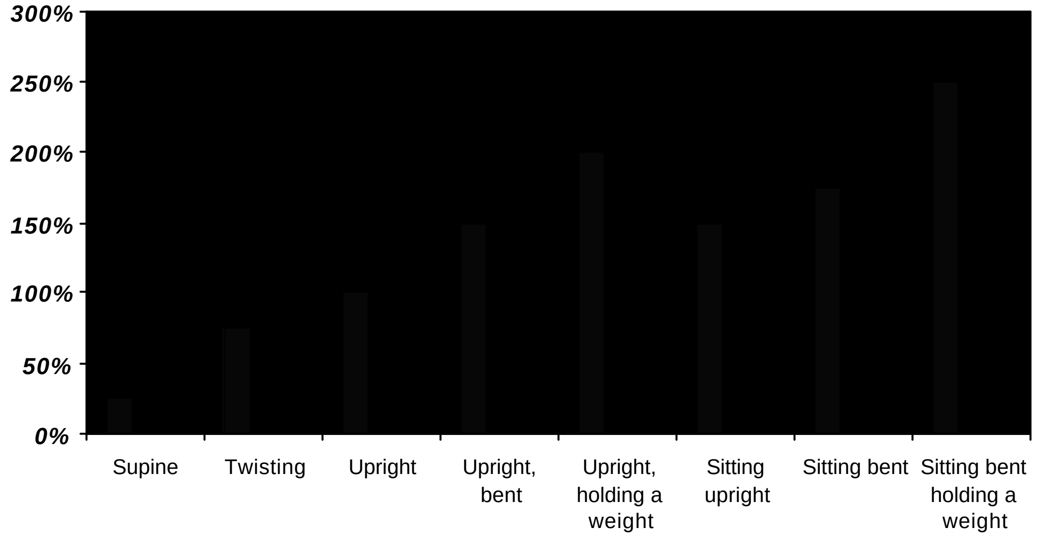

Table 2. Relative pressure within disk L3/4.

The greater the forward bending while sitting, the greater the pressure. When standing and bending forward with a weight in one hand, the pressure increases more. The greatest pressure is generated when the subject sits bent forward with a weight in his hands. The reason for this is that, while sitting, the legs do not assist in the bearing of the upper body's weight as in standing. During sitting, most pressure and load is applied to the low back.

Another study of sitting positions indicates the importance of back-rests for chairs in supporting the lumbar spine and in the reduction of load on the intervertebral disks. As may be seen in table num. 2, the pressure increases when the subject sits unsupported. When the low back was supported during sitting, the pressure decreased. The influence of a lumbar support on the low back can clearly be demonstrated. When the lumbar

support was used, the load on the lumbar spine was reduced by some 150N as compared to sitting without a support (dotted line), and the greater the inclination of the back-rest, the more the load decreased (Andersson, 1990).

Similar data are provided in figure 26, showing the lumbar pressure at various angles of the back-rest (Gilad, 1982).

Figure 24. Intradiscal pressure at various back-rest angles

Gilad, 1982

Following the studies made for posture and loads on the back in the sitting position, it seems that the actions and positions to be avoided, as much as possible, are those of bending forwards, especially during sitting, as demonstrated above.
When performing any activity, the potential damage that may be caused as a result of prolonged body positions, especially static ones with certain muscle groups being markedly contracted must always be considered. This static position causes interruptions in the blood flow of the active muscle, accompanied by an unpleasant feeling which gradually turns into pain. Prolonged, daily, repeated static loading in fixed positions, such as sitting bent forwards (figure 24), in which the load on the intervertebral disks is very high, causes a cumulative injury to tissues whose blood

supply is disrupted, and an accelerated aging in these tissues.
The conclusions derived from the figures above are as follows:

a. Lumbar spine loading is lowest during lying, higher (but still relatively low) while standing, and highest when sitting, especially when bending forward and not using the back-rest (table 3).

Mean pressure from normal in disk (Mpa)

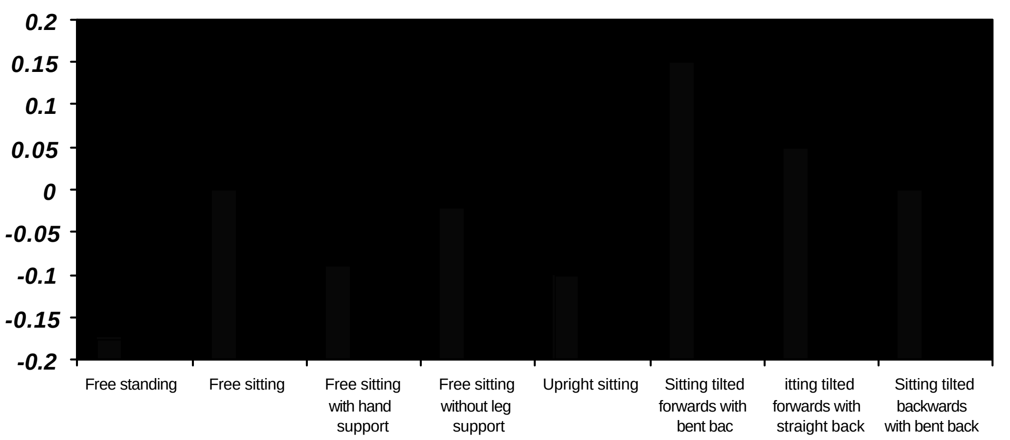

Table 3. Disk pressure when sitting without a back-rest.

b. Bending forwards increases the load of the spinal column proportionally to the bending angle.
c. Twisting of the back causes unequal increase in spinal column loading.
d. Forward bending, especially twisting while bending, is to be avoided.

While sitting on a chair, it is very important to use the lumbar back-rest, and armrests(table 4).

e. Isometric exercises are preferable when treating back problems.

f. The influence of a waist girdle as a spinal support is moderate, being most effective during bending forwards.

g. While lifting, the waist must be kept vertical, and the load lifted should be as close as possible to the body (Andersson, 1990).

Mean pressure from normal in disk (Mpa)

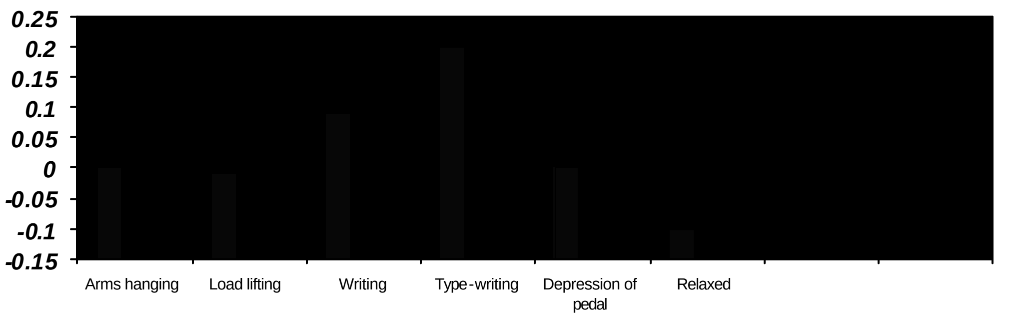

Table.4 Disk pressure in various sitting positions with back-rest.

1.12 Study review of back and posture problems in Israel:

In a study held at Bar-Ilan University's physical education unit, 142 men and women aged 18-37 years were examined. The aim of the study was the assessment of prevalence of back pain. The study's results indicated that 68% of the subjects questioned reported of having suffered or currently suffering from back pain. For 33.6%, the pain started at high school age, and for 28% the pain started at military age (18-21). For most of the women, the pain started at high school age. No significant differences were found between the religious and secular population with regard to the time of pain onset. 89 out of 109 respondents to the question of the cause of their back pain attributed it to poor posture. This study indicates the appearance of back pain problems within the study population earlier than in other western populations. The researchers relate this to the physical conditions and physical education curriculum. Military service also spurs the exacerbation of this problem. (Melis, 1987).

In a study held with middle school pupils at Petach Tikva, posture parameters such as scoliosis, lordosis and others were examined. (Levy, 1986). It was found that 96.4% of the subjects were found to have at least one postural deviation. Postural deviations were present for 96.7% of boys, as opposed to girls, with 95.9%. Most children had more than one postural deviation. From the aspect of back pain, 18% of the boys reported back pain, as opposed to 32.2% of the girls. For all the age groups examined, the rate of girl back pain was higher than for boys. Furthermore, an increase in the rate of back pain was noted for boys and girls in the 9^{th} grade as opposed to the 8^{th}.

The location of the back pain for most study participants was in the lower back region. An assessment of the relation between postural deviations and back pain for 8^{th}

grade girls shows a back pain rate for girls with scoliosis to be 5.1 times greater than the rate of back pain for girls without scoliosis. (P=0.0056). Levy believes that the reason for postural deviation problems lies in the children's environmental variables. School furnishing contributes to this problem. An examination conducted indicated that school furniture was found unsuitable for all pupils, and this may be a reason for the manifold postural deviations (Levy, 1986). In the study held by Ilan and Yekutiel covering 252 pupils at two schools in Ramat Gan, the posture of 2^{nd} to 10^{th} grade pupils were examined. A number of postural deviation parameters were examined. A total of 983 postural defects among the 252 subjects were revealed, indicating a mean 3.9 defects per subject. The most common defect was taught hamstrings, for 42.5% of the study population. Flaccid abdominal muscles was found for 31.3%, and increased lumbar recess for 38.1%. The study authors attributed these defects to environmental influences, including such parameters as family and ethnic background. For families originating from Asia and Africa, and large families, it was found that postural defects were more common. Subjects' mothers' education level also had an effect on the number of postural defects. Yekutiel and Ilan state that there are no objective standards of normality for spinal convexities. There is on information concerning the negative influences of postural deviations on the health of children. This impairs the development of clear guidelines for discovering these deviations during childhood (Ilan and Yekutiel, 1978).

A study held in 1982 by the Sports Medicine Department at the Wingate Institute examined the posture of 318 pupils, 167 boys and 151 girls aged 6-7. a number of parameters of posture and muscle length were examined, including suppleness of spinal column, hamstring tone, abdominal muscle tone, etc. The results of this study indicate that for boys, 51 pupils were found to have sound posture. 88 had slight postural deviations, such as slight lumbar lordosis, scoliosis, flat back, kyphosis and weak abdominal muscles. In the third category, 28 pupils had marginal posture. No significant differences were found in the anthropometrical and physiological measurements and level of physical fitness. It was also found that 62% of boys and 78% of girls within the risk group category had high or average physical

fitness. The conclusion of this study states that 6-7 year old children who were found to have postural deviations in over 50% of boys and 43% for girls, were not found to be different in anthropometrical indices, or in physical fitness, to other children with sound posture. Also, no influence over the children's normal active life was found. (Hanne, 1982).

From a study recently held in Israel covering 750 children aged 12-14 years, it was found that 53% of the respondents experienced back pain at least once, out of whom 20% experienced back pain often or constantly (Levy, 1993). In a 4 year follow-up study conducted by Olsen, concerning the finding of lower back pain within American adolescents aged 11-17, 30.4% of the total study population applied to physicians complaining of lower back pain. Similar data were found in England and Sweden too. (Olsen, 1982).

<u>1.13 The importance of this research:</u>

The main purpose of the current research to elucidate the factors responsible for adverse effects of prolonged sitting in schoolchildren and their influence on the locomotor system of the body, on the overall postural pattern and on the development of postural deformities.

It is hoped that a better understanding of:

a) the inter-relationship between the various functional musculo-skeletal systems of the body and

b) of the spinal curvatures resulting of prolonged sitting in the absence of physical activity, will be achieved

The results of the research will allow for establishing standardized parameters of posture ; of straight leg raising; hip extension ; pelvic rotation ; dorsal kyphotic angles and lumbar lordosis in the school children population of Israel. This will enable comparative studies with the children of other countries.

The results will enable elucidation of the factors involved in producing common postural abnormalities and contribute to the understanding of the behavioral connections between typical patterns of posture, physical activity and sitting habits.

In addition it is hoped to acquire a better understanding of the inter-relationships which will assist in increasing the awareness among therapists and teachers to prevent deterioration of the postural status. This will contribute in developing new preventative

physical educational programs aimed at improving the situation that exists, at the present, among the younger age groups and help to reduce the problem of back pain in the future.

<u>1.14 Aims of the research:</u>

<u>1.14.1 General goals:</u>

a) To investigate the connections between the sitting parameters (duration and type), spinal curves and range of musculo-skeletal motion.
b) To investigate the connections between the sitting parameters (duration and type), the occurrence of back pain and postural parameters.
c) To investigate the diffrences in postural parameters between between active and non-active and the occurrence of back pain.
d) To investigate the diffrences in spinal curves and range of musculo-skeletal motion between between active and non-active groups.

<u>1.15 The Hypothesis of the research:</u>

Prolong sitting and physical unactivity during the growth period will be associated with:

a. Imbalance of the locomotor system.
b. increased pressure on the joints of the hip, knee, pelvis,and facet.
c. greater curvatures of the spine.
d. higher incidence of back pain.
e. higher incidence of postural deformities.
f. muscle tension.

<u>1.16 Questions of the reaserch:</u>

a. What is the distribution of the hamstrings tension, iliopsoas tension and the pelvic rotation (angu1ar motions) according to age and sex?

b. What is the distrubtion of the dorsal kyphosis and lumbar lordosis (spinal curvatures) according to age and sex?

c. What are the common postural physical deformities in schoo1 children of both sexe?

d. What is the collection between the angu1ar motion parameters (SLR, HEand PR) and the spinal curvatures, (lordosis and kyphosis)?

e. What are the differences between the active and the non- active group in the anguIar motion parameters (SLR, HE and PR)?

f: What is the collection between the angular motion parameters (SLR, HE and PR) and the sitting parameters (type and dmation)?

g. What are the conections between the angular motion parameters (SLR, HE and PR) , the postmal parameters and back pain. ?

h. What are the conections between the angular motion pararneters, the anthropometric and demographic parameters?

i. What are the connections between sitting parameters (type and duration) , the typical postmal patterns, the occurrence ofback pain and the spina! curvatmes?

j. What are the differences between the active and the non- active group in the typical postmal patterns, the occurrence ofback pain and the spina! curvatures?

1.17 Lirnitation of the research

The research was carried out dming the normal school ho urs (between 8 a.m. to midday) but it was impossible to examine each child at exactly the SaIne time of the day.

The children who were initially randomly selected for the research were allowed to refrain from answering the questionnaires and could refuse to be physically examined dming each stage of the research. Those who exercised these rights were removed from the research.

The younger children often needed the help of the teacner , school nurse or ,research assistant in order to complete the questionnaires. Thi's may have affected the quality of the results compared to those who answered freely.

Medical histories were taken from each pupi!'s person school file and not from their physician's medical records. This may have affected the quality of the information received.

Several schools were involved in the research so that not the children were examined in the same room, although each examining room and the instruments used were standardized as far as possible.

The research was concemed only with current statistical connections between the various pararneters and was not prospective in nature.

Because there are no accepted international standards for postural deformities it was necessary to employ qualitative as weIl as quantitative parameters in the research.
All the data analysis and the results thereof which are reported in the research paper were those within the range ofp = 0.05 or tess.

2. MATERIALS AND METHODS

2.1 population:

The research population was taken from four Primary Schools in Three different Israeli cities. The cities according to their different demographic attributes provide a representative cross-section of Israeli children. The three cities were Rehovot, Yavne and Ashdod located in the central and south of Israel.

From ' The Shprinzak' Primary School, in Rehovot, there were 42 children (34 boys and 8 girls). From 'The Ben-Gorion Primary School, in Yavne, the sample was 72 children (40 boys, 32 girls). From 'Sinai' Religious Primary School, in Yavne, the sample was 80 children (38 boys and 42 girls). From 'Meginim' Primary School, in Ashdod, the sample was 109 children (42 boys and 67 girls). These schools also represented a cross-section of the various socio-economic levels in Israel.

The six age groups were taken from 2nd to 6th grade schools. All the research population was divided into three age groups according to age – 2nd grade 7-8 years old; 4th grade 9-10 years old; and 6th grade 11-13 years old.

In both sexes the children were randomly selected in each grade.

It was decided to select a large sample from each age group in order to increase the accuracy and reliability of the research. Children with obvious musculo-skeletal orthopaedic deformities were rejected, in addition to those with abnormal Weight and Height over 2SD from the Mean according to age and sex.

2.2 Permission to perform this research

In the course of a meeting with the current research staff, school personel, including the school nurse and the parent's committee, together with the administration of the school permission, was received to perform this research.

During the meeting a full outline of the research was given in addition to its aims and the investigations that will be carried out emphasising the importance of the research in the development and growth of the children with regards to their posture.

All the children in the appropriate age groups will receive an explanatory letter from the school nurse requesting the parents' permission for their child to participate in the research.

2.3. The Procedure of the research:

With the commencement of the investigations, those participating in the research will receive full instructions by the teachers, the school nurse and researchers. Meetings will be arranged with the children and the staff concerning the general procedure and rules of behaviour, with emphasis on the type of clothing necessary during the performance of the research.

The timetable of the research will be during normal school hours on fixed days of the week.

The location of the research will be in the school nurse's office/clinic for each school involved. The room is arranged by the staff so as to perform standardized investigations. The equipment required will be situated in standardized positions according to the research protocol.

2.4 The order of investigation and testing:

a) Filling out of questionnaire

b) Preparation before the testing - appropriate dress

c) Measurement of height

d) Measurement of weight

e) Attachment of special markers on the body in preparation for further testing.

f) Measurement of SLR in the supine position, left and right.

g) Measurement of hip extension in prone position, left and right.

h) Measurement of Pelvic rotation from lying to sitting positions (Toe -touch).

i) Measurement of Kyphotic curve of the spine.

j) Measurement of Lordotic curve of the spine.

k) Assessment of postural parameters standing up in anterior position

l) Assessment of postural parameters standing up in lateral position.

m) Assessment of postural parameters standing up in posterior position.

2.5 Operative Definition of the measurements:

2.5.1 Weight - The pupil is weighed wearing only shorts and vest, bare-footed.

The measurement is performed on medical scales. The pupil stands straight in the centre of the plate on which the feet are placed on specific points.

Accuracy of test to 0.5kg.

2.5.2 Height - The pupil is examined bare-foot with his/her back in contact with a scale anthropometer in the 'relaxed' position (neither tense nor flaccid) looking straight forward. The height is measured by means of a rigid ruler with the head piece placed at 90^o at the maximal height. Accuracy to 0.5cm.

2.5.3 Placement of body markers.

Special coloured markers (1cm. diameter) are attached, in the following locations, with the pupil standing upright, in the relaxed position: All lateral markers are attached to both sides of the body:

a) center of the ear

b) tip of acromion

c) Anterior Superior Iliac spine

d) Iliac crest

e) greater trochanter

f) lateral condyle of the femur

h) lateral malleolus

i) inferior angle of the scapular.

Posteriorly :

j) Posterior spinous process T12

k) Posterior spinous process of L5

l) Point of maximum lumbar lordosis

m) Point of maximum kyphosis

n) Posterior spinous process C7

2.5.4 Straight leg raising (SLR)

The measurement of the hamstrings tension, as an indication of hamstrings length, is carried out with the pupil in lying on the back. The examiner raises the leg of the pupil with one hand beneath the calf and the other holding the front of the thigh. The leg is kept straight while the opposite leg is kept straight and in contact with the examining table by means of a strap. Strict attention is paid to the lumbar spine being flattened onto the table during the raising of the leg. The elevation of the limb is performed without the assistance of the pupil - passive test - until the pupil attempts to bend the knee, resists further motion or if the pupil complains of pain.

The angle measured is between the horizontal line of the table and a line connecting the lateral malleolus to the greater trochanter (Kendall et al, 1993).

The angle is measured using a goniometer or angled wall-chart (protractor). The accuracy to 2.5^{o}.

2.5.5 Hip Extension (HE)- Thomas Test.

The aim is to examine the tension within the Iliopsoas muscle and the anterior hip capsule in full extension.

The pupil lies in the prone position with the arms placed beneath the chin. The examiner raises the lower limb while holding the leg above the knee, keeping it straight. The examiner's other hand keeps the pelvis fixed to the table. During the whole procedure there is emphasis on maintaining the pelvis close to the table.

The angle of examination is taken from the line joining the greater trochanter and the lateral malleolus in relation to the horizontal line of the table (Ahlback & Lindahl 1964).

2.5.6 Pelvic Rotation (PR) - Toe-Touch

Examination of the change in angle of the pelvis when sitting up, with the legs kept straight , from the horizontal to vertical positions of the trunk.

This test demonstrates the limitation of rotation of the pelvis when the hips are flexed. The pupil lies on the back with arms stretched forward and attempts to rise from the lying to sitting position while keeping the arms straight and touch the toes with the knees kept extended.

The point of examination is noted when the pupil reaches an angle at which the knees begin to flex or the end point of the motion when reaching the toes or even overshooting them.

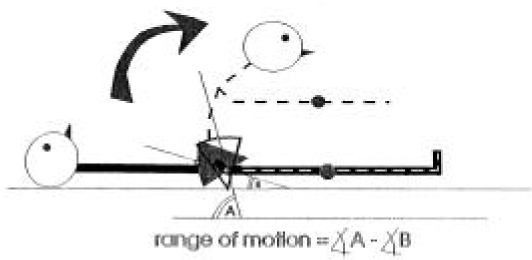

Figure 25. The angle of pelvic rotation

The angle of Pelvic rotation is measured between the line joining the greater trochanter and Iliac crest in relation to the horizontal line (figure 25).

The examination is performed from lying position to the maximal position that the pupil can achieve. The difference between the starting and final angles indicates the Pelvic rotation angle. Accuracy to 2^o. (Kendal et al 1993)

2.5.7 Measurement of Lumbar Lordosis

This examination is performed by means of the Spinograph (a vertical board standing in a fixed position containing a longitudinal vertical slit (3cm. wide) cut

through a transparent central window along which a pointer travels to outline the spinal curves). Details of the Spinograph can be found under ‘Equipment used’.
The pupil stands with back to the board and the spine parallel to the slit in the central window so that the pupil can be observed. The pupil stands erect in ‘relaxed’ position (see above #2) with arms resting at the sides. There is no contact with the spinograph.
The test was performed in the sagittal plane . A special pointer with a grooved wheel traverses the slit in line with the spinous processes which are held within the groove of the wheel while a pencil at 90^{o} to the pointer draws the lateral outline of the spinal curves onto a large chart (the method was adapted from the Wellesley Postural test - MacEwen and Howe 1932). (see fig.11- Johnson and Nelson 1986).
The angle of lumbar lordosis is measured using the methods described by Flint
(Flint 1963 - Fig. 13). Using the lateral drawing of the lumbar curve tangents are drawn from the tips of D12 and L5 markers and the perpendicular lines are dropped from these tangents. The point of intersection of the perpendiculi is the angle measured (Heather 1995).

2.5.8 Measurement of Dorsal Kyphosis

The same procedure is carried out as in #7, except that the angle of Thoracic kyphosis is measured using the perpendiculi from C7 and D12. This is an adaptation of the Flint method for lumbar lordosis (see fig. 13).

2.5.9 Qualitative estimation of postural parameters in the sagittal plane.

The postural estimation is assessed with the pupil standing in front of a postural board (Symmetrigraph) marked out in squares of 5 centimeters. The feet were place in a fixed position on the base of the board. The parameters noted are:

a) head forward
b) sway back
c) flat back
d) hyperkyphosis (round shoulders)
e) hyperlordosis
f) anterior body sway

The assessment is made according to three levels of posture (‘good’ , ‘fair’ , ‘poor’).
These three levels were determined from the vertical line according to the markers fixed to the ear, shoulder, greater trochanter and lateral malleolus. This postural test is adapted from the method of Sally and Altoff - New York Postural Test (see Par.1.5.2.2).

2.5.10 Qualitative Postural parameters in anterior position.

The anterior parameters are assessed opposite the postural board with the pupil standing back to the board.

The parameters are:

a) Acromion level.

b) Iliac crest level.

c) head tilt (eye level) to the side.

The assessment is made according to three levels of posture ('good' , 'fair' , 'poor'). according to the difference in height of these markers opposite the postural board.

2.5.11 Qualitative Postural parameters in posterior position

The posterior parameters are assessed opposite the postural board with the pupil facing the board.

The parameters are:

a) Scapular angle height

b) presence of scoliosis

c) Pelvic tilt

The assessment is made according to three levels of posture ('good' , 'fair' , 'poor'). according to the difference in height of these markers opposite the postural board. (see above 2.5.9)

2.5.12 Estimation of overall postural profile.

The overall postural assessment was fixed according to three categories:

1.'normal' ,

2. 'fair',

3.'bad'.

'Normal' ('good') posture was fixed if the pupil did not demonstrate more than two parameters in category #2 ('fair') and no estimates in category #3 ('poor') of all three positions opposite the postural board.

"Fair' posture was determined if the pupil showed up to four parameters in category #2 ('fair') and none in category #3 ('poor') of all three positions opposite the postural board.

'Bad' posture was estimated if the pupil showed more than four parameters in category #2 ('fair') or, at least one parameter in category #3 ('poor') of all three positions opposite the postural board.

All the postural analyses were estimated by means of:

a) video recordings and

b) a ‘frame-grabbing’ computer program.

2.5.13 Questionnaire

The questionnaire is filled out by the pupil before undertaking any examinations.

Part 1. Demographic details

Part 2. History of back pain - attendance at a physician’s clinic or necessity of stopping an activity because of pain. These questions are answered with the aid of the parents, school nurse and medical certification as well as according to the pupil’s statement.

Part 3. Physical activity - informal activities during leisure time.

Part 4. Sitting habits - as reflected by sitting positions at play on floor etc. or amount of time and/or sitting positions opposite to a television and/or computer or when playing TV/Video games. This is answered with the aid of a series of common, representative pictures.

The questions refer to the type of sitting posture , amount of time and frequency per week.

A research assistant or school nurse is available to help the pupil fill in the questionnaire, especially in the lower school grades.

2.5.13.1 Definition of Physical activity.

Physical activity is a reflection of calorific output resulting from body activity. It is differentiated into three categories: duration; frequency and intensity of activity.

In the present study only duration and frequency were considered without relating to the different types of physical activity. The measurement of activity was the average amount of hours per day including both formal and informal activity.

The three categories of physical activities are:

a. ‘Non-Active’: not active at all, or frequency of one time a week, duration of less than half an hour or very light activity.
b. ‘Active’: Frequency of up to tree times a week and a amount of 1-7 hours activity in a week.
c. ‘Very Active’: Frequency of 4 times or more in a week’ and at least 8 hours or more of physical activity in a week.

2. 5.13.2 Definition of Sitting

Sitting involves minimal calorific output and is characterised by duration and differing postural attitudes in relation to the body's skeleton. Only activities outside the formal study hours are considered. The commonest sitting activities involved in this study are :

a) sitting at a computer,

b) watching television,

c) playing video and television games,

d) other (indicated by the pupil).

Four typical attitudes are defined:

a) sitting with hips and knees at $90^{o}/90^{o}$ or less.

b) back or vertical slouching with knees partially extended. More than 90^{o}.

c) lying position, prone or supine.

d) sitting on the floor.

The average time of sitting was measured according to those attitudes which are known to cause shortening of the hamstrings and iliopsoas muscles and increased or reduced spinal curvatures. The average total duration of sitting is considered.

2.5.13.3 Back Pain

Back pain is defined as :

a) any complaint of irregular disturbance of all, or any part, of the back or

b) that can cause the pupil to cease any activity and/or

c) seek medical advice.

In the present study the occurrence of back pain was determined by any of these categories.

2.6 Equipment employed in the study.

2.6.1 Weighing scale - A standard medical scale, as found in all school premises, is used. Mean error of 0.5kg.

2.6.2 Holtain Anthropometer - The height is measured with a portable model.

The scale was calibrated by means of a standard tape-measure each day.
Mean error of 0.5cm.

2.6.3 Goniometer - Angular measurements are determined by a specially constructed model for this research. One 'arm' of the instrument is strapped to the limb under examination and the second 'arm' is maintained in the horizontal position.

The reliability of this method is well described in the literature and is known to be very high (Kendalet al 1993, Mierau 1989 and Katz 1992).

Mean error of the angular measurements was 2.5^o. (R= 0.983)

Alternatively a large-scale wall-chart protractor is employed with the degrees marked out to 90^o in divisions of 2.5^o. (According to the method of Biering-Sorensen 1984)

2.6.4 Squared Postural Board (Symmetrigraph)

The qualitative postural examination is performed opposite a specially designed board 1.6 m. in height. Each square measures 5 sq.cm. The board is situated on a firm foot-plate with the pupil's heels at 20cm. from the board in all three positions - anterior, posterior and lateral. (This method was adapted from Reedco inc. Auburn,

N.Y. – Johnson and Nelson 1986 ; Althoff 1988).

2.6.5 Spinograph - measurement of spinal curves is performed by means of a large vertical, transparent "Perspex" board with a long vertical slit in its center. Through the slit a specially designed pointer with a grooved wheel at its end is brought into contact with the pupil's back such that the groove in the wheel bounds the spinous processes. At the opposite end of the pointer and situated at 90^o to the wheel is a second arm with a sprung pencil attached to its end The wheel is moved along the length of the slit in contact with the pupil's back, in the relaxed position, which is not in contact with the board and the pencil outlines the spinal curves onto a large chart.

The method was adapted from the Wellesley Postural test - MacEwen and Howe 1932. (Johnson and Nelson 1986).

2.6.6 Video camera - A Japanese Sony Video camcorder (model CCD-TR490E PAL lens 5-65mm.) is employed to record the tests for postural assessment. The camera is positioned on a tripod at a standardized distance from the Symmetrigraph.

2.6.7 Computer software - Frame-grabber and picture analysis (model M205 - TEKRAM Tuner video capture -capture TV) is used to analyse the postural examinations in all postural positions on the Symmetrigraph. Standards of postural parameters are in accordance with the method of the NEW YORK POSTURAL RATING CHART – Johnson and Nelson 1986)

2.7 Statistical Analysis

The statistical analyses are performed with the aid of a statistical analysis program SPSS 8 for 'Windows'.

Categorial parameter analysis of postural types by three categories: 'good', 'fair', 'poor'.

All ‘Postural Types’ are differentiated by sex and age using ‘Cross Tab’ procedure.
A similar procedure was employed for ‘Demographic parameters’ (back pain, activities and sitting).

All the ‘Anthropometric parameters’ and the ‘Spinal curvatures’ parameters , ‘Angular parameters’ (SLR, HE, PR) are described using ‘Descriptive’ procedures by sex and age.

‘Frequency Histogram’ procedure is used in order to check the normal distribution of all research group parameters by sex and age.

Analysis of Quantitative parameters :

‘Anthropometric parameters’, ‘Angular parameters’ and ‘Spinal curvatures’ are analyzed by ‘Pearson Correlation’ test.

Differential analysis of Quantitative parameters‘Anthropometric parameters’, ‘Angular parameters’ and ‘Spinal curvatures’ are compared with Categorial parameters:

‘Postural types’, ‘back pain’, ‘activity’ and ‘sitting parameters’ using the ‘Anova’ procedure by age and sex.

‘Cross tabs’ procedure analysis is used to find the Correlation of the Categorical parameters:’Postural Types’, ‘back pain’ and the ‘activity’ and ‘sitting parameters’ by age and sex.

Differential analysis of Quantitative parameters: ‘Anthropometric parameters’, ‘Angular parameters’ and ‘Spinal curvatures’ using T-test groups procedure by age and sex.

Non-parametric analysis is made by ‘N-Par Test Mann Whitnet U Wilcoxon’ procedure to Quantitative parameters.

The procedure of ‘T-test pairs’ is made to check the differences between the angular parameters (SLR and HE) of both right and left sides. A similar procedure for small groups is performed according to ‘N-Par Test Mann Whitnet U Wilcoxon’.

To determine the effect of ‘Independent parameters’ of Hamstring and Iliopsoas tension and pelvic tilt on the ‘Dependent parameters’ (Spinal curvatures) a ‘Multiple Regression’ procedure is carried out to examine the relative effect of each of the ‘Independent parameters’, together and separately, on the ‘Dependent parameters’ according to age and sex.

2.8 - Pre-test:

The Pre-test was performed on 60 pupils. The following examinations were performed:

2.8.1 Time of examination: For each pupil the duration of examination lasted approximately 50 minutes including filling out the questionnaire.

Analysis of the postural parameters and spinal curvatures lasted approximately half an hour. The time for physical examination using the goniometer lasted 10 minutes. Initially the test was performed without using the straps but this was found not to be satisfactory and the straps were used routinely on all the pupils and found to facilitate and accelerate each examination.

2.8.2 Instruments:

2.8.2.1 Goniometer:

A correlation was found (R=0.96) between repeated examinations using the goniometer (SLR, hip extension, pelvic rotation). In addition a correlation was found

(R=0.98) between three intra-examiner measurements using the goniometer. Inter-examiner comparison showed a high correlation (R= 0.9624) and individual variation of up to 2^{o}. (After completing the pre-test a series of measurements using the wall chart were performed. This was found to be a much simpler method without compromising the results.)

2.8.2.2 Spinograph :

This instrument was found to be simple to use. Initially some difficulty was noted in tracing the spinal curvatures due to movement of the pupil. As a result it was decided to practice moving the wheel on the spine until the pupil became accustomed to the feeling. In addition an anterior support was placed in contact with the chest to prevent forward movement. Some of tracings were initially obscure because the pencil was too short and had no flexibility. This was overcome by using a longer pencil mounted on a spring device set within the drawing arm. After these adjustments the correlation of three tracings was found to be R=0.98. , and the Mean error was 4^{o}.

2.8.2.3 Symmetrigraph:

Symmetrigraph in conjunction with video camera and frame-grabber analysis: The video recordings of the postural parameters were filmed with the pupil standing 20 cm. in front of the squared board in all three directions. The procedure was repeated after an interval of two hours. Using the frame-grabber facility no significant variation in posture was noted between the two sessions.

2.8.2.4 Weighing scale:

This was found to be simple and easy to use. Variation to 0.5Kg.

2.8.2.5 Anthropometer:

This was found to be simple and easy to use. Variation to 0.5Cm. Calibration was made each day using a standard tape measure.

2.8.2.6 Questionnaire:

A Questionnaire Pre-test, with an interval of two weeks between filling out of the questionnaire, was performed which showed a high correlation among the older grades (R = 0.94) and a slightly lower correlation in the youngest grade (R= 0.86). Therefore, a research assistant and the school nurse were made available to help the pupils fill out the questionnaire, especially in the lower school grades.

2.8.3 Reliability of measurements:

In order to minimise the potential difficulties and inaccuracies that can arise from examining postural parameters and motion in various body parts, especially in children of these age groups, attention was placed on the following points:

a) all the examinations were performed twice and where there arose any difficulty a further examination was performed.

The goniometric measurements were performed three times routinely.

The spinograph tracings were taken twice or three times in cases of difficulty.

The average measurements of the repeated tests was taken as the estimated value.

Anthropometric measurements were also taken twice.

b) All the postural parameters were recorded on video-tape and the analysis was performed using the frame-grabber facility. Where any suspicion of inaccuracy was suspected this could easily be detected by recurrent referral to the video recording in contrast to the initial immediate qualitative estimate of posture.

c) Every tenth pupil was examined by two separate examiners in order to assess the accuracy of the measurements taken.

d) The results of the measurements were recorded on separate protocols with the aim of preventing any undue influence, or bias, on the different examiners.

The protocols were:

a) Measurements of angular motion and anthropometeric parameters.

b) Postural parameters.

c) Spinal curvature tracings.

d) Questionnaire.

3. RESULTS

3.1. Research Population.

303 Primary School pupils were examined – 154 boys and 149 girls, taken from 2nd, 4th and 6th grades. From the 2nd grade there were 50 boys and 41 girls, from the 4th grade, 60 boys and 59 girls and from the 6th grade 44 boys and 49 girls. The children were randomly selected from the school lists according to age.

The results relate to six population groups – 3 groups of boys and three groups of girls in the three age groups taken from various Primary Schools (Table #5).

	Grade 2		Grade 4		Grade 6		Total	
	Total	Selected	Total	**Selected**	Total	Selected	Total	Selected
Boys	64	50	73	60	51	44	188	154
Girls	55	41	66	59	52	49	173	149
Total	119	91	139	119	103	93	361	303

Table 5: Numbers of subjects selected for the study, according to grade and gender

3.2 Anthropometric Analysis of the Research Groups

3.2.1. 2nd grade - boys

There were 50 boys in the 2nd grade with the average age of 7.6 years (7-9 years**).** This average is compatible with the 2nd Grade in general. The average weight was 27 kgs. (20-40 Kgs), and the average height was 127.8 cms (118-142 cms.).

According to Tables of Standard Growth – Weight by Height – Ministry of Health (App. 5) – this group is slightly above the 50th percentile. Average Body Mass Index (BMI) was 16.4 Kg/ht^2 (13.3 – 21.9 Kg/ht^2). According to 'TAYSIDE GROWTH STUDY DATA' 'Growth Curve Tables' (1989-1991) (App.6), this group is above the 50th percentile according to age.

3.2.2. Grade 2 – Girls

There were 41 girls in the 2nd grade with the average age of 7.6 years (7-9 years). This average is compatible with the 2nd Grade in general. The average height was 128.2 cms. (119-139 cms.) , greater than the boys in 0.4 cms in this age group.
The average weight was 26 kgs. (20-40 Kgs). Despite the higher average of the girls (0.4cms.) in comparison to the boys in this age group, the average age was lower in comparison to that of the boys.
According to, 'Weight by Height Tables', this group is situated above the 55th percentile (App. 7). The average Body Mass Index (BMI) was 15.7Kg/ht^2 (13.3 – 22.2 Kg/ht^2). According to 'Growth Curve Tables' this age group falls exactly on the 50th percentile (App. 8).

3.2.3– Grade 4 - boys

There were 60 boys with the average age of 9.5 years (9-11 years). This average is compatible with the 4th Grade. The general average height was 138 cms. (124 -150 cms.), and the average weight was 33.2 kgs. (23-46 Kgs). (On 50th percentile of normal growth). The average Body Mass Index (BMI) was 17.4 Kg/ht^2 (13.5 – 23.6 Kg/ht^2). According to 'Growth Curve Tables' this age group falls on the 50th percentile.

3.2.4 – Grade 4 - girls

There were 59 girls with the average age 0f 9.48 years (9. - 11 years). This average is compatible with the 4th Grade in general. The average height was 138.9 cms. (125-162 cms.) . The Average height was 0.9 cms greater than for the boys in this age group. The average weight was 33.2 kgs (25-51 Kgs). This group was the same as for the Average weight of the boys.(50th percentile of NORMAL graphs). Average Body Mass Index (BMI) was 17.1 Kg/ht^2 (13.7 – 25.3 Kg/ht^2). According to 'Growth Curve Tables' this age group falls on the 50th percentile.

3.2.5 – Grade 6 - boys

There were 44 boys with the average age of 11.9 years (11.-13 years) . This average is compatible with the 6th Grade in general. The average height was147.9 cms (136 -163 cms.), and the average weight was 39.9 kgs. (29-61 Kgs) (50th percentile of normal growth).

Average Body Mass Index (BMI) was 18.1 Kg/ht^2 (14– 26.4 Kg/ht^2). According to 'Growth Curve Tables' this age group falls on the 50th percentile.

3.2.6 – Grade 6 - girls

There were 49 girls with the average age of 11.5 years (11-13 years). This average is compatible with the 6th Grade in general. The average height was 151. 3cms. (136 -163 cms.). This was 0.3cms higher than the boys in this age group. Only in this age group, of all three age groups, were the girls found to be significantly taller ($p=0.02$) than the boys. The average weight was 40.5 kgs. (29-61 Kgs). (50th percentile of normal growth). The average Body Mass Index (BMI) was 17.6 Kg/ht^2 (14.2 – 24.6 Kg/ht^2). According to Growth Curve Tables this age group falls on the 50th percentile.

3.3 Demographic Features of the Research Population.

3.3.1. Population according to Country of Birth.

The total population was 303 children. 74.7% were Israeli born. 18.5% were European-American and 6.8% Afro-Asian (Table #6). Of the 147 boys 73.5% were Israeli born. 23.1% were European-American and 3.4% Afro-Asian. A similar distribution was found amongst the girls. Of the 146 girls 76% were Israeli born. 13.7% were European-American and 3.4% Afro-Asian .

N	ISRAEL	EURO-AMERICA	ASIA-AFRICA	TOTAL
BOYS	108	34	5	147
%	73.5%	23.1%	3.4%	100%
GIRLS	111	20	15	146
%	76%	13.7%	10.3%	100%
TOTAL	219	54	20	293*
%	74.7%	18.5%	6.8%	100%

(Table #6). Total Research Population both sexes according to Country of Birth.

*Out of the 303 students ten did not answer this question

The majority of the students from the American-European group were from the former Russian countries. While approximately half of the Afro-Asian group were born in Ethiopia.

3.4 Range of Motion Measurements

3.4.1. Results of Straight Leg Raising Measurements (SLR).

On examination of SLR as a measurement of hamstrings tension, the Average of the whole population was 65.4 degrees (S.D. 11.3 degrees) . Significant differences were found between the sexes . Average SLR – girls 69.1 degrees and the boys 61.8 degrees (P=0.000). The difference was 7 degrees more in the girls (Table #7).

All Average SLR parameters refer to the Average of both legs since no difference was noted between left and Right. The analysis of these measurements will be indicated according to this average.

The 2nd Grade –girls had the highest Average SLR amongst the six groups with an Average of 71.4 degrees. The other two female groups had an approximately similar Average of 68 degrees, 3 degrees lower than the youngest group but not significantly so. The same tendency was seen in the male groups.There is a significant lowering of Average SLR as the age increases. The youngest male group has an Average of 62.8 degrees whereas the oldest group had an average of 59 degrees, a difference of 4 degrees (P=0.05). The Averages of 4th and 6th grade boys were similar (figure 26).

	N	MEAN	Std. D.	MIN.	MAX.
BOYS	154	61.8 ^{A}	8.9602	43.5	89.0
GRADE 2	50	^{BE}62.8	8.7505	44.3	84
GRADE 4	60	^{C}62.8	9.4740	46.3	89
GRADE 6	44	^{DE} 59.0	8.0367	43.5	76
GIRLS	149	69.1 ^{A}	12.3815	41.3	105.5
GRADE 2	41	^{B} 71.4	10.7372	51	105.5
GRADE 4	59	^{C} 68.0	13.3202	41.2	99.2
GRADE 6	49	^{D} 68.3	12.4723	46	96.1
TOTAL	303	65.4	11.3627	41.3	105.5

Table 7 - Results of SLR , Standard Deviation, Average (Maximum and Minimum Ranges) in both sexes and all age groups.

*In this Table, and all subsequent Tables, in each pair of parameters with a similar letter the significant difference will be indicated according to the following list:

(A) P=0.000 (B) P=0.000 (C) P=0.016 (D) P=0.000 (E) P=0.05

In all grades there was a significant difference between the sexes.

The Average of the girls in all age groups was higher by 9 degrees as compared to the boys. (see the list of Significant Differences B,C,D in Table #7)

Figure 26. Mean SLR by sex and age

3.4.2. Results of HIP EXTENSION examinations.

The HIP EXTENSION (HE) while lying prone, reflects the degree of tension in the Ilio-poas muscles. As can be seen in Table #8 the Average HE in the whole population was 26 degrees (S.D. 4.74 degrees). Significant differences were found between the sexes (P=0.004). Average in the girls 26.8 degrees and in the boys 25.2 degrees.

	N	MEAN	Std. D.	MIN.	MAX.
BOYS	154	25.2	4.65	11.8	44.0
GRADE 2	50	25.6 [A]	4.92	11.8	37.0
GRADE 4	60	25.4	5.08	12.2	44.0
GRADE 6	44	[A] 24.3	3.56	18.0	32.0
GIRLS	149	25.6	3.96	15.0	39.0
GRADE 2	41	[B] 26.0	4.71	15.0	35.0
GRADE 4	59	26.1	4.02	17.5	39.0
GRADE 6	49	[B] 24.7	3.00	20.0	30.0
TOTAL	303	25.4	4.32	11.8	44.0

(A) P=0.004 (B) P=0.046

Table 8 - Results of HE Average, Standard Deviation, (Maximum and Minimum Ranges) in both sexes and all age groups.

This data demonstrate that the flexibility of the Ilio-psoas muscle is greater in girls (see also figure 27). This is similar to the SLR findings. The only significant difference in Ilio-psoas tension was found between the 4th grade sexes – the boys average 25.5 degrees and the girls 27.3 degrees (P=0.046).

<u>Figure 27. mean hip-extension by age and sex</u>

Despite a lowered tendency with age no significant differences were found between the different age groups of the sexes. The 6th grade boys had the lowest average measurements, a fact which demonstrates the presence of high tension in the higher age group , similar to the findings in the SLR.

<u>3.4.3 Results of PELVIC ROTATION (PR) measurements.</u>

This examination reflects the tension of the hamstrings in relation to the fixation of the pelvis and rotation about the hip joint.

The Average PR in the whole population was 51 degrees (S.D. 14.1 degrees).

A significant difference was found between the sexes – boys Average 47.6 degrees and the girls Average 54.6 degrees, a difference of 7 degrees (P=0.000) –See Table #9.

	N	MEAN	Std. D.	MIN.	MAX.
BOYS	154	[A]47.6	12.207	24	79
GRADE 2	50	50.2	12.929	24	75

GRADE 4	60	46.5 [B]	11.611	27.5	78.5
GRADE 6	44	[C] 46.0	11.933	27	79
GIRLS	149	[A]54.6	15.106	22.5	86.5
GRADE 2	41	55.7	15.962	28.0	86.5
GRADE 4	59	[B] 52.1	15.726	22.5	81
GRADE 6	49	[C] 56.7	15.238	23.5	85
TOTAL	302	51.2	14.310	22.5	86.5

Table 9 - Results of PELVIC ROTATION Average, Standard Deviation, (Maximum and Minimum Ranges) in both sexes and all age groups.

(A) P=0.000 (B) P=0.028 (C) P= 0.000

Although significant differences were not found between the Average PR in the various age groups amongst the boys, there was nevertheless a reduction of the PR with age . A difference of 4 degrees was found between the youngest and the two older groups and only a difference of 0.5 degree between the middle and oldest group. No significant findings were noted amongst the girls but the tendency was not consistent as it was with the boys. In the 4th grade significant difference were found between the sexes.

Figure 28. mean pelvic rotation by sex and age

In the 4^{th} grade the average PR amongst the girls was higher by about 6 degrees than amongst the boys (figure 28). (P=0.028). In the 6^{th} grade the average PR was greater amongst the girls by 10 degrees compared to the boys (P=0.000)

3.5 Results of Spinal Curve measurements.

3.5.1 Results of Lumbar Lordosis measurements.

This parameter reflects the lumbar lordosis in degrees.

The Average angle in the total population was 41.7 degrees (S.D. ?11 degrees). The Range was 14-80 degrees. See Table #10. The lumbar curve increased with age. Significant differences were found between the youngest and the oldest group with an Average in the 2^{nd} grade of 39.7 degrees and in the 6^{th} grade 45.6 degrees – a difference of 6 degrees.(P=0.000).

In the boys the average was 39.8 degrees, 4 degrees lower than the girls (43.7 degrees) in all the grades (P=0.001). Amongst the boys significant differences were found in the age groups. There is an increase in the Lumbar lordosis angle with age amongst the boys.

In the 2^{nd} grade (boys) the lowest angle was noted of average 36.9 degrees .

	N	MEAN	Std. D.	MIN.	MAX.
BOYS	154	^{B} 39.8	10.4	14	73
GRADE 2	50	$^{C\ D}$ 36.9	8.62	19	55
GRADE 4	60	38.4	10.3	14	60
GRADE 6	44	^{C} 44.8	10.7	18	73
GIRLS	149	^{B} 43.7	11.3	21	80
GRADE 2	41	^{D} 43.1	11.1	26	64
GRADE 4	59	42.1	11.7	21	79
GRADE 6	49	46.4	10.7	23	80
TOTAL	302	41.7	11	14	80
GRADE 2	91	^{A} 39.7	10.2	19	64
GRADE 4	119	40.2	11.1	14	79
GRADE 6	93	^{A} 45.6	10.7	18	80

(A) P=0.000 (B) P=0.001 (C) P= 0.000 (D) P=0.004

Table 10 - Results of LUMBAR LORDOSIS (in degrees) - Average, Standard Deviation, (Maximum and Minimum Ranges) in both sexes and all age groups.

In 4th grade 38.4 degrees and the highest angle was in the 6th grade with average of 44.8 degrees (P=0.000).

In contrast, amongst the all the girls no significant differences were in the age groups.

The tendency to increase was similar to that of the boys except that between the lowest and middle groups there was only a difference of 1 degree in the 4th grade.

The difference between oldest and youngest female groups was 3 degrees.

In the 6th grade (girls) the highest angle , 46.4 degrees, was noted, similar to that of the 6th grade -boys (figure 29).

Figure 29. mean lumbar lordosis by sex and age

In all age groups the average Lumbar Lordosis was greater amongst the girls than the boys. Significant differences were found only in the youngest group between the sexes – boys Average 36.9 degrees and girls 43.1 degrees , a difference of 6 degrees (P=0.004).

In the 4th grade the girls had a 4 degree higher angle than the boys (P=0.07).

In the oldest age groups the highest angles were noted but no significant difference was found in this age group (figure 29).

3.5.2 Results of Dorsal Kyphosis (DK) Measurements.

This parameter reflects the Dorsal kyphosis angle in degrees. The average in total population was 34.1 degrees (S.D. ?8.84 degrees). – Range 15-66 degrees. (See Table #11). The Dorsal kyphotic angle reduced with age in contradistinction to the Lumbar lordosis. Significant differences were found between the youngest and oldest groups with the average in 2nd grade 35.9 degrees and the oldest 32.2 degrees , a difference of 4 degrees (P=0.018).

In the total research population no significant difference were found amongst the sexes.

	N	MEAN	Std. D.	MIN.	MAX.
BOYS	154	34.9	7.456	15	57
GRADE 2	50	36.2	7.104	21	52
GRADE 4	60	33.9	7.312	15	53
GRADE 6	44	[C] 34.8	7.976	18	57
GIRLS	148	33.3	10.041	16	66
GRADE 2	41	[B] 35.5	8.999	20.1	58
GRADE 4	58	34.5	11.178	16	66
GRADE 6	49	[B C] 29.9	8.654	17.1	55
TOTAL	302	34.1	8.84	15	66
GRADE 2	91	[A] 35.9	7.973	20.1	58
GRADE 4	119	34.2	9.378	15	66
GRADE 6	93	[A] 32.2	8.654	17.1	57

(A) P=0.018 (B) P= 0.013 (C) P=0.006

Table 11 - Results of DORSAL KYPHOSIS (in degrees) - Average, Standard Deviation, (Maximum and Minimum Ranges) in both sexes and all age groups.

The average DK (boys) was 34.9 degrees and DK (girls) 33.3 degrees.

In the boys no significant differences were found among the age groups. There is a tendency to reduction of DK with age (see figure 30).

In the 2nd grade boys the average was 36.2 degrees which was the highest DK angle measured within all the research groups. In the 4th grade (boys) average 33.9 degrees and 6th grade (boys) 1 degree more (average 34.8 degrees).

Figure 30. mean dorsal kyphosis by sex and age

Amongst the girls significant differences were found between the age groups with a similar tendency to that found amongst the boys. 6^{th} grade (girls) had the lowest DK angle among all the research groups and had an average of 29.9 degrees, a difference of 6 degrees in relation to the youngest female group(P=0.013).

The Average DK (girls) in all age groups was lower than in DK(boys) but without any significant difference except in the oldest groups where the average difference was 6 degrees less in the girls as compared to the boys (P=0.0006).

3.6 The Relationship between parameters of lumbar lordosis and movement parameters.

3.6.1 The Correlation between Hamstring tension and the angle of lumbar lordosis.

The correlation of the independent parameters of Hamstring tension will be evaluated by means of the SLR parameters (see para.1.7.1.1) in conjunction with the lumbar lordotic angle parameter.

Within the whole research population a negative correlation was found of r= -0.141 (P= 0.014) . This data demonstrates that the angle of lumbar lordosis decreases as the SLR becomes greater. That is to say that as the tension in the hamstrings decreases so too the lumbar lordosis decreases (figure 31).

Amongst the boys a negative correlation was found of r= -0.244 (P=0.002) between the parameters. The highest correlation was found amongst the boys in 2^{nd} grade (r= -0.390. P=0.005). In the 4th grade no significant correlation was noted and in

Figure 31. SLR and Lumbar Lordosis correlation

6th grade the correlation was r= -0.345, P=0.022). Amongst the girls a negative correlation was found of r= -0.196 (P=0.017) between the parameters. The same relationship was noted as with the boys but at a lower correlation. Amongst all the female age groups no significant correlation was found. From this data it appears that the correlation was more significant amongst the boys although among the girls a much weaker correlation was noted but still the tendency was always in a negative direction.

3.6.2 The correlation between Ilio-psoas tension and the angle of lumbar lordosis

The correlation of the independent parameters of Ilio-psoas tension will be evaluated by means of the Hip Extension parameters (para.1.7.2.) in conjunction with the lumbar lordotic angle parameter. These parameters showed the highest correlation amongst all the movement parameters.

In the whole research population the correlation was r= -0.271 (P=0.000). This correlation demonstrates the increase of lumbar lordosis as the Ilio-psoas tension increases i.e. the Ilio-psoas angle decreases (figure 32).

Figure 32. Hip Extension and Lumbar Lordosis correlation

Among the boys no significant correlation was found although there was a negative tendency. On the other hand amongst the girls there was a significant correlation (r= -0.434, P=0.000). It therefore appears that there is a lowering of the correlation with age among the girls. In the 2nd grade the correlation r=-0.536, P=0.000 , 4th grade r=-0.363, P=0.005 and in the 6th grade r=-0.357, P=0.007.

Similar to the results of the SLR parameters so too amongst these parameters a tendency towards a negative correlation was noted. From this data a reversed correlation was found between the sexes with regard to the movement parameters. Whereas the relationship between the hamstring tension and the lumbar lordosis angle in the boys was significant and not so amongst the girls, where the Ilio-psoas tension was concerned the exact opposite was the case.

3.6.3 The correlation between PELVIC ROTATION and the angle of lumbar lordosis

The correlation of the independent parameters of PELVIC ROTATION will be evaluated by means of the Toe-touch parameters in conjunction with the lumbar lordotic angle parameter.

Amongst the whole research population no significant correlation was found.

Amongst the boys a negative correlation was found r= -0.183, P=0.023. When the relationship was analyzed amongst the male age groups a significant correlation was found only in the 2nd grade r= -0.309, P=0.029. This direction demonstrates a decrease in the lumbar lordosis angle with increase in flexibility of motion about the hip joint, which is a function of the tension within the hamstrings.

The results of this correlation are similar to the findings in SLR and lumbar lordosis, both in regard to direction i.e. the greater the hamstrings are shorter (and therefore the tension greater) so the lumbar lordosis increases and that this was true mainly among the boys.

3.7 The Relationship between the Thoracic Kyphosis Angle and Motion parameters.

3.7.1. The Correlation between Hamstring tension and Thoracic Kyphosis.

The correlation of the independent parameters of Hamstring tension will be evaluated by means of the SLR parameters (see para.1.7.1.1) in conjunction with the Thoracic Kyphosis angle parameter. Within the whole research population no correlation was found. Examinations of the correlations by age and sex significant correlations were found only in the 2nd grade in both sexes.In the 2nd grade boys the was a negative correlation r= -0.286 (P=0.044).In the 2nd grade girls a higher negative correlation was found r= -0.354 (P= 0.023).This negative tendency demonstrates that with decrease of the Thoracic kyphosis the is an increase of SLR i.e. as the flexibility of the hamstrings increases there is a flattening of the Thoracic Kyphosis. The connection was found only in the youngest groups, which may indicate a greater relationship between the flexibility of the hamstrings with the spinal curves in the younger ages.3.7.2 The Correlation between Ilio-psoas tension and Thoracic Kyphosis.The correlation of the independent parameters of Ilio-psoas tension will be evaluated by means of the Hip Extension parameters in conjunction with the Thoracic Kyphosis angle parameter. Within the whole research population no correlation was found.3.7.3 The Correlation between Pelvic Rotation and Thoracic Kyphosis.The correlation of the independent parameters of Pelvic Rotation will be evaluated by means of the toe-touch parameters in conjunction with the Thoracic Kyphosis angle. Within the whole research population a negative correlation was found of r= -0.174 (P= 0.002). A similar correlation was found among the female population with a level of r= - 0.189 (P=0.022), (figure 33).

Figure 33. Pelvic Rotation and kyphosis correlation

Significant correlations were found also only in the 2nd grade in both sexes.

In the boys a negative correlation r= -0. 439 (P= 0.001) and in the girls r=-0.367 (P=0.018). This correlation demonstrates a negative tendency between the parameters i.e. as the Pelvic Rotation increases so the Thoracic kyphosis flattens.

The results are parallel to those of SLR in relation to kyphosis which were also found significant only in the younger age groups of both sexes.

3.8. The Connection between the Spinal Curves.

3.8.1. The Correlation between the Thoracic and Lumbar Curves.

Among the whole research population a Positive correlation was found r=0.316 (P=0.000). This demonstrates an increase in the Thoracic kyphosis with a corresponding increase of the Lumbar lordosis. A similar result was found in both sexes. In the boys r=0.236 (P=0.003) in the girls a higher correlation r= 0.415 (P=0.000). From the level of correlation found in the girls we can imply that there is a stronger relationship between the spinal curves in females in general (figure 34). Furthermore, it may expected that a kypho-lordotic deformity will be found more commonly in girls. In the male groups a significant correlation was only found in the 4^{th} grade r= 0.429 (P=0.001).

Figure 34. Lumbar Lordosis and Kyphosis correlation

In the female groups significant correlations were found in the 2^{nd} and 4^{th} grades, 2^{nd} grade r= 0.548 (P=0.000); 4^{th} grades r= 0.586 (P=0.000).

In the oldest grade in both sexes no significant correlation was found. In all the groups a Positive tendency was noted i.e. increase in one was associated with a corresponding increase in the other and vice versa.

3.9. Results of Postural Evaluation.

The overall results in this section were estimated in three categories. The level was determined by the total of postural deformities of each individual examined.

1= “Good”, 2=”Fair” and 3= “Poor” or “At risk”.

3.9.1. Overall Postural Level according to age.

Out of a total of 303 pupils examined , 114 (37.6%) were estimated as “Good”, 133 (43.9%) “Fair” and 56 (18.5%) “Poor” .

	Posture Mark			Row Total
CLASS	**GOOD**	**FAIR**	**RISK**	
GRADE 2 Count Row Pct Col. Pct	 17 18.7% 14.9%	 49 53.8% 36.8%	 25 27.5% 44.6%	 91 30%
GRADE 4 Count Row Pct Col. Pct	 49 41.2% 43%	 49 41.2% 36.8%	 21 17.6% 37.5%	 119 39.3%
GRADE 6 Count Row Pct Col. Pct	 48 51.6% 42.1%	 35 37.6% 26.3%	 10 10.8% 17.9%	 93 30.7%
Column Total	114 37.6%	133 43.9%	56 18.5%	303 100

Table #12 – The Results of Postural Estimation according to Age.

The Postural estimations, according to age, showed that, in the "Good" category lowest percentage of children was among the youngest group (14.9%) while there was a similar percentage amongst the upper age groups in the same category.

In the "Fair" group a similar percentage amongst the 2nd and 4th grades (36.6%) and in the 6th grade only 26.3%.

In The "Poor" category the majority were in the 2nd grade, 25 (44.6%), while in the 4th grade 21 (37.5%) and in 6th grade 10 (17.9%). These findings demonstrate a significant decrease in deformity with age. (See table 12).

	Posture Mark	ROW TOTAL

SEX	GOOD	FAIR	RISK	
MALE Count Row Pct Col. Pct	50 32.5% 43.9%	76 49.4% 57.1%	28 18.2% 50.0%	154 50.8%
FEMALE Count Row Pct Col. Pct	64 43% 56.1%	57 38.3% 42.9%	28 18.8% 50%	149 49.2%
COLUMN TOTAL	114 37.6%	133 43.9%	56 18.5%	303 100.0%

Table #13 – Results of Postural Evaluation according to sex

3.9.2 Postural Evaluation of Total Research Population, by sex.

In Table #13 the results of Postural evaluation are brought according to sex. Approximately half of the 154 boys examined, 76 (49.3%) were found in the “Fair” category, 50 (32%) were “Good” and the remainder 28 (18.2%) were “Poor”.
In the girls “Good” = 64 (43%). “Fair” 57 (38%) and “Poor” 28 (19%). These results show that in the females the percentage distribution decreased as the deformity increased but among the boys the highest percentage was found among those designated as “Fair”.

3.9.3 - Postural Evaluation in the Male Research Population , by age and sex.

Of the 154 boys examined, 76 (49.4%) were found in the “Fair” category. This was the highest distribution of all age groups. In this category the distribution was; 2nd grade – 29 (38.2%) ; 4th grade – 25 (32.9%) ; 6th grade – 22 (28.9%).

	Posture Mark			**ROW TOTAL**
CLASS	**GOOD** **boys** **girls**	**FAIR** **boys** **girls**	**RISK** **boys** **girls**	**boys** **girls**

GRADE 2 Count Row Pct Col. Pct	9 8 22 16 16 14.1	29 20 58 48.8 38.2 35.1	13 12 26 29.3 46.4 42.9	50 41 32.5 27.5
GRADE 4 Count Row Pct Col Pct	24 25 40 42.4 48 39.1	25 24 41.7 40.7 32.9 42.1	11 10 18.3 16.9 39.3 35.7	60 59 39 39.6
GRADE 6 Count Row Pct Col Pct	18 30 40.9 61.2 36 46.9	22 13 50 26.5 28.9 22.8	4 6 9.1 12.2 14.3 21.4	44 49 28.6 32.9
COLUMN TOTAL	50 64 32.5 43	76 57 49.4 38.3	28 28 18.2 18.8	154 149 100 100.

<u>Table #14 - Postural Evaluation in the total Research Population , by age and sex.</u>

In the "Good" category; 2nd grade –8 (14.1%) ; 4th grade – 24 (48%) ; 6th grade – 13(46.9%).
"Poor" category; 28 (18.2%) – 2nd grade 13 (46.4%) ; 4th grade – 11 (39.3%) ;
6th grade –18 (36%)

<u>3.9.4 - Postural Evaluation in the Female Research Population , by age and sex.</u>

Of the 149 girls examined, the distribution was; in the "Good" category 64 (43%) 2nd grade 9 (16%) ; 4th grade – 25 (39.1%) ; 6th grade – 30 (46.9%) which represented 61.2% of the girls in 6th grade. 57 (38.3%) were found in the "Fair" category. This was the highest distribution of all age groups. The distribution was;
2nd grade – 20 (35.1%) ; 4th grade – 24 (42.1%) ; 6th grade – 13 (22.8%).
In the "Poor" category: 28 (18.8%). In the 2nd grade - 12 (42.9%) ; 4th grade – 10 (35.7%) ; 6th grade – 6 (21.4%).

The tendency noted from this data both among the boys and the girls was that there is a decrease in the "Poor" group with increase in age.

3.10 The Differences between the Mean Motion Parameters and The Postural Categories.

This section will present a review of Postural Evaluation according to the significant differences found in Motion parameters in relation to the various Postural levels.

3.10.1 The Differences in the Mean SLR in relation to Postural Levels

The SLR parameter is a measure of Hamstring tension (shortness). In this section will examine whether there is a difference in the MEAN SLR between the different Postural level.

Among the whole research population there were 114 individuals in the "Good" category with a Mean SLR of 68.5^o .

In the "Fair" category, 133 with a mean SLR 64.1^o and "Poor" 56 with Mean SLR of 61.8^o. Within the various Postural levels a significant difference was found with regard to the Mean SLR. (F = 8.2540, P=0.000).

Among the total population of 154 boys no significant differences were found within the postural categories, but nevertheless it is worthy of note that the mean SLR in the "Good" category was 3 degrees higher than in the other two categories.

Among the 149 girls the mean SLR was 72 degrees in the "Good" category, 68.6 degrees in the "Fair" and in the "Poor" category 62.7 degrees. These mean SLR values demonstrated significant differences F = 6.1459 (P= 0.002). In the total 2nd grade, 92 children, significant differences were found among the mean SLR in the postural categories, – "Good" 74 degrees , "Fair" 66 degrees and "Poor" 62 degrees.(F= 7.4371 (P=0.010)

Among the 2nd grade girls the differences were greater (F= 8.8125, P=0.000) and mean differences of 8 degrees between "Good" and "Poor".

In the total 4th grade , 119 children, no significant differences were found within the postural categories, but nevertheless it is worthy of note that the mean SLR decreased with the increase in postural deformities..

In the total 6th grade, 93 children, significant differences were found among the mean SLR in the postural categories,– "Good" 67.5 degrees , "Fair" 60 degrees and "Poor" 59.5 degrees.(F= 5.2358 (P=0.007)

3.10.2 Mean Differences of HIP EXTENSION in relation to Postural categories.

The HE parameter is an indication of Ilio-psoas tension. In the section the Ilio-psoas tension was compared to the various postural categories.

Among the whole research population significant differences were found.
“Good” 26.1 degrees, “Fair” 25.1 and “Poor” 24.6 degrees (F= 2.9139, P=0.055).
Among the total boys no significant differences were found in this category but there is a tendency to an increase in Ilio-psoas tension with increased postural deformities. Similar results were noted among the girls. No differences were found in the mean Ilio-psoas tension and the differences in the mean values were the same as among the boys. In the 4th grade significant differences were found , “Good” 27 degrees, “Fair” 25.2 and “Poor” 24.2 degrees (F= 3.3799, P=0.037).
In the 6th grade significant differences were found , “Good” 25.3 degrees, “Fair” 23.4 and “Poor” 24.7 degrees (F= 3.3702, P=0.038).

3.10.3 The mean Differences of PELVIC ROTATION (PR) in relation to the Postural categories.

The PELVIC ROTATION parameter is an indication of the measure of flexibility around the pelvis and also of hamstring tension. The mean PR in the whole research population was 51 degrees . Significant differences were found among the Postural categories. The mean PR in the Postural categories was “Good” 54.1, “Fair” 50.8 and “Poor” 45 degrees. (F= 7.5799, P=0.000). Among the boys no significant differences of mean PR were noted and also in the age categories. Within the total female population significant differences in PR were found among the postural

categories – “Good” 58.7 degrees , “Fair” 53.7 and “Poor” 46 degrees (F= 7.3969, P=0.000). Among the girls according to age, significant differences were found only in the 2nd and 6th grades – 2nd grade “Good” 64.4 degrees, “Fair” 54 degrees and “Poor” 44 degrees.(F= 5.5753, P=0.000) In the 6th grade “Good” 60.3 degrees, “Fair” 53.5 degrees and “Poor” 45.3 degrees (F= 3.0721, P=0.055). In the total 2nd grade, 91 children, significant differences were found in the mean PR – “Good” 58.5 degrees, “Fair” 54.2 degrees and “Poor” 45.8 degrees (F= 5.5978, P= 0.005). In the 4th grade no significant differences were found but it is noteworthy that there was a decrease in flexibility of the pelvis with increase in the postural deformities.
In the 6th grade, 93 children, significant differences were found in the mean PR within the postural categories – “Good” 55.2 degrees, “Fair” 48.1 degrees and “Poor” 47 degrees (F= 3.0872, P=0.050).

3.11 The frequency of BACK PAIN in the research population.

Within the whole research population 136 children reported BACK PAIN (46.4%), among these 46.3% boys and 53.7% girls, a difference of 7.4%. (See Table #15).

SEX	Backache YES	NO	Row TOTAL
MALE Count Row Pct Col. Pct	63 42.9 46.3	84 57.1 53.5	147 50.2
FEMALE Count Row Pct Col. Pct	73 50.0 53.7	73 50.0 46.5	146 49.8
Column TOTAL	136 46.4	157 53.6	293 100.0

TABLE #15 - The Frequency of BACK PAIN in the research population by sex .

Among the boys, the highest number of BP cases were from the 4th grade 29 boys (49.2%) and in 2nd grade 19 boys (39.6%) , 6th grade 15 boys (37.5%). (See Table #16). The number of girls who reported BP was higher than the boys in each of the age groups. 55% of 2nd grade girls reported BP – this was the highest group from the whole research population even those the actual number of girls was not high.

31 girls from 4th grade reported BP (52.5%), from 6th grade 20 girls (42.6%)

63 boys reported BP , The highest number was from the 4th grade 46%, 2nd grade

30.2% and 6th grade 23.8%.

Among the girls 73 (50% of the total female population) reported BP with a similar distribution as in the boys. 4th grade 31 (42.5%), 2nd grade 22 (30.1%) and 6th grade 20 (27.4%). (see table 16).

	Backache	Row TOTAL

CLASS	YES		NO			
	boys	girls	boys	girls	boys	girls
GRADE 2 Count Row Pct Col. Pct	19 39.6 30.2	22 55.0 30.1	29 60.4 34.5	18 45.0 24.7	48 32.7	40 27.4
GRADE 4 Count Row Pct Col. Pct	29 49.2 46.0	31 52.5 42.5	30 50.8 35.7	28 47.5 38.4	59 40.1	59 40.4
GRADE 6 Count Row Pct Col. Pct	15 37.5 23.8	20 42.6 27.4	25 62.5 29.8	27 57.4 37.0	40 27.2	47 32.2
COLUMN TOTAL	63 42.9	73 50.0	84 57.1	73 50.0	147 100.0	146 100.0

TABLE #16 - The Frequency of BACK PAIN in the research population by sex and age .

3.11.1 The Connection between BACK PAIN and Motion Parameters.

3.11.1.1 The Differences in Mean SLR between the groups with and without BP.

Within the whole research population no significant differences were found in the mean SLR between the two groups. A mean SLR of 65 degrees was found in both groups.

Among the girls a significant difference was found in the mean SLR – those without BP had a mean SLR of 71.1 degrees and those with BP 67.3 degrees, (F= 3.3591, P=0.056).

Among the whole group of girls according to age, a significant difference was found only in the 6^{th} grade, where the mean SLR without BP was 60.8 degrees and the group with BP 52.3 degrees, a difference of 8.5 degrees. (F= 3.8563, P=0.055).

3.11.1.2 The Differences in Mean HIP EXTENSION between the groups with and without BP.

No significant differences were found among all the research groups.

3.11.1.3 .The Differences in Mean PELVIC ROTATION between the groups with and without BP.

Similar to the SLR parameter only in the girls were significant differences found in the mean PR between the groups with and without BP. The mean SLR without BP was 57.8 degrees and with BP 51.8 degrees , a difference 6 degrees. (F= 5.7116, P=0.018).

3.11.2. The Differences in the Spinal curvatures between the groups with and without BP.

Significant differences were found in the mean Lumbar Curve between the two groups only in the 2nd grade. The group without BP, 28 children, had a mean Lordotic curve of 34.4 degrees and with BP, 19 children, 40 degrees., a difference of 5.6 degrees, (F= 5.1526, P=0.027).

3.11.3. The Relationship between Postural categories and frequency of BP.

No significant differences were found among all the research groups.

3.12. The Frequency of visiting a physician because of BACK PAIN

This parameter relates to medical treatment due to BP. Among the whole male research population it was noted that 61 boys (41.5%) attended a physician for treatment (see Table #17). Among the girls 64 girls (43.8%) attended a physician. The highest percentage was among the 4th grade girls (45.3% of all the girls). This group also had the highest reportage of BP amongst the girls. Also among the boys the 4th grade had the highest frequency of medical attendance (44.3%) and similar to the girls this group also had the highest reportage of BP.

The 2nd grade in both sexes had the lowest medical attendance (26%).

In the 6th grade 29% visited a doctor for BP.

	Seen by Doctor		**Row TOTAL**
CLASS	**YES** **boys girls**	**NO** **boys girls**	**boys girls**

GRADE 2 Count Row Pct Col. Pct	16 33.3 26.2	17 42.5 26.6	32 66.7 37.2	23 57.5 28.0	48 32.7	40 27.4
GRADE 4 Count Row Pct Col. Pct	27 45.8 44.3	29 49.2 45.3	32 54.2 37.2	30 50.8 36.6	59 40.1	59 40.4
GRADE 6 Count Row Pct Col. Pct	18 45.0 29.5	18 38.3 28.1	22 55.0 25.6	29 61.7 35.4	40 27.2	47 32.2
COLUMN TOTAL	61 41.5	64 43.8	86 58.5	82 56.2	147 100.0	146 100.0

Table #17 – Medical Attendance of whole research population by age and sex .

3.13. Sitting Parameters.

3.13.1. Sitting at the computer.

The time spent actually sitting at a computer was calculated according to the average number of hours per week. According to the category of 'types of sitting - sitting on a chair with knees flexed or straight' , 98% of those sitting at a computer

typically were found in category 1 – sitting on chair with hips and knees at 90 degrees or less.

Among the whole research population the mean number of hours was 6.5 hours. Among the boys 7.3 hours/week and among the girls 5.6 hours/week. A difference of 1.5 hours between the sexes.

When examined according to age the highest number of hours was found in the 4th grade 7.1 hours/week followed by 6th grade 6.3 hours/week and 2nd grade 5.9 hours/week (see Table #18).

When examined according to sex and age , the highest incidence was among the 4th grade boys, 8.4 hours/week. For 6th grade boys 6.7 hours/week and 2nd grade 6.5 hours/week.

Among the girls the time increased with age, 2nd grade 5.1 hours/week, 4th grade 5.6 hours/week (three hours less than the boys of the same age) and 6th grade 6 hour/week. In all the age groups the use of a computer was greater among the boys.

CLASS	COMPUTER hours per week boys	girls	Total	T.V hours per week boys	girls	Total
GRADE 2	6.5	5.1	5.9	15.4	13.2	14.4
GRADE 4	8.2	5.6	7.1	16	13.3	14.7
GRADE 6	6.8	6.0	6.3	14.6	14.4	14.5
Total	7.3	5.6	6.5	15.4	13.7	14.5

Table #18 – Mean number of hours/week sitting at a COMPUTER or watching TELEVISION by age and sex

3.13.2. Watching TELEVISION.

Watching Television was calculated according to hours/week according to all types of sitting posture. This action was typified by sitting with the legs stretched out on front and in a position of lying or sitting on the floor. This subject will be discussed below. The mean hours/week of TV watching among the whole research population was 14.5 hours, i.e. about 2 hours more per day. Among the boys the mean 15.4 hours/week and for the girls 13.7 hours/week. The time for the boys was about two hours more than for the girls per week.

When examined according to the age groups alone, the mean time/week was similar in all age groups, 14.5 hours/week.

According to sex and age, the highest incidence was found that among the 4th grade boys, 16 hours/week, followed by 2nd grade boys (15.4 hours/week) and 6th grade 14.6 hours/week . Among the girls the mean time was less in all age groups as compared with the boys. It appears that there is a tendency for increased watching with age , 2nd grade 13.2 hours/week, 4th grade 13.3 hours/week and 6th grade 14.4 hours/week.

3.13.3. Number of hours spent sitting per day.

This parameter was calculated according to the total number of hours spent sitting at a computer, watching television and video games*

The following results refer only to the daily hours spent at continuous sitting after school hours. Those typically lying down were not included in the daily calculation. Similarly the time spent sitting at school was not included.

The mean hours sitting per day in the whole research population was 3 hours - among the boys 3.3 hours and the girls 2.7 hours.

According to age , the mean was the same in all the age groups – 3 hours /day similar to the whole research population (see Table #19).

According to sex and age , in all the age groups the girls had a lower incidence than among the boys. In the 2nd grade boys the mean hours/day was 2.6, in 4th grade 2.6 and 6th 2.8.

Among the girls 2nd 2.6 hours/day, 4th grade 2.7 hours/day and 6th grade 2.8 hours/day.

	TOTAL SITTING HOURS PER DAY		
CLASS	BOYS	GIRLS	TOTAL
GRADE 2	3.2	2.6	3.0
GRADE 4	3.4	2.7	3.0
GRADE 6	3.3	2.8	3.0
TOTAL population	3.3	2.7	3.0

Table #19 – Average sitting time per day according to age and sex.

* The number of hours in this category were not noted because of lack of cases but was included in the total amount of sitting per day.

3.13.4 Types of sitting posture.

In the 'Types of sitting' parameter four postural types were included to which the examinee had to relate according each of the following parameters – watching Television, use of computer, video games or other activity mentioned in the questionnaire.

Four categories of sitting are :

1. Sitting with hips and knees at 90 degrees or less
2. Knees straight with the body leaning backwards.
3. Sitting on the floor .
4. Lying either on the back or stomach.

The Mean sitting posture was calculated in those cases where shortness of the hamstrings, Ilio-psoas, or spinal curvature abnormalities were noted according to each of the sitting parameters. In the reportage of "sitting posture – change of position" whichever posture was reported as longest was taken as the relevant parameter.

In the analysis of types of sitting at the computer it was noted that 98% of the whole research population reported type 1 – sitting on a chair with the hips and knees at 90 degrees or less with the body upright or leaning forwards. From this data the most frequent type of sitting posture is when the hips are at less than 90 degrees while the knees are held at an angle of approximately 90 degrees.

The position with the knees extended is less frequent when using a computer because it has the effect on distancing the person from the computer screen and keyboard and there in general the preference to reduce the knee angle to less than 90 degrees. This point will be discussed below.

Analysis of the results of 'Watching television' it was noted that the commonest type of posture in both sexes was in category 2 – legs extended forward either with the back upright or leaning backwards. In this position the most of the joints in body are at an angle greater than 90 degrees, especially the hips and knees. 77 out of 152 boys reported this typical posture (51% of the boys) . 42 boys reported watching television while sitting on the floor (27.6%) and 27 boys reported lying down. Only 6 (4%) of the boys reported sitting according to category 1.

Among the girls a similar tendency was noted as with the boys, 43 girls (60.5%(reported category 2 , the slouching position, 33 girls (22.4%) reported sitting on the floor and 24 girls (16.3%) lying down while watching television.

In the category of 'Video games', several point arose which are noteworthy. There is a wide range of video games for which the posture is dictated according to the type of game played, for example the ‘Play stations’ requires viewing the TV screen as opposed to the ‘Game Boy’ which although it is also hand-held is viewed by the screen of the game instrument itself. The reportage of these postures included more than one typical position. In the analysis we related to the commonest position as reported by the child.

117 reported playing video games, the majority being boys. From the 77 boys, 20 (36.4% (reported sitting on the floor, 26% reported sitting on a chair according to category 1 and 25% lying down. 13% reported slouching (category 2(.

Among the whole female groups, 40 girls , 35% were in category 1, 30% sat on the floor, 22.5% category 2 and 12.5% lying down.

3.13.5 The relationship between the Sitting and Motion Parameters.

In the analysis between the connection between the number of hours/week

sitting and the motion parameters , a significant correlation was found with the SLR. In the whole population a negative significant correlation r= -0.2794)P=0.007) . This demonstrated a decrease of SLR as the number of sitting hours increases, i.e. hamstrings shortening increases with the amount of sitting. Similar but slightly more significant findings were noted in relation to Pelvic Rotation)r=-0.3161, P= 0.002(.

This data shows a connection between the decrease of pelvic flexibility together with fixation of the hip joint with increase in the amount of sitting. This results, among other things, from shortness of the hamstrings, as was seen in the relationship between SLR and the number of sitting hours.

According to sex, the same tendencies were noted in both sexes but to a lesser extent among the boys. In the boys a negative correlation of -0.1536)P=0.06). Although this is not statistically significant the tendency is towards decreased pelvic rotation with increased hours of sitting.

In the girls a negative correlation was found between the SLR parameters and the amount of sitting ,(r= -0.3085 ,P= 0.000), and with Pelvic Rotation the correlation was -0.2603, (P=0.002(. These results are similar to the correlations found in the whole research population except that the differences are in the levels of significance between the parameters. While within the whole research population the greater correlation was noted with the PR, among the girls the correlation was greater with the SLR parameters where sitting concerned.

Within the analysis of the age groups we found results silmilar to the whole population. Among 2nd grade a significant correlation between SLR and sitting hours was found (r= -0.3031, P=0.004) . Significant correlations were found, to a lesser extent, also with PR)r=-0.2053, P=0.057). In 4th grade , average 10years, a negative correlation between SLR and sitting hours)r=-.0 .3309, P=0.000(.

Similarly, but to lesser extent, the PR was borderline in relation to sitting hours (r=-0.1722, P=0.065(. In the 6th grade, 12-13 years old, the highest correlation was found with PR)r=-0.3161, P=0.002) and there was a lower negative correlation with SLR, (r=-0.2794, P=0.007). Among the girls a significant negative correlation was found (r=-.0.4522, P=0.001) between PR and sitting hours and a significant but lesser, correlation with SLR , (r=-0.2960, P=0.003(. No significant correlations were found

between sitting hours and Ilio-psoas tension.

3.13.6 <u>The relationship between Sitting Hours and Postural Deformities.</u>

The analysis of these parameters reflects the effects on the body of the number of sitting hours/day with regard to different sitting activities.

Within the whole research population significant differences were found in the mean sitting hours/day between the various postural categories.

In the "Good" postural category there were 111 children with a mean of 2.9 hours/day 'whereas in the "Poor" category there were 55 children with a mean of 3.4 hours/day, a difference of 0.5 hours/day between these two groups. (F= 2.9331, P=0.054). This data may reflect a connection between the amount of sitting and an increase in postural deformities.

When examined according to sex no significant differences were found between the parameters but it is noteworthy that the tendency was towards an increase in deformity with increased hours of sitting in both sexes.

Among the boys, the "Poor" category the mean equaled 3.8 hours/day as opposed to 3.2 hours/day in the "Good" category (F = 2.352, P=0.09). Although the level of significance is borderline the difference is of more than 0.5hours/day in the "Poor" category.

Among the girls the differences between sitting hours/day were shorter but with the same tendencies as the boys. The mean number of sitting hours was 2.7 in the "Good" category and in the "Poor" category was 3.

According to age, significant differences were only found in the 6th grade. The mean sitting hours/day in this group, 92 children, was 3.1 hours/day. – "Good" 47 children with mean 3hours/day and "Poor", 10 children, with a mean of 4 hours/day, a mean difference of one hour (F= 3.4705, P=0.035).

3.13.7 <u>The Differences between mean sitting hours/day in relation to spinal curvatures.</u>

No significant differences were found between these parameters.

3.14 <u>Activity parameters.</u>

The "Activity parameter's include two categories which test the amount of physical activity of the children out of school hours – a) 'organized activities' within the

framework of sports clubs etc. and b) ‘un-organized activities’ which are carried out according to the child’s personal preference in an unofficial capacity.
The research population was divided into three levels of activity – 1. “None active”, 2. “Active” and 3 “Very active”. These levels were calculated according to the mean hours of physical activity of the children as reported in the questionnaire in the section on “organized and unorganized activities”.
In the whole research population there were 112 children in the “Non-active” category)37%), 128)42.2%) in the “Active” and in “Very Active” 63 children (20.8%).
According to sex, the boys were more active than the girls,. In the “Non-active” category were 65.2% of the girls and 34.8% boys. The number of girls was double that
of the boys in this category.

CLASS	NON ACTIVE	ACTIVE	VERY ACTIVE	**TOTAL**
GRADE 2				91
BOYS	17 (34.0%)	24 (48.0%)	18%	50 (100%)
GIRLS	27 (65.9%)	12 (29.3%)	2 (4.9%)	41 (100%)
GRADE 4				119
BOYS	10(16.7%)	29 (48.3%)	21 (35.0%)	60 (100%)
GIRLS	27 (45.8%)	22 (37.3%)	10 (16.9%)	59 (100%)
GRADE 6				93
BOYS	11(27.3%)	23 (52.3%)	9 (20.5%)	44 (100%)
GIRLS	19 (38.8%)	18 (36.7%)	12 (24.5%)	49 (100%)
TOTAL	112 (37.0%)	128 (42.2%)	63 (20.8%)	303 (100%)
BOYS	39 (25.3%)	76 (49.4%)	39 (25.3%)	154 (100%)
GIRLS	73 (49.0%)	52 (34.9%)	24 (16.1%)	149(100%)

Table #20 – Levels of physical Activity according to age and sex.

In the “active” groups there were 76 boys (59.4%) and 52 girls (40.6%) of the total male/female populations and in the “very active” groups there were 39 boys (61.9%) and 24 girls (38. 1%) respectively.

According to age, the largest number in the “Non-active” group was among the 2nd grade, which was 48.4% of 2nd grade. In 4th grade there 31.1% and in 6th grade 33.3%.
In the “Active” group the percentage increased with age. In this category there were 39.6% in 2nd grade, 42.9% in 4th grade and in 6th grade 44.1%. In the “Very active” group there were 12.1% in 2nd grade, in 4th grade 26.1% and 6th grade 22.6%.

According to sex, it was noted that in all three grades the percentage of girls was higher by 25% than in each group of boys.
In the “Active” group in all grades the boys were 15% more than the girls.
Similarly in the “Very active” the same differences were notes except that 6th grade girls were 4% more than the boys.

3.14.1. The Mean motion parameters according to activity levels.

In this section the mean differences of the SLR, PR and HE parameters were compared to the “Activity levels”.
In the whole population no significant differences were found amongst the various activity levels. But it is noteworthy that the trend was for increase of motion parameters with increase in activity, i.e. there was an improvement in flexibility with increased activity.
The mean SLR in the “Non-Active” group was 65 degrees as compared to 67.2 degrees in the “very active”.
The mean HE was similar in all levels of activity.
PR showed a mean increase of approximately1 degree between each of the three levels of activity.
As was mentioned these results showed no significant differences but there was a tendency for decreased activity in those with short hamstrings according to the SLR and PR parameters.
No significant differences were noted in relation to the Ilio-psoas.
No significant differences were found in the whole population according to sex and the trend was as mentioned above.
Among the boys “Non-active” the mean SLR was 59.3 degrees as opposed to “Active” 62.4 degrees and “Very active 63.1 degrees. These results show a lessening of hamstring tension with increase in activity.
The mean Ilio-psoas tension was similar in all three categories.
Among the girls the differences in degrees were higher than in the boys but still were not significant statistically. The “Active” group showed a mean SLR of 6 degrees more than the “Non-active” group.

No significant difference in Ilio-psoas tension was found in all three levels of activity according to PR – “Non-active” 52.9 degrees, “Very Active” 60.9 degrees (P=0.08).

In the analysis of the results of mean motion parameters, in relation to levels activity, there is a tendency for change only in the SLR and PR according to which we can infer that there is an increase in hamstring tension with decrease in the amount of level of activity.

HE showed no trend whatsoever among the activity levels.

These results were repeated also according to age in the whole research population.

Borderline significance was noted only in the 6^{th} grade in both sexes. In this grade the mean SLR in the “Non-active” was 62.5 degrees and in the “Very active” 69 degrees (P =0.06). In PR higher differences were noted .In the “Non-active” group 47.4 degrees, “Active”52 degrees and “Very active” 56.8 degrees (P=0.07). As mentioned these results demonstrate an increase in hamstrings tension and decreased flexibility of the pelvis in the less active groups.

According to sex, in the 6^{th} grade we found significant differences only in the SLR and PR in relation to activity. The mean SLR in “Non-active” 65.2 degrees, “Very active” mean 76.6 degrees, a difference of 11.5 between the “Very active” group)F= 3.986, P=0.025).

In the 6 grade girls similar significant statistical PR differences were noted but to a greater extent than in the SLR – In the “Non-active” a mean of 50.2 degrees and in the “Very active” group 70 degrees, a difference of 20 degrees (F= 8.195, P=0.001) . Also in the 2^{nd} grade girls significant differences were noted in the mean SLR – “Non-active” 71.6 degrees as opposed to “Very active” with 89.5 degrees.

(F = 3.954, P=0.028).

To summarize this section, it is noteworthy that the tendency of change in the motion parameters was found only in SLR and PR which indicates a tendency to higher hamstring tension and greater fixation of the pelvis in the non active children.

On the other hand no differences were noted in all the whole research population with regard to the Ilio-psoas muscle.

3.14.2 The Relationship between the Spinal Curvature parameters, the Postural Scores and Activity Levels.

3.14.2.1.- The Relationship between the Postural Scores and Activity Levels.

In the analysis of correlations (SPEARMAN’s RHO) in the total research population a negative significant correlation was found R= -0.156 , P=0.0006).

The correlation indicates a poor postural state with decreased activity.

55% of the “Non- active” we found in the “Poor” postural category as opposed to the “Active” 32.1% and the “Very active” 12.5% in the same category.
In the “Good” postural category 43% were “Active” , 31.6% “Non active” and 25.4% “Very active”.
It is noteworthy that among the “Very active “ children of both sexes, 46% had a “Good” postural scores which was four times greater than in those children with the “Poor” scores, (11.1%).(See Table #21)

	POSTURAL MARK			Total
	GOOD	FAIR	RISK	
Activity Level Non Active				
Count % within activity level % within postural mark	36 32.1% 31.6%	45 40.2% 33.8%	31 27.7% 55.4%	112 100% 37.0%
ACTIVE				
Count % within activity level % within postural mark	49 38.3% 43.0%	61 47.7% 45.9%	18 14.1% 32.1%	128 100% 42.2%
VERY ACTIVE				
Count % within activity level % within postural mark	29 46.0% 25.4%	27 42.9% 20.3%	7 11.1% 12.5%	63 100% 20.8%
TOTAL				
Count % within activity level % within postural mark	114 37.6% 100%	133 43.9% 100%	56 18.5% 100%	303 100% 100%

TABLE #21- POSTURAL SCORE & ACTIVITY LEVEL CROSS-TABULATION FOR TOTAL RESEARCH POPULATION

In the distribution according to sex , the same trends were noted as in the total research population. In the boys with “Poor” postural scores, the “Non active” had the highest percentage, 39.3%, “Active 35.7% and “Very active” had the lowest percentage, 25%.
In the “Good” category we found that the “Non active” showed the lowest percentage among the boys as opposed to the “active” groups.(R= -0.145, P=0.072(.

Among the girls, a negative significant correlation was found. The distribution of “Poor” showed the “Non active” to be 71.4%, “Active” 28.6% and none in the “Very

active” category. In the “Good” category 43.8% were in the “Non active”, and in the remaining 56.2%. 34.4% were in the “Active” category, and “Very active” 21.9%.
When the data of the “Good” postural category was compared with all the three activity categories, it was found that the highest percentage of the “Good” category was in the “Very active “ of the girls (58.3%), with “Active 42.3% and “Non active” 38.4%.)r = -0.193, P=0.018(.
According to age no significant correlations were found.

3.14.2.2 The Differences between Mean Spinal Curvatures and the Activity levels.

Among the whole research population differences were found in the mean Kyphotic angles between the various activity levels. The greatest mean kyphosis was noted in the “Non active” groups, 35 degrees, “active” 33.8 degrees and ‘Very active” 32.2 degrees. (F = 2.694, P= 0.06(.
Significant differences were found amongst the girls: “Non active” had a mean Kyphotic angle of 35.6 degrees, “active” 32.9 degrees and the “Very active” 27 degrees, a difference of 8 degrees less than the “Non active” group (F = 7.033, P=0.001).
Among the boys no significant differences were noted and the mean kyphotic angle was 35 degrees in all the three activity levels. According to age, significant differences were only found in the 6th grade: In the “Non active” the mean kyphotic angle was 33.3 degrees and in the “Very active” 28.1 degrees, a difference of 5 degrees less than
in the “Non active” group, (F = 3.166, P = 0.047).
No significant differences were found in the mean lordotic curves in relation to the activity levels. It is noteworthy that the tendency of the lordotic curve was similar in relation to the activity groups as was found in the kyphotic curves.
Within the whole research population the “Non active” had the mean Lordotic angle of 42.8 degrees a’ “Active” 41.1 degrees and “Very active” 40.9 degrees. Similar results were noted in the girls but not among the boys where the mean angles were almost the same 39.7 degrees in all the activity levels.

3.15 The Connection between ANTHROPOMETRIC parameters, Motion parameters and Postural Scores.

3.15.1. The Connection between ANTHROPOMETRIC and Motion parameters.

In this section correlations between the anthropometric parameters – height, BMI – and motion parameters - SLR, HE and PR - were calculated.
Within the total research population a significant negative correlation was found between BMI and SLR. This demonstrated the SLR decreased as the BMI increased,

i.e. as the weight increases in relation to height so the hamstrings become more tense. (r = - 0.160 , P = 0.05(.

A higher negative significant correlation was also found between the HE and BMI) r= -0.228, P=0.00). This indicated, similar to the hamstrings, that there is greater tension in the Ilio-psoas as the weight in relation to height increases.

A negative correlation was also found between the Height and HE in the whole research population (R = -0.118, P=0.041) This also demonstrates a tendency to increased Ilio-psoas tension with age.

No other significant correlations were found among these parameters, nevertheless it is noteworthy that the tendency was towards the negative in all the motion parameters in relation to Height and BMI.

According to sex, among the boys a significant negative correlation was noted between

HE and BMI (r= -0.229, P=0.004) . Similar results were noted among the girls (r =-0.221, P=0.007). These results indicate an increase in Ilio-psoas tension with weight. In relation to height, only among the boys a significant correlation was found with SLR (r= -0.175, P=0.030). This demonstrates a tendency towards increased hamstring tension with age in boys. The results are similar to SLR in relation age groups as was seen in paragraph 3.4.1.

According to sex and age, both sexes in 2nd grade showed a significant correlation between BMI and SLR. In the 2nd grade boys R= -0.371, P=0.008. A higher correlation was found amongst the girls (r=-0.445, P=0.004). These results indicate an increase in hamstring tension with weight in the 2nd grade in both sexes. Only among the girls in 2nd grade was a significant correlation noted between BMI and PR.) r=-0.373, P=0.016). From this result we may infer that flexibility about the pelvis

decreases with increase in weight. Among the 4th grade boys a negative significant correlation was found between BMI and HE)r= -0.386, P=0.002). A similar result was found among the 6th grade girls (r=-0.333, P=0.019). This indicates an increase in tension in the Ilio-psoas with increased weight. .

3.15.2 The connection between the Anthropometric parameters and the Spinal Curves.

In this section we examined the correlations between anthropometric measurements – Height and BMI – and the thoracic and lumbar curves.

On the whole research population a correlation was found between the height and the lumbar curve. (r = 0.248, P= 0.000). Similar but higher results were found among the boys (r =0.375, P=0.000). This data demonstrates a connection between increased lumbar lordosis with an increase in height. In almost all the research groups positive correlations were found between the Lumbar parameters and BMI (see Table of

Correlations #22). This trend indicates an increase in lumbar lordosis with an increase in weight. No significant correlations were found between the kyphotic angle and the anthropometric measurements except in 2nd grade girls, who showed a positive correlation between height and kyphosis (r = 0.380, P=0.014). This data demonstrated an increase on the thoracic angle with increase of height in this age group.
A relatively higher correlation was also noted in the 2nd grade girls between height and the lumbar curve (R= 0.461, P=0.002). This demonstrates an increase in lumbar lordosis with increased height. It should be noted that, in contrast to all the research groups, in girls, 2nd and 4th grades, there was not found a correlation between the BMI and the spinal curves.

	N	R	P
BOYS	154	O.472	0.000
GRADE 2	50	0.472	0.001
GRADE 4	60	0.345	0.007
GRADE 6	44	0.514	0.000
GIRLS	149	0.211	0.010
*GRADE 2	41	0.046	0.774
*GRADE 4	59	0.133	0.317
GRADE 6	49	0.376	0.008
TOTAL	303	0.322	0.000

* NOT SIGNIFICANT

TABLE #22 - CORRELATIONS BETWEEN BMI PARAMETERS WITH LORDOSIS ANGLE FOR TOTAL POPULATION

3.15.3 . The differences between POSTURAL SCORES in relation to ANTHROPOMETRIC parameters.

Among the whole research population significant differences were noted between the mean height and postural scores. In the “Good” category the mean height was 141.5cm “Fair” and “Poor” was four degrees lower . (F = 6.142, P=0.002). These differences resemble the results of age distribution in which the higher grades have a better postural score in comparison to the lower grades.
No significant difference were noted in the postural score in relation to BMI .

3.16. The differences between the ANTROPOMETRIC parameters and country of birth.

In this section we examine the connection between the ANTROPOMETRIC parameters of height, weight and BMI in relation to the country of birth of each child.
Significant differences were noted only in the 2nd grade boys. Israeli-born had a mean Weight of 27.3 kg , America/Europe 24 kg .In this grade there were no Africa/Asian-born children. (F = 5.776, P=0.020(.
Significant differences were also found in the BMI parameters between the same groups :Israeli-born had a mean of 16.6 kg/height^2 , as opposed to 15 kg/height^2 in the American/European group (F = 5.911, P=0.019(.

No significant differences were noted in the remainder of the research groups.

3.17. The differences between the motion parameters and country of birth.

Within the whole research population significant differences were found between all the motion parameters in relation to the three groups of country of birth.

SLR showed significant differences between Israeli-born 63.9degrees, America/Europe 69.9 degrees and Asia/Africa 72.8 degrees (F =10.978, P=0.000).

HE showed significant differences between Israeli-born 25degrees, America/Europe 26.8 degrees and Asia/Africa 26 degrees (F =4.343, P=0.014).

PR showed significant differences between Israeli-born 49.8 degrees, America/Europe 55 degrees and Asia/Africa 55.8 degrees (F =3.960, P=0.020).

In these three motion parameters the Israeli-born were found to have the highest level of muscle shortening as compared to the other two groups.

Among the boys, significant differences were found among the various groups in relation to the mean SLR – Israeli-born 61 degrees, America/Europe 64.9 degrees and

Asia/Africa 66.6 degrees (F =3.259, P=0.041). This is similar to the results of the whole population.

HE , which as was noted is an indication of Ilio-psoas tension, the following differences were noted - Israeli-born 24.5 degrees, America/Europe 27.4 degrees and Asia/Africa 28 degrees (F =5.430, P=0.005).

Among the girls, significant differences were found only in the SLR and PR parameters : SLR - Israeli-born 66.8 degrees, America/Europe 78.4 degrees and Asia/Africa 74.9 degrees (F =10.332, P=0.000).

PR - Israeli-born 53.1 degrees, America/Europe 62.3 degrees and Asia/Africa 57.6 degrees (F =3.560, P= 0.031).

The distribution of the mean SLR and PR overlap in relation to the country of birth with the Israeli-born girls having the lowest mean of the motion parameters in comparison to the other two groups of which Europe/America showed the highest results.

3.18. The differences between the Spinal Curves according to country of birth.

Among the whole research population significant differences were noted among the three birth groups: Lumbar Lordosis - Israeli-born 42.4 degrees, America/Europe 37.4 degrees and Asia/Africa 41.3 degrees (F =4.560, P= 0.011). The Israelis had the largest angle in all the groups.

Among the boys significant differences were found - Israeli-born 40.7 degrees, America/Europe 34.9 degrees and Asia/Africa 35.2 degrees (F =4.813, P= 0.009(.

Also among the boys the Israelis showed the largest angle in all three groups.

Among the girls no significant differences were found.

No significant differences were noted in all the research groups with the Kyphosis .

3.19 The differences between the Sitting hours/day, according to country of birth.

Among the whole research population no significant differences were found in relation to country of birth. Whereas the overall mean sitting hours/day was 3 hours/day, among the Israeli boys the mean was 3.4 hours/day, 0.4 hours/day higher than in the other two groups. These differences were not found to be significant.

4. Discussion

4.1. Results of Hamstring tension measurements.

Hamstring tension was measured according to the SLR and also from Pelvic Rotation parameters. Analysis of the results of the SLR showed that there is a consistent tendency for the SLR to decrease with age, i.e. a reduction in the flexibility of the hamstrings with age is reflected in a decreased range of motion. Flexibility of the hamstring muscles decreased between the ages of 7 and thirteen years with the older group showing a mean difference of 3 degrees less than the youngest group in both sexes (P=0.05)(See Table #7). A significant difference of about 7 degrees was seen between the boys and the girls (P = 0.000) in all age groups. The girls showed the higher range with a mean of 8 degrees more than the boys in all age groups (P=0.000).

The Mean SLR among the boys was found to be 61.8 degrees and for the girls 69.1 degrees. According to Kendall et al, 1993, the normal SLR should reach at least to 80 degrees with an angle of 50 degrees being regarded as marked hamstring shortening (Kendall et al, 1993,).

According to these evaluations all the research groups were found to be sub-normal with regard to hamstring length although there were a few individual who showed an angle above 80 degrees.

The average SLR in the whole research population was 65.4 degrees which is approximately 15 degrees below the normal standard. The boys were 18 degrees and the girls 11 degrees below the normal standard. Norris gives higher ranges of SLR with the normal in a range between 80-90 degrees (Norris 1995).

In comparison to data referring to Canadians within the same age groups, the data brought in this paper showed significant differences in SLR in both the male and female populations of the two countries. The Mean SLR of the Canadian girls (N=128) reached the range of 81.9 degrees (± 7.9 degrees) , which was 11 degrees than among the Israeli girls. Among the Canadian boys (N = 139) a mean SLR of 75.5 degrees (±8.6degrees) was found, 13 degrees higher than the Israeli boys (Miereau 1989). The mean SLR in the Canadians was closer to the normal standards for the Hamstrings (according to Kendall and Norris), as opposed to the Israeli sample, the reason for this being that in addition to being more flexible there was a difference in

the method of estimating the SLR by the Canadians which apparently allowed for some Pelvic motion during the examination. Another possible reason being that they may be involved in more stretching exercises than the Israelis.

In Miereau's research similar differences were found between the sexes as was noted in the present paper. There were also similar differences in SLR with age (See Fig.).

The PR parameter also reflects hamstring tension which has an effect on the amount of rotation about the hip. Significant differences were found between the sexes similar to those of the SLR, the girls having a mean difference of 7 degrees higher than the boys (P=0.000) (See Table 9). Significant differences were found in all the age groups except for the 2nd grade. The trend with age in the boys was similar to that of the SLR, i.e. there was a decrease in PR with age. Among the girls this trend was not consistent and no significant differences were found with age.

According to Kendall et al, 1993, the normal range of PR should be to 80 degrees. In the whole Israeli research population the mean PR was 51.2 degrees, while the mean PR for boys was only 47.6 degrees and for the girls 54.6 degrees, which are far from the expected normal.

Katz, 1992, who examined the hamstring tension in children between the ages of 1 to 3 and 4-10 years old, according to the popliteal angle, found that the mean hamstring motion was in the normal range for all his research groups (Katz, 1992). He also found less shortening in boys between the ages of 4 –10 years and no significant differences between the sexes in this age group. In contradistinction to these findings our results showed significant differences in all age groups.

The tendency to reduction of range of motion of the Hamstring was also found in

Katz's article. He found significant differences between the groups 1-3 years and the older group. In his opinion the increase in hamstring tension from the age of 4 years stems from marked increase in lumbar lordosis and forward rotation of the pelvis which begins already from the age of three years (Katz, 1992). The forward rotation of the pelvis is a compensatory motion due to hamstrings shortening. In Reimers' research on the hamstring tension in Danish children from the ages of 3-17 years it was found that 75% of the boys and 40% of the girls had shortened hamstrings (Reimers, 1993). Similar to the present research and the articles mentioned Reimers also found significant differences between the sexes with the girls having a greater range of hamstring motion. The explanation that Reimers brings for the lower results of hamstring tension in comparison to Katz's results suggests that it is due to a difference in climate between the two countries. In his opinion the climate in Israel allows for better physical activity in the open as opposed to Denmark. Another possibility refers to participation in different types of physical activities between the two countries.

Despite the fact that there are no clear standards to evaluate the hamstring tension in Israeli children we are convinced, from our results of SLR and PR, that a definite problem of hamstring shortening exists in Israeli children attending Primary schools. This problem may be associated with the amount of participation in sport and physical activities in general similar to Reimers' contention.

The activities which typify Israeli children's leisure time, today, are watching television, working at a computer and playing video and many other games which mainly involve passive prolonged sitting. This situation is becoming steadily worse. Cultural and behavioral factors in the modern age tend to encourage passive activity patterns among children which particularly involve prolonged sitting both during school hours and during their leisure time as opposed to physical activity. The consequences of this are to be found in typical postural deformities and imbalance of the musculo-skeletal system which includes hamstrings shortening. This subject will be

amplified below.

4.2. The results of Lumbar lordosis.

The results from measuring the lumbar lordosis demonstrate significant differences between the sexes. The Mean angle was 39.8 degrees for the boys and 43.7 degrees for the girls , 3.9 degrees greater than for the boys (P = 0.0011 – see

Table 7). Among all the boys there was an increase in the lumbar curve with age. This was in agreement with the data found in Asher's book 'Postural Variations in Childhood' describing the changes that occur in pelvic angles among boys of primary school age. In his opinion there is an increase in forward pelvic rotation with age from 34 degrees at the age of 7 years to 39 degrees at the age of 12, and this is reflected in an increase in lumbar lordosis (Asher, 1975). The tendency does not exist in girls but there is an increase in the lumbar curve between the youngest and oldest groups. This trend in the lumbar curve in girls from 7-12 years old, according to Asher, typifies girls with a

mesomorphic build , in which a difference of 6 degrees can be found in PR between the youngest and oldest groups. In our research the oldest female group showed a 3.3 degree increase in angle from the youngest group.

Study on the posture of healthy Japanese children by Iwakami, 1987, showed that the development of the lumbar lordosis is most common in the late juvenile posture, 7-9 years old in male and 7-8 years old in female (Iwakami 1987).

Assmusen, 1985, when describing lordotic values according to height mentions that there is a decrease in lordosis among girls starting from a height of 1.55 meters whereas before reaching this height the lordotic changes increase slightly as the child grows (Assmusen,1982). This description of changes in lordosis with height is consistent with the tendency with the changes in lordosis with age in girls as found in our research.

Similar to our research, both Wilnner and Johnson, and Voutsinas and Macewen, even though they used different methods from ours, found a slight increase in lordosis with age in both sexes although the lordotic parameters were higher in the girls (Wilnner and Johnson, 1983, Voutsinas and Macewen, 1986). In contradistinction to the above Mellin and Poussa did not find any differences in lordosis with age or sex (Mellin and Poussa, 1992). On the other hand both Carr et al and Nissinen did find that the female lumbar curve was greater than the male curve but it decreased with age in both sexes. (Carr et al 1991, Nissinen 1995).

4.3. The connection between the hamstring parameters and lumbar lordosis.

From the results between the independent parameters – hamstrings shortening – and the dependent parameters – lordosis angle , we found a negative correlation which became apparent as an increase in the lumbar curve together with a decrease in Hamstring parameters.

Among the whole research population a significant negative correlation was found between the SLR and Lumbar lordosis angle.(r = -0.141, P = 0.014). Among the boys, a significant negative correlation was found.(r = -0.244, P = 0.02). A higher level of significance negative correlation was found amongst the boys in comparison to the girls with the latter being r = -0.196 , P = 0.017.

According to age significant negative correlations were found only in the 2nd grade boys (r= -0.390, P= 0.05) and the 6th grade boys (r= -0.345, P= 0.022).

The PR parameter also give an important indications as to hamstring tension and the level of rotation about the hips, as showed in the research of Salen et al, 1999, measuring the pelvic rotation to asses the length of hamstrings (Salen et al, 1999). The PR parameter also showed high influence on the lumbar curve. Among the whole research population a low negative correlation with borderline significance was found (r= -0.1006, P= 0.081) . Among the boys a higher correlation was found (r= -0.1832, P= 0.023). Among the girls no significant correlations were found.

According to age, only in the 2nd grade boys was a significant finding noted (r= -0.309, P= 0.029). It is important to note that the tendency between the parameters was negative in all the research groups both in where significant and non-significant correlations were noted. This indicated that there is a reduction in the lumbar lordosis with increased flexibility about the hip and this is also the case with flexibility of the hamstring muscles. The results of the correlations between PR and lumbar lordosis resemble the results of SLR and the lumbar curve, both in relation to the trend ,i.e. when the hamstrings are short the lumbar curve increases, and in relation to the age groups in boys which only became evident in the 2nd grade.

These results show that there is a compensatory relationship between short hamstrings and increased lumbar lordosis since all the correlations demonstrated a negative tendency. The importance of this negative aspect, despite the low levels, demonstrates that increase in hamstring tension with age is connected to increase in the lumbar lordosis and anterior pelvic rotation and not to posterior rotation which results in a flattening of the lumbar curve as is usually mentioned in the literature (Kendall et al, 1993). According to Katz, it is the anterior rotation of the Pelvis, acting as a counter balance which increases the hamstring tension (Katz, 1992). Similar to our results, Toppenberg and Bullock found a significant negative correlation between hamstring tension and lumbar lordosis (Toppenberg and Bullock, 1986). Both Gajdosik et al and Li et al did not find connections between the hamstring length and lumbar lordosis (Gajdosik et al 1994, Li et al 1996). It is not possible to state with certainty that lumbar lordosis will always be accompanied by hamstring tension which supposedly causes the opposite action of flattening the lumbar curve as a result of posterior pelvic tilt, because such situations involve multi-factorial considerations where posture is concerned. It is not without possibility that various other groups of muscles will act

together to cause the resultant posture without the hamstring muscles being necessarily involved, as is noted in “The Pelvic Crossed Syndrome” described by Janda (see Fig.18). This syndrome describes muscle imbalance in the lumbar region which causes anterior tilting of the pelvis with concomitant increase in lordosis but in which the hamstring tension produces resistance to anterior rotation (Norris 1995).

The current researcher maintains that hamstring tension causes a reflex flexion of the knees in order to release the resultant tension, especially when there is also shortening of the Ilio-psoas muscles and this results in a compensatory increase in the lumbar lordosis. This was borne out by both the results shown of a positive correlation between the hamstring and Ilio-psoas parameters (r= 0. 3855, P= 0.000) and a negative correlation between the Ilio-psoas and lumbar lordosis (r= -0.2714, P=0.000). The resultant posture reflects a counter balancing of the pelvis which becomes evident as a result of the compensatory increase in the lumbar curve . All are agreed that Ilio-psoas tension causes anterior pelvic tilting and increased lordosis. Weak abdominal muscles, in such cases, may tend to encourage this situation.

4.4. Ilio-psoas tension.

The amount of Ilio-psoas shortening as measured according to the THOMAS' Test (Ahlback and Lindahl, 1964) was elicited by extending the hip with the subject lying prone. It is noteworthy that this test, as described in the literature, may be performed by two methods 1) with the subject lying as described above (Ahlback and Lindahl, 1964, Svenningsen et al, 1989) and 2) with the subject lying supine (Ekstrand et al, 1982).

The Mean HE in the whole research population was 25.4 degrees ($\pm$4.32 degrees) and there was a tendency to a decrease in the mean with age (F= 2.8554, P=0.05). Among the girls the mean was 0.5 degree greater than among the boys.

Similar results were found also in Svenningsen et al 's research, who examined both sexes in the same age groups. He also describes a decrease in HE with age ,i.e. increased Ilio-psoas tension with age (Svenningsen et al, 1989).

The results of this parameter were similar to those noted by the AAOS (Svenningsen et al, 1989), but were significantly higher from the researches of Boone and Azen who examined girls between the ages of 1.5 –19 years old (Boone and Azen, 1979) and

also from the researches of Roaas and Anderson who examined men between 30-40 years old (Roaas and Anderson, 1982). The differences between these can arise from different methods of measurement such as with the knees extended or flexed or with the subject supine or prone.

4.5 The connection between Ilio-psoas measurements and the lumbar lordosis.

From the results of the correlation between the HE and lumbar curve we showed that there was a negative correlation in all the research groups. This tendency demonstrates an increase in the lumbar curve with increased Ilio-psoas tension. The highest correlation was found amongst the girls (r = -0.434, P=0.000). The level of correlation reduced with age. Among the 2n grade girls (r = -0.536, P=0.000) as opposed to a lower level of correlation among the 6th grade girls. (r =-0.357, P=0.007).

Among the boys a negative correlation of -0.1567 (P=0.052) was noted.

Similar to the correlation between SLR parameters and lumbar lordosis, so, too, the connection between the Ilio-psoas and lumbar curve showed a negative correlation.

The connection between these parameters can result from the action of the Ilio-psoas on the pelvis about the hip. A shortened Ilio-psoas will cause an anterior tilt of the pelvis and as a result this will increase the lumbar lordotic angle.

4.6. Multiple Regression of the independent parameters - Hamstrings tension and Ilio-psoas - with the dependent parameter – lumbar curve.

Examination of the correlation between the lumbar curve and the motion parameters of hamstrings and Ilio-psoas demonstrated a negative correlation in both these motion parameters. This raises the question as to how to evaluate the relative influences of these parameters on the lumbar lordosis. In addition, does the synergistic action of both these muscles when shortened produce a greater effect on the lumbar curve or is this the result of the dominance of one of these parameters?

Multiple Regression analysis of these parameters showed that in the whole research population a negative Regression of -4.438 (P=0.0000) between the Ilio-psoas and the lumbar curve. SLR did not demonstrate a significant correlation with the lumbar curve. According to age we found different results among the sexes.

The boys showed a dominance of the SLR with the lumbar lordosis (R = -2.451, P=0.015) whereas among the girls the Ilio-psoas was dominant with a greater correlation (R=-5.528, P=0.000).

According to age we found the same tendency in all the age groups. 2nd grade boys showed that the SLR had the greatest influence on the lumbar curve (R = -2.578, P = 0.013). A similar finding was noted in 6th grade boys (R = -2.202, P = 0.033).

Among the girls, according to age, only the Ilio-psoas was significant in all age groups in relation to the lumbar curve: 2nd grade R= -3.718, P=0.000); 4th grade R = -2.536, P=0.014 ; 6th grade R = -2.293, P =0.026.

Regression analysis showed no relationship between SLR and the lumbar curve among the girls. The conclusion from these results was that with the exception 4th grade boys there was only a connection between the SLR and lumbar lordosis whereas among the girls the Ilio-psoas was the dominant factor. Furthermore there was no synergistic action of both parameters because one dominant yet dissimilar factor was associated with either the boys or the girls. The reason for it is perhaps related to the fact that influence of the Ilio-psoas muscles on the lumbar spine is dependent upon the vector angle of the muscle in relation to the maximal lumbar curve in the sagittal plane (Nachemson,1968). This vector differs in the sexes because of differences in the shapes of the male and female pelvis i.e. the pubic angle is more acute in boys and the Iliac bones are narrower than in females. Under such conditions the Ilio-psoas vector is shorter and more vertical in boys and will thus have a lesser influence on the pull of the muscles in the lumbar region. Another reason which may help to explain these differences is perhaps related to the different types of activities noted amongst the sexes in childhood, which is typified in the boys by more vigorous activities such as ball games etc. whereas in girls there is a tendency to less active or less intensive activities such as dancing, calisthenics etc.

4.7. The Thoracic Kyphosis

The Mean Thoracic Kyphosis was 34.1 degrees ($\pm$ 8.8 degrees) (see Table 11).

The tendency was for a decrease of the kyphotic angle with age (P=0.018) . This was opposite to the lumbar curve. According to Flint's method an increase in the kyphotic angle indicates a greater thoracic curve (Flint, 1963) (see para.1.5.3).

Among the girls the mean was 33.3 degrees and for the boys 34.9 degrees. No significant differences were found among the sexes except in 6th grade where the mean female angle was 5 degrees less than among the boys (P =0.006).

Among the boys no significant differences were noted according to age but there was a decrease in the kyphotic angle with age. Similar results were noted by both Assmusen (1985) and Willner and Johnson (1983). Each found a decrease in the kyphotic curve with age but Mellin and Poussa (1992) did not find a difference with age. Nissinen (1995) found an increase in the kyphotic curve with age. Iwakami also found that the increase in segmental length and magnitude of the thoracic kyphosis was most characteristic in the adolescent posture of 10 years or older in male and 9 years or older in female (Iwakami 1987).

In the present research the results were compatible with a decrease in the kyphotic angle with age in which the 2nd grade boys showed a mean of 36.2 degrees which was the highest angle noted in the whole research population.

Among the girls the 6th grade showed the lowest kyphotic angle (29.9 degrees) , six degrees less than in 2nd grade (P=0.013). The Thoracic angle in the girls was lower in all grades in comparison to the boys. Wilnner and Johnson (1983), who used a pantograph to measure the thoracic curve also found that the range in boys (29.2 – 33. 7 degrees) was greater than in girls (27.1 – 30.6 degrees). Assmusen ,1985, who used an inclinometer, found that the range of the kyphotic angle in boys was 31.8 – 35.4 degrees, which was lower than the average in girls in his series. Mellin and Poussa (1992), who also used an inclinometer, found that the mean angle in boys was 35.9 – 36.7 degrees and in girls 26.4 – 29.8 degrees. Nissinen, 1995, using a pantograph, found that the average angle in boys was 28 –31 degrees and in girls 26.5 –29.5 degrees. In all the research papers mentioned and in the present research the female angle was lower than the male. Carr et al, 1991, who use the ISIS method, found that the opposite was the case.

4.8 .The Connection between Hamstrings and Thoracic Kyphosis.

Among the whole research population 49 children (16.2%) were found to have an increased kyphosis of 1 SD above the general average. In this group there were 23 boys and 26 girls. 44% were in 2nd grade , 30% in 4th grade and 24% in 6th grade. This demonstrated a tendency to decrease of Thoracic kyphosis with age.

No correlations were found among the whole population between SLR and Thoracic kyphosis except in 2nd grade in both sexes. Among the boys a negative correlation of -0.286 (P= 0.044) and among the girls a stronger correlation - 0.354 (P= 0.023).

This tendency indicates a decrease in the kyphotic angle with an improvement in the SLR i.e. as the hamstring flexibility increases there is a decrease in the kyphotic angle. As has been mentioned these correlations only apply to the ages 7-9 years old, which is perhaps an indication of a stronger connection between the leg muscles and the spinal curves in the younger age group whereas there is an increase in muscle mass with age which become more dominant. In Toppenberg and Bullock 's research, 1986, they examined , adolescent girls about the age of puberty a negative correlation (r=-0.193) was noted between the thoracic kyphosis and hamstrings length. Gajdosik et al, 1994, found that higher kyphotic angles correlated with shorter hamstrings in males.

Lambbrinudi, 1934, claims that one of the most common sign of thoracic kyphosis is the existence of tight hamstrings . Toppenberg and Bullock, 1986 states that the relationship between hamstring tension and the increase on the thoracic curve refers to Scheuermann's disease.

PR was found to have a negative correlation with thoracic kyphosis (r = -0.174, P= 0.022) in the whole research population. Similar to the SLR here too there was a significant correlation only in 2nd grade of both sexes. The correlation with PR where greater than with SLR.

Among the boys in 2nd grade a negative correlation of -0.439 (P=0.001) and among the 2nd grade girls -0.367 (P=0.018).

This connection indicates that as the flexibility about the hips increases so the thoracic kyphosis becomes less. These results show an overlap with the hamstring parameters, which were found only in the youngest age group in both sexes who showed the highest incidence of thoracic hyperkyphosis. Asher, 1975, notes that tight hamstrings can cause an increase in kyphosis in childhood especially in ectomorphic girls. This postural deformity is also typical in boys between the ages of 9-12 years old.

Reimers, 1993, is convinced that this deformity is related to abnormal sitting posture in which sitting with the hips flexed at 90 degrees causes the whole spine to assume a kyphotic stance. Deformities of this type can be part of the causes of Scheuermann's disease.

4.9. The connection between Ilio-psoas tension and Thoracic kyphosis.

No significant correlations were noted between the Ilio-psoas and dorsal kyphosis in all the research groups. This data is surprising because shortening of the Ilio-psoas directly influences anterior tilt of the pelvis which increases the lumbar curve. As a result of the changes in the position of the pelvis and the increase of the lumbar curve it would expected that there would also be a concomitant change in the dorsal kyphosis as a compensatory motion in the vertical plane of the spinal curvatures.

4.10. Multiple Regression of the independent parameters - Hamstrings tension and Ilio-psoas - with the dependent parameter – thoracic kyphosis.

In the Regression Analysis of these parameters no correlation was found among the whole research population. Analysis by sex showed differences with age. In the 2nd grade in both sexes the dominant factor influencing the thoracic kyphosis was the SLR measurement. Among the boys R= -2.597 , P=0.012 and among the girls R= -2.209, P= 0.033. It was also found that in 6th grade boys the dominant factor was the Ilio-psoas (R = -2.049, P =0.0469) with the hamstring playing showing no synergistic action.

These results indicate that the relative effect of the Ilio-psoas does increase, when examined according to Multiple Regression, especially when taking into account that no correlations were found between these parameters in 6th grade boys.

4.11. Postural types.

In the present research twelve typical postural deformities were examined in three planes, anterior, posterior and lateral. The Postural score was give according to the total evaluation of the subject (see para. 3.9) . Within the whole research population 62.4% were found to have postural deformities and only 37.6% were noted to have good posture. Several previous studies carried out in Israel have shown that the percentage of postural deformities was higher than in the present research (Levi 1986, Hanne 1982 and Levi 1993).

From among the children who were noted to have postural deformities 43.9% had a "Fair" score and 18.5% showed "Poor" posture. 44.6% of the "Poor" category were from the 2nd grade which was the highest percentage in all the groups. On the other hand, in the "Good" category the 2nd grade children showed the lowest percentage in all the groups (14.9%).

The reason for the high percentage in the lower grade is apparently connected to relative instability of the musculo-skeletal system which becomes more stable as the musculature develops with age. This tendency we found in both sexes in so far as the percentage of postural deformities reduced with age.

4.11.1. The Differences between Mean motion parameters and Postural scores.

Significant differences were found in the mean SLR and PR between the various Postural categories . A greater range of motion of both SLR and PR was found in those in the "Good" category" while those with "Poor" and "Fair" score showed higher levels of hamstring tension. In the "Good" category 114 children with a mean SLR of 68.5 degrees; 133 in "Fair" with a mean SLR 64.1 degrees and in the "Poor" category 56 children with a mean SLR of 61.8 degrees (F = 8.2540, P=0.000). Similar results were found with the PR parameter in which a difference of approximately 10 degrees was noted between those with "Good" and "Poor" posture (F = 7.5799, P=0.000). In the research of Jozwiak et al, a population of 920 healthy children from Poland was studied with the aim of assessing the incidence of hamstrings muscle and plantar foot flexor tightness in relation to posture and back pain. It was found that short hamstrings and decreasing of dorsiflexion and lumbar lordosis lead to postural deformities, bending-forward deficit, discomfort when sitting, and a shambling gait

(Jozwiak et al, 1997). Another research on the flexibility of the hamstring muscles and posture assessment in relation to hamstring injured group and non injured group, revealed a significant difference ($p<0.01$) between groups only in low back posture , lumbar lordosis. No other differences occurred in the remaining nine posture components; head erectness; shoulder symmetry; spinal curvature; hip symmetry; foot and ankle alignment; knee hyperextension; upper back roundness; trunk erectness; and abdomen protrusion (Hennessey and Watson, 1993).

In the Ilio-psoas measurements the same tendency as the SLR was found but at a lower level.

In the "Good" the mean Ilio-psoas was 26.1 degrees, "Fair" 25.1 degrees and "poor" 24.6 degrees. Although there was only an overall difference of approx. 2 degrees there is a clear tendency for decrease in Ilio-psoas flexibility with increase in postural deformities (F = 2.9139, P=0.05).

According to sex, significant differences were found in both SLR and PR only among the girls. Similar tendencies were found only in a portion of the research population when examined by age. This was more obvious in the 2nd grade girls where the differences reached up to approx. twenty degrees in pelvic rotation in comparison to the “Good” category (F = 5.5753, P=0.000). All the significant differences noted with the motion parameters were found in those with increasing postural deformity and decreased motion. As was noted above, the 2nd grade had the highest distribution in the “Poor” category and also had the highest differences in mean SLR and PR in relation to the postural categories.

It appears that the combination of a high distribution of postural deformities and large differences in range of motion are especially common in the younger age groups and it is possible that the influence of tight muscles, short range of motion and a lack of mobility of the joints concerned affects those in the 8-9 year-old group in particular as opposed to the older age groups.

4.12 .Back pain.

Among the whole research population 136 children (45.4%) reported back pain. Of these 46.3 % were boys and 53.7% were girls.

Among the 154 boys in this research, 42.9% reported back pain and similarly exactly 50% of the 149 girls.

The highest incidence of back pain was found between 9-10 years old (4th grade) with 50.8%. This was followed by 2nd grade (7-8 years old) with 46.6 % and 6th grade (11-13 years old) with 40.2%. In all the age groups the incidence of back pain was higher among the girls, especially in 2nd grade. In researches carried out in Israel in relation to the incidence of back pain in children similar data was noted. The reasons given for this phenomenon were related to unsuitable school furniture in relation to the heights of the children and also to their carrying heavy school bags (Levi 1987, Levi 1993).

Reis et al, 1996, in his paper on “The Incidence of low back pain in High School children” reported on 71% of 243 children who suffered from LBP. The reason for this, in his opinion, was because of lack of awareness as to how to lift up weights, the attitude of the youth to correct posture , tight hamstrings and ignorance as to the performance of correct back exercises. On this point, Reis et al notes the importance of educational health care programs for the prevention of backache Reis et al, 1996
.

In another study, Viry et al, 1999, reported on 123 children with an average age of 14 years, in which the cumulative incidence of backache in one year reached 82.9% of which 16.3% reported a single episode of back pain, 57.7% reported recurrent back pain and 8.9% reported chronic backache. Only 18.7% of these children reported visiting a doctor and 14.6% missed school or sports activities because of backache.

Similar to our research also in the study by Viry et al, was found that the incidence of LBP was higher amongst the girls than the boys (odds ratio 2.7, P=0.05). It was also found that the weight of the school bag was connected to the incidence of back pain especially in those who carried their bags in their hands rather than on their shoulders. This was the case, as well, in those who went to school on foot as opposed to those who were driven there and as result had to carry their bags for longer periods of time. Sitting on the edge of a chair was also found to increase the incidence of back pain Viry et al, 1999 .

Mierau, 1989, found a significant difference in the history of LBP between the sexes only from the age of 14 to 18 years old. From 6 -13 years old no difference was found among the sexes.

In a prospective epidemiological study involving 1715 Swiss school children 33% reported back pain and significant correlations were found with sex, age, watching television, smoking and competitive sports (Balague et al, 1988 .

Similar levels of LBP were found a review study by Duggleby and Kumar, 1997, among juveniles . The data demonstrates that Cumulative Prelevance Rate was 30%. The majority complained of moderate back pains whereas 8% required medical care and 8.1% were found to have recurrent or chronic back pain. The Cumulative Prelevance Rate increased with age. In his opinion disk degeneration was not the cause of the LBP and is rare in adolescents. It was also found that bulging disks were found more among those with back pain as opposed to those who were asymptomatic, especially amongst the girls. A correlation was noted between competitive sports, age and more than 15 hours of activity in relation to a high incidence of spondylotic changes Duggleby and Kumar, 1997 .

In contra-distinction to a study in France of 1178 school children the cumulative level was higher and stood at 51.2%. The most common pain was either dorsal or lumbar (Troussier et al, 1994). In this study a positive correlation was found in girls between

BP and the parameters of age, early back injuries , playing volley ball and watching television .

In a study carried out in Finland involving 1171 children and adolescents a very low incidence of only 1% was found among children of 7 years old and 6% among the 10 year olds but from 14 –16 years old the incidence rose to 18%. No differences were found between the sexes. 26% of the boys and 33% of the girls reported recurrent or chronic back pain. In the opinion of the authors the Finnish study recurrent and chronic pain as significant at the 14 year old and complaints of back pain became more frequent in the teens (Taimella, 1997 .

Gunzburg, in a research on 392 Belgian children with an average of 9 years old reported an incidence of 36% with at least one episode of back pain. He found a significant correlation between the number of hours occupied with video games and backache. The incidence of back pain was higher among the children who played video games for more than two hours/day and also in those who suffered from over-fatigue,

lack of sleep especially in unhappy children. No connection was found with the parameter of television viewing. Differently from our research no differences were noted between the sexes and back pain (Gunzburg, 1999 .

In a study of the risk factors resulting in low back pain in 1389 Danish school children, a cumulative prevalence of 58.9% was reported and there was an increase of 6.4% between the ages of 14-15 years old. A positive significant correlation was found

between backache and the various parameters of BMI > 25, competitive sports among boys, low physical fitness, smoking, and a high daily exertion (heavy work . The combination of these parameters was connected with severe back pain in adolescents (Harreby, 1999 .

In the study by Balague et al, on the social factors involved in back pain in 1755 children between the ages of 8-16 years old it was found that competitive sport and time employed watching television markedly increased the risk of backache (Balague et al 1994 .

In view of the above data it is not easy to determine the exact overall incidence of back pain in children and young people. The differences in estimation of LBP among children apparently stem from the various methods and definitions of what is to be regarded as a case of back pain, but this does not contradict the fact that there is a definite prevalence of at least 30% or more LBP in children. Other common causes of LBP may be derived from the various life-styles, sitting habits and physical activities that differ in nature between different countries and cultures.

4.12.1 The connection between motion parameters and back pain.

Among the girls significant differences were found in hamstring tension, both in SLR and PR, between the groups with and without back pain. Among those who were asymptomatic the mean SLR was 71.1 degrees and in the symptomatic group it was 67.3 degrees, a difference of approx. 4 degrees (F = 3.3991, P=0.056). In the PR parameter, the asymptomatic group had a mean of 57.8 degrees as opposed to 51.8 degrees in the symptomatic group a mean difference of 6 degrees (F = 5.7116, P=0.018). Biering-Sorrensen, 1984, found that hamstring length was a prognostic factor in women.

It was also found in the studies by Fairbank et al, 1984, and Li et al, 1996, that there is a significant decrease in the motion parameters of the lower limbs in the symptomatic group. On this point Fairbank et al is of the opinion that back pain occurs more often in those not active in sport. In Pope et al's study on 321 males between the ages 18-55 years old it was found that in the group with severe LBP there was a significant decrease in SLR, i.e. the Hamstrings were shorter (P = 0.04 Pope et al, 1985 .

Mellin found a negative correlation between the mobility of the hip joint both in flexion and extension in relation to the level of back pain in adolescents of both sexes. The reason given being that the limitation of mobility of the hip joint can cause increasing load on the spine (Mellin, 1988 .

In a prospective study of LBP and muscle tightness in a group of 600 army recruits pre- and post military service) no connection between hamstring tension and Ilio-psoas tension was found in relation to current back pain or its incidence Hellssing, 1988 .

4.12.2 The connection between the spinal curvature angles and Back Pain.

In the present study significant differences were found in the lumbar curve in relation to back pain only in 2nd grade. The mean lumbar curve angle of the syptomatic group was 34.4 degrees which was 6 less than in the asymptomatic group. (F =5.152,

P=0.02). The study by Tuzun et al , who studied the radiographic aspects of the lumbar curve, no significant differences were found in the spinal curves between the groups with chronic back pain, moderate back pain and the control groups (Tuzun et al, 1999 .

On the other hand, in a study by Jackson and Mcmanus, who examined the spinal curves in a series of 100 symptomatic and 100 asymptomatic adults, it was noted that " Total lordosis was significantly less in the patients and was not age or sex related in either group. Patients tended to stand with less distal segmental lordosis, but more proximal lumbar lordosis, a more vertical sacrum and, therefore, more hip extension……"(Jackson and Mcmanus, 1994 .

In another study by Christie et al, the opposite results were noted in comparison with Jackson and Mcmanus's study. Three groups with different levels of back pain were examined in relation to the spinal angles. It was noted that on standing the lumbar curve increased in comparison to the control group ($P < 0.05$). In the case of acute back pain there was a greater connection with increased dorsal kyphosis on sitting ($P < 0.05$). In his opinion these findings have a moderate prognostic value in LBP (Christie et al, 1995 .

In a prospective study by Gautier et al, 1999, on 1500 men between the ages 16–23 years old in France no significant correlations were found between the lumbar curve and pelvic balance in those with a history of back pain. In a study on the frequency of back pain in young children and youths. Taimela states "Sagittal postural abnormalities have been reported in association with adolescent LBP. Also, big skeletal size and trunk asymmetry have been more frequent among adolescent with LBP….." (Taimela, 1997 .

In a research carried in Israel by Milgrom et al , 1993, on 395 army recruits, it was found that an increase in lumbar lordosis reflected an over-exertional risk factor to dorsal back pain ($P =0.005$). In addition it was noted that low BMI was a over-exertional risk factor in lumbar pain ($P=0.005$.

Although not all the studies mentioned above deal with the same age group as the present study it appears that there is no consistency of findings in relation to spinal curves and back pain. In particular, it would be natural to assume that deeper lumbar lordosis would increase pressure on the lumbar intervertebral disks since in fact in this situation the alignment of the vertebral bodies is not parallel and thus there is an increase of pressure on the posterior arc of the vertebral bodies which affects the whole curve together with its surrounding soft tissues thus increasing the interdiscal pressures. This is also associated with increased spondylotic changes following severe exertion as described by Duggleby and Kumar, 1997 . This increased pressure can be a source of back pain and it would be expected that it would occur more under the conditions described. In the present study only in the 2^{nd} grade (7-8 years old) was there an observable connection between spinal curves and backache. It appears that the reason for this is the relative weakness of the spinal musculature in relation to age which cannot provide sufficient support to the curvatures of the spine when it is abnormally increased. Unfortunately, from the studies mentioned above, there is great confusion among the different authors as to their methods of examination and in the

understanding of the biomechanical effects on the spinal curves resulting from different postures both sitting and standing in which congenital and/or acquired skeletal deformities and torque play an important role in the development and occurence of back pain.

4.13. Sitting parameters during leisure time in children.

In the present research the amount of sitting hours was calculated per day after school. We focussed on typical sitting postures which become apparent following prolonged sitting in which there is not a great deal of movement.

The parameters we examined were a) using a computer b) playing video games c) watching television and d) other activities involving prolonged sitting reported.

Each sitting activity was described by each child according to the type of postures adopted (see para. 2.5.13.2 .

The typical lying postures noted, especially when watching television, were not included in this category. It was found that among the whole research population the average sitting was 3 hours/day. Among the boys the average was 3.3 hrs/day and among the girls 2.7 hrs/day. No differences were noted with age and the average in the girls was lower in all the age groups in comparison to the boys.

In comparison of our data to other studies carried out both in Israel and other countries similar results were observed.

In the report of the The Central Bureau of Statistics, 1996, on the allocation of time for different activities in the Israeli population e.g. work, studies, family leisure time etc. it was found that the majority of time, except while sleeping (34%), was during leisure time (23% of a 24 hour day) in which the commonest activity was watching television (The Central Bureau of Statistics, 1996). Also, in the present research, this was the dominant finding. Schneller, in his research on the place of television in the leisure activities of Israel school children, found that television watching occupied most of the leisure time from 4th to 7th grade (20%) and less in the 10th grade (10%). In his opinion the reason for this decrease in 10th grade children is that from this age there is more selection in their choice of programs (Schneller, 1984). In the present study no differences were found in the average times in relation to age. The average in all age groups was 14.5 hrs/week. In Lamich and Libs's study, examining the use of multi-media among children and youth (N=1071) in the age groups from 6-7 7years, 9-10 years, 12-13 years and up to 15-16 years, it was found that television is the central medium of communication in these age groups. In his opinion, socio-ecomonic status and social values were the most important influences in the use of more modern multi-media entities such as computers, Internet etc. The understanding of social and cultural processes is important to the understanding of the uses of various different types of communication in comparison to children of other countries (Lamich and Libs, 1999). In another study, carried out in Israel on the interest taken by children from 4th to 6th grades in reading, watching television and using a computer, it was found the children in both sexes showed the highest interest in television watching followed by boys using computer and then reading whereas reading was preferred to computers by the girls. The authors of this study maintain that there is sexual stereotypism in the fields of interest and the types of multi-media preferred and this was most obvious amongst the boys (Tal, 1996 .

The same trends of preference were found in our present study in which the preference was expressed by the duration of time occupied by each activity as reported by the children. Television watching of 15.4 hrs/week in boys was double that of using a

computer (7.3 hrs/week) whereas with the girls watching television occupied 13.7 hrs/week and using a computer only 5.6 hrs/week. Similar results are brought by Kaufman, 1985, in a study on television viewing in children and adolescents. He found

that the average was 15 hrs/week (in our study 14.5 hrs/week) and states that there is a lessening of television time with increasing age. The amount of television time was higher with the boys than with the girls. In the present study, as has been previously mentioned, the amount of television time was higher among the boys and it seems that the girls prefer reading in comparison to the boys.

If we compare television watching today to that of 25 years ago , then in a series of 505 children living in Jerusalem (age 9-11 years) the average/day was 1.14 hours which is half of the present amount. There is no doubt that the influence of multi-channel television programs has dramatically increased the watching time and it appears that this will only increase in the future.

In comparison to data from other countries we do not find that there is a better situation than that noted in Israel. In a study by Anastassea et al, 1996, on 4876 children in Greece, it was found that the average television time was 21-32 hours/week. In his opinion these habits contribute to low educational achievements and obesity.

In a French study on television watching in relation to back pain somewhat different data was found on 1178 children and young adults (6-20 years old) in that the average television time was considerably less than that in Greece at about an average of only 11 hours/week. It was stated that 55.2% of the whole of this French study watched less than one hour per day , 30.5% less than two hours/day and only 5.3% watched television more than two hours per day. In this research there was a prevalance of back pain in more than 50% who watched television for over one hour per day (P=0.00)

(Troussier et al, 1994 .

The three most common leisure time activities of 2200 third and fourth grade children from Carolina, America, in the research by Harrell et al, showed that boys were involved in playing video games (33%) , playing football (32%), bicycling (31%), and

only in fourth place came watching television (28%). The girls reported homework 39% , bicycling (31%), watching television (30%), dancing (27%).(Harrell et al 1997 .

As opposed to the data from Harrell et al, in the present study it was found that among the boys video games came only in third place after television viewing and computer use. However, among the girls there were similar results in both studies. With regard

to the physical activities included in Harrell et al's research this will be discussed below.

In another study, of 387 Canadian children, from 3-10 years old, television time for

45.2% was reported at 7-16 hours/week and the rest had longer hours of television watching (Bernard-Bonnin et al, 1991 .

In a report by Tuncer and Yalcin, 1999, from Turkey concerning the influence of Multi-media on Turkish children similar findings were found to those already mentioned. In his opinion the children, apart from sleeping, were involved mostly in watching television. 31% of all the children were involved in television watching for 4 hours/day during the weekdays and on the weekends this figure rose to 71.7%.

The use of a personal computer has risen annually and he found that among the Turkish urban population the use of a computer has doubled between 1993-1998 .

He claims that within the next few years, most of the countries with a substantial Internet infrastructure will employ the Internet as the major medium for disseminating information, including information designed especially for children (Tuncer and Yalcin, 1999 .

It is noteworthy than since the 1970's television has undergone enormous changes and today in the era of cable television and computers the place of Multi-media is occupying more and more importance in both the children and adult populations in addition to its being much more readily available. It is reasonable to assume that this pattern of leisure time activity will not lessen in the future and its place will not be adversely affected in the modern highly technological age. With regard to the younger generation, it appears that the computer will occupy more and more place in the leisure activities of children as a result of its introduction into all the educational subjects taught in schools and by the increase in the amount of educational programs and games

designed especially for children in their leisure time. A further development is the advent of the Internet system into all walks of daily life.

4.13.1 Typical sitting postures employed in television viewing, using computers and playing video games in relation to motion parameters, posture and back pain.

The commonest leisure activity is watching television. From the reports given by the children regarding their sitting habits the most common attitude was sitting with

the legs straight forward and the trunk inclined somewhat backwards (Sitting posture type 2 , 51% in boys and 60.5% in girls). In this position the hips and knees, in addition to the back, are extended greater than 90 degrees. Such a posture tends to reduce pressure on the intervertebral discs especially when the back is supported by a suitable soft back-rest.

As is described extensively in the literature, (Nachemson and Elfstorm,1970, Anderson et al 1974, Gilad 1982 and Anderson 1990) the interdiscal pressure between L4-5 reduces as the back is extended more than 90 degrees while in the sitting position with the back supported (see Figs. 8 and 9 and Table 3 provided that the hip inclination is not greater than that of the back-rest (see below). In addition the position of the hips and knees must be above 90 degrees in order not to encourage muscle shortening such as is found when sitting on a chair with the hips and knees at less than 90 degrees (Sitting posture type 1 . Only a small percentage (2% of the whole research population) reported actually sitting on a chair while watching television. On the other hand when sitting opposite a computer 98% of the whole population and 30% of those playing video games reported sitting forward on a chair with the knees at less than 90 degrees type1). In this position the upper back is flexed forwards (increased kyphosis) and the lumbar curve is reduced (see Fig.20) . In the study by Lord et al, on the influences of sitting and standing on the lumbar lordosis, he states that the mean lordotic angle when standing was approximately 50% greater than when sitting. In his opinion there is a correlation between increased lumbar pressure and sitting, apparently due to the reduction of the lumbar angle (Lord et al 1998). Similar results are brought by Harrison et al, 1999, in a review study of sitting biomechanics, in which it was noted that sitting causes the pelvis to rotate backward and causes reduction in lumbar lordosis, trunk-thigh angle, and knee angle and an increase in muscle effort and disc pressure. However, seated posture is affected by seat-back angle and seat- bottom angle. He also states that the configuration of the spine, postural position, and weight transfer is different in the three types of sitting; anterior, middle, and posterior. In relation to this, the lumbar lordosis is affected by the trunk-thigh and the knee angles. Subjects in seats with backrest inclinations of 110 to 130 degrees, with concomitant lumbar support, have the lowest disc pressures and lowest electromyography recording from the spinal muscles. A seat-bottom posterior inclination of 5 degrees and armrests

can further reduce lumbar disc pressures and electromyography readings while seated Harrison et al, 1999 .

Decker,1984, who examined the differences of the lumbar curve from sitting to standing found that there is a “posterior displacement of the vertebral bodies to an unexpected degree as a sign of instability of the lumbar spine .

In observations of children using a computer is appears that the knees are usually held in a flexed position (<90 degrees) . When there is extension of the knees while sitting, this posture pushes the body away from the screen and the keyboard. As such there is a notable preference for decreasing the hip and knee angles and sitting in the forward position. As mentioned above these angles greatly influence the pelvic rotation and the lumbar curve and at the same time cause maximal interdiscal pressures in the lumbar region Nachemson and Elfstorm, 1970).

In research by Stokes and Abery, on the influence of the hamstrings on the lumbar curve when standing, in sitting with the knees flexed and in sitting with knees partially

extended, it was noted that people with a small range of SLR had the most pronounced changes in the spine curvature when sitting with the knees extended. (Stokes and Abery, 1980 . The shortened hamstring muscles tend to restrict hip flexion, causing compensatory changes in pelvic rotation and in the spinal curves which arkedly raise the stresses in that region.

Similar finding also were noted in the research of Yasukouchi and Isayama,1995. They measured the lumbar lordosis and pelvic tilt in standing and in three different sitting postures with the trunk-thigh angles at 120 degrees, 90 degrees and 60 degrees while the knee angle remained constant at 90 degrees and at other angles of the knees. He found that the lumbar curve decreased and the pelvis rotated significantly rearward as the trunk-thigh angle and the knee flexion decreased. He also noted that great alteration of the lumbar curve occurs between standing and sitting with the trunk-thigh angle of 120 degrees. In his research, there was a high correlation coefficient between the lumbar curve and the pelvic tilt (r=0.909 . When the knee angle is constant, the pelvic tilt is related significantly to the hamstrings between standing and sitting with a angle of 120 degrees, and to the gluteus maximus between the angles of 120 degrees to 60 degrees of the trunk-thigh in sitting. When the thigh-trunk angles of 90 and 60 degrees involve different knee flexions, the hamstrings, in addition to the gluteal

muscles, significantly affect the lumbar curve and pelvic tilting (Yasukouchi and Isayama,1995 .

A chair's back-rest can aid in reducing the interdiscal pressures and give greater support to the pelvis and lumbar region. It is known that even though a chair may

have a back-rest children prefer to lean forward, especially when writing or using a keyboard. In this position the back assumes a kyphotic ,or round-back, position with the pelvis rotating backwards. In the present study, as the number of hours using a computer increased so the kyphosis tended to increase. These results however were of borderline significance (P=0.09) .This situation, with the body leaning forward and the
back held in a kyphotic attitude, has been found to cause the highest interdiscal pressures on the lumbar spine in comparison to all other sitting positions (see Tables 2,3,4 .

Typical sitting habits are to be found in other studies. Floyd and Ward, on sitting posture in schools during different activities, noted that the children used their back-rest on average only for 50% of the time. The main reason for leaning forward was in order to write (Floyd and Ward,1976) . This is similar to the position when using a computer keyboard by the latter is far more dangerous because the arms lack support (unlike when writing at a desk) and this may tend to increase the back pressures.

When reading from a screen is compared to writing, the back-rest is used more often. In the present study the spinal curves were not measured while sitting and we must take note that during sitting at a computer or writing at a desk it is possible that the back may have both a dorsal kyphotic and a lumbar lordotic curve especially when held in the erect posture.

In research investigating the spinal curves in relaxed standing, relaxed sitting, erect sitting and writing while seated, electromyographic activity in muscles close to the spinal apexes was recorded. The direction of lean and the changes in the spinal apex angles from standing to sitting varied depending upon whether the spinal curve was single or double. Subjects with single curve, whether lordotic or kyphotic, tended to lean laterally toward the convexity of their curve apex i.e. the lean was in a direction that reduced the apex angle. Subjects with double curves, thoracic and lumbar, in all postures except “relaxed sitting”, tended to lean toward the convexity of the lumbar curve, thereby reducing the lumbar apex angle and exacerbating the thoracic angle.

Most subjects’ apex angles were smaller in relaxed or erect sitting than in relaxed standing Gram and Hasan, 1999 .

In the study by Bennet et al, investigating the integrated electromyographic activity of the erector spine muscles and the lumbar curvature during static and dynamic postures of writing and typing in three different chairs, a Balance Multi-Chair (BC), office chair (OC), and a straight back chair (SBC), he found that during relaxed postures, there was more electromyographic activity and a greater lumbar curve on standing than with the OC or the SBC. During erect postures, there was more electromyo graphic activity with standing than in the OC and no difference in the lumbar curve was noted between chairs. Electromyographic activity at L5 was greater on the left side across chairs. In typing and writing significant differences in electromyographic activity were found between the sides, but not between chairs. The lumbar curve was greater in the BC than in the SBC in relaxed sitting, typing and writing (Bennet et al, 1990 .

In another research held by Schroder relating to the different types of furniture for school children in Germany. He investigated variations of sitting posture and physical activity in different types of school furniture. The analysis of his findings showed numerous differences of movement patterns with respect to sex and age and the type of furniture. He also measured all the movement frequencies and the possibility of choosing extreme postures in order to interrupt monotonous permanent positions, and freedom of movements for the legs. Surprisingly, the ordinary standardized school furniture, under his investigating, turned out to meet the ergonomic demands better than a school type of furniture which has been considered to be ‘ergonomic’

Schroder, 1997 .

One of the dangers of prolonged sitting, as the results showed, is the reduction in the range of motion of the hamstrings with increase in the number hours involved

P=0.007). In addition a significant correlation was found between the flexibility of PR and the number of sitting hours. From these results it becomes clear that there is a reduction in hip and pelvis flexibility as the number of sitting hours increases

P=.0.002). Similar results were found in all ages groups. Shortening of muscles and reduction in pelvic flexibility begin at a young age group, apparently due to sitting habits adopted over prolonged periods both during school hours and leisure time.

There is a large percentage of children who sit with sharp angles of the knees and hips both when sitting either on chairs or on the floor as was observed in the main when sitting opposite a computer or when playing video games while sitting on the floor. In this sitting position continuous harm is caused due to the muscle shortening and the resultant imbalance of various muscle groups which in turn influence the degree of pelvic rotation, the spinal curves and the incidence of back pain in children.

With respect to back pain in relation to sitting parameters, Gunzburg noted significantly more LBP in children who reported playing video games for more than 2 hours per day. This was not so for television watchers (Gunzburg, 1999 .

In another study, on the risk factors for LBP in 1389 Danish children there was a significant correlation between back pain and a reduction in the quality of life which was made evident with the lack of physical activity in addition to prolonged sitting as required by the use of computers, playing video games and television viewing (Harreby 1999 .

In the present study significant differences were found in the frequency of use of computers and LBP (P=0.007). Also, among all the children who complained of back pain 73.9% who defined themselves as computer users. It should be recalled that 98% of computer users reported 'Sitting type1 ' (see para. 3.13.4 .

In a study on a population comprising 1755 children , 8-16 years of age, carried out by Balague et al, 1994, a significant correlation was found between time spent watching television and low back pain. Similar results were noted by Troussier et al 1994 and

Balague et al 1998.

In the present study ,where watching television, no connection was found between the number of hours and LBP but in this activity sitting with legs extended forward (Type 2 showed the highest incidence of back pain in relation to all sitting postures (P=0.06). A similar incidence was noted by Viry et al, who reported a significant connection between sitting forward on the edge of a chair, with legs extended, and attendance at a physician's office for LBP.(P=0.05) (Viry et al, 1999 .

The results of our study showed clearly that there is an increase in the number of different postural deformities in relation to the amount of hours sitting in all the research groups (F= 2.9331, P=0.054 . Since sitting is almost invariably associated with unfavourable biomechanics, the term 'correct' seating is to some extent a contradiction in itself. The sitting position on conventional seats both at school and at home, usually causes overstress of the discs, ligaments and muscles. A chain of events is created which begins with muscles tightness and postural deformities and ends in a high incidence of back pain.

The aim can only be to minimize the damage caused by prolonged sitting and to define a seat which causes the least amount of harm.

4.14. Physical Activity Parameters.

The physical activity parameters relate to the total amount of hours occupied by each child out of school hours and include both organised and un-organised activities as reported by each child.

This parameter is divided into three categories which are determined by both their average duration and frequency per week.

From the results of our research we note that 37% (112 of the whole population) were in the non-active group and 42.2% were in the active group while 20.8% were in the 'very active' group (see Table 17 .

In all the age groups the girls were less active than the boys.

In a survey that examined the cultural leisure activities in Israel, 1998, 1300 were interviewed as to their involvement in different forms of leisure activity. From the figures it is evident that only 40% of this sample were actively engaged in sport (Haas,1999). It is noteworthy that this survey was carried out on the adult population and that the numbers involved in sports activities is lower that among children. Nevertheless attention should be paid to this data because it reflects the life style of Israelis and its effect on their children.

In the study by Taimela, on the physical activities of Finnish children, it was found that a total of of both boys and girls reported some participation in leisure physical activity outside school hours. The frequency of physical activity was at maximum once a week in 22%, twice a week in 22%, three to four times a week in 33%, and more than four times a week in 23% Taimela, 1997 .

As was shown above, in the present research, there was a much higher percentage in the non-active group among the Israeli children as compared to the Finnish children.

An index for leisure time physical activity was calculated, in Taimela's research, from the intensity times/duration times, weekly frequency. The level of activity was expressed as "low", "moderate" and "high". The same levels of activity were used in the present research, relating to the frequencies of the activity in a week, and the intensity was expressed by the duration of activity according to the amount of hours of activity at each session. In the category of "the non-active group" in this research, there were only those who reported not to be active at all, and a small number who reported only a few minutes of light activity once a week.

The level of physical activity relating to the 'Active' category, was taken as a frequency of up to three times a week and 1-7 hours activity in any particular week. The 'Very Active' category had a frequency of 4 times or more in a week' and, at least, 8 hours or more of physical activity in any week.

Similar results to the research of Taimela, 1997 , were found in the study of Troussier et al, in 1178 French children. It was found that 8.3% (95) participated in competitive sports; 69.2% (787) trained regularly at least twice a week; 19.4% (229) only irregularly; and 2.3% (27) did not participate in any sport activity (Troussier et al, 1994 .

In the research of Myers et al, on physical and sedentary activity, in 995 school children from grades 5-8 in America, similar results were reported to the present research, i.e. that ,in general, boys were more physically active than girls and engaged in more heavy physical activity, while girls reported a larger percentage of time spent in light and moderate physical activities. Myers also noted a decrease in moderate physical activity with increasing grade levels in school and an increase in sedentary behaviour (Myers et al, 1996 . In this connection, Durant et al, who examined the relationship between television viewing, physical activity and BMI in children from Boston, USA, noted that television had only a weak negative correlation with physical activity levels Durant et al, 1994 .

Contrary to the results given by Myers et al, on the relationship of physical activity by age, in the present study the highest percentage of "non-active" was typically in 2nd grade. 50% of the children in the "non-active" category were from 2nd grade. The percentage of children involved in physical activity levels increases with age. It appears that these differences can be explained by the different age groups that were examined by Myers et al which also included older ages than were included in our study.

Myers et al, also stated that black children reported more sedentary activity than white children, and in this case the girls reported more than boys (Myers et al, 1996). Another study, carried out in America , by Harrell et al, investigating the three most common leisure time activities among 2200 American children, it was noted , as in the former study, that girls who reported fairly sedentary activities showed an average metabolic equivalent level of 4.2 and for boys the equivalent was 4.8. The activities reported most often by the boys were playing video games (33%); playing football (32%); riding a bicycle (31%); watching television (28%) and playing basketball (26%). The girls reported doing homework in 39%; riding a bicycle in 31%; watching television in 30%; dancing in 27% and reading in 23% (Harrell et al 1997 .

It was also noted that, with regard to intensity of activity, African-Americans boys reported more vigorous activities than whites, while with the girls the opposite was the case. Children with a higher socio-economic status, especially boys, reported a great proportion of sedentary activities than in the lower socio-economic levels Harrell et al, 1997 .

In the present study similar results were noted to those of Harrell et al. In the "very-active" category the percentage of Afro-Asian boys was almost double that of the Israeli and European-Americans. The opposite was found among the girls where the Afro-Asians in the "non-active" category showed the highest percentage.

<u>4.14.1. Physical activities in relation to motion parameters, postural deformities and back pain.</u>

Analysis of the motion parameters in relation to physical activities showed that there was a tendency towards better ranges of motion, both with regard to SLR and PR, in those more involved in physical pastimes. (P=0.06).

Significant differences were also found in the 6th grade. Among the girls significant differences were found in the level of SLR such that the "very-active" showed a mean of 76.6 degrees (more than 11 degrees greater than in the "non-active" group (F=3.986, P= 0.025 . Higher differences were found in PR where there was a par of 20 degrees between these two groups (F=8.195, P=0.001). Significant differences were also noted in the 2nd grade girls where the mean SLR in the "very-active" group was 25 degrees higher than in the "non-active" group.(F=3.954, P=0.028). Significant differences in motion parameters were found, in SLR and PR only, in those in which muscle shortening characterised the "non-active" group. No studies were found in the literature describing muscle shortening in relation to physical activities in children. Many article were found describing the degree of flexibility in muscles among both active sportsmen and non-active individuals etc. The majority of these studies relate to different age groups and specific activities which do not allow for comparison one with the other e.g. the study by Wang et al, 1993, who examined the muscle tension in the lower limbs in 20 long distance runners as compared to a control group. It is possible that similar or parallel results may be found in other studies but there is no place for comparison among the articles because of the reasons mentioned.

Reduced musculo-skeletal development and even muscle atrophy resulting from lack of physical activity often causes imbalance in the skeletal system which may result in postural abnormalities already at a very young age. In the present study a significant negative correlation was found between the level of activity and postural deformities in both sexes. This connection indicates a low postural score as the level of physical activity decreases. 55% of the “non-active” children were in the “Poor” postural category. However, the “very-active” group showed the lowest level of postural deformity. (r= -0.156, P=0.06). It was also noted that the dorsal kyphosis was greater in the “non-active” group and there was tendency towards increased kyphosis with decreased physical activity (F= 2.694, P=0.006). Among the girls these findings were more obvious than among the boys (F=7.033, P = 0.001). No significant differences were found in the lumbar curves in relation to activity levels but it should be noted that the mean differences in the lumbar curves showed a decrease, i.e. improvement, with an increase in the amount of physical activity.

It is apparent that the overall tendency is typified by a higher risk of postural deformities in those who are not involved in physical activity especially those involved

in passive occupations. The reason for this, as we have mentioned, is weakness of musculature and inadequate development of the locomotor system which cause harm to both the musculo-skeletal and nervous systems arising from bad postural habits adopted at a very young age, as is widely reported in the literature. This state of affairs may be a central cause for back pain in the young person.

Although the direction of causality in musculo-skeletal performance and postural deformities is not fully known, these ‘abnormalities’ may be either a cause or a consequence of LBP. Measurements of musculo-skeletal performance have revealed poor endurance strength of abdominal and back extensor muscles and decreased spinal mobility among subjects with recurrent or prolonged LBP in cross-sectional studies (Taimela, 1997). Harreby, 1999, found significant correlation between LBP and poor physical fitness.

Taimela, 1997, found in his study a borderline association between a high level of habitual physical activity and LBP. Among those with LBP, relatively more subjects were, physically, “highly” active (47.4%), compared with “moderate” (25%) and “low” physically activity (27.6%), (p=0.082) .

However, it also was noted that severity (duration) of the pain increases with age and physical impairment is often associated with more severe and long-lasting symptoms Taimela, 1997).

Troussier et al, found no correlation between intensity of sport participation and back pain. The explanation for the high prevalence of back pain among 12 years old, they relate to the growth spurt at the age of puberty, and also to the increase in the stress and constraints on the back such as are produced by a greater satchel weight and longer duration in the sitting position (Troussier et al, 1994). The sitting position found to be unpleasant for school children and 41.6% experienced back pain when sitting in the classroom, and 69.5% of back pain occurred after 1 hour of sitting.

It was estimated that the total duration of sitting in the classroom in primary and secondary schools during the life of an individual in France was more than 15,000 hours (Troussier et al, 1994).

Balague et al, also found that the duration of sitting hours in school is considered to be a risk factor for back pain in young children(Balague et al, 1988).

In several articles we can find a connection between competitive or vigorous activity and back pain (Harreby 1999, Balague et al 1994, Kujala et al 1999, Balague et al 1988) . In the present research a significant correlation were found only among the boys. There was a higher prevalence of reporting back pain in the 'very active' group 31.7%) as compared to the non-active group (14.3%). (P=0.055). Troussier et al, 1994, also found a high prevalence of back pain (78.2%) among volley-ball players. He explained that volley-ball seems to be a sport which affects the back because it induces

hyperextension of the spine and causes considerable spinal compression.

It appears that hyperextension of the back causes increased pressure on the vertebrae not only in volley-ball and this pattern of activity can be noted in many other sports activities such as gymnastics, dancing, athletics and martial arts etc. In addition jumping, landing and running on hard surfaces contribute a great deal to the development of back pain. As is noted in Reis et al's study, 1996 , lack of awareness with regard to physical activity and poor technique with regard to lifting up objects may also add to the risks in young children and adolescents. This is especially so in those who, on the one hand, are involved in heavy physical activities which cause overuse of the soft tissues and, on the other hand, also in those relatively inactive children where disuse of the body's musculo-skeletal systems causes a consequent increase in the incidence of back pain. Other reasons we can relate to the discrepancy of back pain in the very active group are: a) The combination highly excessive activity together with a lesser degree of tension is more likely to show itself as a cause of back pain than in those with only sedentary activities. b) Even under normal conditions of muscle tension, highly active sport are likely to elicit musculo-skeletal problems depending on the conditions of fitness and training, this would be amplified in those also having increased muscle tension, reduce flexibility and relative poor fitness, as mentioned in volley ball players who hyperextend their backs. c) Congenital anomalies of the lower limbs and spine are common but were not included in the evaluation of the children in this research, apart from the qualitative parameters mentioned, because many of such deformities are only found on radiological examination. In addition, Pes Cavus, for example, is often found in highly active children but may be unnoticed as a physical deformity which can be shown only on X-ray, to have connection with back problems. d) The additional of physical activity is a potent force in producing back problems due to exertion of excessive pressure on joints and tight musculature, especially of the back, among the highly active children.

The problems of the pediatric spine have only been raised in the last two decades, and there is not adequate awareness, suitable published material or discipline in this area. In addition to the need for further prospective studies, an urgent effort has to be made in developing appropriate health, educational and sports programs by the relevant multidisciplinary authorities in all the aspects of this topic.

5. SUMMARY

Modern society is regarded as belonging to a “sitting culture” with a continuous reduction in physical activity. Already as children enter into primary school they spend hours sitting on a chair, and the same is true after school hours, when they continues with similar passive activities, mostly watching television, playing video games or sit-ting at a computer, etc. “The continuous sitting culture” and lack of physical activity can cause severe bodily damage, as a result of poor muscular equilibrium within the body’s skeletal system. This may become apparent as a problem of posture together with back pain. Prolonged sitting may cause changes in the musculature of the back, spinal curves, loins and legs, including shortening of the hamstrings, ilio-psoas muscle together with the joints and ligaments especially around the hip and knees.

One of the main goals of this research was to examine the sitting habits of children in an era of rapid technological development which finds its expression in the specific character and social climate of the "sitting culture". In addition to assess the ra-mifications of this type of behavior on the bio-physical systems of young children. In this connection we examined the relationships between duration of sitting and the type of sitting with regard to television viewing, working at a computer and playing video games etc. These measurements were carried out in relation to the spinal curves, muscle length, flexibility about the pelvis, postural deformities and the frequency of back pain.

The amount of physical activity of each child was also correlated with these parameters. All the analyses were performed according to age and sex and included de-mographic and anthropomorphic analyses as well.

The research population was taken from four Primary Schools in three different Israeli cities and involved both sexes in the 2nd, 4th and 6th grades. The cities according to their different demographic attributes provided a representative cross-section of Is-raeli children.

The three cities were Rehovot, Yavne and Ashdod which are located in the central and south of Israel. The research was carried out in specially prepared exa-mination rooms in each school and the measurements were taken according to a strict protocol and standardization between the hours of 8a.m.-noon.

The connections between all the motion parameters and the spinal curves were examined. In addition, the connections were compared between the qualitative para-meters, such as postural deformities, (head forward, lumbar lordosis, dorsal kyphosis, sway back, shoulder height, scapular levels and pelvic equilibrium), as well as anthro-pometric measurements - height, BMI, activity levels, sitting types, presence of low back pain, in relation to the pelvic rotation, hamstring and ilio-psoas tension and spinal curve parameters. All the statistical analyses were performed by age and sex. We examined the mutual effect of various motion parameters with the aid of multiple regression procedures.

The results of the study demonstrate significant differences in hamstring tension and pelvic rotation. The girls showed higher levels of both hamstring range and flexi-bility in pelvic rotation (PR) as compared with the boys. The values of lordosis showed an increased tendency with age, i.e. there was a greater tendency towards hyper-lordosis,. The average of lumbar lordosis was greater amongst the girls than the boys in all age groups. The opposite was found with regard to dorsal kyphosis, although, no significant differences were found between the sexes.

A significant correlation was found between the parameters of SLR and lordosis in both sex groups. The tendency was in a negative direction. The findings indicate an increase in lordosis levels corresponding to an increase in the hamstring tension. A sig-nificant negative correlation was found between SLR values and the levels of lordotic curves in both sexes.

The connection between Ilio-psoas measurements and lordosis showed a significant negative tendency only in the female group. These findings show an elevation of the lordotic levels in association with increased Iliopsoas tension. In the differentiation of age groups a significant negative tendency was noted in all age groups in girls.

No synergistic effects were noted. between Iliopsoas and hamstring muscle tension on the lordotic measurements. Multiple regression analysis demonstrated that, in boys, the dominant parameter concerning hyperlordosis was the tension in the hamstring muscles, while in girls Iliopsoas tension was the dominant factor. In the whole research population the connection between hamstring measurements and dorsal kyphosis was found to be significantly correlated only to the PR parameter, while the SLR parameter was significantly correlated only among the 2^{nd} grade in both sexes. The majority of postural deformities was found in this age group. Reduced SLR values showed a definite connection with

a) increased spinal curves,

b) poor postural scores, as demonstrated by the qualitative postural assessment values.

Greater postural deformities were associated in a significant way with higher values of hamstrings tension, lower values of SLR and PR and greater Iliopsoas tension. 45.4% of the whole population reported back pain. The highest incidence of back pain, 50.8%,. was found between 9-10 years old (4^{th} grade). Among the girls, significant differences were found, between the groups "with" and "without" back pain, in relation to hamstring tension, with regard to both SLR and PR. In the male population no significant correlation was found with backache. In the present study significant differences were found in the lumbar curve, in relation to back pain, only in 2^{nd} grade.

The parameters examined relating to sitting activities were:

a) using a computer,

b) playing video games,

C) watching television and,

d) other activities reported which involved prolonged sitting.

Each sitting activity was described by each child according to the type of postures adopted. Four typical sitting posture were defined:

a) sitting with hips and knees at $90^o/90^o$ or less,

b)backward or vertical slouching with knees partially extended more than 90^o,

c) lying in prone or supine position,

d) sitting on the floor.

It was found that, among the whole research population, the average sitting was 3 hours/day. Among the boys the average was 3.3 hrs/day and among the girls 2.7 hrs/day. Comparison of our data with other studies carried out both in Israel and other countries showed similar results.

The commonest leisure activity was watching television. Television watching of 15.4 hrs/week in boys was double that of using a computer (7.3 hrs/week) whereas with the girls watching television occupied 13.7 hrs/week and using a computer only 5.6 hrs/week.

From the reports given by the children regarding their sitting habits while watching television, the most common attitude was sitting with the legs straight forward and the trunk inclined somewhat backwards (Sitting posture type 2). 51% of the boys and 60.5% of the girls reported this. 98% of the computer users and 30% of those playing video games reported sitting forward on a chair with the knees at less than 90 degrees (type1). In this position the upper back is flexed forwards (with increased kyphosis) and the lumbar curve is reduced. In this position the knees are usually held in a flexed position (<90 degrees) . These angles greatly influence pelvic rotation and the lumbar curve and at the same time cause maximal interdiscal pressures in the lumbar region.

One of the dangers of prolonged sitting, as the results showed, is a reduction in the range of motion of the hamstrings as the number of sitting hours increases. In addition, a significant correlation was found between the flexibility of PR and the number of sitting hours. From these results it becomes clear that there is also a reduction in hip and pelvic flexibility as the number of sitting hours increases.

Similar results were found in all age groups. Shortening of muscles and reduction in pelvic flexibility begin at a young age, apparently due to sitting habits adopted over prolonged periods both during school hours and leisure time. A large percentage of children sit with their knees and hips at sharp angles when sitting either on chairs or on the floor. This was observed, in the main, when sitting opposite a computer or when playing video games while sitting on the floor. In this sitting position continuous harm is caused due to resultant muscle shortening and the consequent imbalance of various muscle groups which, in turn, influence the degree of pelvic rotation, the spinal curves and the incidence of back pain in children.

In the present study significant differences were found in the frequency of use of computers and LBP (P=0.007). Also, among all the children who complained of back pain, 73.9% defined themselves as computer users. It should be recalled that 98% of computer users reported 'Sitting type1'.

In all the research groups, the results of our study showed clearly that there is an increase in the number of postural deformities in relation to the amount of hours sit-ting (F= 2.9331, P=0.054). It was also noted that 37% (112 of the whole population) were in the "non-active" group. In all age groups the girls were less active than the boys. The highest percentage in the "non-active" category was typically in 2nd grade, i.e. 50% The percentage of children involved in physical activity increases with age. Analysis of the motion parameters in relation to physical activities showed that there was a tendency towards better ranges of motion, both with regard to SLR and PR, in those more involved in physical activity (P=0.06).

A significant negative correlation was found between the level of activity and postural deformities in both sexes. This connection indicates a higher incidence of postural deformities as the level of physical activity decreases. 55% of the "non-active" children were in the "Poor" postural category. It was noted that dorsal kyphosis was greater in the "non-active" group. No significant differences were found in the lumbar curves in relation to activity levels but it should be noted that the mean differences in the lumbar curves showed a decrease, i.e. improvement, with an increase in the amount of physical activity.

5.1 Conclusions.

The results of this research indicate:

a. A higher occurrence of muscle tension in the population examined, when compared with similar groups from other countries.

b. Muscle tension was significantly negatively correlated with hyperlordosis and increased dorsal kyphosis, in addition to poor postural parameters.

c. Shortness of the hamstrings was significantly correlated with back pain only among the girls.

d. Multiple Regression analysis showed that increased hamstrings tension was dominant with regard to lumbar lordosis in boys, whereas among the girls the ilio-psoas was more dominant.

e. Prolonged sitting and reduced activity are noted to involve a greater inci-dence of postural deformities and a higher frequency of back pain, especially in young children.

f. There was a reduction in hip and pelvic flexibility as the number of sitting hours increased.

g. The most harmful sitting posture was found to be while sitting at a computer. This activity usually involves sitting forward with the knees and hips at less than 90 de-grees. This position generates the greatest amount of pressure on the lumbar interver-tebral discs.

h. The most common leisure activity was watching television – a mean of 14.5 hours per week. The sitting position most commonly noted when watching television was with both the back and legs extended and this found to be the highest incidence of backache among the sitting types of watching television.

i. In general, reduced physical activity was associated with poor posture and increased muscle tension.

j. Of all the sitting activities, the frequency of back pain was found to be highest amongst those using a computer (78%).

k. This study together with a wide review of other international studies confirms that the modern generation of young children is growing up in a situation where pos-tural deformities and back pain resulting from short or imbalance musculature is so common as to represent epidemic proportions.

l. At the present time, it appears that, despite evidence from all over the world, very little is being done to improve the situation.

m. There is an urgent need for standardisation of methods of study among in order that appropriate conclusions may be drawn on an international basis.

5.2 Recommendations.

In view of the above results, it is recommended that this type of research should be continued in order to identify the sitting patterns involved in various situati-ons occurring in the daily life of a child and to establish relevant standards which will result in less physical damage to the human body. This will necessarily involve not only improving the state of the human body but also all aspects of ergonomic furniture de-sign and arrangement including whatever accessories are needed to assist in improving the present sorry state of affairs.

It is important to raise the level of awareness about the damage caused by prolonged sitting and inactivity habits amongst children, parents, school nurses physicians, media and all concerned in every respect. This situation, which is considered to be the most dangerous, chronic epidemic of the modern era, will, probably, become worse in the future because the amount of sitting hours and inactivity will increase as modern high technology continues to develop. On the other hand, great importance must be attached to encouraging physical activity and sport exercises as a inseparable part of our cultural life. Increased activity is essential to maintaining a correct or ac-ceptable posture and good locomotor functioning.

From the perspective of the educational and medical authorities, it is desirable to distribute a greater amount of relevant information, via the various media available, in conjunction with increased participation in physical activity in order to prevent and/or decrease the unhappy phenomena described in this study.

It is clear that a new and improved program must be designed, utilising all aspects of modern communication and aimed at increasing physical activity, will have a beneficial effect on the whole range of physical parameters, both in prevention and rehabilitation. This is a relatively inexpensive method of improving the overall health of the population, both physically and mentally, especially if it is commenced at a relatively young age.

Összefoglaló

Háttér: A modern kultúra egyfajta ”ülõ kultúrának” mondható a fizikai aktivitás folya- matos háttérbe szorulása folytán. A gyermekek már az általános iskolába kerüléskor órákat ülnek az iskolapadban, majd tanítás után hasonlóan passzív idõtöltésként televí-zióznak, videó-játékokat játszanak vagy órákat töltenek a computer elõtt, stb. A folya-matos ülõéletmód és a fizikai aktivitás hiánya

természetesen hatással van a vázrendszer deréktáji szakaszának és az izomrendszernek a fejlõdésére is.

Célok: A hosszótávú ülés hatásainak vizsgálata (idõtartam, testhelyzet) és a fizikai aktivitás hatásainak elemzése a törzsizmok erejére, a medence-rotáció kiterjedésére, a gerinc görbületeire, a testtartási deformitásokra valamint ezek kapcsolatának elemzése a hátfájással.

Alkalmazott módszerek: A vizsgálatot négy izraeli kisváros, random módon kiválasz-tott 303 tanulójánál (154 fiú és 149 leány) végezték el. A mintát az a nem és az életkor alapján rendezték. A vizsgált jellemzõk: nyújtott lábemelés (SLR), medence rotáció (PR), csípõ hajlítás (HE), lumbális lordózis (LL), káti kifózis (TK), a testdeformitá-sokat bemutató szögeltérések, a hátpanaszok gyakorisága, a habituális fizikai aktivitás idõtartama és jellege, a naponta üléssel töltött idõtartam.

Eredmények: A kapcsolat szignifikáns és fordított az SLR és az LL szögek között (r = -0.14, p = 0.01). A mozgástartomány nagyobb volt a ”jó” kategóriájú testtartás esetén, a ”gyenge” és elégséges kategóriákban a hátizmok nagyobb feszülése volt a jellemzõ. A gyermekek 45.4%-a jelzett hátfájást. A leányok mintájában szignifikáns volt a külkönb-ség a hátfájást jelzõk és nem jelzõk hátizom feszülése között, valamint a nyújtott lábe-melés és a medence rotáció átlagai között.

A lumbális görbületet bemutató szög nagyobb volt a hátfájást jelzõk csoportjában (F= 5.15, p=0.02). A vizsgált gyermekek az iskolai elfoglaltságon túl, átlagosan 3 órát töltöttek ülõ tevékenységgel naponta. Szabadidejük legnagyobb részét televíziózással töltötték. A televíziózás idõtartamaának heti átlaga (15.4 óra) kétszerese volt a computer használat idõtartamának (7.3 óra hetente). A leányok mintájában a televíziózás átlagos idõtartama ”csak” 13.7 óra hetenként és õk kevesebb idõtt töltöttek a computer képernyõje elõtt is (5.6 óra). A vizsgált mozgások kiterjedése az ülõ tevékenységgel töltött idõtartam függvényében kismértékben csökkent.

A compuer használat és a hátfájás között szignifikáns a kapcsolat (p = 0.007). A hátfájásra panaszkodó vizsgáltak 73.9%-a valotta magát rendszeres computer használónak. A rendszeresen computerezõknél a jellemzõ csípõ és térdszög kevesebb, mint 90-fok. A nyújtott térddel computerezõk csoportjában volt a legnagyobb a hátfájásra panaszko-dók aránya. A minta 37%-a egyértelmûen hipoaktív volt. A naptári életkor függvényé-ben azonban nõtt a fizkailag aktívabbak aránya.

Az SLR és az LL alapján jellemzett mozgástartomány kismértékben nagyobb volt a fizikailag aktívabbak csoportjaiban (p=0.06) és a hipokatívak 55%-ának testi felépítése a ”gyenge” kategóriába volt sorolható.Az átlagosat meghaladó fizikai aktivitáshoz tartozott a legkisebb testtartási deformitási arány (r= -0.16, p=0.06). A dorzális kifózis na-gyobb volt a fizikailag aktívak mintájában (F=2.69, p=0.006).

Következtetések: A hosszú ideig tartó ülés és a mérsékelt fikai aktivitás hatása bizonyított a testtartási deformitások kialakulásában és az ülõ életmódot folytatók mintájában gyakoribb volt a hátfájás. Ez utóbbi jellemzõben az életkor hatása is szignifikáns. Ilyen tekintetben a legártalmasabb a computerezés. Ez a testtartás jelenti a legnagyobb terhelést a gerinc ágyéki szakászn elhelyezkedõ porckorongokra. Az egyenes derékkal és nyújtott lábbal televíziózás okozta a hátfájás legnagyobb gyakoriságát.
Javaslatok: Kiemelkedõen fontos lenne a rendszeres testmozgás beépítése a napi életvitelbe. Ez a relatív olcsó megoldás hatékony eszköz a gyermekkorú és serdülõ- populációk általános egészségi állapotának javítására, a fizikai és mentális terhelhetõség nö-velésére. Az általános hipoiaktivitás tekinthetõ az egyik legveszélyesebb ”járvány” a gazdaságilag fejlett országokban. A termelõ technika folyamatos fejlõdésével az ember fizikai aktivitásának további csökkenése prognosztizálható.

Abstract

Background: Modern society is regarded as belonging to a ‘sitting culture’ with continuous reduction in physical activity. Already with a child’s entry into primary school he spends hours sitting on a chair, and after school hours he continues with similar pas-sive activities mostly watching television, playing video games or sitting at a computer, etc. The continuous sitting culture and lack of physical activity seems to effect the postural development and the muscular-skeletal of the back and the lower limbs.

Objectives: To examine the effect of the prolonged sitting parameters (duration, type) and physical activity parameters, and their influence on the tightness of the hamstrings and iliopsoas muscles, the range of pelvic rotation, the spinal curvatures, postural deformities and prevalence of complaining back pain.

Methods and Measures: 303 pupils (154 boys and 149 girls) were randomly selected from four primary schools in three different Israeli cities. All the research population was divided into three age groups according to age and sex. Straight leg Raising (SLR), Pelvic Rotation (PR), Hip Extension (HE), Lumbar Lordosis (LL), Thoracic Kyphosis (TK) angles and postural deformities were measured, and past complains of Back pain, 'Physical activity parameters' and 'Sitting parameters' were recorded.

Results: A significant negative correlation was found between the SLR, and LL angle ($r = -0.14$, $P = 0.01$). A greater range of motion of both SLR and PR was found in those in the "Good category" posture, "Poor" and "Fair" posture score showed higher levels of hamstring tension. 136 children (45.4%) reported back pain. Among the girls, significant differences were found in hamstring tension, both in SLR and PR, between the groups with and without back pain ($p<0.05$).

The mean lumbar curve angle was greater in the symptomatic group ($F = 5.152$, $p=0.02$). The average sitting was 3 hours/day. The commonest leisure activity was watching television. Television watching of 15.4 hrs/week in boys was double that of using a computer (7.3 hrs/week). Among the girls watching television occupied 13.7 hrs/week and using a computer only 5.6 hrs/week. There was a reduction in the range of all motion parameters with increase in the number sitting hours involved ($p<0.05$).

Significant differences were found in the frequency of use of computers and back pain ($p=0.007$). Among all the children who complained of back pain 73.9% defined themselves as computer users. 98% of computer users reported 'Sitting type1 (Sitting with hips and knees at 90 degrees or less). Sitting with legs extended forward (Type 2) showed the highest incidence of back pain in relation to all sitting postures among TV watchers ($p=0.06$). 37% (112 of the whole population) were in the non-active group. The percentage of children involved in physical activity levels increases with age. There was a tendency towards better ranges of motion, both with regard to SLR and PR, in those more involved in physical activity ($P=0.06$). 55% of the "non-active" group were in the "Poor" postural category. The "very-active" group showed the lowest level of postural deformity ($r= -0.156$, $p=0.06$). Dorsal kyphosis was greater in the

“non-active” group and there was tendency towards increased kyphosis with decreased physical activity (F= 2.694, p=0.006).

Conclusions: Prolonged sitting and reduced activity are noted to involve a greater in-cidence of postural deformities and a higher frequency of complaining back pain, espe-cially in young children and increased muscle tension. The most harmful sitting posture was found to be while sitting at a computer. This position seems to generate the great-est amount of pressure on the lumbar intervertebral discs. The sitting position most commonly noted when watching television was with both the back and legs extended and this found to be the highest incidence of backache among the sitting types of watching television.

Recommendations: Great importance must be attached to encouraging physical acti-vity and sport exercises as an inseparable part of our cultural life. This is a relatively inexpensive method of improving the overall health of the population, both physically and mentally, especially if it is commenced at a young age. This situation, which is con-sidered to be the most dangerous, chronic epidemic of the modern era, will, probably, become worse in the future because the amount of sitting hours and inactivity will in-crease as modern high technology continues to develop.

Publications of Ben-Zion Adar

Adar, B-Z., Weinberg, H., Simkin, A., Roth, V. (2004): Relationship among hamsting and iliopsoas lengths, posturee and back pain in schoolchildren - gender differen-ces. *Hungarian Review of Sports Medicine*, **45:** 3. 197-215.

Adar, B-Z., Weinberg, H., Simkin, A., Roth, V. (2004): Relationship among hamsting and iliopsoas lengths, posturee and back pain in schoolchildren. *Studia Kinathro-pologica,* (in press, letter of acceptance presented).

Roth V., **Adar B-Z.**, Kohen-Raz R. (2003): Tetra-axiometric integrated balance sys-tem- An accurate adjunct to orthopedic diagnosis: Clinical experience in over 500 patients. Annual Congress of the Israeli Orthopedics Association, *Ortho Bulletin*, **23:** 48.

Adar B-Z., Roth V. (2003): *The practical basics of everyday ergonomics*. Posture-graph Center Publishing, Jerusalem. 131.

Adar B-Z., Weinberg H., Frenkl R., Roth V. (2003): Prolonged sitting posture and physical inactivity – a modern epidemic in schoolchildren. International Sympo-sium on Sport Medicine–Israel, Program and Book of Abstracts, Israeli Ortho-pedics Association, Tel-Aviv, 45.

Adar B-Z. (1998): *Program of Epidomology principles in public health, matricu-lation*. The Educational and Cultural Ministry, Jerusalem, 22. (in Hebrew).

Adar B-Z, Weinberg H., Simkin A., Roth V. (1997): Postural Evaluation of normal Is-raeli primary school children – The thigh hamstrings syndrome. International Or-thopedics Congress, SIROT, Inter-meeting, Haifa. Program and Abstracts, Tar-get, Tel-Aviv, 61.

Ben Tov M., **Adar B-Z.** (1995*): Health promotion in school and in Community – Interventions Programs.* The Educational and Cultural Ministry, Tel-Aviv. 170.

Roth V., **Adar B-Z.** (1995): Postural and Gait Abnormalities in Israeli School Child-ren. Department of Physical Education, Givat Washington, 55.

Adar B-Z. (1994): *Backache and Physical Activity.* Aspects of Medical and Health in Physical Activity workshop. Hebrew University, Jerusalem. 39.

Karplus M., Veinstein R., Peled R., Brown O., Apstein Y., **Adar B-Z.** (1993): *Re-duction in Passive smoking among Embryo and newborns.* C.O.P.C., Public Health, School of Medicine Hadassah, Jerusalem, 56.

Adar B-Z. (1993): Physical and CHD risk factors. Seminar of Human Physiology in Rest and Strain, Hebrew University, Jerusalem, 25.

REFERENCES

1. Adams M.A., Hutton W.C. (1980): The effect of posture on the role of the apophysial joints inresisting intervertebral compressive force. *Journal of Bone and Joint Surgery,* **62:** 358-362.
2. Adams M.A., Hutton W.C. (1985): The effect of posture on the lumbar spine. *Journal of Bone and Joint Surgery,* **67:** 625-629.
3. Adar B-Z. (1996): The conection between tight Hamstrings muscles, lumbar lordosis and postural prameters among primary school children in Maale Edomim. Unpublished MA Thesis, Faculty of Medicine, Public Health, Hebrew University Jerusalem.
4. Ahlback S-O, Lindahl O. (1964): Sagittal mobility of the hip-joint. *Acta Orthopaedi-ca Scandinavica,* **34:** 310-322.
5. Anastassea-Vlachou K., Fryssira-Kanioura H., Papathanasiou-Klontza D, Xipolita-Zachariadi A, Matsaniotis N. (1996): The effects of television viewing in Greece, and the role of the paediatrician: a familiar triangle revisited. *European Journal of Pediatrics,* **155:** :1057-1060.
6. Andersson E., Oddsson L., Grundstrom H., Thorstensson A. (1995): The role of the psoas and iliacus muscles for stability and movement of the lumbar spine, pelvis and hip. *Scandinavian Journal of Medicine and Science in Sports,* **5:**10-16.
7. Anderson G.B., Orengren R. (1974): Myoelectric back muscle activity during sitting. *Scandinavian Journal of Rehabilitation of Medicine,* 1974 ;Supplementum, **3:** 73-90.
8. Anderson G.B., Orengren R, Nachemson A., Elfstorm G., (1974): Lumbar disc pressure and myoelectric back muscle activity during sitting. *Scandinavian Jour-nal of Rehabilitation of Medicine,* **6:** 104-114.
9. Anderson James E. (1983): *Grant's Atlas of Anatomy.* Williams and Wilkins, International Edition, Baltimore.
10. Andersson G.B. (1990): Intradiscal pressure changes and the clinician. Back pain - An international review. In: Paterson J.K., Anthony C.P., Kolthoff N.J. (Eds.): *Anatomy and Physiology*. The C.V. Mosby Co., Saint Louis.
11. Anthony C.P., Kolthoff N.J. (1975): *Anatomy and Physiology*. The C.V. Mosby Co., Saint Louis.
12. Angles F.G., Manubens X.B., Angels F.C. (1997): A surgical technique for length-ening tight hamstring muscles in patients with low back pain. *International Or-thopedics,* **21:** 52-53.
13. Althoff Sally A. (1998): Posture screening - a program that works. *Journal of Orthopedic and Sport physical Therapy,* **10: 2**6-32.
14. Asher C. (1975): *Postural variations in childhood.* Butterwort and Co., London, Boston.
15. Asmussen E. (1959): Form and function of the human spine in growing children-posture, mobility and strength of the back in boys 7 to 16 years old. *Acta Orthopaedica Scandinavica,* **28:** 174-189.

16. Balague F., Nordin M., Skovron M.L., Dutoit G., Yee A., Wald Burger M. (1994): Non- specific low-back pain among school children: a field survey with analysis of some associated factors. *Journal of Spinal Disorders,* **7:** 374-379.
17. Balague F., Dutoit G., Waldburger M. (1988): Low back pain in schoolchildren. An epidemiological study. *Scandinavian Journal of Rehabilitation of Medicine,* **20:** 175-179.
18. Bartlett M.D., Wolf L.S., Shurtleff D.B., Stahell L.T. (1985): Hip flexion contractures a comparison of measurement methods. *Archives of Physical Medicine and Rehabilitation,* **66:** 620-625.
19. Basmijian J.V. (1958): Electro myograph of ilio-psoas. *The Anatomical Record,* **7:** 127-132.
20. Baumann J.U. (1980): Hamstrings lengthening in C.P. *International Orthopedics,* **3:** 305-309.
21. Bell D.F. (1988): Brace treatment for symptomatic Spondylliosthesis. *Clinical Orthopedics,* **236:** 188-192.
22. Bendix T, Beiring-Sorensen F. (1983): Posture of the trunk when sitting on forward inclining seats. *Scandinavian Journal of Rehabilitation of Medicine,* **15:** 197-203.
23. Bendix T., Hagber G.M. (1984): Trunk posture and load on trapeziuos muscle while sitting at sloping desks. *Ergonomics,* **27:** 873-882.
24. Bennet H.E. (1994): A study of school posture and sitting . *Elementary School Journal,* **26:** 50-57.
25. Bennett D.L., Gillis D.K., Portney L.G., Romanow M., Sanchez S. (1990): Comparison of integrated electromyography activity and lumbar curvature during standing and during sitting in three chairs. *Physical Therapy,* **70:** 397-398.
26. Bernard-Bonnin A.C., Gilbert S., Rousseau E., Masson P., Maheux B. (1991): Television and the 3-to 10-year-old child. *Pediatrics,* **88:** 48-54.
27. Bernhardt M., Bridwell K.H. (1989): Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spine and thoracolumnbar junction. *Spine*; **14:** 717-721.
28. Biering-Sorensen F. (1984): Physical measurements as risk indicators for low back trouble over a one year period. *Spine,* **9:** 106-119.
29. Boone D.C, Azen S.P. (1979): Normal range of motion of joints in male subjects. *Journal of Bone and Joint Surgery,* **61-A:** 756-759,
30. Brandt T. (Ed.). (1990): *Disorders of posture and gait*. FRG, Munchen.
31. Bridger R., Wilkinson D., Van H.T. (1989): Hip joint mobility and spinal angles in and different sitting posture. *Human Factor,* **31:** 229-242.

32. Bridger R.V., Eisenhart C., Henneberg M. (1989): Effect of slope and hip flexion on spinal angles in standing and sitting. *Human Factor,* **31:** 679-688.

33. Cachera M., Rolland F. (1993): Body composition during adolescence: methods, limitations and determinants. *Hormone Research,* **39:** Supplementum 3., 25-40.

34. Cady LD. (1979): Strenght and fitness and subsequent back injuries in fire fithers. *Journal of Occupational Medicine,* **4:** 269-272.

35. Carlsoo S. (1961): The static muscle load in different work position: An electromyography study. *Ergonomics,* **8:** 292-294.

36. Carmeli A. (1993): *The anatomy of the motor system.* Carmeli Publisher, Ohalo, Israel, (in Hebrew).

37. Carr A.J., Jefferson R.J., Turner S. (1991): An analysis of normal back shape measured by ISIS scanning. *Spine,* **16:** 656-659.

38. Central Bureau of Statistics (1996): *Statistical abstract of Israel 1996.* The Central Bureau of Statistics, Jerusalem, (in Hebrew).

39. Christie H.J., Kumar S., Warren S.A. (1995): Postural aberrations in low back pain. *Archives of Physical Rehabilitation,* **76:** 218-224.

40. Clarkson H.M., Gilewich G.B. (1989): *Musculoskeletal assessment: Joint range of motion and manual muscle strength.* Williams and Wilkins Publisher, Baltimore.

41. Corlett E.N, Bishop R.P. (1976): A technique for assessing postural dis confort. *Ergonomics,* **19:** 175-182.

42. Daniels L. (1972): *Muscle testing*. W.B. Saunders Co., Philadelphia.

43. Day J.W. (1984): Effect of pelvic tilt on standing posture. *Physical Therapy,* **64:** 510-516.

44. Dauer V.P. (1983): *Dynamic physical education for elementary school children.* Burgess Publisher Co., Minneapolis.

45. Decker K. (1984): Man and the chair - radiography of the lumbar vertebrae and pelvis in sitting osition. *Radiology,* **24:** 133-138.

46. Duggleby T., Kumar S. (1997): Epidemiology of juvenile low back pain: a review. *Disability and Rehabilitation,* **19:** 505-512.

47. Durant R.H., Baranowski T., Johnson M., Thomphson W.O. (1994): The relationship among television watching, physical activity, and body composition of young children. *Pediatrics,* **94:** 449-455.

48. Ekstrand J., Wiktorsson M., Ober G.B., Gillquist J. (1982): Lower extremity goniometric easurements: a study to determine their reliability. *Archives of Physical Medicine and Rehabilitation,* **63:** 171-175.

49. El-Bohy A.A., King A. (1986): Intervertebral disc and facet contact pressure in axial torsion. In: Lantz S.A., King A. (Eds.): *Advances in bioengineering,* American Society of Mechanical Engineers, New York, 26-27.
50. Embrey D., Edicott J., Glenn T. (1983): Developing better postural tone in grade school children. *Physical Therapy,* **3:** 6-10.
51. Ernst E. (1992): Medically correct sitting, does it exist? *Wiener Medizinische Woc-henschrift,* **142:** 513-516.
52. Fairbank J.C.T., Pynsent P.B., Poortvliet J.A.V., Phillips H. (1984): Influence of anthropometric factors and joint laxity in the incidence of adolescent back pain. *Spine,* **9:** 461-464.
53. Farfan HF.(1975): Muscular mechanism of the lumbar spine and the position of power and efficiency. *Orthopedic Clinics of North America,* **6:**135-138.
54. Feldenkrais M. (1950): *Body and mature behavior.* Alef Publisher, Tel Aviv.
55. Fisk JW. (1979): The passive hamstrings stretch test; Clinical Evaluation. *New Zealand Medical Journal,* **89:** 209-211..
56. Fisk J.W., Baigent M.L. (1981): Hamstring tightness and scheuermann's disease. *American Journal of Physical Medicine,* **60:** 122-125.
57. Flint M.M. (1963): Lumbar posture: A study of roentgenographic measurement and the influence of flexibility and strength. *Research Quarterly,* **34:** 15-20.
58. Floyd W.F., Ward J.S. (1976): Anthropometric and physiological consider-ations in school, office and factory in sitting posture. *Ergonomics,* **12:** 132-139.
59. Floyd W.F., Silver P.H.S. (1955): The function of the erectors spinae muscles in certain movements and postures in man. *Journal of Physiology,* **129:** 184-188.
60. Gajdosik R.L, Albert C.R, Mitman J.J. (1994): Influence of hamstring length on the standing position and flexion range of motion of the pelvic angle, lumbar angle, and thoracic angle. *Journal of Orthopedic and Sport physical Therapy,* **20:** 213-219.
61. Gautier J., Morillon P., Marcelli C. (1999): Does spinal morphology influence the occurrence of low back pain? A retrospective clinical, anthropometric, and radio-logical study. *Review du Rhumatism (English edition),* **66:** 29-34.
62. Gilad Y. (1982): *The ergonomics and biomechanical aspects of the back system*. Techniun, Israel, (in Hebrew).
63. Goeken L.N, Hof A.L. (1993): Instrumental straight-leg raising: results in healthy subjects. *Archives of Physical Medicine and Rehabilitation,* **74:** 194-203.
64. Gram M.C., Hasan Z. (1999): The spinal curve in standing and sitting postures in children with idiopathic scoliosis. *Spine,* **24:** 200-201.
65. Gunzburg R. (1999): Low back pain in a population of school children. *European Spine Journal,* **8:** 439-443.

66. Haas H. (1999): *The culture of leisure time in Israel, 1998. Panim* **10:** 107-139, (in Hebrew).

67. Hanne Paparo N. (1982): *Posture, body measurements and physical fitness of children aged 6-7.* Wingate Institute Publisher, Netanya.

68. Harreby M., Nygaard B., Jessen T., Larsen E., Store-Paulsen A., Lindahl A., Fisker I., Leagaard E. (1999): Risk factors for low back pain in a cohort of 1389 Danish school children: An epudemiologic study. *European Spine Journal,* **8:** 444-450.

69. Harreell J.S., Gansky S.A., Bradley C.B., Mcmurray R.G. (1997): Leisure time activities of elementary school children. *Nursing Research,* **46:** 246-253.

70. Harrison D.D., Harrison S.O., Croft S.O., Harrison D.E., Troyanovich S.J. (1999): Sitting biomechanics part 1: review of the literature. *Journal of Manipulative Physical Therapy***, 22:** 594-609.

71. Heather J. (1995): Postural aberrations in low back pain. *Archives of Physical Medicine and Rehabilitation,* **76:** 218-224.

72. Hellsing A.L, (1988): Tightness of hamstring- and psoas major muscles. A prospective study of back pain in young man during their military service. *Upsala Journal of Medical Sciences,* **93:** 267-76.

73. Hennessey L., Watson A.W. (1993): Flexibility and posture assessment in relation to hamstring injury. *British Journal of Sports Medicine,* **27:** 243-246.

74. Hines T.F. (1980): Posture, therapeutic exercise. In: Licht S. (Ed.): *Backpain Solutions*. M.D. Williams and Wilkins, Baltimore, 486-515.

75. Ilan S. Yekutiel M. (1978): *Posture of school children in Ramat Gan*. Bar Ilan Pubisher, Israel, (in Hebrew).

76. Iwakami T. (1987): Studies on the posture of the healthy Japanese child - a classification of posture and their relation to changes in different age groups. *Nippon Seikeigeka Gakkai Zasshi,* **61:** 185-196.

77. Jackson R.P., Mcmanus A.C. (1994): Radiographic analysis of sagittal plane align-ment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. *Spine,* **19:** 1611-1618.

78. Johnson Barry L., Nelson Jack K. (1986): *Practical measurements for evaluation in physical education.* Burgess Publishing, Salem, Ohio.

79. Jozwiak M., Pietrzak S., Tobjasz F. (1997): The epidemiology and clinical manifestations of hamstring muscle and planter foot flexor shortening. *Review of Medical Child Neurology,* **39:** 481-483.

80. Katz K. (1992): Normal ranges of popliteal angle in children., *Journal of Pediatric Orthopeadics,* **12:** 229-231.

81. Kaufman R. (1985): Characteristic of TV viewers among children and adolescence in Israel. *Otot*, **6:** 32-34. (in Hebrew).

82. Keats S., Morgese A.N. (1969): Excessive lumbar lordosis in ambulatory spastic children *Clinical Orthopaedics,* **65:** 130-137.

83. Kendall F.P., McCreary E.K., Provance P.G. (1993): *Muscles testing and function. International Edition with Posture and Pain.* Williams and Wilkins, Baltimore, Maryland.

84. Kendall H,O. (1971):, *Muscles testing and function.* Williams and Wilkins, Baltimore.

85. Klausen K.(1986): The shape of the spine in young male with and without back complains. *Clinical Biomechanics,* **1:** 81-84.

86. Kujala U.M., Taimela S, Viljanen T. (1999): Leisure physical activity and various pain symptoms among adolescents. *British Journal od Sports Medicine,* **33:** 325-328.

87. Lambrinudi C. (1934):, Adolescent and senile kyphosis. *The British Medical Journal,* **2:** 800-804.

88. Lamish D, Libs T. (1999): *Children and youth in changing communication environment in Israel*. Hebrew University. Jerusalem, 1999. (in Hebrew).

89. Levine D., Whittle M.W. (1996): The effects of pelvic movement on lumbar lordo-sis in the standing position. *Journal of Orthopedic and Sport Physical Therapy,* **24:** 130-135

90. Levy M. (1986): *The aspects of postural deviations and backache among children in Petah-Tikva.* Hebrew University, Jerusalem, (in Hebrew).

91. Levy M. (1993): Backache in junior high school students**.** Unpublished University Doctoral Thesis, Magyar Testnevelési Egyetem, Budapest.

92. Li Y., McClure P.W., Pratt N. (1996): The effect of hamstring muscle stretching on standing posture and on lumbar and hip motions during forward bending. *Physical Therapy,* **76:** 836-849.

93. Lindh M. (1980): *Biomechanics of the lumbar spine. In basic Biomechanics of the skletal system.* Lea and Febiger, Philadelphia, 255-290.

94. Lohman TG. (1988): *Anthropometrics Standardization-reference manual.* Human Kinetics Books, Champaign, Illinois.

95. Lord M.J., Small J.M,, Dinsay J.M., Watkins RG. (1997): Lumbar lordosis. Effects of sitting and standing. *Spine,* **22:** 2571-2574.

96. Ludwig NG, Hof L. (1991): Instrumental straight leg raising: a new approach to Lasegue's test. *Archives of Physical Medicine and Rehabilitation,* **72:** 959-966.

97. Macnab I. (1990): *Bachache.* Williams and Wilkins, Baltimore.

98. Magora A. (1975): Investigation of the relation between low back pain and occupation. *Scandinavian Journal of Rehabilitation of Medicine,* **7:**146-151.

99. Magora A., Schvartz A. (1976): Relation between the low back pain syndrome and X-ray findings. *Scandinavian Journal of Rehabilitation of Medicine,* **8:** 115-125.

100. Malcolm J. (1976): *The lumbar spine and back pain.* Pitman Medical Publishers, London.

101. Malina R.M., Bouchrd C. (1991): *Growth, maturation, and physical activity.* Human Kinetics Publishers inc., Champaign, Illinois.

102. Mandal A.C. (1982): The correct height of school forniture. *Human Factors,* **24:** 257-269.

103. Mckenzie R.A. (1981): *The lumbar spine. Mechanical diagnosis and therapy.* Spinal Publishers. Waikanae.

104. Melis H. (1987): *Physical activity and backache.* Bar-Ilan University, Physical Education Department, Ramat-Gan, (in Hebrew).

105. Mellin G. Poussa M. (1992): Spinal mobility and posture in 8- to 16- year old children. *Journal of Orthopedic Research,* **10:** 211-216.

106. Mellin G. (1988): Correlations of hip mobility with degree of back pain and lumbar spinal mobility in chronic low-back pain patients. *Spine,* **13:** 668-670.

107. Mellin G., Poussa M. (1992): Spinal mobility and posture in 8-to 16-year-old children. *Journal of Orthopedic Research,* **10:** 211-216.

108. Mierau D.R., Cassidy J.D., Hamin T. (1979): Sacroiliac joint dysfunction and low back pain in school aged children. *Journal of Manipulative and Physiological Therapeutics,* **2:**146-150.

109. Mierau D. (1989): Low back pain and straight leg raising in children and adolescents. *Spine,* **14:** 526-528.

110. Milgrom C., Finestone A., Lev B., Wiener M., Floman Y. (1993): Overexertional lumbar and horacic back pain among recruits: a prospective study of risk factors and treatment regimens. *Journal of Spinal Disorders,* **6:** 187-193.

111. Million R. (1982): Assessment of the progress of the back pain patient. *Spine,* **7:** 204-212.

112. Milne R.A, Mierau D.R. (1979): Hamstrings distensibility in the general population: Relationship to pelvic and low back stress. *Journal of Manipulative and Physiological Therapeutics*, **2:** 146-150.

113. Mundale M.O., Hislop H.J., Rabideau R.J., Kottke F.J. (1956): Evaluation of extension of the hip. *Archives of Physical Medicine and Rehabilitation,* **12:** 75-80.

114. Myers L., Strikmiller P.K., Webber L.S., Berenson G.S. (1996): Physical and sedentary activity in school children grades 5-8: the Bogalusa heart study. *Medicine and Science in Sports and Exercise,* **28:** 852-859.

115. Nachemson A. (1990): Exercise, fitness and back pain. In: Couchard C., Shephard R.J., Stephens, T. (Eds.): *Exercise Fitness and Health. A Consensus of Current Knowledge*. Human Kinetics Publishers, Inc., Champaign, Illinois.

116. Nachemson A.L. (1963): The influence of spina movments on the lumbar intradiscal pressure and on the tensile stresses in the annulus fibrosus. *Acta Ortopaedica Scandinavica,* 33: 183-187.

117. Nachemson A.L. (1966): Electromyography studies on the vertabral portion on the psoas muscle. With special reference to the stabilizing function of the lumbar spine. *Acta Ortopaedica Scandinavica,* **37:** 177-200.

118. Nachemson A.L., Evans J.H. (1968): Some mechanical properties of the third hu-man lumbar interlaminar ligament. *Journal of Biomechanics,* **1:** 211-212.

119. Nachemson A.L., Elfstorm G. (1970): *Intravital dynamic pressure measurements in lumbar discs: A study of common movements, maneuvers and exercises.* Almqvist and Wiksell Publishers,. Stockholm.

120. Nachemson A.L. (1975): Towards a better understanding of low-back pain: A review of the mechanics of the lumbar disc. *Rheumatology and Rehabilitation* **14:** 129-143.

121. Nachemson A.L., Schultz A.B., Berkson M.H. (1979): Mechanical properties of human lumbar spine motion segments. Influence of age, sex, disc level and dege-neration. *Spine,* **4:** 1-5.

122. Nachemson A.L. (1981): Disc pressure measurement . *Spine,* **6:** 93-97.

123. Nachemson A. (1968): The possible importance of the psoas muscle for stabilization of the lumbar spine. *Acta Orthopaedica Scandinavica,* **39:** 47-57.

124. Nissinen M. (1995): Spinal posture during pubertal growth. *Acta Paediatrica,* **84:** 308-312.

125. Norris C.M. (1995): Spinal stabilization: Muscle imbalance and low back. *Physio-therapy,* **81:** 127-139.

126. Ochipinti T., Colombini D. (1985): Seating posture; Analysis of lumbar stress with upper Limbs supported. *Ergonomics,* **28:** 1333-1346.

127. Olsen T.L., Anderson R.L., Dearwater S.R., Kriska A.M., Cauley J.A., Aaron D. J. Laporte R.E. (1992): The epidemiology of low back pain in an adolescent population. *American Journal of Public Health,* **82:** 606-608.

128. Oxford HW. (1976): Anthropometric data for educational chairs. Sitting posture. Proceeding of the Symposium. Taylor and Francis Publishers,. London, 26-47.

129. Panjabi M.M., Krag M.H., White A.A., Southick W.O. (1977): Effect of preload on load displacement curves of the lumbar spine. *Orthopedics Clinical of North America,* **88:** 181-189.
130. Paterson J.K. (1990): *Back pain: an international review*. Kluwer Academic Pub-lisher, New York.
131. Pope M.H., Bevins T., Wilder D.G., Frymoyer J.W. (1985): The relationships be-tween anthropometric, postural, muscular, and mobility characteristics of males ages 18-55. *Spine,* **10:** 644-648.
132. Raine S., Twomey L. (1994): Attributes and qualities of human posture and their relationship of dysfunction or musculoskeletal pain. *Physical Rehabilitation of Medicine,* **6:** 409-437.
133. Raskin H. (1990): *Physical activity and publich health: prevention, promotion and rehabilitation*. Gil Pubisher, Wingate Institut, Netanya, (in Hebrew).
134. Raskin H. (1990): *Cultural aspects of recreation and leisure time: principles, attitudes and patterns*. Part 2, Gil Publisher, Wingate Institute, Netanya, (in Hebrew).
135. Reilly T. (1990): Physiological strain unique to field Hokey. *Journal of Sport Me-dicine,* **30:** 142-146.
136. Reimers J. (1993): The incidence of hamstring shortness in Danish children 3-17 years old. *Journal of Pediatric Orthopaedics,* **2:** 173-175.
137. Reis J., Flegel M., Kennedy C. (1996): An assessment of lower back pain in young adults: implications for college health education. *Journal of American College Health,* **44:** 289-293.
138. Roaas A., Andersson G.B.J.(1982): Normal range of motion of the hip, knee and ankle joints in male subjects, 30-40 years of age. *Acta Orthopaedica Scandina-vica,* **53:** 205-208.
139. Rolander SD. (1966): Motion of the lumbar spine with special referece to the sta-bilizing effect of posterior fusion. An experimental study on autopsy specmens. *Acta Ortopaedica Scandinavica,* **90:** 140-144.
140. Salen M., Hirschfeld H., Olsson A. (1999): Forward leaning reaching task in sit-ting (FLRS): a new measure for clinical evaluation of hamstring length in child-ren. *Physiotherapeutic Research International,* **4:** 262-277.
141. Salminen J.J. (1984): The adolescent back. *Acta Ortopaedica Scandinavica,* Supplementum, 3. 120-122.
142. Cohen S.G. (1976): *TV viewing of 9 and 11 years old*. Communication Institute, Hebrew University, Jerusalem, (in Hebrew).
143. Schroder I. (1997): Variations of sitting posture and physical activity in different types of school furniture. *Collegium Antropologicum,* **21:** 397-403.

144. Shneler R. (1984): TV and leisure time. *Iunim Bahinuch,* **39:** 137-156. (in Hebrew).
145. Stokes I.A., Abery J.M. (1980): Influence of the hamstring muscles on lumbar spine curvature in sitting. *Spine,* **5:** 525-528.
146. Svenningsen S., Terjesen T., Auflem M., Berg V. (1989): Hip motion related to age and sex. *Acta Orthopaedica Scandinavica,* **60:** 97-100.
147. Taimela S., Kujala U.M., Salminen J.J., Viljanen T. (1997): The prevalence of low back pain among children and adolescents. A nationwide, cohort-based questionnaire survey in Finland. *Spine,* **22:** 1132-1136.
148. Tal P. (1996): *The attention paid by children in 4th, 5th and 6th grades in regard to TV, Reading and Computer*. Tel Aviv University, (in Hebrew).
149. Toppenberg R.M., Bullock M.I. (1986): The interrelation of spinal curve, pelvic tilt and muscle length in the adolescent female. *The Australian Journal of Physiotherapy,* **32:** 35-41.
150. Troussier.B., Davoine.P., de Gaudemaris.R., Fauconnier J., Fheli X. (1994): Back pain in school children a study among 1178 pupils. *Scandinavian Journal of Re-habilitation of Medicine,* **26:** 143-146.
151. Tuncer A.M., Yalcin S.S. (1999): Multimedia and children in turkey. *The Turkish Journal of Pediatrics,* **41:** Supplementum, 27-34.
152. Tuzun C., Yorulmaz I., Cind A.S.A., Vatan S. (1999): Low back pain and posture. *Clinical Reheumatology,* **18:** 308-312.
153. Vedantam R., Lenke L.G., Keeney J.A., Bridwell K.H. (1998): Comparison of standing sagittal spinal alignment in asymptomatic adolescents and adults. *Spine.* **23:** 211-215.
154. Viry P., Creveuil C., Marcelli C. (1999): Nonspecific back pain in children. A search for associated factors in 14-year-old schoolchildren. *Review du Rhumatism (English edition),* **66:** 381-388.
155. Voutsinas S.A., Macewen G.D. (1986): Sagittal profiles of the spine. *Clinical Orthopaedics,* **210:** 235-242.
156. Wang S.S., Whitney S.L., Burdett R.G., Janosky J.E. (1993): Lower extremity muscular flexibility in long distance runners. *Journal of Orthopedic and Sports Physical Therapy,* **17:** 102-107.
157. White A.A., Panjabi M.M. (1978): *Clinical Biomechanics of the spine*. JB Lip, Philadelphia.
158. Wiles M. (1937): Postural deformities of the anteroposterior curves of the spine. *The Lancet,* **297:** 911-919..

159. Wilnner S. (1981): Spinal panthograph. A non invasive technique for describing kyphosis and lordosis in the thoraco-lumbar spine. *Acta Ortopaedica Scandinavica*, **52:** 525-529.

160. Wilnner S., Johnson B. (1983): Thoracic kyphosis and lumbar lordosis during the growth period in children. *Acta Ortopaedica Scandinavica*, **72:** 873-878.

161. Willner S. (1981): Spinal pantograph- a non-invasive technique for describing ky-phosis and lordosis in the thoraco-lumber spine. *Acta Ortopaedica Scandinavica*, **52:** 525-9,1981.

162. Willner S., Johnson B. (1983): Thoracic kyphosis and lumbar lordosis during the growth period in children. *Acta Paediatrica Scandinavica*, **72:** 873-878.

163. Woollacott M.H., Shumway-Cook A. (1989): *Development of posture and gait across life span.* University of South Carolina, Columbia.

164. Yasukouchi A., Isayama T. (1995): The relationships between lumbar curves, pel-vic tilt and joint mobility in different sitting postures in young adult males. *Appli-ed Human Science*, **14:** 15-21.

165. Youdas J.W., Garrett T.R., Harmsen S.H., Suman V.J., Carey J.R. (1996): Lum-bar lordosis and pelvic inclination of asymptomatic adults. *Physical Therapy*, **76:** 1068-1081.

166. Zacharow D. (1987): *Posture: Sitting, standing, chair design and exercise*. Charles C.T. Publishers, Springfield.

167. Zulberg G. (1993): Are there any universal standards for good posture? *Journal of Physical Education and Sport*, Wingate Institute, (in Hebrew).

APPENDIX 1

THE JERUSALEM POSTUROGRAPHY CLINIC

QUESTIONNAIRE*

This questionnaire is confidential and designed for research purposes only.

Please answer all questions as accurately and as completely as possible

Code number:

SECTION 1. - Personal data.

1. Family name: 2. First name: 3. Date of birth:
4. Place of birth: 5. Grade: 6. Sex
7. Name of school:

SECTION 2 - Back pain.

1. Have you ever suffered from back pain in the past? Yes No
2. Have you ever stopped physical activity because of back pain? Yes No
3. Have you ever been treated by a doctor for back pain? Yes No

SECTION 3 - Leisure activities.

1. Are you participating in any organized activity out of school hours? Yes No
   If "no" go to number 4.
2. If "yes" please name all your organized activities
   a) b) c) d) e)

3. a) How many times a week do you attend each activity?
   b) How long does each activity last?

4. Are you involved in non-organized physical activity during your leisure-time? Yes No

   If "yes" please name each activity
   a) b) c) d) e)

5. How long does each of your leisure-time physical activities last?
   a) a few minutes b) half an hour c) one hour d) more than one hour

6. How often do you participate in leisure-time physical activities?
   a) Every day b) Several times a week c) Several times a month.

SECTION 4 -TELEVISION VIEWING -VIDEO GAMES -CO:MPUTER

1. Do you watch television at home after school hours? Yes No
2. If"yes" How many times a week do you watch television?
a)every day b) 2-3 times a week c) once or twice a week.
3. How long in your estirnation do you spend watching television each time?
a) less than one hour b) more than one hour c) more than two hours
d) more than three hours
4. Do you play Video garnes such as Sony Play Station; Megason ;Game Boy etc.?
Yes No
5. If"yes" how many times a week do you play Video games?
a) every day b) 2-3 times a week c) once or twice a week.
6. How long in your estirnation do you spend Video games each time?
a) less than one hour b) more than one hour c) more than two hours
d) more than three ho urs.
7. Do you have a computer at home? Yes No
8. Do you use a computer? Yes No
9. If "yes", How long in your estimation do you spend at a computer each time?
a) less than one hour b) more than one hour c) more than two hours
d) more than three hours.
10. How many times a week do you use a computer?
a) every day b) 2-3 times a week c) once or twice a week.
* Translated from the original Hebrew.

PLEASE TURN OVER mE PAGE AND INDICATE nm TYPE OF SITTING POSroRE IN EACH ACTIVITY -(APPENDIX 2 -PICroRE QUESTI ONNAIRE)