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The effect of backpack load on the posture of children and its relationship to trunk muscle activity during walking on a treadmill

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The list of abbreviations

ANOVA = Analysis of variance
A/D = Analog to Digital
BMI = Body-Mass-Index
BPM = Beats per minute
BW = Body weight
CCA = Craniocervical angle
Cm = Centimeter
CMRR = Common mode rejection ratio
CV = Conduction velocity
DP = Dorsal pain
DST = Double support time
DBP = Diastolic blood pressure
e.g. = For example
EMG = Electromyography
FEV1 = Forced expiratory volume
FF or IIb = Fast-twitch, fatigable
Fig. = Figure
FR or IIa = Fast-twitch, fatigue-resistant
FFT = Fast Fourier transform
FVC = Forced vital capacity
GRFs = Ground reaction forces
H = Hypothesis
HR = Heart rate
Hz = Hertz unit of frequency in cycles per second
IEMG = Integrated electromyography
Kg = Kilogram
LBP = Low back pain
LT = Lower trapezius
M = Mean
MNF = Mean power frequency
MPS = Midcervical paraspinals
MRI = Magnetic resonance imaging
MU = Motor unit
MUP = Motor unit potential (same as MUAP)
MUAP = Motor unit action potential
MV = Minute ventilation
MVC = Maximum voluntary contraction
RA = Rectus abdominis

RF = Respiratory frequency
RMS = Root mean square
ROM = Range of motion
RR = Respiratory rate
RPE = Rating of perceived exertion
S or I = Slow-twitch
SBP = Systolic blood pressure
SCM = Sternocleidomastoid
SD = Standard deviation
sEMG = Surface electromyography
SST = Single support time
Tab. = Table
TFL = Trunk forward lean
UT = Upper trapezius
VO2 max = Maximal oxygen uptake
VT = Tidal volume
Ω = Ohm
µV = Microvolt

1 Introduction

A common phenomenon is that most school children carry heavy backpacks for a long period of time. The primary reason is that they are usually forced to carry homework between school and home. The ideal load carrying system would be one that did not disturb the body’s natural posture, balance and movements. The load must be dispersed onto the skeletal structure in a balanced way and not put strain on the body in any direction.

Not only do oversized backpacks of school children dangerously strain their bodies but also increase the risks of tripping up or down stairs, getting stuck in narrow pathways, or unconsciously hurting other pedestrians. When a backpack with a load is added to the trunk, an automatic postural modification to restore balance is triggered. While a heavy load is carried on back, the body responds by regulating its posture, and the trunk forward lean increases (Li & Hong, 2004). Everywhere in the world, doctors, parents and educationists are worrying about the weight that children have to take and the influences it has on their backs, shoulders, and general health.

In various countries, backpacks are identified with students, and are a primary means of carrying materials to and from school. The purchase of an appropriate, fashionable and effective backpack is a crucial back-to-school ritual for many students (Voll & Klimt, 1977; Pascoe et al., 1997; Sheir-Neiss et al., 2003; Forjuoh et al., 2004; Al-Hazzaa, 2006). In regards to the appropriateness of backpacks, however, reports from European and Asian countries have found that most students carry weights that are more than 10 % of their body mass, with many backpacks weighing over 20 % (Sander, 1979; Negrini & Carabalona, 2002).

Several investigations on backpack related injuries and lower back pain have been reported. Studies have been reporting that the factors associated with back pain have included age, a family history of back pain, back injury, high-level participation in sports, spinal alignment disorders and backpack weight. Research on adolescents show that low back pain appears more commonly, and some physicians and therapists have noted that the rate of adolescent low back pain is approaching that of adults (Salminen et al., 1992; Andersson, 1999; Maniadakis et al., 2000; Clifford & Fritz, 2003). The cumulative prevalence of back pain in children and adolescents from carrying backpacks has ranged across studies from 20 to 60 % (Burton et al., 1996; Taimela et al., 1997; Troussier et al., 1999; Whittfield et al., 2001; Sheir-Neiss et al., 2003). Studies have explained that prolonged loading of the spine raises the risk of lower back pain in adolescents, and the most common contributing loads are from backpacks (Negrini et al., 1999). Researchers have shown that wearing heavy backpacks could also result in changes in body posture and muscle activity (Goh et al., 1998; Li & Hong, 2001; Hong & Cheung, 2003; Shasmin et al., 2007). Orloff and Rapp (2004) showed that upright posture associated with the lumbar position of the load could be associated with increased curvature of the spine and when subjects do not balance the weight of the backpack with trunk flexion.

Previous examination on adolescents has shown that body posture is affected by placement of a loaded backpack (Charteris, 1998; Grimmer et al., 1999; Hong et al., 2000). Furthermore, the upper trapezius muscle has been the object of many electromyography studies for its role in work-related musculoskeletal disorders in the neck-shoulder region (Madeleine et al., 1999; Larsson et al., 2001; Westgaard et al., 2001; Schulte et al., 2006).

Numerous researches have been completed to determine the influences of backpack weight on the body posture both while level walking as well as while walking on a treadmill. The average weight of backpacks reported in different studies changes from 4.0 to 7.7 kg (Simbruner et al., 1990; Casey et al., 1996) with the mean weight of the backpack being about 10 % to 20 % of children's body weight (Pascoe et al., 1997; Whittfield et al., 2001). With many schoolchildren carrying heavy loads, sometimes in excess of 30 % of body weight, (Negrini et al., 1999; Negrini & Carabalona, 2002), the future health of these children would benefit from an improved method of carrying the books and other essentials of modern schooling.

A review of pertinent literature reveals that the vast majority of studies on backpacks have been conducted with adults. Furthermore, children are physically different from adults in size, proportion, and musculoskeletal maturity. While previous studies focused on a selection of either physiological or biomechanical parameters, this study focuses on both changes in physiological factors (surface electromyography EMG) of three muscles and biomechanical, kinematic body postures while children walked on a treadmill under different load conditions.

This study investigates two new variables in relation to backpack carrying behavior: the distance from the floor to the earlobe joint (height) and the step length of children when the weight of the load that the children carry is changed. It also records both trunk muscle activity and kinematic body postures with different quantities of load carriage on children: one without a backpack and three while carrying backpacks that have a weight of 10 %, 20 % and 30 % of the child's total body weight (BW).

The aim of this study is to analyze how different weight loads affect the general body posture of the children.

To find out how the different load conditions affected the general body postures, we, through electromyography and video analysis, found out:

- The kinematic body postures and also how these variables in turn possibly affect the body posture during a stride length.
- The electromyographic parameters (muscle activity and muscle fatigue) of back muscles.
- The ratio between the weight of the child and the child’s backpack.

2 Theoretical bases and literature

It would be better to say that our survival depends on the act of moving. Our moving is essential for performing the duties of daily living as well as experiencing the joy and elation of dance, physical exercise, and competitive sports. As British author Laurence Sterne notes ,,So much of motion, is so much of life, and so much of joy‘‘(Sterne, 1980, p. 345). Correct posture and balance are essential for the well-organized performance of both simple daily tasks and more complex movement patterns. On the other hand incorrect posture and loss of balance can result in poor performance, injury, or even death.

Posture can be described straightforwardly as the alignment, or position, of the body and its parts or more expansively as ,,a position or attitude of the body, the relative arrangement of body parts for a specific activity, or a characteristic manner of bearing one's body‘‘(Smith et al., 1996, p. 401).

Balance can be explained as the maintenance protection of postural stability, or symmetry, and frequently is utilized synonymously with the term expression postural control. Control of the body's alignment is essential to maintain a certain posture or change from one posture to another (Whiting & Rugg, 2006, p. 143). This control of posture is called balance. In fact for all tasks we perform, posture and balance are certainly essential. Improper posture or loss of balance can negatively affect performance, decrease movement capability and increase the risk of injury (Whiting & Rugg, 2006, pp. 142-143).

2.1 Body posture

The combination of muscles, ligaments, joints and skeletal system is understood under body posture. The spine plays a supporting function in particular. The goal is that the body - with the participation of active and passive motion apparatus-is in a stable balance and maintain upright.

König points out what the usual posture between a maximum of relaxed and a maximum of upright posture is (König, 1999, p. 370). In addition to the biomechanical processes, the posture is also influenced by psychological state.

2.1.1 The posture types by Staffel

The body posture plays a definitive role in balancing loads on the back. To calculate deviations and variations of it, a normal posture has been defined. For the first time such a posture types were created by Staffel in 1889. He differentiates in the normal spine, Kyphose back, Flat back, Lumbar lordosis back and Kypholordotic back.

Staffel describes the normal body from an aesthetic perspective, thus defining a normal posture as „posture that the well-built, strong man involuntarily bears on display, and in which the specific human expresses the most characteristic and typicality“(Staffel, 1889, p. 12).

In the analysis using schematic drawings in the sagittal direction, a body is in a normal posture when the spine is in a so-called physiological oscillation in double-S shape, the neck one cervical lordosis and has the head on the trunk or resting on the neck, without it being moved forward. The thoracic spine is in a normal kyphosis of the lumbar spine in a normal lordosis, the normal posture is a prerequisite for a strong muscle corset. Crucial is also the position of the pelvis.

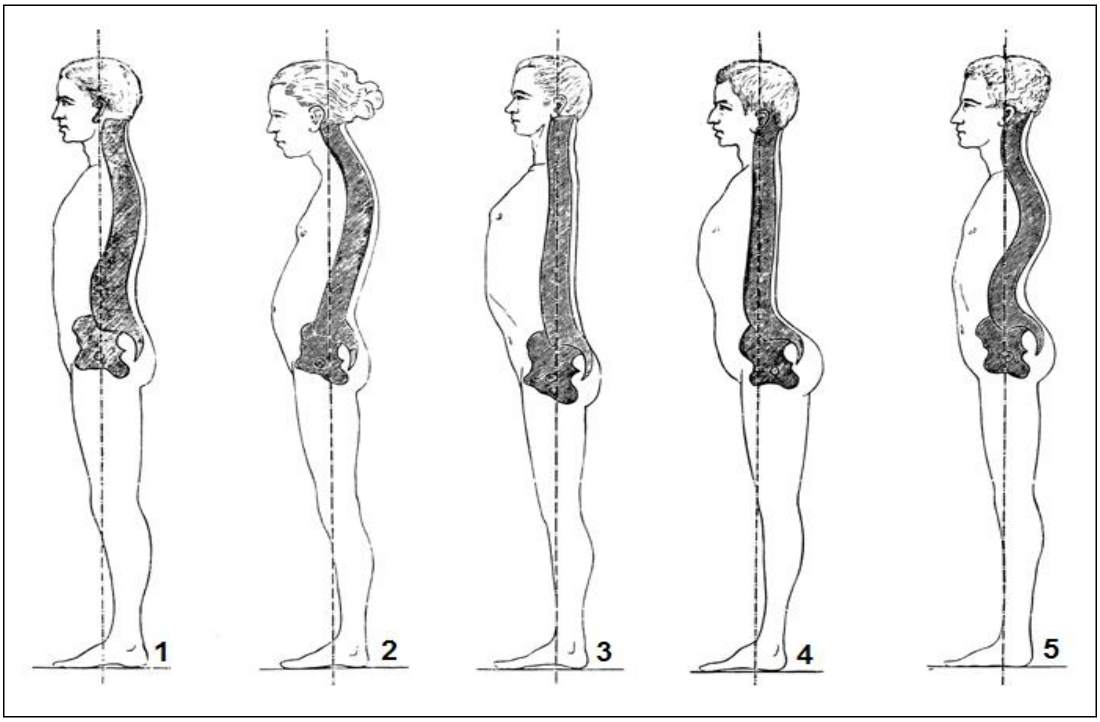


Figure 1: The different posture types by Staffel: Normal back (1), Kyphose back (2), Flat back (3), lumbar lordosis back (4), Kypholordotic back (5) by [Adapted from Staffel, 1889, as cited in Wydra, 2004, p. 6].

To date, the model of Staffel is used to describe deformations of the spine. There is therefore an increase in kyphosis of the thoracic kyphosis without concomitant pelvic tilt forward (with increased lordosis).

This bad posture can be found both in muscular e.g. lack of exercise as well as chronic conditions or sport, e.g. common in tennis players.

During a Kypholordotic a Kyphose back with increased lumbar spine in anterior tilt of the pelvis is existent. The pelvis tilt is often caused by weak abdominal muscles or there exist other imbalances in the pelvis muscles to begin with. Causes may be the biomechanical factors such as the backward shift of the acetabulum, spondylolisthesis, or contracture of the hip flexors muscles. A flat back is when the sagittal spine vibration is flattened and simultaneously diagnosed pelvic alignment can be caused by a contracture of the hip extensors (Ischiocrurale muscles). Mostly this poor posture is based on family history. During a Lumbar Lordosis, back tilt of the pelvis is forward and increasing of the inner curvature of the lumbar lordosis is located forward in the direction of the abdomen. The pelvic tilt is caused by weakly trained stomach muscles. In addition, there is tension or shortening of the hip flexors and back muscles (lumbar-iliac muscle, muscles of front thigh muscles) and the back muscles in the lumbar spine.

2.1.2 The posture test by Matthiass

While Fröhner is recording the posture, the Matthiass test is used to assess the posture efficiency (Matthiass, 1966). The holding force of the trunk muscles is also visually recorded, for which the test subjects stand in a straight posture and are asked to position themselves at maximum straightness. In this active posture, they stretch out their arms horizontally in front of the body.

The subjects close their eyes and are observed over 30 seconds of time, to see to what extent they can stay upright. The stretching of the arms causes the center of gravity to shift forward. Before this tilt of the upper body, it must compensate for the trunk stabilizing muscles which are tense. Muscle weakness occurs when the arms are raised above the front to reduce the lever arm, or if the subject tries to center the body's center of gravity back over the feet of space, so that the shoulders are moved behind the hip joint axis. The degree of posture weakness is the difference between the first recording at the beginning of the examination and at the end.

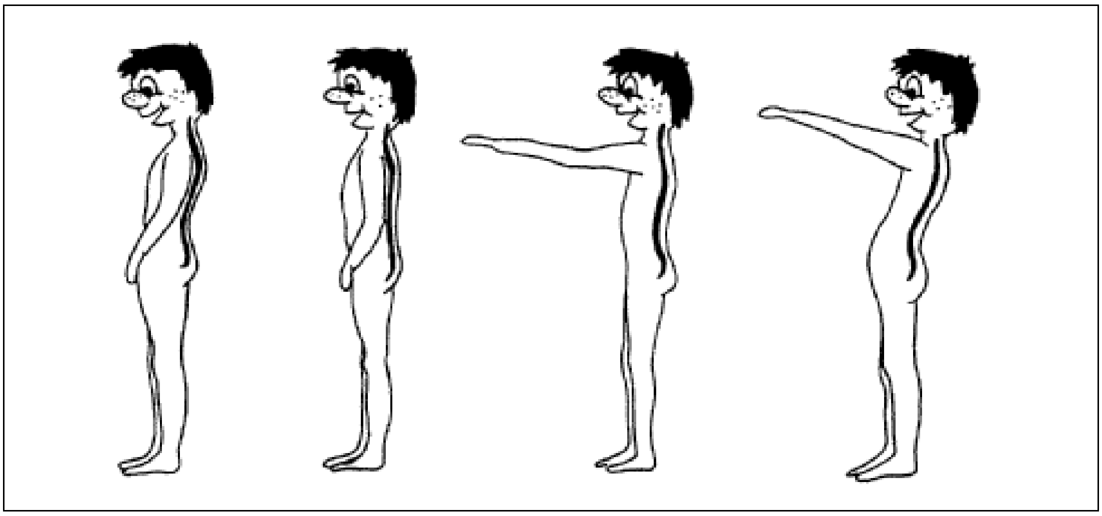


Figure 2: The „Armvorhaltetest“by Matthiass (Kollmuss & Stotz 1995, p. 25).

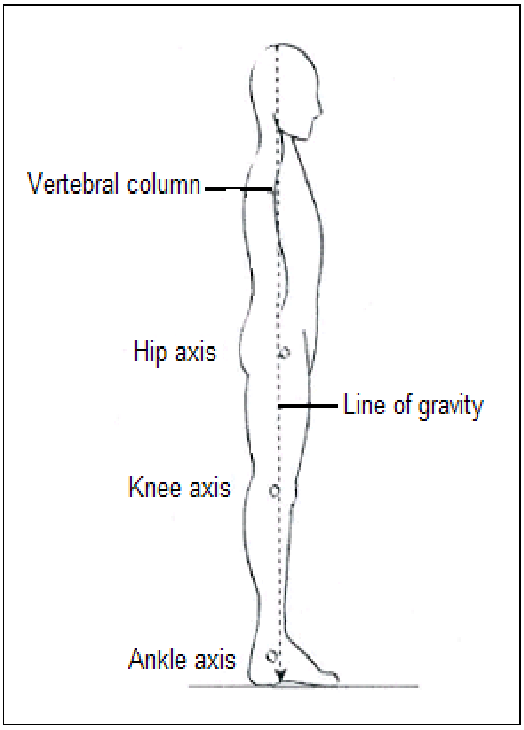
Meanwhile, the validity of the Matthiass test is being challenged, as Klee (1994, p. 166) suggest that the tested attitude change is not related to the back muscles and just slightly to train the abdominal muscles.

2.1.3 Types of posture

Since childhood, most of us have been obtaining postural counsel. Parents warn their children to stand up straight and pull your shoulders back. Teachers instruct their students to sit tall and tell them don't lean back in your chair. These cautions try to persuade us to keep good posture. They also suggest several different types of posture (Whiting & Rugg, 2006, pp. 143-147).

- Static postures (standing, sitting, lying)
- Dynamic posture

Standing posture: While the concept of a normal posture can be explained as a single best posture, due to the variability in anatomical structure and physiological function, no single posture can be recommended for everyone. Normal posture depends on different factors, including body type, joint structure and laxity, and muscular strength. In upright standing, these characteristics include the following:



- Head is held in a straight position.
- Body weight is distributed evenly between the two feet.
- From a frontal view, bilateral structures (e.g., iliac crests, acromion processes) are at the same horizontal level.
- From a sagittal plane (side) view, the line of gravity passes posterior to the cervical and lumbar vertebrae, anterior to the thoracic vertebrae, posterior to the hip joint, and anterior to the knee and ankle joints.
- Appropriate spinal curvatures are apparent in the cervical, thoracic, and lumbar regions.

Figure 3: The line of gravity during standing [Adopted from Whiting & Rugg, 2006, p. 144].

Sitting posture: As many people experience long hours in a seated position, correct sitting postures is essential in decreasing spinal loading and the possibility of injury. Perfect sitting posture can be described by the ischial tuberosities acting as the major base of support, anterior pelvic tilt (which maintains appropriate lumbar curvature), spinal support provided by a slightly inclined seatback, and the feet contacting the floor to support the body's weight (Whiting & Rugg, 2006, p. 145).

Lying posture: While resting or sleeping, we assume a lying posture due to the fact that it is the least physiologically demanding. Basic lying postures include lying face down (prone), lying face up (supine), and lying on one side, each with advantages and disadvantages. Also, sleeping on too soft a surface can lead to problems, including excessive lumbar flexion when in a supine position, exaggerated lumbar extension in a prone posture (Whiting & Rugg, 2006, pp. 146-147).

Dynamic posture: Dynamic posture is the posture of action while walking, running, jumping, throwing, and kicking. Each of these movements requires its own repeated changes in the position of the trunk and extremities that must be controlled to keep the dynamic equilibrium required for task completion (Whiting & Rugg, 2006, pp. 147).

2.1.4 The posture Index by Fröhner

Another method of external observation of posture weakness was developed by Fröhner (1998) in the form of a posture index. For this purpose, the subjects are recorded using an upright camera by the side. The following four points of the body are considered in relation to a plumb-line, starting at the ankles set: location of the strongest thorax kyphosis (a), Sternum (b), the location of the strongest lumbar lordosis (c) and at the maximum abdominal bulge (d).

It is calculated using the following formula: HI = (a + b):(b + c)

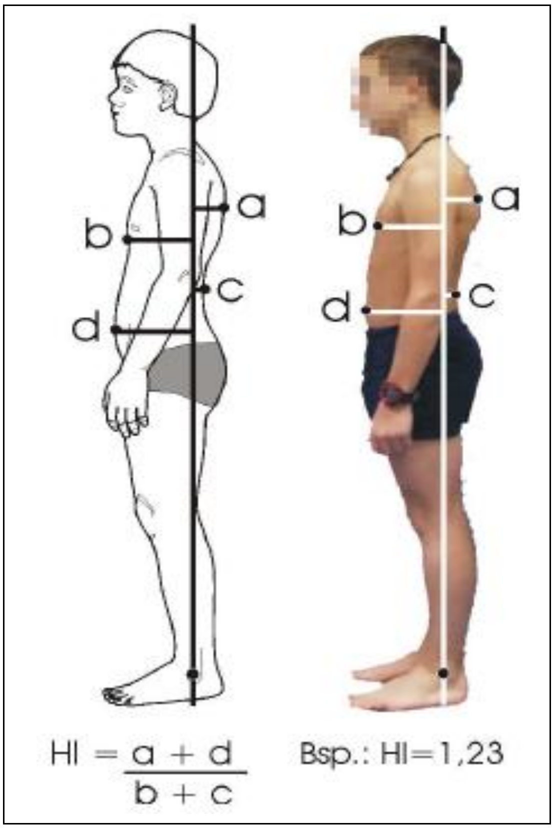


Figure 4: The Calculating the consumer posture index by Fröhner (Ludwig, Mazet & Schmitt, 2003, p. 166).

Fröhner described a posture index to be harmonious if it is between 1.0 and 1.2 as values between 0.9-1.0 and 1.2 to 1.4 are classified as weaker posture. Ludwig, Mazet & Schmitt (2003) point out that the values are only valid and reliable if the consumer posture index has been stabilized with the children and only if there are feedback terms and conditions to be existent. They advocate an extension of the ideal normal range to 1.3, since their own studies indicate otherwise three-quarters of surveyed children would be outside the normal range. It is also to consider the posture correction process, which can be accomplished best by means of video analysis.

2.1.5 Mechanisms of postural control

Before corrective postural actions of the neuromuscular system can begin, information from the visual, vestibular, and somatosensory systems is required. The postural sway essential to standing is detected by sensory receptors in the eyes (visual), ears (vestibular), skin (tactile), and joints (proprioceptive). The nervous system then responds by recruiting muscles to create moments (torques) that counteract the gravitational moments (Whiting & Rugg, 2006, p. 148).

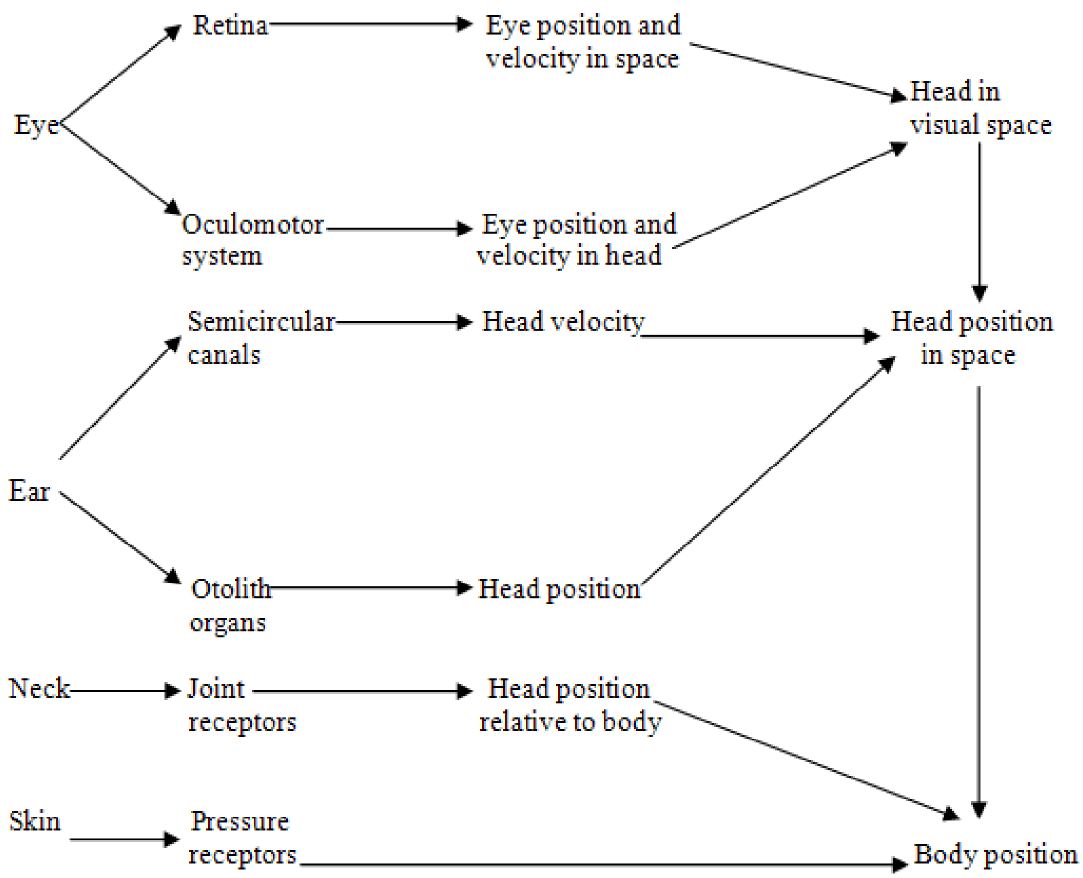


Figure 5: Nervous system's response to postural sway [Adopted from Whiting & Rugg, 2006, p. 148].

Winchenbach (2003) examined the relationship between strength and posture. She studied the abdomen (M. rectus abdominis), back (M, erector spinae) and hip flexion muscles (m. iliopsoas) of a group of 47 children from sports clubs and mass-static isometric strength measurement using a strength measurement chair. The obtained strength values were set in relation to body weight. The investigation provided the following results: the relationship between the strength values and the posture index for Fröhner (1998) were low, between the strength values depending on the result of the tests Mathiass were not significantly different and no significant difference between the strength values as depending on the shortening of the iliopsoas muscle were found.

Specht (2003) subjected 78 children and adolescents (30 girls, 48 boys) aged eight to 16 years to an investigation on posture and the coordination test by Bös and Mechling (1983). In addition, the amount and kind of sports activities in free time were recorded by a questionnaire.

The test confirmed that children and adolescents who had better coordination had better posture, as measured by posture index for Fröhner (1998). Moreover the children, who in addition to school sports are more physically active, achieved higher total scores in the coordination test. In addition, Orosz (2003) tested the same subjects to see if better balance leads to better posture. The investigation was carried out using a posture investigation and a balance test for motor sport Bös, Wydra and Karisch (1992). The balance test showed no significant difference between the children and adolescents with a posture index below 1.2. Highly significant differences in the observation of calendar generic age and the consumer price index ($p<0.01$) determined the benefits of balance ($p<0.01$).

This study by Alfermann et al. (2003) examines the question of what psychological effects on the subjective condition can be achieved by 'integrative back school programs. At the quasi-experimental scale study over six months were two intervention groups (15 women and 6 men, M=50.2, SD=13.71) and a control group (17 women and 11 men, M=40.0, SD=13.15). The study investigated: aspects of physical self-concept, the subjective complaint pressure, and self-efficacy. It was shown that if the volunteers stopped by the back school program improved the welfare, because the subjective complaint pressure decreased. The other variables showed no effects.

After the explanation of different intervention approaches such as back exercises, strength training of the trunk muscles and fitness training, the authors Köstermeyer et al. (2003) concluded that primary interventions aimed at physical activation, a lower cost than educational interventions such as back schools. However, the heterogeneity of the existing literature allows no final assessment of intervention strategies.

Wydra (2004) expounded in his paper the problems of some standards on body posture. He criticized with reference to Staffel (1889), that according to its disposition, postures are based purely on aesthetic principles. Furthermore, it shows in the application of the posture index Fröhner for Ludwig, Mazet & Schmitt (2003), and the limitations of the system. Although it works with objective categories, the subjects only reached the normal distribution approximately after a training program, so that the categories would have to be reconsidered.

The first of two Ludwig et al. (2009) studies described influence of backpack weight on posture and balance related to parameters in primary school children standing up. In the study a total of 60 students (31 girls, 29 boys) in grades one and two participated. Both before the investigation and after the course of a 15-minute movement with backpack measurements on posture and balance were carried out. The average backpack weight was 17.2 (± 3.5) kg of body weight. The investigation found that rising backpack weight in relation to the weight of the child results in the upper body moving forward while the position of the hip joint remains unchanged. There were no changes in the balance state, and neither weight nor backpack weight significantly affected the balance of regulation. However, strategies have been identified to upright posture, in particular, the trunk center of gravity adjourned to the back. In addition, the change in muscle activity while standing was studied in five subjects for different weight loads. Individual children showed with a backpack load of more than 30 % of body weight a significant increase in activity of the rectus abdominis muscle and a decrease in the activity of the erector spinae.

In the study series by Ludwig et al. (2003) about posture weakness in children and adolescents 379 children and adolescents aged 9 to 17 years, who are active in sports clubs participated. An investigation group of 82 children who were not necessarily attending sports clubs themselves was added. The children were assessed pre orthopedically regarding their muscle strength which was measured by a strength chair and after the posture index of Fröhner. The posture was recorded via digital video recording and could be corrected by the adolescents on a visual self-perception. In addition there was a written, standardized questionnaire applied to sports and exercise intensity. In examination, where clear and smooth muscle shortening was detected, 38.5 % had a shortening of the iliopsoas muscle. With regards to the posture shown, only 45 % of adolescents had a stable posture. Differences were found in part in the results according to the sports played. In particular, martial arts athletes have a good posture, while it was not significant in tumblers and gymnasts. There were also differences in the flexibility, with the best values favoring gymnasts and martial artists. However, there was no significant difference in sports in the abdominal muscles. In the posture correction mainly the gluteal muscles and biceps femoris were used, not the straight or oblique abdominal muscles.

2.2 Biomechanical Gait Analysis

Studies on kinematics and kinetics

Kinematics: This is the quantification of motion without paying any regards to the forces producing the motion. The analysis data includes linear and angular displacements, velocities, acceleration, and the range of motion for each individual body part and the complete body center of mass. It also involves such variables as stride length, step width, step length, stride frequency, and relative time in single and double-support (Whittle, 2003, p. 43; Winter, 2004, p. 9; Sutherland, 1997).

Kinetics: This is the analysis of the forces and torques that bring about motion, including both internal and external forces. Internal forces come from muscle activity, ligament, or from friction in the muscles and joints. External forces come from the ground or from external loads, from active bodies, or from passive sources, ground reaction forces, and joint bone-on-bone forces, the temporal-spatial parameters and muscle torques (Whittle, 2003, p. 38; Winter, 2004, p. 10; Sutherland, 1997).

2.2.1 Human walking

,,Of all the ways of ´going forward´, walking is by far the most common. Walking in humans can be defined as a form of upright, bipedal locomotion, or gait, in which at least one foot is always in contact with the ground. It is a cyclic activity involving the alternation action of the legs to advance the body forward‘‘(Whiting & Rugg, 2006, p. 152). Human walking is a naturally complex phenomenon. In general, human motion can be described by two phases and the body goes through all these phases every so often. As the phases are visited periodically, the human gait is produced. It can be roughly divided in two phases during a complete walking cycle:

- Double support Phase
- Single support Phase (Right, Left support)

Double-support phase: The period during a gait cycle when both feet are touching the walking surface at the same time (both feet are in their individual stance phases). Every complete gait cycle involves two double-support phases. It begins with the right heel striking the ground, while the left foot is still stationary. It then continues as the body weight is shifted from the left foot to the right foot and then ends when the toe of the left foot leaves the ground. It continues as the left heel strikes the ground (Kirtley, 2006, p. 17; Whiting & Rugg, 2006, p. 153).

Single-support: This is the period during the gait cycle win which one foot is in contact with the ground and hence carries all the weight of the body, while the other leg is in the swing phase.

The single-support period of the other foot begins at the toe-off of the left foot and ends at the following heel-strike of the left foot. Every complete gait cycle includes a single-support phase on each foot (Whiting & Rugg, 2006, p. 153).

Right support: In this phase the body is supported by the right leg (support leg) only and the left leg is the swing leg.

Left support: In this phase the body is supported by the left leg (support leg) only and the right leg is the swing leg.

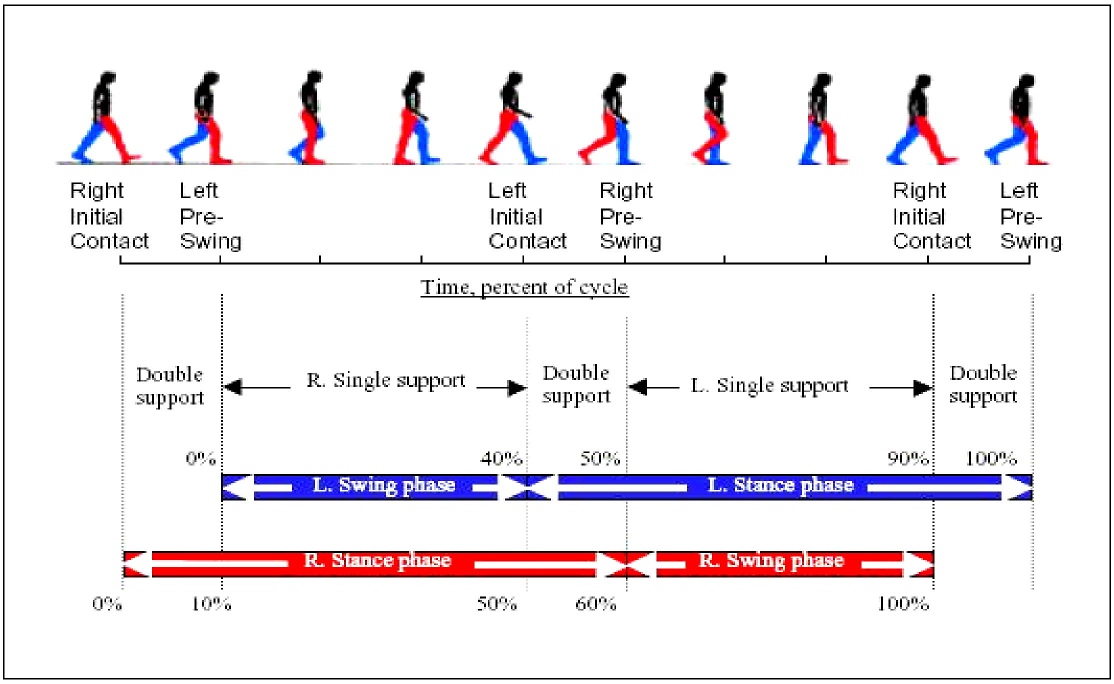


Figure 6: Gait cycle for the left and right legs during walking [Adapted from Inman et al., 1981, p. 26].

Stride length: The distance between two consecutive ipsilateral heel strikes. It is measured as the horizontal distance between the locations of two consecutive right heel-strikes.

Stride time: The time for a full stride, which includes both a left and a right step. It is measured as the time between consecutive right heel-strikes.

Step length: The step length is the distance between anterior-posterior models. The side of the more forward heel strike is given credit for the step. For example, the length in between the heel strike on the right and the successive heel strike on the left is called a step with the left side. Increasing load decreased step lenght as reported by (Imms & Edholm, 1981; Oberg et al., 1993; Lord et al., 1996; Bohannon, 1997; Menz et al., 2003). Researchers in biomechanics (Nilsson et al., 1985) describe person walking as a series of period unconnected by footstrikes (the foot is in contact with the ground) and takeoffs (the foot leaves the ground). In gait terminology a stride is described as a complete cycle from a left foot takeoff to further left foot takeoff, while the component of the cycle between the takeoffs of the two feet is called a step. Four footstrike and takeoff events occur during a stride: left takeoff, left footstrike, right takeoff and right footstrike. This leads to the characterization of two motion phases for each leg. Step length and stride period variety, however, appear to change very little with age or with eyes open vs. closed. No significant changes were detected in these variables, consistent with the treadmill results (Owings & Grabiner, 2004a; Owings & Grabiner, 2004b; Grabiner et al., 2001).

Step width: The side-to-side distance between the lines of the two feet.

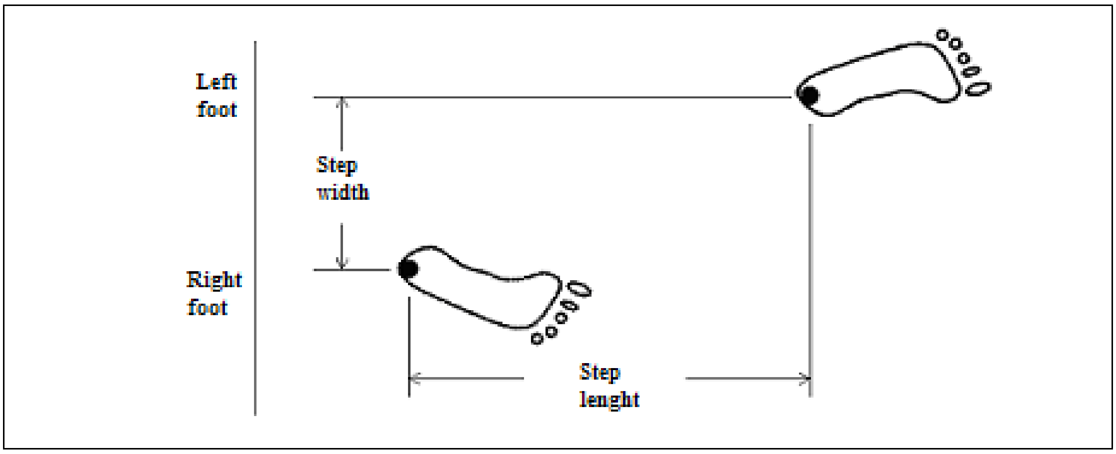


Figure 7: Gait parameters regarding distance and width [Adapted from Demura, 2010].

Walking angle: The walking angle is the angle between the direction of movement and bilateral pattern line.

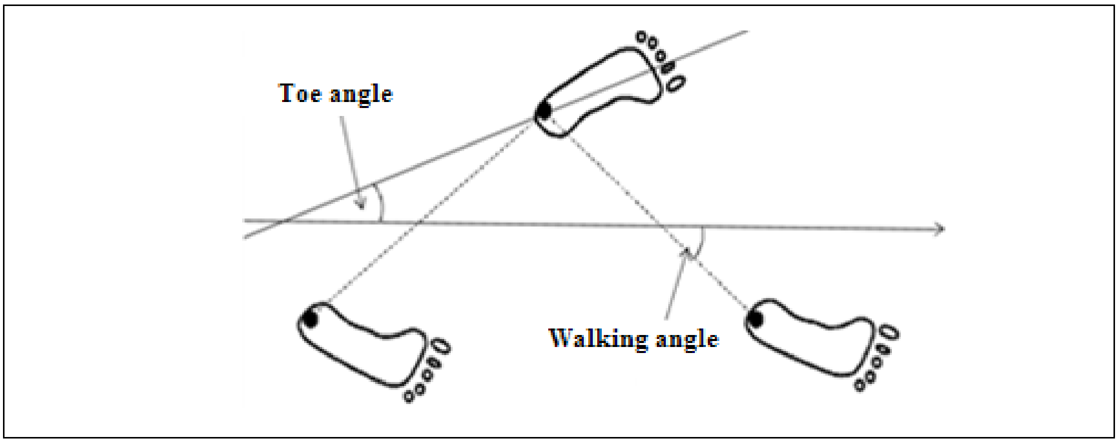


Figure 8: Gait parameters regarding angle [Adapted from Demura, 2010].

A study by Demura (2010) reported that leg strength decreases gradually with age over a long period of time after youth. Therefore, it is very problem to test the effect of decreasing leg strength on gait for a short period. On the other hand, walking with loads inflicts a large load on the lower limbs, even in young adults. With heavier loads, the load inflicted on the lower limbs is large. In addition, the connection between swing and double support time and walking speed, as well as between walking angle, step length and walking speed alters greatly with loads to keep a stable posture. In addition, walking angle increases with age (Murray et al., 1964).

Temporal and spatial: Several timing (temporal) measures of gait are commonly used. Three general spatial gait measures are step length, stride length, and step width. Men and women average a stride length of 1.46 m and 1.28 m, respectively (Perry, 1992, p. 12). Combining temporal (time) and spatial (distance) measures tells us how fast a person is walking. Danion et al. (2003) showed that spatial and temporal variability does tend to increase in concert with respect to alter in stride parameters. Sekiya et al. (1997) found that the step frequency (120 steps per min) leading to minimal spatial variability kept alike across different walking speeds. Indeed, gait is characterized by a favored relationship between stride frequency and stride length.

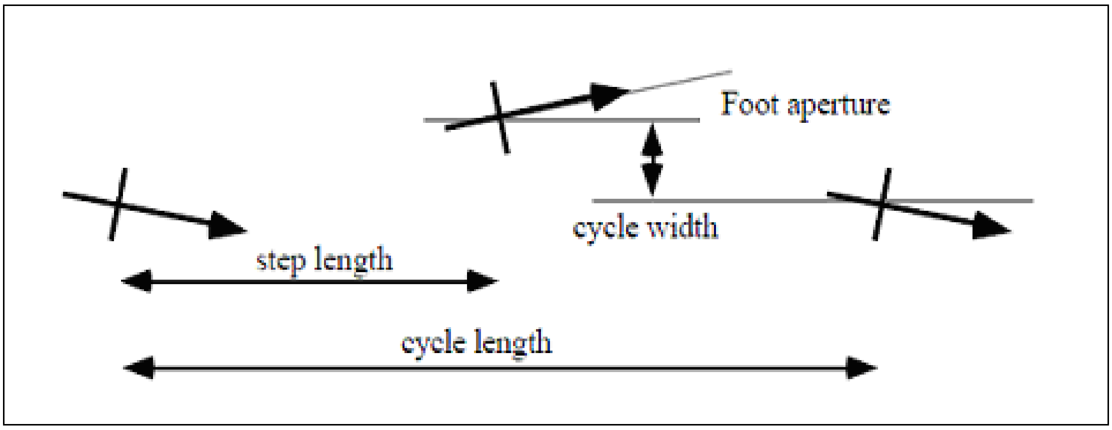


Figure 9: Spatial structure of the walking cycle [Adapted from Boulic et al., 1990].

2.2.2 Walking speed

Walking speed can vary substantially based on a number of parameters including age, gender, physical condition, environmental conditions, and purpose. Though everyone has a natural (free or self- selected) walking speed, the actual speed is continuously adjusted according to the conditions. When walking quicker, the stride length increases. An increase in velocity relationally prolongs single stance and shortens the two periods of double stance. When double stance period is left out and substituted by double float running has begun (Kirtley, 2006, p. 18).

Walking speed can be calculated through the equation:

Speed = Distance / Time

Orendurff et al. (2004) found that the stride length and step length increased, and stride width decreased as walking speed increased.

Cadence or step rate: The number of steps taken during the sequence divided by the time passed for the sequence. Since there are two steps (left and right) in every stride, and 60 seconds in one minute, steps per minute may be altered to strides per second by dividing by 120. In additions, that the stride time is simply 120/Cadence. Normal cadence is a little less than 120 steps/minute approximately one gait cycle per second. The mean free walking cadence for adults is about 113 steps per minute. Females usually walk with a higher cadence (117 steps / min) than do males (111steps / min) to partly recompense for their shorter step length. Walking speed is related to both cadence and stride length, so it can be increased by faster cadence, longer stride length, or both (Whiting & Rugg, 2006, p. 155; Kirtley, 2006, pp. 19-24).

2.2.3 Gait cycle

The gait cycle of a person is normally includes the following steps:

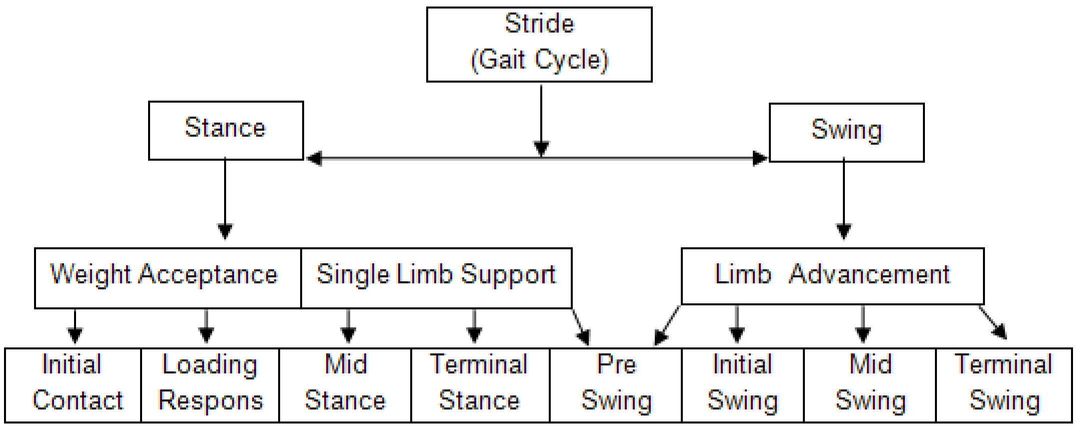


Figure 10: Division of the gait cycle [Adapted from Perry, 1992, p. 10].

Stance phase: The stance phase begins when the contralateral foot makes contact with the ground with its heel strikes and then continues making contact all the way to the toe. Every complete gait cycle includes a stance phase for each foot. The stance phase makes up about 60 % of the stride and consists of two periods of double limb support, when the contralateral foot is in contact with the ground, with minimal alteration for age and height at normal walking speed (Perry, 1992, pp. 10-11).

Swing phase: When the contralateral foot is not in contact with the ground. The swing phase begins with the foot's toe-off, continues as the foot swings forward, and finally ends with its heel-strike. During the pre-swing period, the weight is transferred onto the contralateral limb in preparation for the swing phase. The swing phase makes up about 40 % of the walking gait cycle (Perry, 1992, pp. 10-11).

Highlights during phases of the gait cycle (using the system described by Perry, 1992, pp. 11-16) include the following:

Initial contact in stance phase: The walk normally begins with the feet already at the extended position, which is the position where the feet are farthest apart and the characters weight start changing to the forward foot (Figure 11; a).

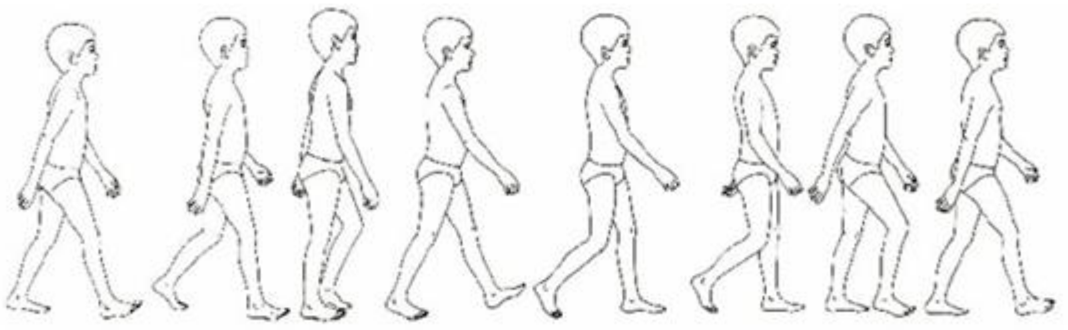
Loading response in stance phase: While the weight of the body is relocated to the forward foot, the forward knee bends to absorb the shock. This position is known as the recoil position, which happens to be the lowest point in the gait-cycle (Figure 11; b).

Terminal stance in stance phase: While the knee is flexing and the foot is coming forward, the heel is forced to strike on the surface and the process continues with the other foot beginning to swing (Figure 11; d).

Pre swing in swing phase: The free leg makes contact with the ground, finishing thereby the half cycle. The second half is in fact an exact mirror of the first. If it differs, the character may seem to hobble (due to possible causes such as injury) (Figure 11; e).

Mid swing in swing phase: Midway through the first step, the forward knee straightens out and lifts the body, bringing it to the highest point in the cycle. In this passing position, the free foot passes the leg supporting the body weight (Figure 11; g).

Terminal swing in swing phase: As the character moves forward, the weight-bearing foot lifts off the ground at the heel, there by conveying the force to the ball of the foot. The body then begins to fall forward so that the free foot swings forward like a pendulum to make contact with the ground and catch the body’s weight (Figure 11; h).



Initial Contact (a)	Loading Respons (b)	Mid Stance (c)	Terminal Stance (d)	Pre Swing (e)	Initial Swing (f)	Mid Swing (g)	Terminal Swing (h)

Figure 11 : Complete gait cycle [Adapted from Perry, 1992, pp. 11-16].

Gait is also influenced by different factors involving footwear, clothing, injuries, age, walking speed, and much more alike with other biometrics. The gait pattern is influenced by the different footwear as people are observed to walk differently when wearing trainers as to when wearing flip flops. This has been performed by study carried out by Dobbs et al. (1993). Based on the investigational results, it was showed that the stride and cadence factors of the walking pattern are influenced by footwear as opposed to walking barefoot. Furthermore, recent studies by Nurse et al. (2005) found that changing the footwear texture causes variations in the gait pattern. In the study carried out by Sarkar et al. (2005) for gait identification using the silhouette-based approach, the identification rate dropped sharply to 3 % for the succeeding combined covariant parameters: time, footwear and clothing.

The results showed that very large step lengths and slow leg swinging produce very high collisions, while short step lengths and very fast leg swinging produce very high leg swinging, with the optimum lying in between. Some amount of task to increase leg swing frequency is better than passive leg swing (Donelan et al., 2002a; Donelan et al., 2002b; Doke et al., 2005). A similar influence can be found in step width in three-dimensional models and in human gait, where collision increased with increasing step width (Donelan et al., 2001).

Movement of the body's centre of gravity is a reviews indicator of the mechanics of human pathological gait an experimented by Detrembleu et al. (2000) in about musculoskeletal disorders. Musculoskeletal disorders, involving injury to a lower extremity disturb normal movements of the body parts during gait and these abnormal movements effect the movement of the body's centre of gravity. A compensatory kind of gait occurs where movement of the centre of gravity is such that there is a regulation in gait samples to reduce muscle attempt by the influenced leg and the pain in it. The main compensatory mechanism that occurs in abnormal gait is the Trendelenburg lurch (Hurmuzlu et al., 1996; Bhave et al., 1999). A further study by Debi et al. (2009) concerning gait showed that men and women had different gait samples. Men walked with a smaller stance and double limb support, and with a larger swing and single limb support collation to women. Moreover, men walked with a greater toe out angle collation to women.

In a study by Chung et al. (2010) females found more prolonged trunk posture during gait than males, caused by alter lumber lordosis which may describe the altert prevalences of lumbar diseases between gender. Coronal trunk rang motion and transverse trunk rang motion were correlated. The trunk rang motion proposed its task to counterbalance the lower extremity throughout swing phase in sagittal plane and to decrease the angular velocity toward the contralateral side instant before the contralateral heel strike in the coronal plane.

2.2.4 Biomechanical studies of backpacks in children

Although the large number of children who carry backpacks, the literature regarding the influences of backpacks in children is limited.

Several studies have used physiological and biomechanical measures to investigate the effect of backpacks on human walking. Gait analysis has been examined to see how the body alters and attempts to keep balance and stability during walking. Adaptations in gait, involving walking speed, stride length, and stride frequency are due in part to the increase in muscular forces and moments from the load capacity, load placement, trunk inclination angle, trunk motion range, curvature of the spine, and postural regulation (Hong & Cheung., 2003; Orloff et al., 2004; Rahman et al., 2009). A biomechanical model can help evaluate the mechanical stresses on the body from load carriage that can lead to back problems.

Researchers investigating the influences on children have used much less weight. Goh et al. (1998) recorded stride and kinematic data from 10 male subjects-where the mean weight, height and age were 57.1 kg, 170 cm and 19 years respectively-while walking with no load, a 15 % load of their body weight and a 30 % load of their body weight. No significant differences were found in the walking speed, stride length and cadence or trunk motion. The mean trunk angle, however, was significantly different as the trunk went from an extension angle with no load to a flexed position with a load of 30 %. Peak lumbosacral forces were determined and found to significantly increase. Walking with no external loads and with a load of 15 % BW increased the peak force at the lumbrosacral spine by 26.7 % and at a 30 % BW backpack load the peak lumbosacral force increased by 29.5 %. These results reflect the subjects' attempt to keep stability while continuing with forward progression. The backpack load alters the center of gravity posteriorly and is compensated for by a visible forward flexion of the trunk. While the anterior movement of the center of gravity balances the body, the load is still present and results in a greater lumbosacral force, largely consisting of a compressive load.

Another similar study on backpacks by Wang et al. (2001) evaluated the effect of backpacks on gait pattern and accumulated ground reaction force for stride/per meter. The integral of mean force divided by total mass on time was expressed as the accumulated force index. A total of 30 college students-15 male and 15 the female-with a mean age of 21 years, height of 174 cm and a healthy body mass of 68, experienced walking without load and walking with a load 15 % of their body weight in a backpack. The cadence was either chosen by the subjects or fixed at the 55.5 steps/minute by a metronome. When carrying the 15 % load, there was a decrease in speed and single support time (SST) while the double support time (DST) increased. According to the experimental procedure, the force plate only recorded the ground reaction force of the left foot. With respect to the kinematic variables, carrying the load with backpack had a significant effect on the average walking speed while walking the cadence did not. Single support time was decreased and double support time was increased as shown by the results.

Hong and Brueggeman (2000) studied the gait pattern of 15 boys aged 10 as they walked for 20 minutes on a treadmill under four different conditions: no bag, schoolbag with 10 % of body weight, schoolbag with 15 % of bodyweight and schoolbag with 20 % of body weight. No significant differences were found in stance duration, swing duration, double support duration, and trunk inclination angle and trunk motion range. Trunk forward lean angle was significantly increased with loads of 15 % and 20 % of body weight (with no significant different between the two) compared to 0 % and 10 % respectively. Carrying backpacks of 20 % did result in significant increase in double support duration and a significant decrease in swing duration when compare to the

0 and 10 % loads. In another study of gait and posture by Hong and Cheung (2003), 23 male students completed carrying backpack loads of 0 %, 10 %, 15 % and 20 % of their body weight while walking around the perimeter of a basketball court (28 m long and 15 m wide) 23 times: a total of 1978 m which was approximately the average distance children carried backpacks while walking to school. Stride and temporal factors, trunk lean angles and trunk motion range were analyzed. The mean trunk inclination angle increased with the weight carried as there was a significant increase in trunk inclination angle for the 20 % load as compared to those of 0 %, 10 % and 15 % of body weight.

However, the backpack load and walking distance showed no significant influence on stride and temporal parameters. The study series on trunk kinematics by Li et al. (2003) showed that the trunk inclination angle progressively increased as the load increased, while the trunk motion range progressively decreased with the increase of the load carried. This study found a negative correlation between trunk motion range and load carried. The minimal trunk motion range was associated with the load conditions of 15 % (7.88°) and 20 % (7.90°) of the body mass after a 20-minute walk. A similar study also from Li et al. (2004) in Hong Kong recorded trunk posture and trunk kinematics during walking with different backpack weights in 6 to 12 year old children. Two groups of boys, aged 6 and 12 from a local primary school performed in four walking experiments of 20 minutes each on a treadmill on four different days, with unloaded backpacks as well as, 10 %, 15 % and 20 % of the child's body weight. Trunk inclination angle progressively increased in both age groups with the increase in backpack weight. The magnitude of the increased trunk inclination angle, when carrying an additional load on the back, was signifycantly larger in 12 year old children than their 6 year old counterparts.

Another factor affecting load and backpack weight changed in the trunk forward lean (TFL) as a postural adaptation to increases in backpack load and spinal forces have been presumed based on TFL recording to Goodgold et al. (2002a). Two healthy males aged 11 and 9 volunteered to serve as participants and were then videotaped under nine experimental conditions, including three levels of backpack carrying with loads of 0 %, 8.5 % and 17 % of the body weight, and three levels of task demand: stand, walk and run. The order was of conditions randomized. For the standing condition, seven frames taken approximately two minutes after the onset of the standing condition were digitized and analyzed. For the walking and running conditions, frames during the stance phase, determined by onset of right foot heel strike to termination of toe off on the same foot, were digitized and analyzed. Although reported that heavy backpack loads and increased task demands cause increases in trunk forward lean, it is a leap to suppose dependent connection between load, task demand, trunk forward lean, and increased spinal forces that can lead to back injury.

Cottalorda et al. (2003) used 41 children with a mean age of 12.2 years to investigate the influence of school bag carrying on gait kinetics. All children walked at a speed of 3.5 km/h on a treadmill, first without a backpack and then carrying a 10 kg school bag on the right shoulder or on both shoulders. The children performed stride, stance, double stance, 13 specific GRF parameters and the symmetry index. Right and left leg ground reaction forces (GRFs) were recorded, averaged, and analyzed for 30 steps for each carrying condition. There was a significant increase in stride, stance and double stance when the backpack was carried on one or two shoulders compared with the normal condition of no backpack; but no difference was found between one strap and two straps and the propulsive fore-aft forces were higher on the right than the left leg. All the children carried their backpack on the right shoulder. Carrying a 10 kg schoolbag makes a difference to gait kinetics. Other studies have reported of backpack load on gait.

Chow et al. (2005) performed an experiment on a group of 22 normal schoolgirls between the ages of 10 and 15. Each participant was required to walk under the following five load conditions: 0 %, 7.5 %, 10 %, 12.5 % and 15 % body weight. Temporal-distance, ground reaction force (GRFs) joint kinematic, moment and power parameters were recorded with factors of backpack load and left or right side. Increase in backpack load resulted in significant decrease in step length, cadence, walking speed and the single support time. However, increasing the load caused a decreased pelvic range of motion (ROM) in the coronal and transverse planes and increases in all the recorded GRFs parameters. There was no significant difference between the magnitudes of both of these parameters at 0 %, 7.5 % and 10 % BW backpack loads, but the magnitudes at 15 % BW backpack load were significantly larger than all other loads except the peak extension moment of the knee during stance at 12.5 % BW backpack load. Similar results were found in a study by Fiolkowski et al. (2006), who examined gait kinematics and posture of 13 healthy adults, free of any injury. All participants walked on a treadmill at the 0.75 strides/s in five conditions: light backpack, heavy backpack, control, light front pack, and heavy front pack. The light load was 10 % of BW, while a heavy load was 15 % of BW. The leg length of all participants was measured from anterior superior iliac spine to calculate the stride length and to determine the speed of the treadmill. This was consistent whether the loads were heavy or light in the backpacks and also reflected in the forward head position in the backpack condition. Carrying a backpack resulted in a forward lean of the body in gait, with an increase in hip flexion. The front pack showed a significant change in hip flexion/extension values, along with a significant reduction in forward head position. Shear forces acting on the spine - which has been identified as a risk factor for back injuries-may be reduced with the more upright posture seen with the use of a front pack.

Attwells et al. (2006) studied the influence of carrying heavy loads on posture and gait of soldiers. A total of 20 male soldiers performed four different conditions, which included 7.9 kg rifle, 15.9 kg webbing, 39.9 kg backpack, and 50.05 kg light antitank weapon. Subjects walked at a self-selected speed after seventeen active markers were placed on the body to identify movements of the lower limb, torso, head and backpack. The results found that as the load weight increased, stride length had a decreased trend and the double support period increased. This result found increase in double support period and could provide greater stability to reduce the possibility of losing balance. When loads were added, they also showed that for lower limbs, the maximum angle of ankle, knee's range of motion, and the femur angle there was both an insignificant and significant increase. The upper body, the torso and craniovertebral angles had a significant change with added load.

Connolly et al. (2008) examined the effects of backpack carriage on human movement system. 32 children between the ages of 12 and 13 years were recruited and put under two load conditions using the GAITRite system. The GAlTRite system evaluates temporal and spatial gait factors via an electronic walkway. All experiments performed to assess walking base of support, stride length, double support time, and velocity when backpacks were carried on one or two shoulders. The results showed that there were no significant differences in base of support, stride length, or velocity when compared with the unloaded baseline walk. The double limb confirmation significantly increased with both load conditions when was analogy with the baseline, but not between the one shoulder and the two shoulders carriages.

A review by Rahman et al. (2009) also suggested the effects of varying backpack loads on trunk inclination. Two boys with mean age 6.5 years during level walking were required to walk on an 8 m track with four different load conditions: 0 %, 10 %, 15 % and 20 % of their body weight. The trunk inclination angle increases more than 5º with loads of 15 % and 20 % of the body weight compared to that of 0 % and 10 % load conditions and no significant difference in trunk inclination angle was between 0 % and 10 % of load conditions. However a significant difference in trunk inclination angle was found between 0 % and 15 % of body weight and also between 0 % and 20 % of load conditions. The trunk inclination angle also increased as the load of the backpacks increased.

Singh et al. (2009) conducted research on the effect of backpack load position on spatiotemporal parameters and trunk forward lean of 17 primary school boys with mean age, height and weight of nine years, 134 cm and 31 kg. All experiments performed on backpack load carriage and its vertical position on the back on temporal-spatial and kinematic factors were related with gait and postural stability for static and dynamic conditions. The children carried three different backpack loads of 10 %, 15 % and 20 % of their body weight in the upper (U) and lower (L) load configurations. The six loaded conditions will be referred to as L10, L15, L20, U10, U15 and U20. The results showed that spatiotemporal parameters were significantly different for the L20 condition. The spatiotemporal findings for the L20 condition indicate that possible alters in gait occur to minimize either an induced instability or to decrease mechanical strain on the system. However, for static condition the trunk forward lean was significantly increased for all load conditions. The dynamic conditions of 15 % or higher loads were significantly increased. Also the findings on the trunk forward lean showed significant increase for the dynamic conditions, compared to the static conditions apparently, to compensate for the induced gait instability to movement.

Backpack weight of 10 %, 15 % has been suggested as an acceptable limit for schoolchildren. Chow et al. (2010) used 11 boy and 8 girl participants to investigate the effects of backpack load placement on spinal deformation and repositioning ability. The changed spinal curvatures of cervical, upper and lower thoracic, upper and lower lumbar regions as well as pelvic tilt and repositioning error when carrying a backpack loaded at 15 % of body weight at different centre of gravity locations (anterior or posterior at T7, T12 or L3) in school children were measured. These findings suggested that anterior carriage with centre of gravity located at T12 was preferred to the other load placement conditions as it resulted in comparatively less spinal deformation and less alteration in repositioning ability. The same backpack centre of gravity level showed different amounts or directions of spinal deformation between anterior and posterior carriages. It was also found that changing carriages by alternating backpack positions occasionally between anterior and posterior might help to relieve the influences of spinal deformation related to backpack carriage.

Table 1: Select studies on biomechanical of backpacks

Researcher	Investigation	Criteria	Results
Goh et al. 1998	Effects of varying backpack loads on peak forces in the lumbosacral spine during walking	backpack, Load carriage, lumbosacral, peak forces, motion analysis,	- No sig. Differences in walking speed, stride length and cadence or trunk motion. - Increase the peak force at the lumbrosacral spine 26.7 % with no external loads with 15 % BW, at 30 % BW backpack load the peak lumbosacral force increase 29.5 %.
Hong and Brueggeman 2000	Changes in gait patterns in 10-year-old boys with increasing loads when walking on a treadmill	Gait, Backpack Heart rate, Load carriage, Children	- Sig. Increase with 15 % load in trunk forward lean. - The compare to the 0 % load with 20 % load: Sig. increase in trunk forward lean, double support, stance duration, decrease in trunk angular motion and swing duration.
Wang et al. 2001	Evaluation of book backpack load during walking	Single support impulse(SST), Double support impulse(DST), Bookbag	- Decrease speed with 15 % load, a decrease in (SST), and an increase in (DST). - Sig. Increase in DST per stride - Sig. Decrease in SST per stride
Goodgold et al. 2002a	Effect of backpack load and task demand on trunk forward lean: Pilot finding on two boys	Trunk forward lean (TFL), backpack, Stand, walk, run (0 %, 8.5 %, 17 %)	- Stand: increase TFL with conditions load increase Differences small in peak TFL the walking and running in the 17 %.

Researcher	Investigation	Criteria	Results
Li Xian et al. 2003	The effect of load carriage on movement kinematics and respiratory parameters in children during walking	Backpack, Trunk inclination angle, Trunk motion range (ROM), Respiration	- Increase the trunk inclination angle with load increase. - Decrease trunk motion range with increase load The negative correlations between trunk motions range (ROM) and load carriage.
Cottalorda et al. 2003	Influence of school bag carrying on gait kinetics	Ground reaction forces, gait analysis, backpack, children	- Sig. Increase in stride, stance and double stance with backpack by one or two shoulders and compare with the normal condition of no backpack. - The carrying a 10 kg schoolbag makes a difference to gait kinetics.
Li Xian et al. 2004	Age difference in Trunk kinematics during walking with different backpack weights in 6 to 12 year old children	Trunk posture Walking, load carriage (0 %, 10 %, 15 %, 20 %) 20 minutes on a treadmill	- Increase: trunk inclination angle with the increase backpack weight in both age groups. - Sig. increase trunk inclination angle with 15 % of body. - Sig. lager amplitude in the trunk inclination angle for 12 -year-old then 6 -year-old.
Chow et al. 2005	The effect of backpack load on the gait of normal adolescent girls	Adolescent idiopathic scoliosis, Backpack, gait	- Sig. decreases in step length, cadence, walking speed and single support time with increase load backpack. - Increase load cause a decrease pelvic range of motion (ROM), coronal and transverse planes and increases in GRFs parameters.

Researcher	Investigation	Criteria	Results
Fiolkowski et al. 2006	Changes in gait Kinematics and posture with use of a froth pack	Backpack , front pack Body weight(10 %,15 %), Gait	- Sig. difference noted in angles of hip flexion. - Sig. change in neck motion (backpack, front pack). - Increase forward head with wearing the backpack.
Attwells et al. 2006	Influence of carrying heavy loads on soldiers' posture, movements and gait	Military, Gait load carriage (8, 16, 40 to 50 kg) Posture	- Decrease in stride length and increase in double support period. - Increase in Knee and femur ranges of motion. - Decrease the craniovertebral angle with a more forward position of the head.
Rahman et al. 2009	A Preliminary studies on effects of varying backpack loads on trunk inclination during level walking	Trunk Inclination Angle, School Children, load carriage (0 %, 10 %, 15 %, 20%)	- Increase the trunk inclination angle than 5º with loads of 15 % and 20 % of BW. - Sig. difference in trunk inclination angle between 0 % and 15 % of BW and between 0 % and 20 %.
Singh et al. 2009	Effects of backpack load position on spatiotemporal parameters and trunk forward lean	Spatiotemporal, Locomotion, Backpack, load (10 %, 15 %, 20 %) BW	-Sig. difference spatiotemporal parameters for the L20 of BW. - For static condition: Sig. increase the trunk forward lean for all loads. - For dynamic condition: Sig. increase the trunk forward lean for 15 % BW.
Chow et al. 2010	Short- term effects of backpack load placement on spinal deformation and repositioning error in schoolchildren	Spinal deformation, Repositioning ability, Load carriage (15 %)Anterior or posterior at T7, T12 or L3	- Decrease comparatively spinal deformation and less altered repositioning ability at T12. - Different of spinal deformation between anterior and posterior.

2.3 The Electromyography (EMG)

An electromyography (EMG) is a used for evaluating the motor unit or neuro-muscular physiology (Merletti et al., 2001). EMG signals are the result of many physiological, biochemical and anatomical factors (De Luca, 1997, p. 137; Winter, 2004, p. 11; Reaz et al., 2006). It can measure the location, harshness, assess gait and fatigue, prognosis of injuries and provide biofeedback to patients or other compromises of the motor unit. There are, however, many potential pitfalls in the use of EMG as an instrument (Lewek et al., 2006; Abe et al., 2010). In addition, the explanation of the EMG signal requires a thorough knowledge of the basis of the signal.

2.3.1 Amplifier

An amplifier is a device that multiplies its input voltage, current, or power through a fixed or controllable parameter, normally without changing its waveform (Pease et al., 2007, p. 88). ,,Every amplifier has a dynamic range and should be such that the largest EMG signal expected will not exceed that range" (Winter, 2004, p. 237). The essential components of an amplifier are the:

- Gain and dynamic range
- Input impedance (resistance)
- Frequency response
- Differential gain or common mode rejection ratio (CMRR)

Gain and dynamic range: The relationship between the output voltage to the input voltage or the increase at the output of an amplifier in voltage, current, or power of the signal applied to its input (Winter, 2004, p. 237).
Input impedance (resistance): The impediment to electrical current flow in a changing current circuit. It involves the influences of resistance, capacitance, inductance and frequency (Kamen & Gabriel, 2010, p. 74; Winter, 2004, pp. 238-239).
Frequency response: The rate in cycles per second that a changing current signal variations, before it is digitized by the computer. The unit of frequency is the Hertz and it explains the velocity range of potential waveform alters that will be showed by the EMG system (Winter, 2004, pp. 239-240; Kamen & Gabriel, 2010, p. 78).
Common mode rejection ratio (CMRR=Differential gain): The basic function of the amplifier is that emerge as different between the signals at the two input terminals and amplifier takes to reject or minimize common mode sig-

nals to decrease noise interference (Winter, 2004, pp. 241-242; Kamen & Gabriel, 2010, pp. 72-74).

2.3.2 Amplitude

The potential measured in volts is for any type of recorded response in electrodiagnostic examination. An amplitude diagram may involve the complete range of amplitude values both positive and negative, distributed into equal intervals (Clancy & Hogan, 1999). The absolute amplitude of the surface EMG is normally used in reports that compare adolescent and old adults to decide whether differences exist in the ability of the nervous system to activate muscle (Keen et al., 1994). The EMG can be calculated with standard amplitude parameters, including mean, peak and minimum value as well as area (integrated EMG).

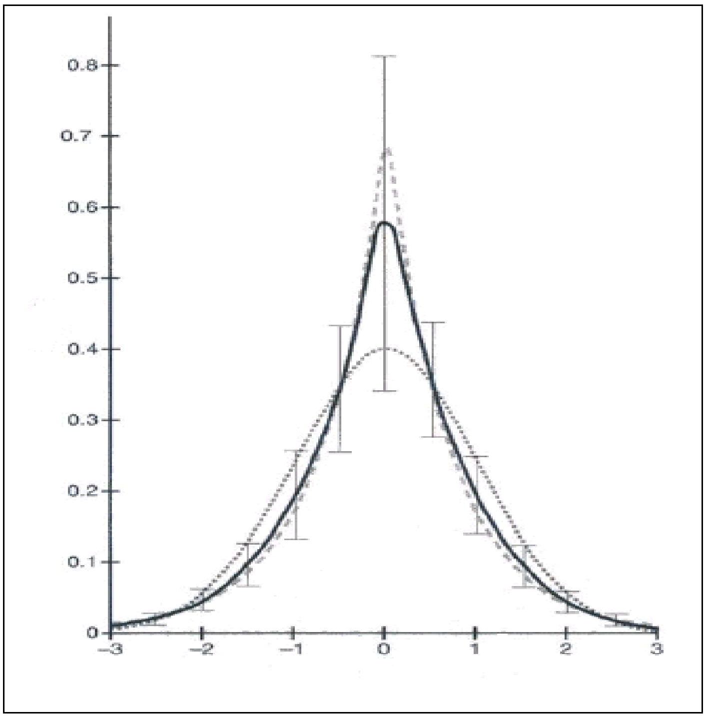


Figure 12: The frequency distribution curve for surface EMG amplitude [Adapted from CIancy and Hogan, 1999, p. 733, as cited in Kamen & Gabriel, 2010, p. 106].

2.3.3 Types of filters

All EMG amplifiers use a bandpass filter to weaken noise. Filters can be hardware devices or signal-processing algorithms instrumented in software which can be described by a low a high-frequency filter (with a cutoff frequency near 300-500 Hz), that does not interfere with lower frequencies or a high a low-frequency filter (with cut off frequency near 10-20 Hz), which does not interfere with higher frequencies and the high-pass and low-pass filters are used to reduce noise and artifacts (Merletti & Parker, 2004, pp. 120-121; Pease et al., 2007, p. 90).

2.3.4 Cross-talk muscle signals

Crosstalk is the signal detected as electrical activity from adjacent muscles travel through greater distances recorded by the electrodes over the muscle of primary interest, which will be subjected to more spatial filtering. Hence, they will contain less energy in the higher frequencies (Winter et al., 1994; Farina et al., 2002a; Merletti & Parker, 2004, pp. 91-92; Winter, 2004, pp. 245-246; Kamen & Gabriel, 2010, p.125).

2.3.5 Analog to Digital (A/D) converter

The analog to digital converter measures the EMG signals at regular time intervals (Kamen & Gabriel, 2010, p. 95). A current that receives the discrete coded signal of a digital system produces the voltages of the amplitudes analogous to the numbers shown by the digital codes. A 12-bit code represents 2^{12} = 4096 levels, If a 16 bit A/D converter with a ± 5V input range is selected, a fixed gain amplifier of 1600 to 2000 will be required to exploit the full A/D range (Winter, 2004, pp. 31-32; Merletti & Parker, 2004, pp. 121-122; Freiwald et al., 2007, p. 48).

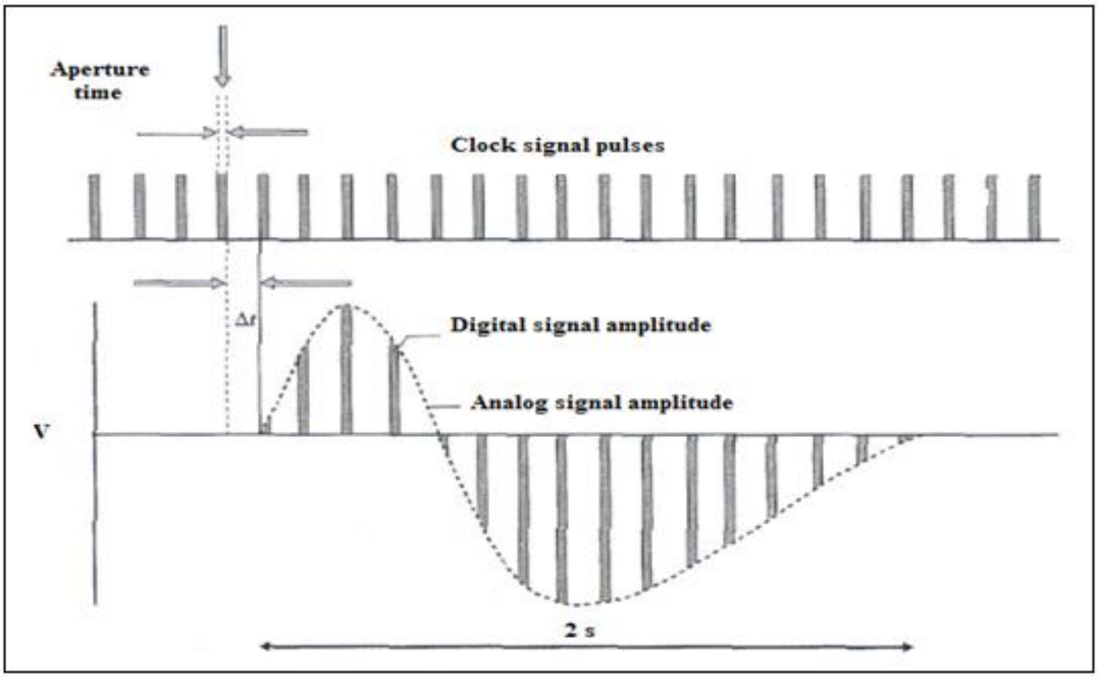


Figure 13: The sampling analog to digital signal [Adapted from Johnson and Pease, 1997, p. 467, as cited in Kamen & Gabriel, 2010, p. 96].

2.3.6 Normalized EMG

It is general practice to normalize EMG values to the amplitude of the EMG at maximal levels of stimulation so that comparisons can be made across muscles, between subjects, and between days. In order to obtain representative data, MVC normalization requires healthy subjects to perform at a true maximum muscular effort. ,, Normalized EMG values are less variable than absolute values, and thus take into consideration a more reliable index of muscle activation''(Keenan et al., 2005; Yang & Winter, 1983; Day & Hulliger, 2001). The original microvolt data of all trials are expressed as a percentage of the highest innervation level (% MVC).

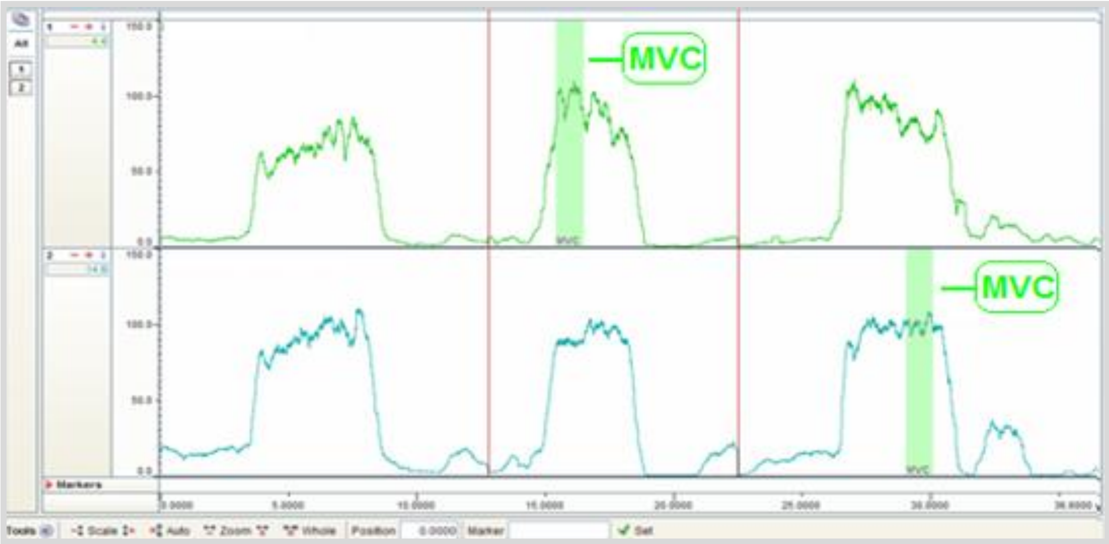


Figure 14: MVC (Maximal Voluntary Contraction) test for 2 muscles in a static [Modified, Adapted from Rudroff, 2008, p. 34].

2.3.7 Electromyography signal processing

Raw EMG: The raw EMG signal provides unfiltered (with the exception of amplifier bandpass) and without further signal processing limited information to an ergonomist (Merletti & Parker, 2004, p. 345; Freiwald et al., 2007, p. 47).

Full-wave rectification: The full-wave rectifier creates the absolute value of the EMG, with a positive polarity where all negative amplitudes are converted to positive amplitudes (Freiwald et al., 2007, p. 93; Winter, 2004, p. 249; Kamen & Gabriel, 2010, p. 111).

Linear envelope: ,,Linear envelope exploration of the EMG signal is centered on the idea that it is an amplitude-modulated noise signal. Optically, linear envelope detection is analogous to creating a moving average for the EMG signal''(Kamen & Gabriel, 2010, p. 111).

Integrated EMG: The integrated EMG is a time-varying potential with instant amplitude similar to the complete area under the curve (mV.s) accumulated from a designated beginning point under an EMG waveform. It provides a measure of total electrical activity (Winter, 2004, p. 252).

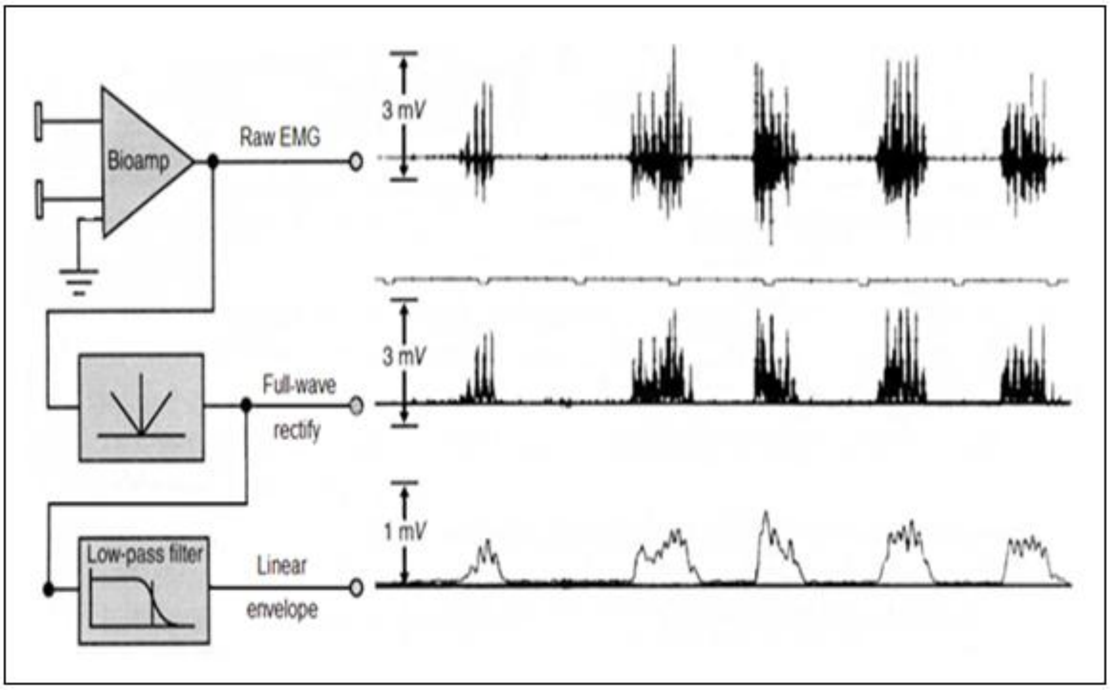


Figure 15: Based on the raw signal, the signal full wave rectified and linear envelope *[Modified, Adapted from Winter, 2004, p. 250]*.

2.3.8 Electrode types

Electrodes are sensors that recognize electrical potential produced by nerves and muscles. EMG recordings are typically made with two bipolar recordings electrodes, where signal represents the potential difference between the two electrodes. To acquire good readings there should be sufficient contact between the signal generators and the recording electrodes.

There are three basic types of electrodes: surface, fine wire (needle) and vaginal/anal. The metal plates of a surface electrode contact the skin during muscle contraction. Electrolytic gel is used to improve contact between the electrode and skin, whereas needle electrodes are inserted through the skin directly into the muscle and used for deeper muscles. Vaginal and anal are used for pelvic floor muscle evaluation are established and often utilized for incontinence testing and biofeedback training. (Freiwald et al., 2007, pp. 50-53; Kamen & Gabriel, 2010, pp. 56-62; Pease et al., 2007, p. 87).

The reference electrode should be placed at a location in which the muscle activity is minimal, preferably on joints, bony area, frontal head, processus spinosus, Christa iliaca, tibia bone and inactive tissue (Merletti & Parker, 2004, p. 127).

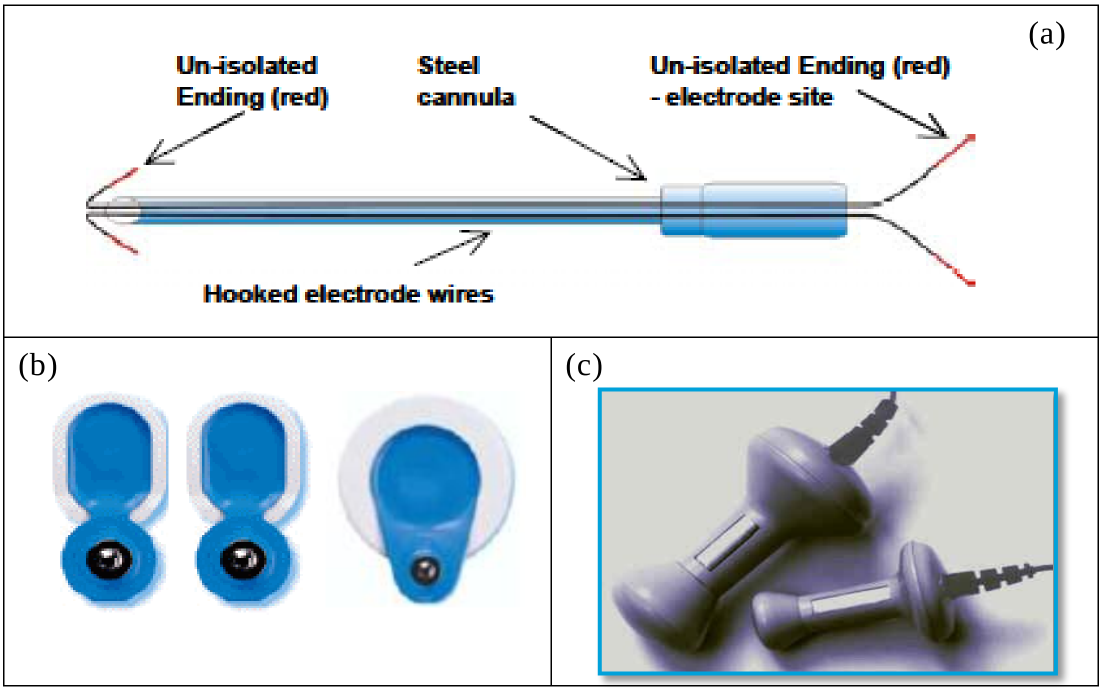


Figure 16: Selection of special EMG electrodes: (a) Fine wire (needle) electrodes, (b) Surface electrodes, (c) vaginal and anal electrodes [Adapted from Konrad, 2005, pp. 14-16].

2.3.9 Electrode configuration and size

,,The electrode configuration defines the area and shape of the electrode detection surface which determines the number of active motor units that are detected by the number of muscle fibers in their vicinity‘‘(De Luca, 1997, p. 138; Farina & Merletti, 2001; Farina et al., 2002b). The electrode size influences amplitude and frequency content (Farina et al., 2001; Farina et al., 2002c).

In theory smaller electrodes are preferable, while larger ones introduce excessive low-pass filtering. It is suggested that the size of the electrodes in the direction of the muscle-fiber not exceed 10 mm. The physical size of an electrode also impacts the EMG signal (Dimitrova et al., 1999; Farina et al., 2002c).

2.3.10 Electrode orientation on the muscle

The orientation is the direction of the bipolar sensor with respect to the direction of the muscle fibers, affecting the value of amplitude and frequency of signal (De Luca, 1997, p. 138; Merletti & Parker, 2004, p. 125).

2.3.11 Factors physiological and physical influences on the electromyogram

The EMG variables are sensitive to a number of physical and physiological factors (De Luca, 1997, pp. 160-161; Kamen & Gabriel, 2010, pp. 14-15; Merletti & Parker, 2004, pp. 249-250).

The most important factors are:

- Muscle temperature
- The subcutaneous tissue layer
- Noise contamination
- Fiber diameter
- Signal stability
- Depth and location of the active fibers
- Muscle length and fiber length
- Tissue filtering
- Inclination of the detection system with respect to the muscle fiber orientation
- Location of the electrodes over the muscle
- Spatial filter used for signal detection
- Electrode size, shape and distance
- Cross-talk

Muscle temperature: ,,Muscle fibre temperature affects conduction velocity and frequency of the action potential and influences the frequency of the EMG signal” (Kamen & Gabriel, 2010, p. 15; Winkel & Jørgensen, 1991).

The subcutaneous tissue layer: The subcutaneous tissue layer acts as a low-pass filter, reducing frequency amount and signal amplitude and thus the value of the median frequency (Farina & Rainoldi, 1999).

Noise contamination: To decrease the electrode impedance, clean the skin using electrolytic gel, and place the ground electrode between the stimulating and recording sites. Also maintain recording cables away from power cables and stimulator leads (Grimnes, 1982; Gondran et al., 1995).

Muscle length and fiber length: Both muscle fiber conduction velocity and the frequency of the EMG signals can be influenced by muscle length (Jensen et al., 1993).

The location of the electrodes over the muscle: The location of the electrode with regard to the tendon junction and innervation zones affects the amplitude and frequency of the detected signal (Rainoldi et al., 2000; Roy et al., 1986).

2.4 EMG analysis during fatiguing contractions

Directories of fatigue are defined on the basis of the time evolution of the surface EMG signal appears during the contraction (De Luca, 1984). The power frequency distribution can be calculated by the Fast Fourier Transformation (FFT). Furthermore, the mean value of the spectrum will be zero. The frequency spectrum domain uses spectral feature frequencies, such as the mean, median and the mode of the power spectral, as researched by the following (Lindstrom., 1970; Chaffin., 1973; De Luca et al., 1986; Ament et al., 1993; Li & Sakamoto, 1996; Ament et al., 1996). The power frequency was calculated on a band-passed (10-500 Hz) surface EMG signal.

The median power frequency is the fatigue index calculated from the frequency spectrum of the EMG signal and divides the total power area into two equal parts. Because it is less sensitive to noise, signal aliasing, and in most cases more sensitive to the biochemical and physiological factors that occur within the muscles during sustained contractions, median frequency is preferred and mostly applied. The mean frequency is the mathematical mean of the spectrum curve and total power is the integral under the spectrum curve. The mean and median power frequency is used to quantify changes in motor unit recruitment, firing statistics and muscle fiber conduction velocity (De Luca, 1997, pp. 156-157; Freiwald et al., 2007, pp. 146-147).

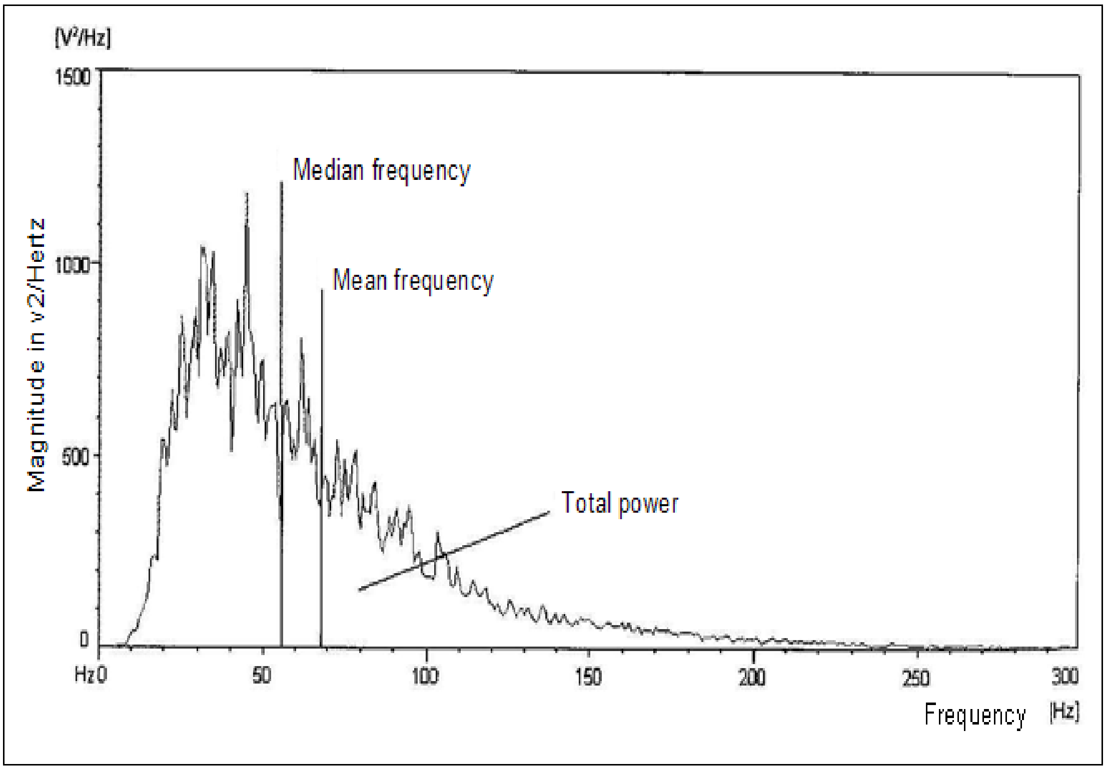


Figure 17: EMG standard frequency parameters median frequency, mean frequency and total power based on FFT calculations [Modified, Adapted from Freiwald et al. 2007, p. 146].

The major EMG measures of fatigue-which decreases the muscle force and changes the shape of the motor action potentials-are an increase in the amplitude of the EMG and a decrease in its frequency spectrum (Winter, 2004, p. 256).

The force output of a muscle as the index of muscle fatigue is normally utilized by physiologists. The point at which a contraction can no longer be maintained (the failure point), in particular, is normally considered to be the point at which the muscle is said to fatigue (De Luca, 1997, pp. 156-157).

Figure (18) shows the EMG signal as a fatigue index

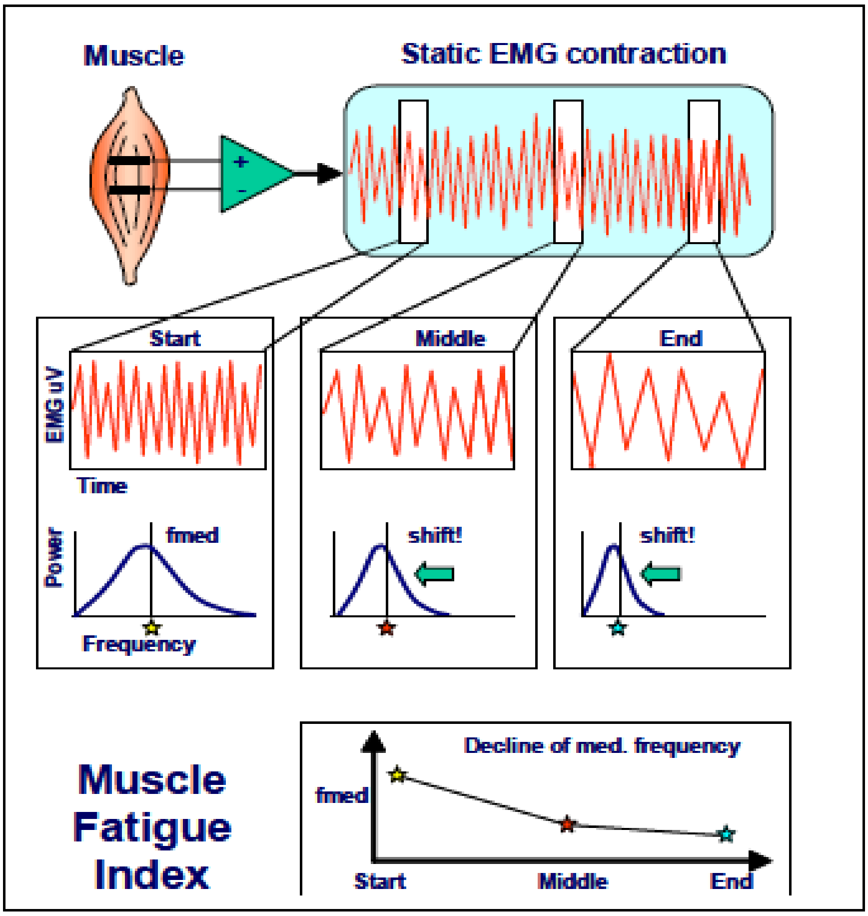


Figure 18: The spectral modification which occurs in the EMG signal during sustained contractions. The muscle fatigue index is represented by the median frequency of the spectrum [Adapted from de Luca, 1997, p. 157, as cited in Konrad, 2005, p. 50].

2.4.1 Factors affecting surface EMG of muscular fatigue on isometric and dynamic contractions

- During a maximal isometric contraction, the following processes occur: the signal amplitude of the surface EMG, the motor units, the parallel output and the median or mean power frequency of the electromyogram all decrease (Gerdle & Fugl-Meyer, 1992; Moritani et al., 1986; Garland et al., 1994; Hunter et al., 2003; Pincivero et al., 2006; Yeung et al., 1999; Bilodeau et al., 2003; Freiwald et al., 2007, p. 149).
- During a dynamic contraction, both the median or mean power frequency of the EMG signal recorded and the signal amplitude of the surface EMG in dynamic contractions alternatively decrease (Arendt-Nielsen et al., 1991; Ament et al., 1993; Gerdle et al., 2000).

- During a sustained longer maximal contraction, the amplitude of the surface EMG initially increases but then declines (Bilodeau et al., 2003; Freiwald et al., 2007, p. 142).
- During a submaximal contraction, the amplitude of the surface EMG is initially stable but then increases along with the motor unit, parallel in output and the median or mean power frequency of the electromyogram, which decreases (Freiwald et al., 2007, p. 149; Krogh-Lund & Jørgensen, 1991).

Median Power Frequency Formula:

The following formulae are used to calculate the median power frequency.

The *fm* is the frequency of the power spectral density function below which half the power lies and above which the other half of the power lies:

$$\int_0^{f_m} X^2(f)\,df = \int_{f_m}^{\infty} X^2(f)\,df = \frac{1}{2}\int_0^{\infty} X^2(f)\,df$$

,,X *(f)* is the amplitude of the harmonic at frequency *f* and $X^2(f)$ is the power at frequency *f*.

Öberg et al., (1994) reported that mean power frequency is an alternate and general statistical calculate ‘‘(Winter, 2004, pp. 256-257).

$$\mathrm{MPF} = \frac{\int_0^{F} f \cdot X^2(f)\,df}{\int_0^{F} X^2(f)\,df}\ \mathrm{Hz}$$

Where F is the maximum frequency analyzed.

2.4.2 Basic electromyography of load carriage in children

Bobet and Norman (1984) measured the EMG activity on the trapezius pars descendens muscles and the erector spinae muscles. 11 healthy men aged 19-22, height 166-190 cm; mass 53-85 kg carried a 19.5 kg load around a flat 90 m course at a speed of 5.6 km/h, as timed by photocells. The effective frequency response of the system was 30-300 Hz. A 19.5 kg load was placed at the C1-C7 region and the T1-T6 region. For static situations, there were similar moments for both the high and low load placements. As for dynamic situations, the C1-C7 region created a significant increase in the levels of muscle activity of both the trapezius and erector spinae muscles compared to the T1-T6 region. As a result, higher load placements can cause relatively high muscle forces to maintain postural stability. Therefore, positioning the load around the T1-T6 region places the load's center of mass as close to the body as possible, creating a more efficient mode for load carriage.

Hong et al. (2002) studied the electromyography (EMG) of 23 primary school boys aged between nine and ten years old as they walked for approximately 2 km under four conditions: no bag, school bag with 10 % of body weight, schoolbag with 15 % of bodyweight and schoolbag with 20 % of body weight. Surface electrodes were used in the recording of myoelectric activity from the muscles of upper trapezius, thoracic erector spinae at T12 and lumbar erector spinae at L3. The results showed that the load carried significantly influenced the degree of fatigue and muscular activity of upper trapezius. The load of 15 % body weight also resulted in significant increase in IEMG and decrease in mean power frequency (MNF). On the other hand, walking distance significantly influenced the degree of fatigue of the lumbar erector spinae. However, the EMG activity of lumbar erector spinae decreased as the weight increased and the erector spinae at T12 did not show either a significant main effect or interaction in the EMG responses.

Motmans et al. (2006) also reported of trunk muscle activity by the modes of carriage. The participants were 19 healthy students with mean age 20 who carried a load of 15 % of their body weight. The students stood erect with the knees extended and feet 15 cm apart in the frontal plane. Electromyographic (EMG) activity from rectus abdominis and erector spinae was recorded in both the right and the left side in the five static conditions: no bag; shoulder bag; backpack; front pack; double pack. The result showed decrease in erector spinae activities during the carriage of 15 % bodyweight backpack and increased with the shoulder bag and the front pack. The abdominal muscles showed a slightly significant asymmetry for the shoulder bag and for the backpack. A front pack showed a global higher working rate, especially for the back muscles.

Piscione et al. (2006) conducted research on the effect of backpack carrying on fatigue of two shoulder muscles during sustained low force static contraction: the middle deltoid muscle and the upper trapezius muscle on which the backpack strap exerted direct compressive force. 8 males with mean age, height and weight of 24 years, 182 cm and 77.5 kg respectively volunteered to carry backpacks load of 0, 10, and 20 kg. The parameters were computed from the recorded signals of electromyographic (EMG) amplitude of root mean square (RMS) and spectral mean power frequency (MNF). The results showed that increased local fatigue of upper trapezius muscle could be explained by direct compressive force of backpack's strap on this muscle. From the results concerning RMS, the larger fatigue of upper trapezius muscle cannot be explained by the increase of muscle activity when carrying load. Activation level of upper trapezius muscle was not higher during the exhausting task in the conditions of load carrying. On the contrary, its increase was lower, so that at the failure task time compared to the reference condition has shown either no significant divergence for a load carrying mass of either 10 kg or 20 kg the muscle activation was significantly smaller.

Another factor affecting the physiology and biomechanics was evaluated by Devroey et al. (2007). The effect of backpack load and position during standing and walking were analyzed. This studied changes in physiological variables of surface electromyography (EMG) of seven muscles (trapezius pars descendens, sternocleidomastoideus, erector spinae longissimus, rectus abdominis, obliquus externus abdominis, rectus femoris and biceps femoris) and heart rate, biomechanical (joint angles) as well as subjective (Borg scale, position preference) variables during standing and gait under different load conditions. A total of 20 college students including 12 males and 8 females with a mean age of 23 years, body height 175 cm and weight 69 kg were chosen to try four load conditions: carrying an empty backpack of 0 %, 5 %, 10 % and 15 % of the subject's BW. Muscle activities of erector spinae longissimus decreased, rectus abdominis and obliquus externus abdominis increased for the heaviest loads. However, for the back extensor muscles and thorax flexion placements, EMG results showed a decrease of back extensor (erector spinae longissimus) activity with an increase of abdominal muscle activation when increasing loads.

Another similar study of backpacks on head posture and neck muscle electromyography by Kim et al. (2008) used 15 children with a mean age of 10.3 years to investigate four load conditions: no pack, a backpack, a double pack, a modified double pack. All participants walked on a treadmill at the speed of 0.8 m/s with 5 % and 10 % of body weight. The EMG activity of the amplitudes was recorded of upper trapezius (UT), sternocleidomastoid (SCM) and midcervical paraspinals muscles (MPS). The EMG activity of the UT was significantly higher while carrying the backpack, double pack and modified double pack. For the double pack, the UT and SCM, EMG activity was also significantly higher than without a backpack or with the modified double pack. When carrying a modified double pack, the forward head angle and forward head distance reduced contrasted to when carrying a backpack.

Another study by Bauer et al. (2009) examined backpack load limit for middle school students. 20 healthy students aged 11 to 14 (10 female and 10 male) volunteered. The students completed two examinations, standing stationary and walking on a treadmill. Surface electrodes were placed over the muscle belly in alignment with the muscle fibers to examine the EMG of the trapezius, latissimus dorsi, and erector spinae muscles. They took 5 % incremental loads from 0 % body mass (BM) to 20 % BM. The results showed that there were no significant differences in the standing trials for EMG trapezius, EMG latissimus dorsi, and EMG right erector spinae. The only significant changes in the EMG were the decrease in activity between loads of 0 % and 20 % BM and

10 % and 20 % BM for the left erector spinae muscle.

In another study on the effect of prolonged walking with load carriage on muscle activity and fatigue in children by Hong et al. (2008), 15 male children, aged 6, height 120, mass 22.9 kg participated from local primary schools. Subjects performed 20-min walking on the treadmill and the four testing loads liked 0 %, 10 %, 15 % and 20 % of the subject’s body weight (BW). Electromyography (EMG) signals from upper trapezius, lower trapezius and rectus abdominis were recorded at several time intervals (0, 5, 10, 15 and 20 min), and were normalized to the signals collected during maximum voluntary contraction. The results showed that a load of 20 % body weight significantly introduced muscle fatigue in upper trapezius in 10 min and in lower trapezius in 15 min and that no fatigue was found when the load was within 15 % body weight. Also no increased muscle activity or muscle fatigue was found in rectus abdominis with the 20 % body weight (BW) load range while walking 20 min. The research reported that backpack loads for children should be limited to no more than 15 % body weight for walks of up to 20 min period to prevent muscle fatigue.

Al-Khabbaz et al. (2008) used 19 male university students of age 21. All subjects were healthy with normal body mass of 20.7, height 170 cm, weight 59.7 kg. Each participant was asked to stand in four modes: unloaded standing, 10 %, 15 % and 20 % BW load. Bilateral sEMG activities of erector spinae (trunk extensor), rectus abdominis (trunk flexor), vastus medialis (knee extensor) and biceps femoris (knee flexor) were recorded during all standing modes. The rectus abdominis muscle activities declined increasingly and disproportionably as the backpack weight increased. Also no significant alters happened to erector spinae, vastus medialis or biceps femoris.

Table 2: Select studies on electromyography of backpacks.

Researcher	Investigation	Criteria	Results
Bobet & Norman 1984	Effects of load placement on back muscle activity in load carriage	EMG, load Carriage, load placement	- Sig. Increase the C1-C7 region in the levels of muscle activity of both the trapezius and erector spinae muscles compared to the T1-T6 region. - No sig. Different heart rate between the two placements.
Hong & Cheung 2002	Electromyographic responses of back muscles during load carriage walking in children	IEMG, MNF Load carriage	- Sig. increase IEMG, decrease MNA (upper trapezius) The load of 15 % body weight. - No sig. Difference for Weight (Lumbar erector spinae). - Sig. Effect Distance in all EMG data. (Lumbar erector spinae).
Motmans et al. 2006	Trunk muscle activity in different modes of carrying schoolbags	EMG, Load carriage	- No sig. Difference in EMG activity with unloads standing (double pack, front and a backpack). - Sig. Increase shoulder bag and front bag. - Decrease backpack (erector spinae). - Sig. Higher EMG in backpack (Rectus abdminis).
Piscione et al. 2006	Effect of mechanical compression due to load carrying on shoulder muscle fatigue during sustained isometric arm abduction: an electromyographic study	IEMG, MNF, Backpack, Compression	- Increase local fatigue of (upper trapezius) muscle by direct compressive force of backpacks. - No sig. divergence for a load carrying mass of 10 kg either or for a mass of 20 kg, muscle activation significantly smaller.

Researcher	Investigation	Criteria	Results
Devroey et al. 2007	Evaluation of the effect of backpack load and position during standing and walking using bio-mechanical	EMG, load carriage Musculoskeletal Subjective score	- Sig. Increase thorax flexion, activation of abdominals, heart rate and Borg scores for the heaviest loads. - Sig. Reduced activity of M. eretor spinae vs. (15 % of body weight).
Hong et al. 2008	Effect of prolonged walking with load carriage on muscle activity and fatigue in children	EMG, MPF, Load carriage, schoolbag	- Sig. increase IEMG (Lower trapezius) The load of 15 % body weight from 15 min and a 20 % BW increase IEMG from 5 min, MPF increase from 15 min (LT). - No increase IEMG (Upper trapezius) the 20-min period, MPF increase from 10min. - No increase IEMG or MPF in rectus abdminis.
Al-Khabbaz et al. 2008	The effect of backpack heaviness on trunk-lower extremity muscle activities and trunk posture	EMG, Trunk posture, Backpack, Load carriage (0 %, 10 %, 15 %, 20 %)	- No sig. erector spinae, vastus medialis or biceps femoris. - Increase EMG the rectus abdominis progressively and disproportionably as the backpack heaviness increase.
Kim et al. 2008	Changes in neck muscle electromyography and forwaed head posture of children when carrying schoolbags	EMG Forward head posture,schoolbag Upper trapezius Sternocleido-mastoid Midcervical paraspinals	- Sig higher, the EMG activity of (UT, SCM, MPS) forward head angle, forward head distance with backpack. -Double pack: increase negative (FHA) - Increase signal EMG (SCM), decrease (AHD) und EMG (MPS). -A modified double pack: decrease (FHA, AHD).
Bauer et al. 2009	Backpack load limit recommendation for middle school students based on physiological and psychophysical measurements	EMG, Backpack, Child safety, Percent body mass	- No sig. Different in the standing trials for EMG trapezius, EMG latissimus dorsi, and EMG right erector spinae.

2.5 Backpacks cause back pain in children

Hertzberg A. (1985) recorded information on 302 healthy subjects (152 female and 150 male) between the ages of 9 and 12, due to the recent attention on the role of backpack use in the development of cervical and lower back pain in children. The results showed that certain physical factors, particularly muscular tension in the neck and shoulders during adolescence, there consist a significant risk factor for the later excess morbidity from the cervical pain. No harmonious risk factor for lumbar pain was found. Cervical pain happened more frequently in the females than in the males.

Cumulative prevalence of back pain was 51 %, with 14.9 % of subjects having frequent or continual back pain in Troussier et al. (1994) cross-sectional study of 1178 French children, ages 6 to 20. Risk factors for back pain included previous history of injury, increased time watching television, participation in volleyball, and female gender. The researchers recommend that volleyball, the only competitive sport related with back pain after multivariate analysis, may persuade hyperextension of the spine and reason spinal compression. Though a more of time sitting in school and bigger backpack weight were cited as reasoning increased stress and constraints on the back, neither were found to significantly correlate with back pain.

Burton et al. (1996) conducted a 5-year long study of back pain in 216 adolescents attending a state school in northern England. The mean age at the beginning of the study was 11.7 years. They reported that back pain rose steadily from 11.6 % at age 11 to 50.4 % at 15 and that back pain was more common in boys than girls, especially by age 15. There was a positive relationship between sports and back pain, but only for boys. Although recurrence of back pain increased over the five years, most recurrences were in the first year.

Grimmer et al. (1999) examined the association of pain and environmental features of 985 students, aged 12 to 18 years and from five different grade levels. Backpack loads and preference while carrying the backpack were included in the list of environmental features. Specific classes were chosen from the participating high schools. Only one class was measured per day and the schools chose the day of the week. The study included backpack and student weights, student height, and questionnaire information. 72 % of the students who carried backpacks preferred to carry them over two shoulders. They found that one-fifth of each high school level carried more than 10 % of their body weight. Subjects with low back pain were carrying heavier backpacks in relation to their body weight. This was true for all subjects except for boys at age 8 and girls at ages 11 and 12. These differences have to do with the developmental alter occurring at this age. The study also found that carrying loaded backpacks was associated with low back pain for boys and girls.

Another study by Negrini et al. (1999) examined backpack loads on Italian children. Data was obtained from 6th graders (number 237, mean age 11.6 years) and was collected six days a week for three weeks. Teachers and students were not informed of the exact dates backpacks were to be measured. The average load carried by the children was 9.3 kg and the maximum load was 11.5 kg. The researchers found that the average load carried was 22 % of bodyweight and the maximum load was 27.5 % of bodyweight. At least once during the week 34.8 % of the students carried more than 30 % of their bodyweight. The maximum load carried by these children was equal to an 80 kg man carrying a backpack with an average load of 17.6 kg and a maximum load of 22 kg.

Iyer S.R. (2001) studied chronic musculoskeletal pain in 248 Indian and 103. American schoolchildren aged 9 to 20.6 while carrying a standard 10 kg, or 7 kg. The chronic musculoskeletal pain reasoned by the weight of carry-on items in the school backpack was found, as a significant problem. Pain represents a symptom, not a sign. A number factors influence pain among school children who carry backpacks-including the actual weight carried, body mass index and percent body fat-despite the fact that the perception of pain is very personal and subjective.

Negrini and Carabalona (2002) performed a study using 237 of 6th grade children in a school catchment area of Milan who were weighed on six school days. The data was analyzed in groups according to the schools and classes involved the single children, and the days of the week. A validated questionnaire was also administered to 115 schoolchildren (54 boys and 61 girls; average age, 11.7 years) whose anthropometric characteristics and loads carried daily were known. In the studied school backpacks were felt to be weighty by 79.1 % of children, to reason fatigue by 65.7 %, and to reason back pain by 46.1 %. Fatigue was related the time spent backpack carrying, but not the backpack’s weight, was related with back pain.

A study in Boston, Massachusetts by Goodgold et al. (2002b) determined to gather information on demographics, leisure activity level, bag type, locker use, students’ perceptions of bag weight and comfort, and students’ reports of history of back pain. The research showed that 55 % of 345 schoolchildren aged between 11 and 14 years, grades five through eight, carried backpack loads greater than 15 % of their body weight and almost one third of the students reported a history of back pain.

,,The types of backpack injuries reported in children include back pain, rucksack palsy, shoulder pain and muscle soreness. A correlation between backpack use and back pain has been documented by numerous authors with children ranging from 9 to 18 years of age''(e.g. Grimmer & Williams, 2000; Sheir-Neiss et al., 2003).

Wiersema et al. (2003) examined the effects of backpack-related injuries in 247 6 to 18-year old children who were analyzed from an American first-aid database. The data shows that the main causes for backpack connected injuries were tripping more the backpack 28 %, getting hit by the backpack 13 %, wearing a backpack 13 % and lifting a backpack 8 %. The most common injuries were to the head/face 22 % followed by the hand 14 %, wrist/elbow 13 %, shoulder 12 % and, foot/ankle 12 % with only a small percentage affecting the back 11 %. Back pain started during carrying a backpack in 6 % of the cases, and during lifting of the backpack in 1 % of the cases. These numbers, based on data from the US Consumer Product Safety Commission, are derived from those injuries treated in hospital emergency departments and likely reflect the acute, external trauma associated with backpacks.

Sheir-Neiss et al. (2003) reported that greater backpack weight was also found to be a predictor of back pain. The completed of 1126 children, ages 12 to 18 years, from a questionnaire about their health, activities, and backpack use. Of the 1122 students who used backpacks or had a backpack weighed upon them, 74.4 % reported back pain. The mean backpack load in group was only 4 kg. This mean load was slightly lighter than most preceding review of schoolchildren from different countries ranging from 4 to 8.3 kg.

Two studies examining the relationship of psychologic factors to back pain in children did not find a relationship between the weight of school bags and back pain. A recent study by Van Gent et al. (2003) of 745 young adolescents in the Netherlands reported that complaints of neck, shoulder, and back pain were related to psychosomatic factors and not to the weight of the schoolbag. In an inhabitant of young adolescents, neck and/or shoulder grievances and back complaints were found by 43.6 % and 46.5 %, respectively. A similar study by Jones et al. (2003) in England reported of 1046 schoolchildren, aged 11 to 14 years at baseline, identified as being free of LBP, from 39 secondary schools in Northwest England. In children who were in the beginning free of low back pain, opposite psychosocial factors and preexisting somatic pain symptoms were predictive of future low back pain.

Wall et al. (2003) reported that an estimated 393 injuries in patients were associated with backpack utilize between 1998 and 2001 but few were associated with backpain. Exclusion criteria were between age 6 and 18 years. Of the 346 patients involved in this investigation, only one child characterized back pain to wearing a backpack. Three patients reported that their back pain was made worse by carrying their backpack. A phone survey showed that 80 % of the patients in this investigation wore a backpack for school purposes.

Siambanes et al. (2004) studied load carriage of 3,498 students living in two counties in California. Each student's weight and backpack load were measured, and over 64 % of the students showed having back pain at some time, 41.3 % felt this pain when carrying their backpack, and almost all of them confirmed feeling relief upon taking off their backpack. Of those who found back pain, 12.5 % showed that their pain was "not bad," 87 % indicated that their pain was "bad" or "very bad," and 16.1 % showed that they had missed school, gym class, or after-school sports because of the pain. In additional, 16.9 % had been to a doctor for the back pain. 21 of the subjects reporting back pain showed their pain had persisted for over 6 months. Furthermore, 59 % of the subjects noted recurring pain (23 % monthly, 17 % weekly, and 19 % daily).

Korovessis et al. (2004) in United States investigated the correlation between backpack carrying, spinal curvatures, the athletic activities on schoolchildren's dorsal pain (DP) and low back pain (LBP). 3441 students aged from 9 to 15 years who carried backpacks to school were asked for DP and LBP experiences. Dorsal pain (DP) increased with increasing backpack weight ($p<0.05$). The method (one versus both shoulders) of backpack carrying did not relate either with DP or with LBP and girls significantly more LBP and DP than boys ($p<0.001$). Students' age, height, the body weight of kyphosis, lordosis, and scoliosis did not relate with either LBP or DP. Girls at the age of 11 indicated the highest occurrence of LBP (71 %), while for the boys, it was at the age of 15 years (21 %). Girls at the age of 11 also indicated significantly more LBP ($p<0.05$) than boys and girls who subject in sports activities seem to performed more of-ten DP and LBP than boys.

Another similar study also of backpacks, back pain, Sagittal Spinal Curves and Trunk Alignment in adolescents was conducted by Korovessis et al. (2005). A total of 1263 students aged 12-18 years old were measured for craniocervical angle (CCA), thoracic kyphosis, lumbar lordosis, and shoulder shift (BL) with a Kyphometer and Scoliometer. Backpack carrying decreased CCA and changed shoulder and upper trunk shift. Asymmetrical backpack carrying increased DP and LBP. BL-shift increased dorsal pain. Dorsal pain (DP) and low back pain (LBP) increased with coronal trunk shift and sagittal trunk shift increased LBP. Asymmetrical carrying of backpacks added back pain and shoulder change in holidays and also coronal trunk change while carrying backpacks asymmetrically added back pain in holidays. Thus asymmetric backpack carrying and frontal trunk change is connected with high intensity pain. Not only is the load of the backpack a difficulty, but the lack of lockers can also be a related factor of adolescents' musculoskeletal symptoms.

Chiang et al. (2006) of Boston University reported that carrying backpack was an effect of gender and age environmental associates of middle school students' low back pain. Subjects were 55 children between 13-14 years old, and weights of students, loaded backpacks, backpack contents, and students' heights were measured separately. Over 8 % of them favored to carry the load over two shoulders. The average load weighed 4.9 kg (approximating 9.6 % of the participants' body weight). Daily backpack carrying is a frequent cause of musculoskeletal discomfort for adolescents. The association between backpack carrying time and low back pain may provide the impetus for parents, teachers, and school administrators to decrease the prolonged carrying of backpacks. There was a significant relationship showed between backpack taking time and adolescent' low back pain. Also ninety-four percent of the 55 children's utilized school lockers at school; half of them used lockers at the beginning and end of the day, nearly half of them utilized locker between classes, only 11.3 % of the children's used lockers "not often" and 2 % never utilized lockers.

A study in Iran by Mohseni-Bandpei et al. (2007) investigated the nonspecific low back pain in 5000 Iranian school-age children. They randomly recruited 5000 secondary schoolchildren aged 11-14 years in the north of Iran and completed a questionnaire designed to determine point, last month, last 6-month period, and annual prevalence of LBP. The Point, last month, last 6 months, and annual prevalence were 15 %, 14.4 %, 15.6 % and 17.4 %, respectively. No connection was found between backpack weight and prevalence of low back pain. Low back pain was significantly correlated with age, position and time spent watching television, position and duration of homework. There was no relationship between low back pain and body mass index.

Chow et al. (2007) determined the changes in spinal curvature and proprioception of schoolboys carrying different weights of backpack. They used 15 healthy male ages of 15 and 16 while carrying a specially adapted backpack loaded at 10 %, 15 % and 20 % without any musculoskeletal deformity or history of pain or injury of the spine or shoulder. There was a significant flattening of the lumbar lordosis and the upper thoracic kyphosis was showed with increasing backpack load, in addition to a significant decline in the thoraco-lumbar and lumbar shifting consistencies.

Macias et al. (2008) used four male and five female participants to investigate the asymmetric loads and pain associated with backpack carrying by children. The backpacks were loaded at 0 %, 10 %, 20 % and 30 % body weight (BW) under two conditions: low on back or high on back. Subjects' age, height, and weight were 13 years, 136 cm, and 62 kg respectively. The repeated measures revealed a significant main effect for load; when standing with the backpack straps over both shoulders in the low-back condition, contact pressure beneath the shoulder straps increased significantly over the 10 %, 20 % and 30 % BW loading range and with the backpack straps over both shoulders in the low-back condition. The contact pressure beneath the right shoulder was significantly greater compare to the left shoulder over the 10 %, 20 % and 30 % BW loading range. In addition, the effect for donning style did not show a significant difference in contact pressures in the low back condition versus the high-back condition over the 10 %, 20 % and 30 % BW loading range.

Another factor affecting load and backpack weight was changing in the lumbar spine response to typical school backpack loads in healthy children. A review by Neuschwander et al. (2010) suggested that the lumbar spine in this setting was measured for the first time by an upright magnetic resonance imaging (MRI) scanner. Three boys and five girls, aged 11 experiences T2 weighted sagittal and coronal MRI scans of the lumbar spine while standing. Scans were confirmed with 4.8 and 12 kg backpack loads, which indicated approximately 10 %, 20 % and 30 % body weight. Increasing backpack loads significantly compressed lumbar disc heights. Measured in the midline sagittal plane ($P < 0.05$) Lumbar asymmetry was: 2.23° ± 1.07° standing, 5.46° ± 2.50° with 4 kg, 9.18° ± 2.25° with 8 kg, and 5.68° ± 1.76° with 12 kg. Backpack loads significantly increased ($P<0.03$) lumbar asymmetry.

Table 3: Select studies on back pain of backpacks.

Researcher	Investigation	Criteria	Results
Hertzberg 1985	Prediction of cervical and low-back pain based on routine school health examinations	Backpack, School health, cervicobrachial disorders, low-back pain	- Sig. The muscular tension in the neck and shoulders for later excess morbidity from cervical pain. - Cervical pain more frequently in the females than in the males. - Lumbar pain somewhat more in capacitating than cervical pain.
Troussier et al. 1994	Back pain in school-children: a study among 1178 pupils.	Lumber pain, Thoracic pain , Leg pain , Back pain	- A greater of time sitting in school and greater backpack weight. - Cause increase stress and constraints on the back.
Burton et al. (1996)	The natural history of low back pain in adolescents	history of back pain (boys, girls) , sport, lumbar flexibility	- Positive (sports and back pain) for boys. - Severity and flexibility were not related to sex, or sport.
Grimmer et al. (1999)	The associations between adolescent head-on-neck posture, backpack weight, and anthropometric features	Backpack, students (weight, height), questionnaire	- Sig. The craniovertebral angle at every year level, standing posture (no backpack with backpack)- - Load backpacks associated with low back pain for boys and girls.
Iyer S.R. (2001)	An ergonomic study of chronic musculoskeletal pain in school children	Chronic Musculoskeletal Pain, Backpacks, Pain Prevention Screening	- No sig different in the mean pain level by both the younger and older groups in both countries. - No sig different the Indians compared to the Americans for the standard 10 kg backpack.

Researcher	Investigation	Criteria	Results
Negrini and Carabalona (2002)	Backpacks on! Schoolchildren's Perceptions of Load, Associations with Back Pain and Factors Determining the Load	Questionnaire, backpack, children of the load (fatigue, feeling it to be heavy, pain)	- School backpacks were felt to be heavy by 79.1 % of children, to cause fatigue by 65.7 %, and to cause back pain by 46.1 %. - There was an association between load and back pain, although the relationship is not direct.
Goodgold et al. (2002b)	Backpack use in children	Child, adolescence, body weight, weight-bearing, physiology low back pain, Questionnaire	- Sig different of grade on weight, bag weight and percentage of body weight. - No sig different for children their backpack was uncomfortable and those carrying greater than 15 % of body weight as compared with children carrying lighter loads. - One third of the children carrying more than 15 % of their body weight did not identify the backpack as heavy.
Sheir-Neiss GI et al. (2003)	The association of backpack use and back pain in adolescents.	Backpack, questionnaire, neck or back pain, sports	- Sig different in the 22 schools into eight types of back pain. - No sig different of back pain between one strap and two straps. - The mean weight carried by the adolescents was 14.7 % of their body weight. - Most of the students (79.6 %) carried more than 10 % of their body weight; 47 % of the students carried more than 15 % of their body weight; and 18.9 % of the students carried more than 20 % of their body weight.

Researcher	Investigation	Criteria	Results
Van Gent et al. (2003)	The weight of school-bags and the occurrence of neck, shoulder and back pain in young adolescents	questionnaire, complaints of back, neck, and/or shoulders,	- Neck and/or shoulder complaints and also back complaints about 45 % of young adolescents. - Severe complaints of neck and/or shoulder 6 %, and severe back complaints 7 % of schoolchildren.
Korovessis et al. (2004)	Correlation between Backpack Weight and Way of Carrying, Sagittal and Frontal Spinal Curvatures, Athletic Activity, and Dorsal and Low Back Pain in Schoolchildren and Adolescents.	Children, low back pain, dorsal pain, school backpack, scoliometer, kyphometer	- No difference in the prevalence of LBP and DP between adolescents and children. - Girls much more LBP and DP than boys. - No correlation between scoliosis and DP and LBP. LBP and DP and backpack weight percentage.
Korovessis et al. (2005)	Backpacks, Back Pain, Sagittal Spinal Curves and Trunk Alignment in Adolescents.	Adolescents, low back pain, dorsal pain, kyphosis, Lordosis, craniocervical angle, backpacks.	- No sig. correlation between DP, LBP, and percentage of backpack in relation to body weight. - Backpack carrying, particularly asymmetrically, results in shift of upper trunk and shoulder and cervical Lordosis, furthermore seem to increase back pain in school period and holidays. - 59 % students went to school on foot, 40 % were transported by bus or car, and 1 % by bicycle.
Chiang et al. (2006)	Gender-age environmental associates of middle school students' low back pain	Dolescents, backpack load, ergonomics	- Sig. between backpack carrying time and adolescent low back pain. - The average load weighed 4.9 kg (approximating 9.6 % of the participants' body weight).

Researcher	Investigation	Criteria	Results
Mohseni-Bandpei et al. (2007)	Nonspecific Low Back Pain in 5000 Iranian School-age Children	Low back pain, schoolchildren, prevalence, risk factors	- No sig. between schoolbag weight and prevalence of LBP. - Sig. correlated low back pain with age, position and time spent watching television. - The prevalence of LBP in schoolchildren is relatively high.
Chow et al. (2007)	Changes in spinal curvature and proprioception of schoolboys carrying different weights of backpack	Backpack, schoolboys, Spinal curvature load (0 %, 10 %, 15 %, 20 %),	- Sig. the lumbar lordosis and the upper thoracic with increasing backpack load and decrease in the thoraco-lumbar and lumbar repositioning consistencies.
Macias et al. (2008)	Asymmetric Loads and Pain Associated With Backpack Carrying by Children	Backpacks, low back pain, shoulder pain, children, Body weight (10 %, 20 %, 30 %)	- Sig. the backpack straps over both shoulders in the low-back. - Sig. shoulder pain with the backpack over 1 shoulder than that for donning with 2 shoulders in the low-back condition.

2.6 Physiological effects of backpacks use in children

Recently, load carriage investigations have been concentrating on quantifying the metabolic energy cost of carrying loads. Metabolic energy costs, measured as oxygen consumption rates, represent the net physiological cost of the working body. It is related to an individual's aerobic fitness level and an important variable for predicting physical work capacity and fatigue. However, measurement of oxygen consumption alone is not sufficiently sensitive to reflect typical biomechanical adaptations to load carriage (Graafmans et al., 1996; Matheson et al., 1999).

Merati et al. (2001) investigated the cardio-respiratory adjustments and cost of Locomotion in school children during backpack walking. A group of 17 girls and 18 boys, mean age 11 years were measured for oxygen consumption (VO_2), pulmonary ventilation, and heart rate. The results showed that the oxygen consumption increased from 24 % VO_2max to 26.4 % VO_2max in boys and from 28 % VO_2max to 39.7 % VO_2max in girls when comparing the unloaded and loaded situations. The differences between males and females are due to the variation in the relative weight of the load (17.6 % of the mean male BW and 21.4 % of the mean female BW). Without using relative weights for each subject, it is difficult to compare or group the responses.

Li et al. (2003) introduced the effect of load carriage on movement kinematics and respiratory parameters in children while walking. 15 boys with a mean age of 10 years were selected from a primary school to participate in four walking experiments on a treadmill: one with a load of 0 % of body mass, and three whilst carrying loads that weighed 10 %, 15 %, and 20 % of the child's body mass. They were alterations of (VT=Tidal volume), (*f*R=Respiration rate) and (VE=Minute ventilation) in different load conditions at the 20^{th} min of walking. That VE showed a significant increase in the 15 % and 20 % load conditions when compared with that measured in 0 % load condition. Walking for 20 min with a backpack loading 10 % of body mass did not significantly alteration the (VE). In the two components related to (VE), (*f*R) and (VT), significantly faster (*f*R) was shown in the 20 % load condition compared with 0 % load condition , while (VT) did not show any significant difference between the four load conditions.

The first of two Hong and Brueggemann (2000) studies described, used 15 boys aged ten years from a local primary school to investigate the changes in gait patterns in 10 year boys when increasing loads while walking on a treadmill. The heart rate and blood pressure in children carrying school bags of 0 % as control, 10 %, 15 % and 20 % of their body weight whilst walking on a treadmill were measured. Heart rate increased significantly in the first 5 min of walking for all load conditions and continued gradual increase thereafter. There were no significant differences in heart rate during the walk over time. No significant differences were found in heart rates among the different loads carried and the blood pressure fell to the level of baseline when carrying loads of 0 % and 10 % body weight, after 3 min of recovery. However, even after 5 min of recovery, the blood pressure when carrying loads of 15 % and 20 % of body weight was still higher than the baseline. The study series by Hong et al. (2000) about the effects of load carriage on heart rate, blood pressure and energy expenditure in children used 15 male primary school children aged ten with a mean body weight of 33 kg and a mean body height of 141cm. They carried school bags of 10 %, 15 % and 20 % of their own body weights, where 0 % body weight was used as a control. Maximum oxygen uptake (VO_2max) examinations were conducted on a motorized treadmill utilising a continuous incremental protocol. Blood pressures were measured before, immediately following, and at 3 and 5 min intervals. A significant difference in VO_2 was observed when the load reached 20 % body weight. Blood pressure showed to be dependent on the load carried. A significant add in systolic and diastolic blood pressure was found after 20 minutes of walking for the 20 % BW states compared to the unloaded state with 10-year boys. Diastolic blood pressure recovery was found significantly faster for the lighter weights (0 % and 10 % BW) than the loads of 15 % and 20 % BW.

Stuempfle et al. (2004) similarly found the effect to the center of gravity of load on physiological response. 10 female subjects carried 25 % of their body weight with a backpack and the load was placed in the high T1-T6, medium T7-T12, or low position L1-L5. The variables included oxygen consumption (VO_2), heart rate (HR), respiratory exchange ratio (R), respiratory rate (RR), minute ventilation (VE), and rating of perceived exertion (RPE). Oxygen consumption and minute ventilation of the increased location were significantly lower than those at a low location. This result was consistent with that of investigations by Obusek et al. (1997), in which it was shown that the lowest metabolic cost occurred when the 25 kg load was positioned on the highest position and closest to the body. These researchers suggested that the load in the increased position was close to the center of gravity of the body and generated relatively small movements. Usually talking, the external weight in backpack adds the energy expenditure during walking with respect to the oxygen consumption.

The oxygen consumption associated with unloaded walking and load carriage was investigated using two different backpack designs by Lioyd et al. (2000). They used nine volunteers-five female and four male-who walked at 3 km/h at various uphill and downhill gradients on a treadmill without a load and carrying a load of 25.6 kg in each of the backpacks. In adults, weights of as much as 20 % body weight could be taken with no additional increases in oxygen consumption. Beyond this limit, increases in backpack weight were associated with proportionate increases in O_2 consumption. Any position close to the body requires less effort. This fact can be used to an advantage in backpack design. An internal frame pack can be carried close to the body and is associated with better perception of comfort by the users compared with external frame designs.

In a review by Daneshmandi et al. (2008) in Iran, 15 students voluntarily participated in different tests of carrying backpacks. The mean body mass index, height and weight of these 15 subjects were 20 kg/m^2, 160 cm and 50 kg respectively. They took schoolbags with 0 % as a control group, 8 %, 10.5 % and 13 % of their body weights on a treadmill at 1.1 m/s for 15 min. Physiological parameters studied included cardiovascular parameters (in terms of HR, systolic blood pressure (SBP) and diastolic blood pressure (DBP)) and respiratory parameters (in terms of minute ventilation (MV) and respiratory frequency (RF)). The DBP added significantly only at the 13 % body weight load state, after 15 min of walking. The weight of schoolbags for high school subjects can be suggested as 8 % of their BW, because carrying 8 % BW load did not significantly alter cardio-respiratory parameters. During and 3 min after carrying schoolbags 10.5 % and 13 % of body weight the SBP and MV were significantly higher than under 0 % and 8 % BW load states.

In another study by Chow et al. (2009), 22 children-15 males, 7 females, with a mean age, height and weight of 12 years, 151 cm and 40 kg respectively were recruited. This study investigated the effects of backpack load placement on pulmonary capacities of normal schoolchildren during upright stance. The parameters of the participants were measured of respiratory forced vital capacity (FVC), forced expiratory volume (FEV1) FEV1/ FVC ratio, peak expiratory flow (PEF) and forced expiratory flow (FEF 25-75 %) were recorded under unloaded condition and different load placement conditions. However, no significant effect of load placements on the pulmonary function of schoolchildren was found. The results showed that backpack load carriage of 15 % body weight a significant decrease in FEV1 and FVC, but with no significant effects on FEV1/FVC, PEF and FEF 25-75 %.

Table 4: Select studies on physiology of backpacks.

Researcher	Investigation	Criteria	Results
Hong et al. 2000	Effects of load carriage on heart rate, blood pressure and energy expenditure in children	Energy expenditure, Blood pressure, Heart rate, Load carriage	- Sig. differences in VO2 the load 20 % body weight. - Blood pressure dependent on the load carried. - Sig. increase in systolic and diastolic blood pressure after 20 minutes of walking for the 20 % BW.
Lioyd et al. 2000	The oxygen consumption associated with unloaded walking and load carriage using two different backpack designs	Oxygen consumption, Energy expenditure, Rucksacks, Load carriage	- Increases in backpack weight with proportionate increases in O_2 consumption. - In adults, loads of as much as 20 % body weight: no additional increases in oxygen consumption.
Hong et al. 2000	Changes in gait patterns in 10-year-old boys with increasing loads when walking on a treadmill	Load carriage, Backpack, Heart rate, Children, Blood pressure	- No sig. difference in the measure parameters between the 10 and 0 % load conditions. - Even after 5 min of recovery, the blood pressure when carrying loads of 15 % and 20 % of body weight still higher than the baseline.
Merati et al. 2001	Cardio-respiratory adjustments and cost of locomotion in school children during backpack walking	External Load, cost of locomotion in, backpack	- Increase from 24 % VO_2 max to 26.4 % VO_2 max in boys and from 28 % VO_2 max to 39.7 % VO_2 max in girls when comparing the unload and load situations.

2.7 Basic backpack design considerations

A backpack (also known as a rucksack, schoolbag, knapsack, etc.) is a cloth sack carried on one's back and secured with two straps that go over the shoulders, although there can be exceptions. The word backpack was penned in the United States during the 1910s. Knapsack and packsack were used before although now they mostly occur in select regions in North America. The word rucksack is a German word mainly used in the UK and in the US Army: 'der Rücken' meaning 'the back' in German.

Load carriage and different types of schoolbag design have been researched over time (Lioyd & Cooke, 2000; Reid et al., 2004; Jacobson et al., 2004).

One of the first studies that looked at load carriage in children was by Malhotra et al. (1965) who studied the most efficient method (rucksack, low back, across the shoulder and in the hand) of carrying school bags for children. 6 schoolboys between 9 and 15 years of age volunteered as subjects. Though, in concept, carrying weights on the head is the most efficient, this is a difficult task to manage; thus, it was concluded that the schoolbag is the most realistic way of weight carriage for children.

Legg et al. (1997) compared the effect of different schoolbag designs on comfort levels and ratings of perceived exertion in adult test subjects under standardized conditions. The study discovered that users experienced less discomfort if the backpacks included good back support, optimal size and fit, ease of adjustment and wide and well-fitting shoulder and waist straps. In one study, 73.2 % of the surveyed carried their backpack with only one strap while others reported that the majority carry the backpack on both shoulders (Pascoe et al., 1997).

Knapik et al. (1997) showed that a double pack design calculated in more neck and hip pain than a standard pack, but the double pack also calculated in less low back pain, produced fewer deviations from normal walking, and a lower prevalence of blisters (Knapik et al., 1996), suggesting that there is no universal pack design that can be used to accommodate all human needs.

Goh et al. (1998) reported that when a load is applied to the back, the center of gravity shifts posteriorly (causing the body to tilt slightly backwards. To counteract this off-balanced position, a person has a forward flexion of the torso to maintain the body’s center of mass over the feet, which shifts the center of gravity and creates a sense of stability (Bloom & Woodhull-McNeal, 1987; Vacheron et al., 1999). The two main forces on the spine are the compressive and shear forces with increases in the former due to the weight of the external load placed on the back and the increase in the muscle forces used to support the load on the torso. Adds in shear forces are a result of the external weight and the forward flexion. The mass moment of inertia also adds about the L5/S1 joint, creating extra challenges during dynamic activities. Backpacks will decrease the amount of stress placed on the body. The load capacity is an important variable in a backpack, since load has a direct effect on the amount of stress placed on the back (Lioyd & Cooke, 2000).

A study in Boston by Feingold et al. (2002) used an experimental design applied to a convenient sample of children. The subjects were randomly sorted into a control group and an intervention group. Both groups were calculated wearing their own backpack in four different states. The four states were: without bag, with bag carried by one strap, with bag worn with both straps, with bag carried in preferred way of wearing. No quantitative significance showed between control and intervention groups to education on proper backpack wearing improving posture.

Grimmer et al. (2002) completed the only published paper that examines any aspect of design in children’s schoolbags on human subjects. There were nine investigational states: combinations of backpack loads (3.5 or 10 % of body weight) and positions (backpack centred at T7, T12 or L3) on 250 adolescents (12-18 years). The study examined the effects of different loads and load placements of children’s schoolbags on standing posture in the sagittal plane. Horizontal movement was minimized when the load was placed at L3, indicating that less postural adjustment is required to maintain the body’s position in space.

Frank et al. (2003) showed that lower load placements produced less lumbar and shoulder forces but created a significant change in head angle. Therefore, lower forces were applied but posture was adversely affected. To design and configure a load carriage system, certain design criteria should be established as to produce a backpack that decrease the forces and moments on the back.

According to Stevenson et al. (2004), a backpack ought to: transfer the load off the shoulders to the hips via a hip belt; use lateral stiffness rods, when applicable, to help transfer the load to the hips; place the load’s center of gravity as close to the body as possible; position the load around the T1-T6 region. Studies do report even with a variety of features, that backpacks are usually carried over one shoulder or over two shoulders with few carried only in one hand (Talbott et al., 2009).

Making comparisons to school backpacks is difficult as most other backpacks are often prototypes, military packs or backpacks designed for recreational activities (Grimmer & Williams, 2000; Whittfield et al., 2001).

A study by Knapik et al. (2004) reported that the two most common forms of framed backpacks are the internal frame pack and the external frame pack. Internal frame packs have two metal confirming structures sewn into the back panel of the pack which allows the pack to be closer to the center of mass of the body lowers the center of mass and allows the weight to ride directly on a person back, creating a better sense of constancy and control, but decreases back ventilation. Higher energy expenditures showed when weights were distributed to extraneous body parts, such that energy expenditure added by 4 % per kg when added to the thigh region and 7 % to 10 % per kg when added to the lower limbs. Low or mid-back weight placements performed to be most comfortable on uneven terrain, whereas high weight placement was preferred for even terrain.

Using a load carriage simulator, Mackie et al. (2005) examined 32 combinations of gait speed, schoolbag weight, load distribution, shoulder strap length, and use of a hip-belt during load carriage with a backpack. It was shown that schoolbag weight was the greatest influence on shoulder strap tension and shoulder pressure, but hip belt use and shoulder strap adjustment were also significantly related to strap tension and shoulder pressure. Data from human trials on the effects of strap tension, or hip-belt tension could not be found.

Compression of the brachial plexus can cause tingling, numbness, and weakness in the arms and hands. Additional ergonomic features developed for heavier loads and activities include chest and hip belts, compression straps, and rigid internal and external frames. These features stabilize the weight and add comfort. They are, though, more costly and less commonly utilized by children of school age. Additionally, rigid frames need more storage space. (Kidshealth Schoolbags, 2010).

Table 5: Select studies on design of backpacks.

Researcher	Investigation	Criteria	Results
Legg et al. (1997)	Subjective perceptual methods for comparing backpacks	questionnaire, Backpack, weight 20 kg, Pack A (New Zealand), Pack B (British) design, category ratio scale (CRS)	- Comfortable with regard to balance and posture and for shoulder, back and leg muscular tension. - Pack B was initially more comfortable but required more lumbar support. - Overall preference was for Pack A (seven subjects) rather than Pack B (three subjects).
Lloyd et al.(2000)	The oxygen consumption associated with unloaded walking and load carriage using two different backpacks designs	Oxygen consumption, Load carriage, Energy expenditure, Rucksacks	- Sig.decrease with the AARN pack was than that with the traditional pack at the 0 %, 5 %, 10 % and 20 % gradients.
Feingold et al. (2002)	The effect of education on backpack wearing and posture in a middle school population	school-aged children, trunk forward lean, ergonomics	- No sig. quantitative between control and intervention groups in regards to education on proper backpack wearing improving posture. - The 87.5 % of the intervention group members proceeded to continue wearing the backpack properly after the education intervention.
Grimmer et al. (2002)	Adolescent standing postural response to backpack loads: a randomised controlled experimental study	load (3, 5 or 10 % of BW),positions (backpack centred at T7, T12 or L3)	- Neither age nor gender was a significant factor when comparing postural response to backpack loads. - The horizontal position of all anatomical points increased linearly with load.

Researcher	Investigation	Criteria	Results
Stevenson et al. (2004)	Asuite of objective biomechanical measurement tools for personal load carriage system assessment	Backpacks, Mobility circuit, Range of motion stiffness tester	- A dynamic load carriage simulator was developed to simulate cadence of walking, jogging and running. - A stiffness tester for range of motion provided Force-displacement data on pack suspension systems.
Knapik et al. (2004)	Soldier load carriage: historical, physiological, biomechanical, and medical aspects	Load (15 kg), soldier, weapons energy cost	- Hip belts on rucksacks used reduce pressure on the shoulders and increase comfort. - The injuries associated with prolonged load carriage include foot blisters, stress fractures, back strains, metatarsalgia, rucksack palsy, and knee pain.
Mackie et al. (2005)	The effect of simulated school load carriage configurations on shoulder strap tension forces and shoulder interface pressure	Strap tension, Pressure, Schoolbag, gait speed	- The schoolbag weight was the greatest influence on shoulder strap tension and shoulder pressure. - The hip belt use and shoulder strap adjustment were also significantly related to strap tension and shoulder pressure.

2.8 Determination of backpack location

Studies suggesting a difference in posture and gait factors while load is located in a backpack that is placed at different heights of the spine are reflective of the essential for objective aid required to make advices about appropriate backpack wear. Researchers have placed backpacks in multiple locations including at waist height, high on the back, etc. (Holewijn, 1990; Hong & Brueggemann, 2000; LaFiandra et al., 2002; Malhotra & Sengupta, 1965). Classified with the superior feature of the backpack, a high location was defined as being placed at C7 while the low location was placed at the level of the inferior angle of the scapula.

Grimmer et al. (2002) functioned backpack position centered at T7, T12 or L3,weight 3, 5 or 10 % of body mass and measured horizontal shift of markers on the ear, neck, shoulder, hip, 68 thigh, knee and ankle. Position was a significant factor in horizontal shift of the ear, spinous process of C7, mid acromion of the shoulder and the lateral superior iliac crest. Backpacks at T7 made the largest forward horizontal shift in all points except the shoulder and fibula providing some protect for a more inferior placement of load. Weight also significantly influenced the horizontal shift of all markers in a like manner recommending that location and weight must be studied separately.

Everett et al. (1992) investigated the differences between a backpack and a front backpack focusing on walking position as 20 males carried a weight of 61 kg in each backpack. There was a significant alteration in trunk angle and hip angle with both backpacks. The front backpack, however, did not result in as much forward lean as the backpack.

How to measure backpack sizing place on the back

- Position a piece of tape on the seventh vertebra-which is the technical term for the boney bump found at the base of neck between the shoulders (1a)
- Find the appropriate location at the small of back that is precisely at level with the top of the hipbones. Then, slide your hands down the sides of the body until they rest directly on top of hips. Make your Thumbs point towards the spine. Also then ensure that the thumbs are on the same horizontal plane across spine (2a).
- Position another piece of tape at the location on the part of the subject's spine in which the two imaginary horizontal planes would have intersected (3a).
- Finally, position one end of a soft measuring tape on the seventh vertebra (1a) and follow the contour of spine to the other tape mark on lower back (3a) all the way to (4a).

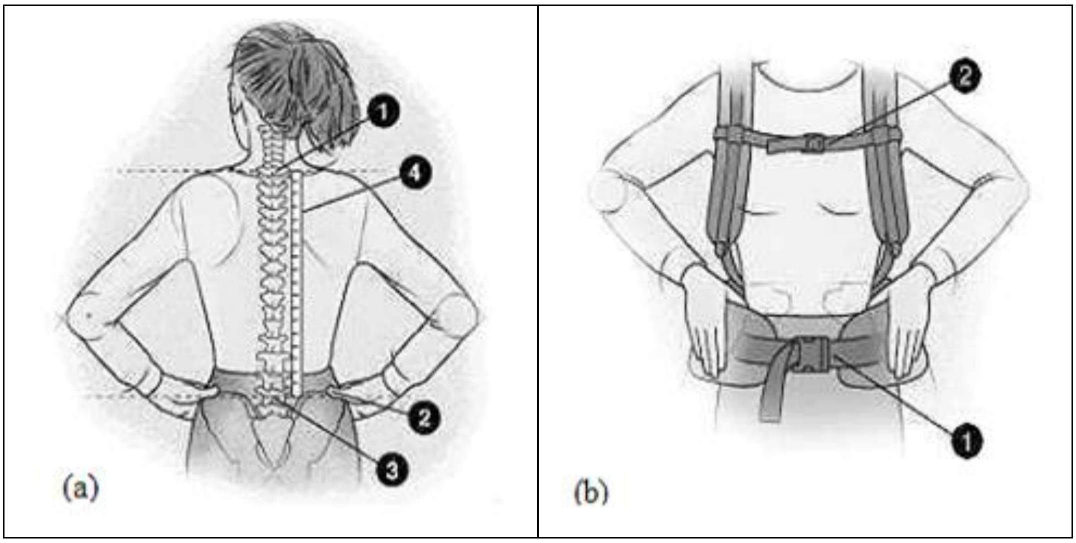


Figure 19: The backpack sizing place on the back [Adapted from backpack sizing, 2010].

Hip belts: Females with narrow hips will have little or no trouble with the standard hip belts while individuals (male or female) with more curves on their hips will need a female style belt (1b).

Shoulder straps: These shoulder straps should anchor more or less around the backpack in an area just below the seventh vertebra and thereby also near the crest of shoulders. They should be able to wrap comfortably around the shoulders and the strap padding should end no closer than 12.5 centimetres below armpits.

Sternum straps: These are meant to keep the shoulder straps from sliding off if put under a load (2b). They are not meant to support body weight and should never be pulled too tightly as they could prevent breathing.

Load-lifters: These load-lifters should preferably form a 45-degree angle with the frame of the backpack from a point at or above the clavicle (Backpack sizing, 2010).

Size chart for children's backpacks: The backpack should be no larger than the child's back. It should rest 2.54-5.08 centimeters below the shoulders and should not rest more than 10.16 cm below the waistline. (1 inch=2.54 centimeter).

Table 6: The size chart for children's backpacks.

Torso Lenght	Under 45 cm	45 to 50 cm	52 cm and over
Suspension Size	Small	Medium	Large

Fitting Guide for a Child's Backpack

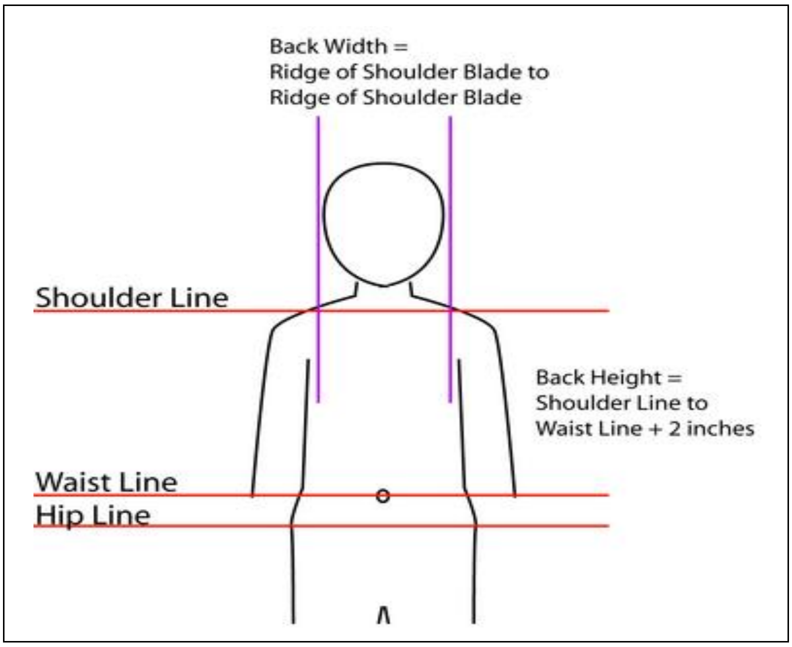


Figure 20: Fitting Guide for a Child's Backpack [Adapted from Chris Adams, 2006].

Age, size and comfort backpack

A proper sized backpack will be worn about 5.08 cm above the waist with both shoulder straps in use. This will lessen the likelihood of position problems and back pain. Consider backpacks with padded shoulder strap, padded back and possibly a waist belt which will transfer weight to the hips. Density straps on the side of the backpack tighten up the compartment.

Safety and durability

Consider backpacks that have some sort of reflective material on the back and the sides. Shorten any straps that too long. Look for a tough durable design if the backpack is to last the full school year. Water-resistant designs also last longer.

Features and style

Select a backpack that has multiple compartments, involving one that is concealed inside a small zippered pocket to keep valuables. Check for a side pocket that will hold a water bottle without falling out. Older schoolchildren tend to lean towards the messenger method bags as an option to the normal backpack. Adolescent schoolchildren may insist on a cartoon-character backpack (backpack sizing, 2010).

2.8.1 Weight of backpack

We all believe and know that kids are the future. Everyone wants their kids to go to the best schools they may provide and have the best of education. In general, high loads are needed to effect changes in these responses.

The amount of weight being carried in the backpacks by adolescents appears to be of great concern to many parents and educators. Legislation of load limits has been suggested but recommendations about what those limits should be are hampered by the lack of research regarding the acute and chronic effects of backpack use.

At the same time, it is evident that loads carried by students are of a large magnitude. Epstein et al. (1988) found that a load of 37 % of body weight (25 kg) carried by adults did not significantly alter total energy cost during a two hour walk but carrying a weight of 59 % (40 kg) of the body weight did change oxygen requirements after only 20 minutes. The importance of muscular strength was demonstrated by Johnson et al. (1995) who reported that increasing loads from 34 kg to 61 kg was linked to corresponding increases in fatigue, levels of muscle discomfort; as well as diminished feelings of well-being and alertness.

Davis et al. (1995) performed a study using nine subjects whose mean age was 36 years old (range, 29-55 years old). They were compared walking on level ground to walking downhill using an 18.2 kg backpack and reported that uneven terrain caused slower walking velocities, greater knee flexion and greater popliteus muscle activity which would require greater strength to reduce the likelihood of injury, particularly in the lower limb region. Shoenfeld et al. (1977) also showed that loads of 30 or 35 kg did not change heart rate, maximal oxygen uptake or laboratory tests in a group of well trained males. Another study by Pascoe et al. (1997) performed an experiment of carrying book bags on static posture and gait kinematics of youths aged 11-13 years. They carried the backpacks from home to school with mean amounts ranging from 10.2 % of the body weight and Vacheron et al. (1999), reported that subjects walking on a 5 % incline for 25 minutes with 10-12 kg load, found signs of shoulder stress, abnormal angular swaying in the trunk, and decreased stride length, exemplifying the need for muscular strength, particularly in the shoulders and trunk regions.

Gunzburg et al. (1999) reported that a greater number of children who walked to school complained of back pain when compared to children who used public or private transportation to get to school. Even with this indication that the time a backpack is carried may be important, few studies have attempted to quantify this factor. Lee et al. (2001) found that work needful agility with an 8.4 kg backpack generated risk factors high muscle forces near isometric maxima, proposing that substantial muscle strength would be required for backpackers to work in environments requiring agility with light to heavy loads.

Wang et al. (2001) showed decreased gait speed and unusually high stress during the single leg support of gait. Backpack weight has been found to vary by grade, increasing in the older grades. In one study by Whittfield et al. (2001), weight was found to average 10.3 % of the body weight for sixth formers (16 years) and 13.2 % for third formers (13 years).

When asked to rate the weight of their backpack, a majority of the students (65.5 %) described their bags as heavy while only 4.9 % considering their bags light. A recent survey of students in the Greater Cincinnati area by Talbott et al. (2009) found that backpacks were considered heavy by 50 % of the students, medium by 46 % and only 4 % of the respondents indicated the backpack was light. Weight, in this study, also appeared to be affected by grade. Fourth grade students carried lighter backpacks and ninth grade students carried the heaviest.

LaFiandra et al. (2002) reported that task needful maneuverability using a payload of 40 % of body weight caused a large 225 % increase in upper body torque at a treadmill speed of 1.6 m/s, reporting that strength limitations may substantially impede maneuverability in some environments. Likewise, Lafiandra and Harman (2004) showed the importance of trunk strength during heavy load carriage with a 40.8 kg schoolbag. Knapik et al. (2004) reported that prolonged load carriage may result in a wide kind of common injuries, involving: foot blisters, stress fractures, back strains, metatarsalgia, rucksack palsy, and knee pain.

Backpacks weighing up to 30 kg have been reported in the literature (Karkoska et al., 1997) with mean amounts carried ranging from 10.2 % of the body mass (Grimmer & Williams, 2000; Pascoe et al., 1997) to amounts that top 20 % or even 25 % of the body mass (Negrini et al., 1999; Whittfield et al., 2001). Quesada et al. (2000) reported that knee extensor muscular fatigue occurred as a result of weights of 15 % and 30 % of body mass. However, only when the payload reached 30 % of subjects' body mass, did they perceive the exertion to be high (e.g. recorded by significantly higher ratings of perceived exertion).

The perception of weight, however, may be influenced by the time the backpack is carried. Voll and Klimt (1977) found the mean time the schoolbag was carried from home to school was 28.5 minutes. In the previously mentioned review (Talbott et al., 2009), the amount of time students wore their backpack was much less. One-third of the students reported wearing the backpack a complete of 10-20 minutes per day with 41 % indicating they spent less than 10 minutes wearing the backpack.

Further, researchers were reported that heavy loads could also increase foot pressure and also maybe causing stress fractures of the foot (Drerup et al., 2003; Arndt et al., 2002). Rosendal et al. (2003) investigated of strength, lower body, aerobic-focused, for 12- week military training program while carrying a 15 kg backpack and showed it improved body position and aerobic fitness, then reduced agility by 5-13 % and made a fourfold increase in injuries, suggesting that muscle strength may have been a principal missing ingredient to the aerobic training plan.

Bahr et al. (2004) concludes that the negative consequences of increased rigidities are loss of functional range of motion and flexibility thus increasing the probability of sprains or strains. Based on the research discussed thus far, greater muscular strength could serve as a defensive mechanism during heavy load carriage. Additionally, Lyons et al. (2005) examined that persons with high amounts of lean muscle mass and low body weight, combined with large body size were negatively correlated with the metabolic request during heavy load carriage ($R= -0.52$ to -0.64, $p<0.01$), explaining the importance of muscle strength for tolerance to load carriage.

2.9 Summary

The aim of this literature review was to examine evidence to support the combined influences of heavy load, position of the load on body, design and location of the load, load distribution and carrying time. In society, backpacks are commonly used to transport loads by foot and bike, though they have also been associated with causing injuries.

Previous studies have reported that weight carriage by children and adolescents during the school period is a general subject discussed by parents and physicians. There is a widely held belief that repeated heavy backpack carriage increases the stresses applied on the spinal structures of children and adolescents. Because back pain at a young age is an important risk factor for experiencing back pain in adult life, investigation and prevention of back pain in adolescents and children seems to be of great value.

The increased load on the back produces an extra pelvic moment and thus contractions of the abdomen muscles increase. Furthermore, swing of trunk when carrying higher loads would cause the abdomen, back and leg muscles to work harder to maintain dynamic balance.

When a load is positioned posterior to the body in the form of a backpack, because of alterations to center of gravity it changes the body posture. The body attempts to maintain the center of gravity between the feet, so with a backpack, the trunk is in a more forward position, thus placing abnormal forces on the spine. These alterations can lead to back pain and injury by changing the forces applied to the intervertebral discs or stressing ligaments and muscles in the back. As the individuals fatigue and these changes become more pronounced, there is potential for the risk of injury to the load carrier.

Many authors in the past have investigated the influences of carrying load on muscle activity, lung function and energy expenditure in children. School children are adolescent who experience a period of accelerated growth and development of skeletal and soft tissue.

Electromyography technique has been used to provide information on the pattern and the magnitude of back muscle activity and muscle fatigue during carriage of various loads distributed on the body in different ways. Numerous factors which can affect the muscle electrical activity and muscle fatigue during load carriage have been investigated. Muscle fatigue could lead to injury either directly through muscle damage or indirectly through alters in coordination, development of muscle imbalances, kinematic and muscle activation variability, and/or movement instability.

This study used electromyography technique to objectively determine both muscle activity and muscle fatigue responding to the load carrying on back in subjects with backpack in the upper trapezius, the thoracic erector spinae at T12 and the erector spinae at L3. Therefore, it is interesting to investigate MVC, IEMG and MPF, while walking with carrying the backpack with different weights.

There are currently no studies concerning backpack weight and carrying time on the distance from the floor to the earlobe joint and (height) the step length of children while walking with carrying the backpack.

Investigations into the changes in posture function with backpack weight in adolescent schoolchildren are therefore recommended for future study, as well as further investigation into the left and right side differences seen in some parameters and the effects on the lower body.

A number of the following questions will be answered in this study while a number are for future investigations:

1) How much should a backpack weigh and which types are better for school?
2) After carrying a backpack, do subjects feel tired without exactly knowing why notice that they cannot relax their muscles properly?
3) What relation is there between weight of the backpack and occurrence of neck, shoulder, and/or back pain complaints?
4) What is the determining ratio between the weight of the child and the child’s backpack?
5) While carrying heavy loads, how can children adjust trunks inclination angle to maintain body posture and balance while walking?
6) What is the relationship between low back pain and backpack weight as percentage of body weight?
7) What is the effect of carrying backpack on shoulder and back posture of schoolchildren following dynamic activities?
8) What changes (including muscle fatigue) occur in the back muscles with the addition of backpack load?
9) What changes does the addition of backpack load have on the distance from the floor to the earlobe joint and step length?

3 Purpose and statement of problem

Previous studies on the load carriage by children can be classified as follows: those who most importantly focused on the influence of load on gait performance, body posture and musculoskeletal deformities (LaFiandra et al., 2002; Korovessis et al., 2005; Chow et al., 2005; Attwells et al., 2006; Rahman et al., 2009; Chow et al., 2010) and those who mainly emphasized on the EMG activity and the fatigue of back muscles (Hong & Cheung, 2002; Motmans et al., 2006; Devroey et al., 2007; Kim et al., 2008; Bauer et al., 2009; Hong et al., 2008).

In addition others concentrate on the daily loading on the spine which has been found to be associated with the risk of increasing back pain (Grimmer et al., 1999; Negrini et al., 1999; Iyer, 2001; Chiang et al., 2006; Mohseni-Bandpei et al., 2007; Chow et al., 2007; Macias et al., 2008). Finally some are concerned with the effects of load carriage on physiological strain (Hong et al., 2000; Li et al., 2003; lai & Jones, 2001; Daneshmandi et al., 2008; Chow et al., 2009).

The investigation which made up our study consisted of researching three parts: (a) subject's backpack carrying and physical activity habits through a questionnaire, (b) backpack's effects on kinematic body posture and (c) electromyographic parameters of back muscles. The current study investigated not only the trunk posture (the trunk inclination angle and the trunk motion range) but also the distance from the floor to the child's earlobe joint and the child's step length to examination.

Therefore, the purpose of this study was three-fold: (1) to investigate the effects of four different load distributions on the activity and fatigue of selected muscles during load carriage; (2) to determine whether the distance from the floor to the child's earlobe joint, the child's step length measures, the trunk inclination angle and the trunk motion range differentiated between the effects of the four backpack loads on body posture and (3) to determine the ratio between the weight of the child and the child's backpack.

3.1 Experimental approach to the problem

The following questions will be answered in this study:

What increase occurs in the trunk inclination angle with added backpack weight?

What trunk motion range decrease is evident after weight has been added to the backpack?

What changes appear in the step length once backpack weight increases?

What effects are apparent in the distance from the earlobe to the floor (height) after adding backpack weight?

Will there be significant changes in muscle activity (IEMG) and muscle fatigue (MPF) of the upper trapezius, thoracic spinae T12 and lumber spinae L3 muscle with the addition of backpack load?

What is the difference in the kinematic body posture and electromyographic parameters of kindergarteners versus schoolchildren when backpack weight is increased?

What is the relationship between body posture and EMG analysis while children walk on a treadmill with various load conditions?

3.2 Materials and Method

This is a prospective study on the effects of loads heavier than 10 % of body weight on the body, muscular activity and fatigue of the upper trapezius, the thoracic erector spinae at T12 and the erector spinae at L3. It also includes changed body posture kinematic characteristics that including; the trunk inclination angle, trunk motion range, the distance from the floor to the earlobe joint and the child's step length. The findings were obtained from subjects of kindergarten and schoolchildren age.

For this investigation, the parents were asked to fill in a questionnaire about the distance walked between home and school, method of transportation, backpack carrying behavior, backpack's weight, daily physical exercise habits, attendance in sports clubs/activities, etc. The questionnaire is based on the Dordel et al, 2007 article and the Motorik-Modul Bös et al., 2009, PP. 348-350 book.

Pascoe et al. (1997) found that there were significant reduces in stride length and increases in cadence with normal walking while children walked on the ground with a schoolbag. Furthermore, Hong and Brueggemann (2000) shown that walking on a treadmill with a weight of 20 % of body mass induced a significant increase in double leg aid period with reduce in swing phase. The theoretic center of backpack weight is approximated to be located at the level of T11 and L2 depending on the relationship between size of backpack and body height of each individual (Korovessis et al., 2005). In addition, Grimmer and Williams (2000) also reported that schoolchildren with LBP carried weighty backpacks comparative to their body mass than those without LBP with a stronger association noted between load carrying and LBP for boys than girls. Moreover, another study on the effect of carrying backpack on trunk posture was reported by Goodgold et al. (2002a) examined the combined influences of increasing schoolbag weight and work on trunk inclination angle on two boys, aged 11 and 9 years old. Their results showed that though trunk inclination angle mostly increased with the increases in schoolbag weight and work, trunk inclination angle was not dose dependent. For this study, we hypothesized to characterise the comparative kinematic body postures for control condition when not carrying a backpack and when carrying the backpack.

Regarding muscle activity, Motmans et al. (2006) reported that the muscle activity reduced in erector spinae activities during the carriage of 15 % body mass backpack and increased with the shoulder bag and the front pack. In addition, Bauer et al. (2009) investigated that were no significant differences in the standing tests for EMG trapezius, EMG latissimus dorsi, and EMG right erector spinae. The only significant alters in the EMG were the reduced in activity between weights of 0 % and 20 % BM and 10 % and 20 % BM for the left erector spinae muscle.

We hypothesized that increasing load will introduce higher muscle activity and muscle fatigue in the upper trapezius, thoracic erector spinae at T12 and lumbar erector spinae at L3.

Unlike the preceding studies which mainly concentrated on the effect of load carriage of backpacks and its impact on the trunk posture, shoulder pain, and muscle soreness, the present study is the first to investigate the effect of increasing the load carriage on the distance from the floor to the earlobe joint and step length in children.

3.2.1 Subjects

The subjects volunteered to participate from all across the state of Saarland through the Saarbrücker Zeitung.

Table 7: An anthropometric data chart specifying the mean and the standard deviation, separately for age and gender.

	Kindergarten children n=41		Primary schoolchildren n=35	
	Girls	**Boys**	**Girls**	**Boys**
n=76	23	18	12	23
Age (months)	73.26 ± 3.99	74.16 ± 4.43	88.16 ± 2.51	88.08 ± 2.60
Height (cm)	119.12 ± 6.06	120.11 ± 3.98	127.39 ± 4.60	126.78 ± 4.38
Weight (kg)	21.79 ± 3.50	23.52 ± 2.99	25.87 ± 4.16	25.06 ± 3.48
BMI (kg/m²)	15.26 ± 1.41	16.28 ± 1.63	15.85 ± 1.54	15.56 ± 1.77

3.2.2 Variables

The variables in this investigation measured and asked through a questionnaire are the following: the distance schoolchildren travel to school and kindergarten, their carrying behaviors, the backpack's weight, their complaints of back pains, and their other daily activities. Further variables were measured through video analysis. The variables include the child's body posture in the trunk inclination angle, the trunk motion range, the distance from the floor to the child's earlobe joint, the child's step length.

The final measured variables were done with a DASYLab10 using EMG (Electromyography) calculating the MVC (Maximal Voluntary Contraction), the muscle activity IEMG, and the muscle fatigue MPF (upper trapezius, thoracic erector spinae at T12, lumbar erector spinae at L3).

3.2.2.1 Questionnaire

The following questionnaire is based on studies by Dordel et al, 2007 and the Motorik-Modul (MoMO) by Bös et al., 2009 to (Appendix1).

The following questions made up the questionnaire:

- The distance from the child's house to his/her school or kindergarten and back, and the transportation used (by foot, bike, car, bus, etc).
- Carrying behavior: Carrying time (the whole way, part of the way), backpack weight (weight of the backpack, whether food and drink are brought, subjective backpack weight).
- Complaints about back pain: Yes / no, if yes, where, level of pain, improvements in pain when removing the backpack, additional complaints.
- Daily physical activities in kindergarten/school. Whether he/she plays outdoors during the week, is member in a sport club, what kind of sports and how often? (Modified, Wunsch, 2010, p. 67).

3.2.2.2 Electromyography (MVC, IEMG and MPF)

The muscles selected for analysis were the upper trapezius (pars descendens), thoracic erector spinae at T12 and lumbar erector spinae L3 muscles. The erector spinae was selected because of the likely relation between its tension and degenerative intervenebral disk disease (Chaffin, 1973), and because it is the principal back extensor. The upper trapezius was selected because previous work had shown the upper trapezius to be sensitive to changes in the conditions of load carriage (Bobet & Norman, 1984).

The lumbar erector spinae L3 is level with the tertiary lumbar vertebra, the thoracic erector spinae at T12 is located 2 cm lateral to the posterior spinous at the level of T12 and trapezius is level with the sixth cervical vertebra.

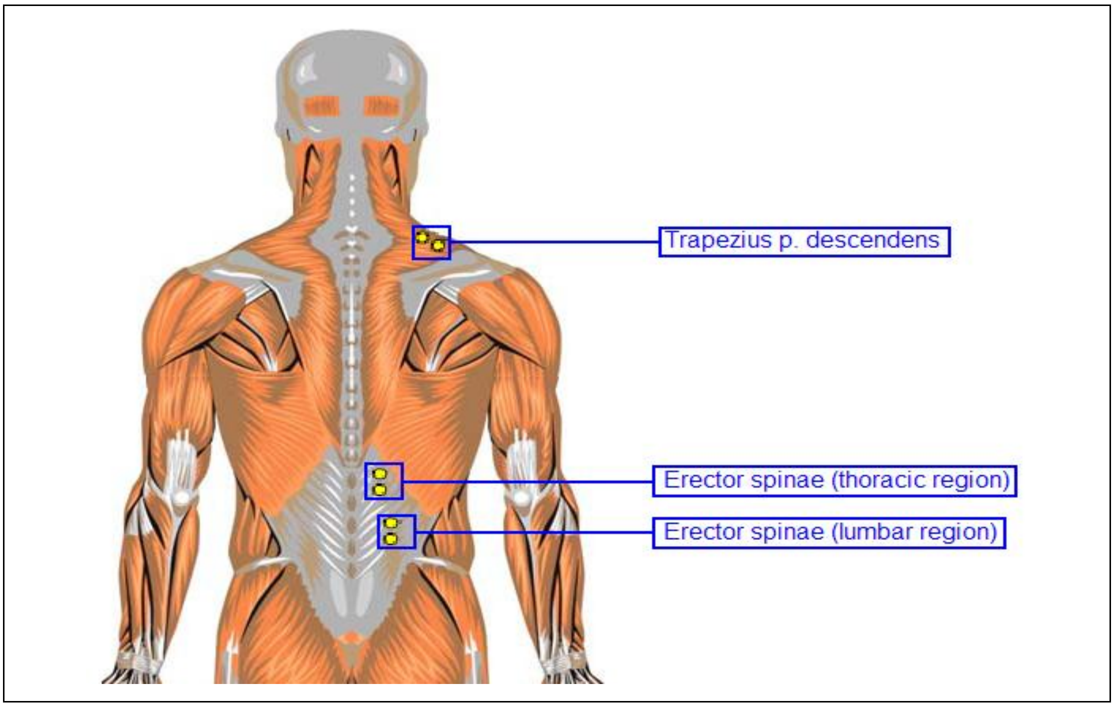


Figure 21: Anatomical positions of selected electrode sites-dorsal view. The positions of recorded muscles are marked [Adapted from Konrad, 2005, p. 20].

The instruments used in this study are presented in figures 22 and 24:

- A two-strap backpack that was used by all children. The model „Scout Easy II“with a weight of 1.25 kg. To replace the school material, a number of books were placed in the backpack.
- Electromyography with 16 channels (DASYLAB 10, Germany)
- Surface EMG electrodes (Ambu Blue Sensor N, Malaysia)
- Polar (POLAR ELECTRO OY, FINLAND) A machine measuring the hearth frequency.
- An alcohol solution (Spray Hansaplast),
- Weight scale (Sanitas, diagnose scale SBG 19)
- A stopwatch
- Adhesive circular flat markers (Classic Hansaplast)
- Crème (Panthenol-ratiopharm Wundbalsam)
- Cotton (Elkos)

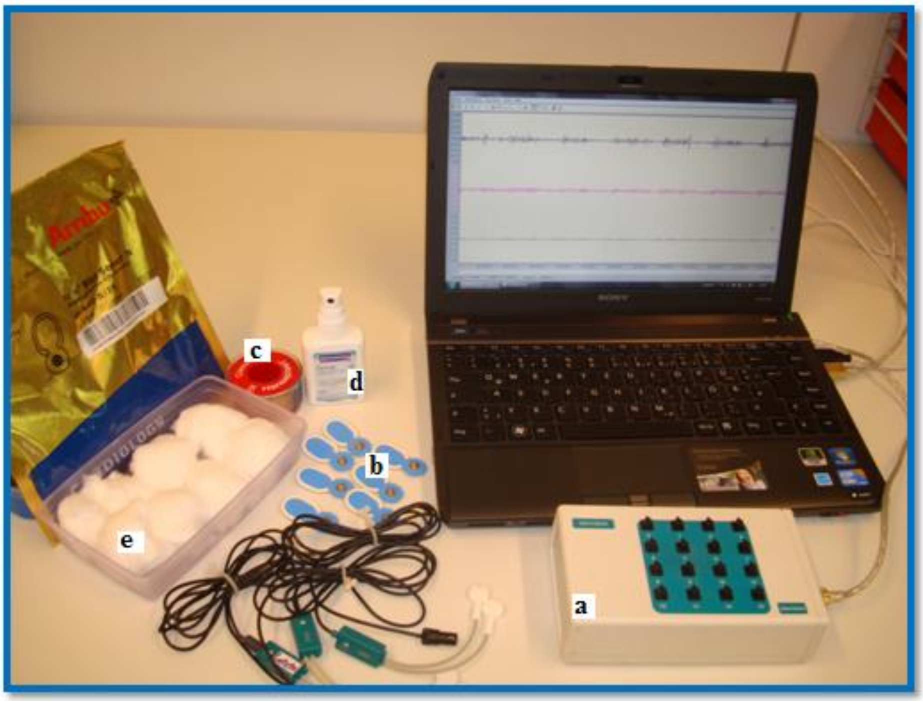


Figure 22: Electromyographic device with 16 channels (a), Surface EMG electrodes (b), Adhesive circular flat markers (c), Alcohol solution (d), Cotton Elkos (e).

The following process was used for EMG-recording and processing.

3.2.2.2.1 Preparation

Skin: For recording an EMG signal, the electrodes can be placed on the skin over a muscle (surface EMG). Once the subjects became accustomed to the MVC test and walking on the treadmill, they removed their shirts to allow for placement of surface electrodes. Before the surface electrodes were placed, the areas were cleaned with rubbing alcohol to allow for better electrical conduction. This is needed to improve the adhesion of the electrodes, especially under dynamic movement conditions.

Position of electrodes: The surface electrodes were placed on the right upper trapezius (pars descendens), thoracic erector spinae at T12 and lumbar erector spinae L3. The surface electrodes were applied with a distance of 2 cm apart in the direction of muscle fibers. The active surface electrodes were orientated approximately parallel to the direction of the fibres of the muscles of interest. They were fastened on with tape to prevent the backpacks from accidentally removing them. The skin was cleaned and slightly abraded before electrode positioning. Electrolyte paste was used to ensure best contact between the electrodes and skin.

At least one neutral reference electrode per subject was positioned. The reference electrode was put to level with the thoracic erector spinae at T12. However, on the occasion, the electrode on the thoracic erector spinae could not obtain a good signal and therefore the electrode was placed on the sixth cervical vertebra of the trapezius (left) which also helped reduce the unwanted noise.

Position of cables / EMG: During the EMG and MVC tests, the cables were fixed to avoid movement. During the MVC, the cable was left on the floor as it did not cause excess movement. During the treadmill test, it was fastened and taped to the wall to avoid movement artifacts.

3.2.2.2.2 Recording

EMG (type): Electromyography was with 16 channels (DSYLAB 10, Germany), surface EMG electrodes (Ambu Blue Sensor N, Malaysia) and a reference electrode (Electrocardiography, Germany). In this investigation four channels were utilized: the first for upper trapezius, second for thoracic erector spinae at T12, third for lumbar erector spinae L3 and fourth the ground electrode respectively.

Sampling rate: Measurement of sample data, the EMG signals during MVC test and during treadmill walking test were collected, amplified and transmitted by an EMG system (DASYLab10 & Systems, Germany) at 1000 Hz to a computer via a 12-bit A/D conversion board.

PC (storing): All signals were recorded via a worksheet for data-collection that included signals from two exercises of MVC test and signals from four load conditions (totaling eight signals), all at 10 seconds which were then stored in a DASYLab-file. The program automatically stopped recording after 10 seconds.

MVC setup: During the research, two tests were performed to investigate the MVC of the subjects. The first test was related to the upper trapezius *(pars descendens)* and maximum strength. The subjects were to sit down on a mat, place both their feet against the wall and for the duration of 10 seconds, pull on a handle which was fastened against the wall with as much strength as possible.

For the second test, which dealt with the thoracic erector spinae at T12 and lumbar erector spinae L3, the subjects were asked to lie on their stomachs, lock both hands behind their neck and push up against the pressure which a research assistant was placing on their backs for 10 seconds.

Using the EMG device, signals created by both tests were recorded.

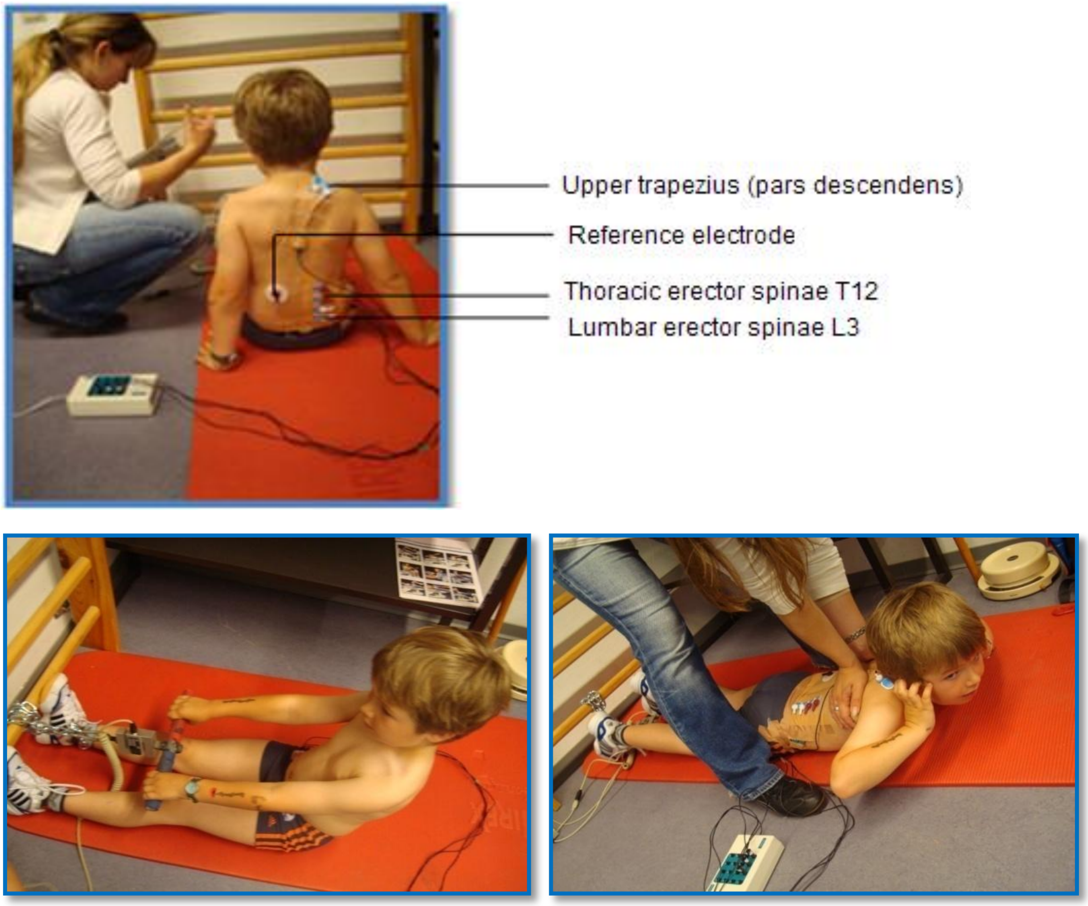


Figure 23 : The first test MVC (upper trapezius) and the second test MVC (thoracic erector spinae at T12 and lumbar erector spinae L3).

A two-strap „Scout Easy II“ backpack with a weight of 1.25 kg was used by all subjects. Books were used to fill the backpack in place of usual school supplies. During the examination for recorded better signal the dorsal middle part of the backpack was removed to avoid pressure on the electrodes that could cause artifacts.

Figure 24: Original (left) and modified (right) backpacks.

3.2.2.2.3 Signal processing

Raw data: The Raw EMG Signals, the sample of EMG signals (the 10 seconds recording) were measured from each of the three upper trapezius, thoracic erector spinae at T12 and erector spinae at L3 muscles. Also in the worksheet all signals have been recorded as raw and unprocessed.

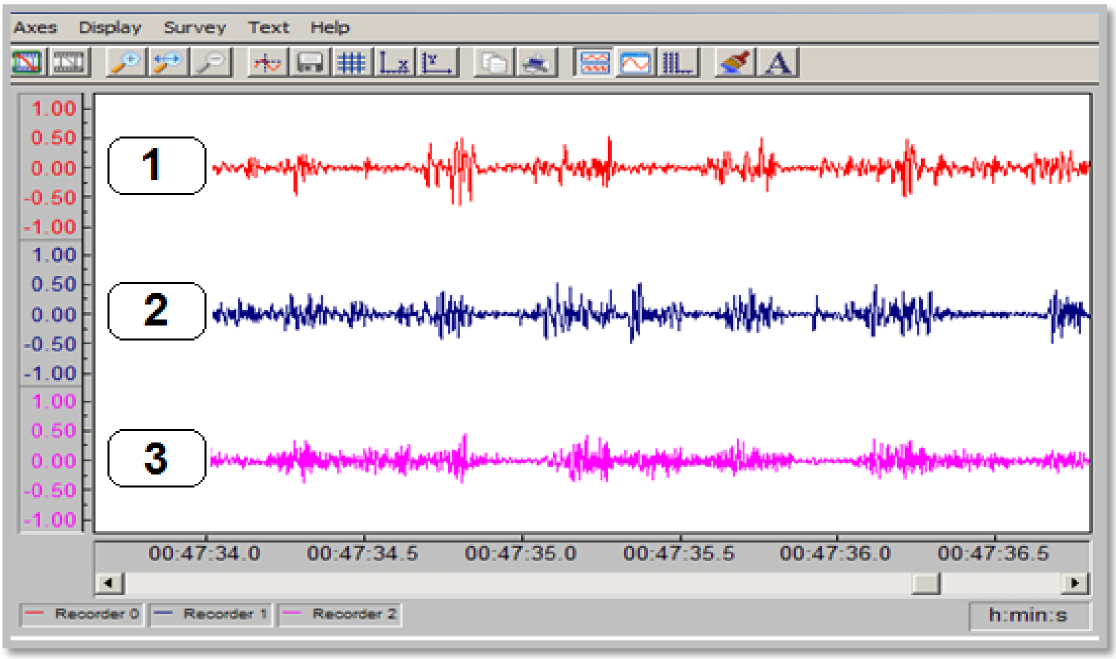


Figure 25: Worksheet from recording raw EMG signals: 1. EMG of the upper trapezius [mV], 2. EMG of the thoracic erector spinae at T12 [mV], 3. EMG of the lumbar erector spinae L3 [mV].

Trimming of data:

All EMG segments were analyzed in the amplitude and frequency domains.

The worksheet from MVC, EMG and MPF: For each MVC performance, a sample of EMG and MPF signals (the 2nd, 3rd and 4.1th seconds from the 10 second recording) was trimmed for evaluation. This was to avoid the effect introduced by trimming at different durations within the raw sample.

This worksheet includes; read data, linear scaling, chart recorder, digital filter, arithmetic operations, data window, FFT (Fast Fourier Transformation), Y/t chart, statistical values and digital meter.

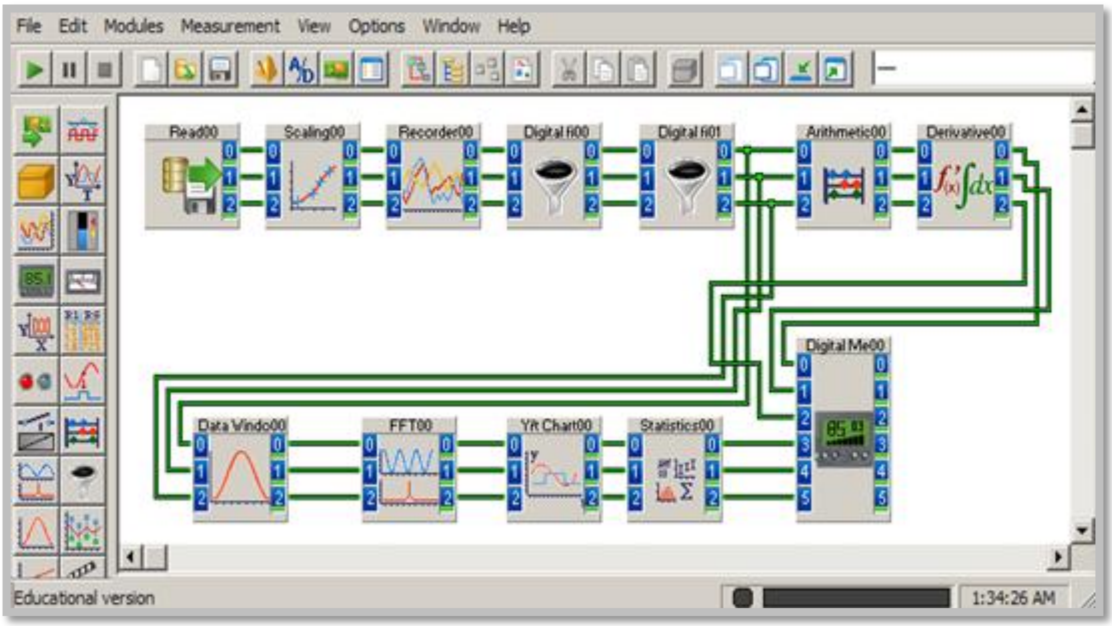


Figure 26: Worksheet from MVC EMG and MPF signals.

Read data: This is a worksheet of read data to calculate start and end signals (fig. 26). All the raw signals recorded in the original window were read data. Opening read data options could pass all the signals in order (begin 1 second, end 4.1 second). There were two MVC and eight IEMG and MPF signals.

Rectification: A sample of full-wave rectifying signals (the 2nd, 3rd and 4.1th seconds from the 10 second recording) were trimmed for evaluation from each muscle.

Filtering: For each load and each point in the treadmill walking test, the same data trimming procedure was employed. The raw EMG signals were band pass filtered to reduce noise with low pass (300 Hz) and high pass (20 Hz), where the filter was used for integration as well as for power spectrum analysis by Fast Fourier Transform (Hong et al., 2008).

Integration (IEMG): The integral or the surface under the data channel is calculated. Integrated EMG signal (IEMG) was calculated to evaluate the muscle activity. The integrated IEMG (taken from the 2nd, 3rd and 4.1th seconds of the 10 second recording) was used to represent the muscle activity of the upper trapezius, thoracic erector spinae at T12 and the erector spinae at L3 as absolute during load carrying.

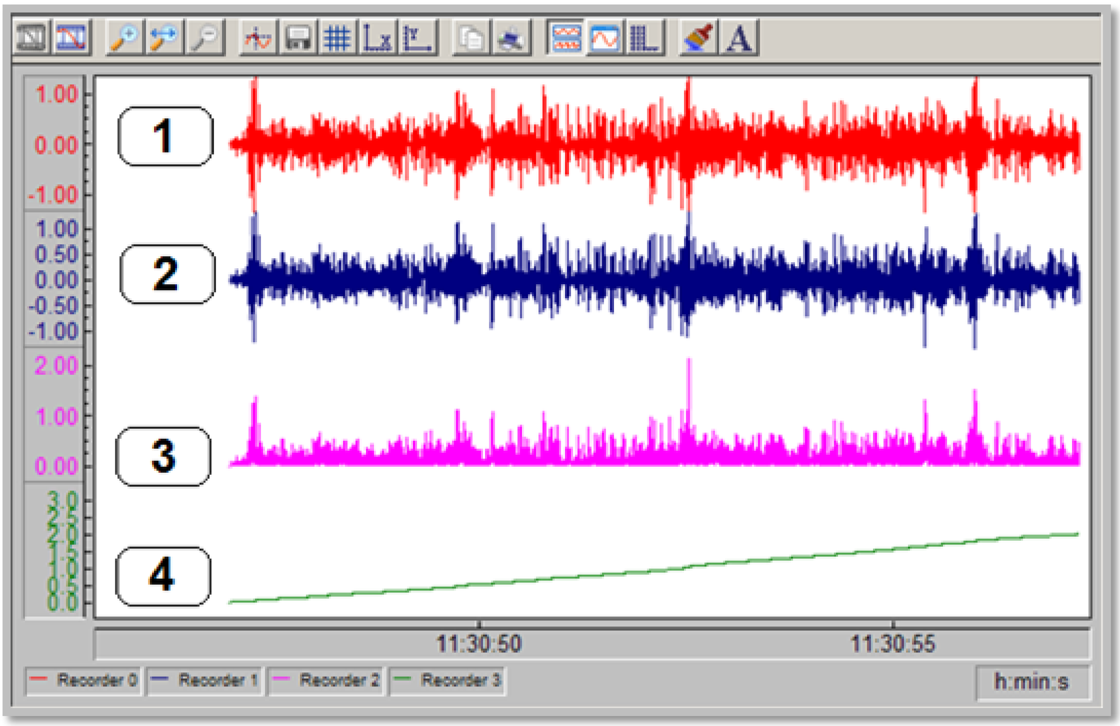


*Figure 27: EMG signals processing: 1. Raw signal [mV], 2. EMG-filtering [mV], 3. EMG-full-wave rectifying [mV], 4. EMG-calculating the integrated EMG value [mV*ms].*

Normalization (MVC): In the present study the IEMG was normalized as a percentage of the corresponding maximum values determined from 100 % maximal voluntary contraction. A sample of IEMG (integrated EMG) signals (the 2nd, 3rd and 4.1th seconds from the 10 second recording) were trimmed for evaluation from each of the three muscles.

FFT→MPF: Median power frequency (MPF) was calculated to evaluate muscle fatigue of amplitude spectrum. In the research, Fast Fourier Transform was utilized to compute the EMG power spectral density for the 3.1 second samples.

Median power frequency (MPF) which was indices of the EMG power spectrum was calculated. In this study a shift in the frequency components of the surface EMG signal toward the low end was used to indicate local muscle fatigue. To obtain the MPF, a filter was used.

Due to it being less sensitive to noise and more sensitive to the biochemical and physiological processes that occur within the muscles during sustained contraction, median power frequency was used for muscle fatigue analysis (De Luca, 1997).

In this study, the phases of signals passing through this window were for the following; for amplitude spectrum, FFT without the power of two and then for filtering disable. The type of window used prior to taking the Fast Fourier Transform was Hamming. A sample of MPF signals (the 2nd, 3rd and 4.1th seconds from the 10 second recording) were trimmed for evaluation from each of the three muscles.

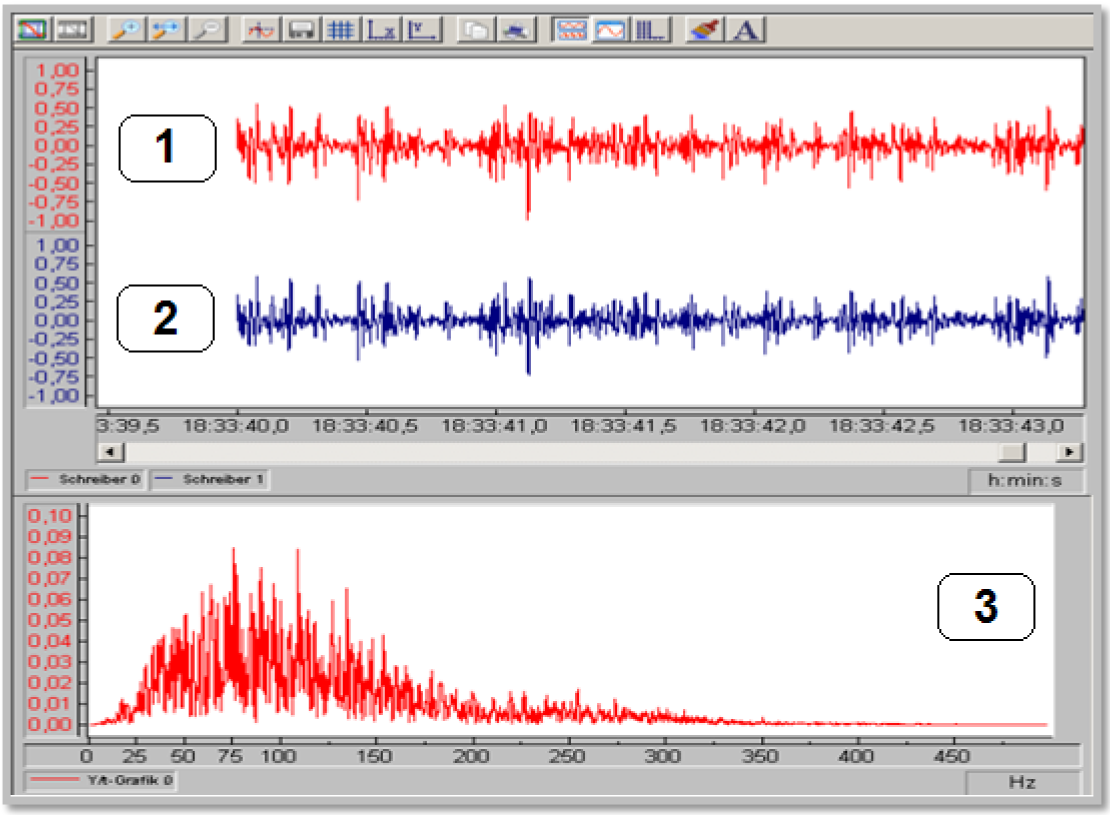


Figure 28: EMG signals processing: 1. Raw signal [mV], 2. EMG-filtering [mV], 3. FFT-Median power frequency [Hz].

3.2.2.3 The kinematic body postures

The present study was to examine the changes of the kinematic body postures due to carrying two-strap backpack while level walking. The recorded video was digitized and analyzed by a motion analysis system (Dartfish software version 5.5) to provide movement kinematics. The subject's movement was recorded by a video camera (Panasonic NVG-500) positioned laterally to the subject with the lens axis perpendicular to the movement plane, and the camera height was set at the height of the hip joint. Therefore, only the movements in the sagittal plane were considered. The reflective markers were placed on four surfaces of the body for video analysis: joint earlobe, shoulder (acromion process), hip (greater trochanter) and ankle (lateral malleolus). In examination, three complete gait cycles or six step lengths were taken for two time points. The first was at the 1st min after the commencement of walking and the next at the 5th min, where the child's gait was observed as being stable.

Stable walking was defined by the secure feeling reported by the subject and visibly consistent stride lengths and cycles (Hong & Brueggemann, 2000a). For each complete step length, the mean trunk inclination angle and the trunk motion range were calculated using the software in the motion analysis system (Dartfish software version 5.5).

3.2.2.3.1 Calibrating the camera with the treadmill

The horizontal alignment of the camera was adjusted by using the Dartfish analysis software which displayed a horizontal line pattern shown in real time camera image. The on-screen reference lines were compared with the treadmill mounted horizontal marker points by tilting the camera sideways so that markers and lines were exactly congruent. To avoid a parallax error, the video camera was placed in front of a treadmill. To record videos, a camera was placed laterally to the subject, 235 cm away from the treadmill, with a height approximately at the subject's hip joint (90 cm).

To make sure that the horizontal line used to measure the trunk inclination angle and step length were perfectly straight, automatic lines were created on the Dartfish program to make sure that the line drawn to measure the angle aligned.

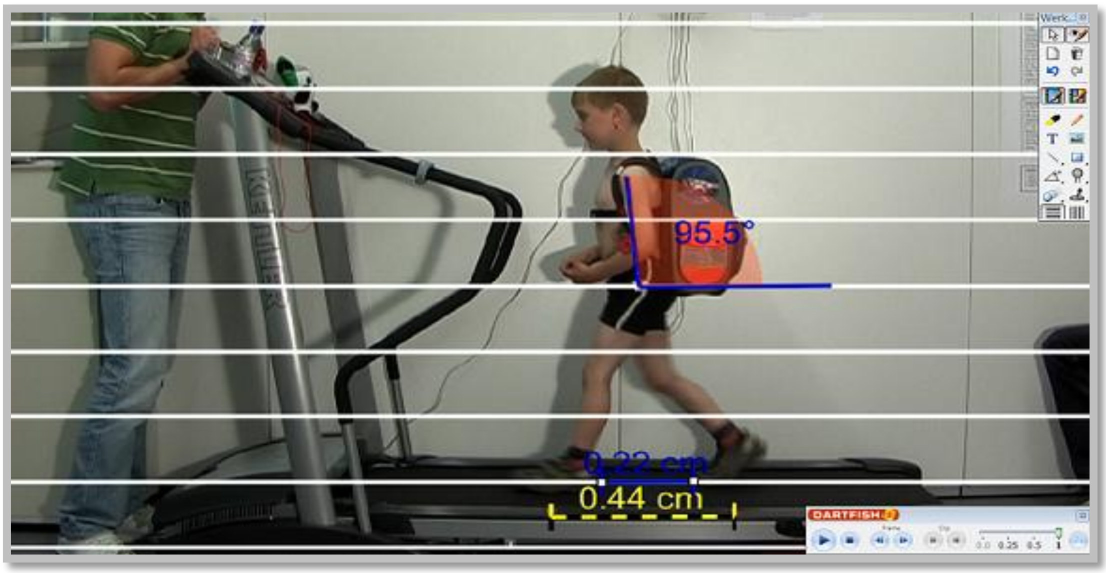


Figure 29: The horizontal line to measure the trunk inclination angle and step length.

To ensure that the line drawn to measure the distance from the earlobe joint to the floor was straight, the Dartfish software was used to create automatic vertical lines with which the original line could be compared.

Figure 30: The straight to measure the distance from the earlobe joint to the floor (height).

The instruments used in this study are presented in figure 31:

- A treadmill (KETTLER, MARATTHON HS, Germany)
- A digital video camera (Panasonic NVG-500)
- Dartfish software version 5.5
- Height (using a centimeter scale)
- A stopwatch
- Reflective marker

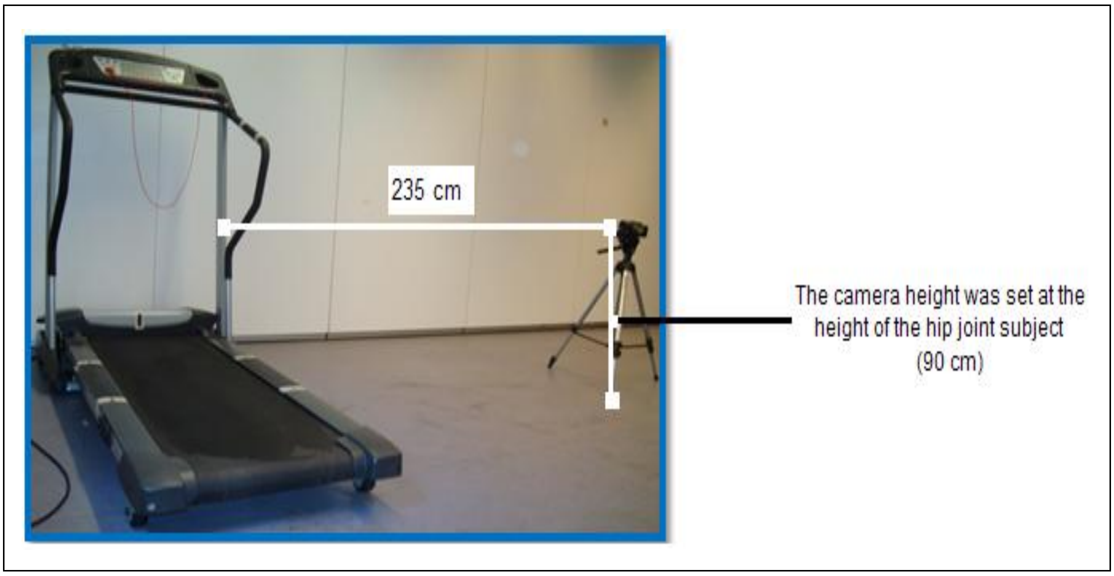


Figure 31: A treadmill with a digital video camera.

All participants were filmed while walking with different load conditions on the treadmill. Then each film from any state that already saved for analysis by the analysis system was transferred to Dartfish. Two points-44 cm apart-were placed next to the treadmill for reference so that the subjects and the Dartfish program were aware of how much walking space they had to stay within the camera's picture while on the treadmill. Reference set for all modes of freight were identical.

Figure 32: Screenshot from reference Dartfish analysis system.

3.2.2.3.2 Trunk inclination angle

First, the angle (Winkel) option on the right window was selected. There was no need for set reference. The trunk inclination angle was measured when the backpack carrying children were walked on a treadmill. The trunk inclination angle refers to the angle of the line connecting the shoulders (acromion process) and the hips (greater trochanter) in relation to the horizontal line across the hips.

Figure 33: Screenshot from trunk inclination angle of Dartfish analysis system.

At greater than 90°, a forward lean implied, while at values less than 90° a backward leaning trunk is being represented (Li et al., 2003).

The trunk inclination angle was measured in three positions: when the left foot was in front (initial contact), the mid stance, and when the right foot was in front (terminal stance / pre swing, chapter; 2.3.4 Gait cycle).

The trunk inclination angles were also measured in three complete gait cycles (six step lengths) during the first ten seconds of the first minute and the last 10 seconds of the fifth minute of walking. The entire measurement process was repeated three more times, each time with different load weight.

Left foot (initial contact)

Mid stance

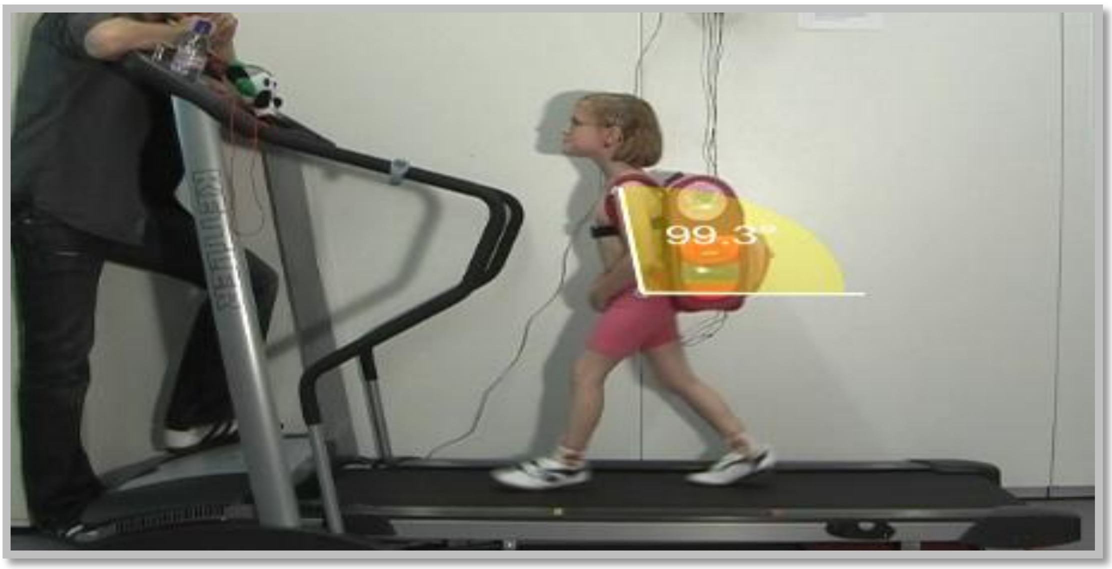
Right foot (terminal stance / pre swing)

Figure 34: The trunk inclinations angles during the three phases of a stride.

3.2.2.3.3 The trunk's motion range

The trunk's motion range was measured when the children (with backpacks) were walked on a treadmill. The Trunk's range of motion refers to the range of the trunk inclination angles observed in the stride (the maximal trunk inclination angle range minus the minimal inclination range in the two steps). The trunk's motion range was measured in three complete gait cycles (six step lengths) during the first ten seconds of the first minute and the last 10 seconds of the fifth minute of walking. The entire measurement was repeated three more times, each time with different load conditions.

Left foot (initial contact)



Right foot (terminal stance / pre swing)

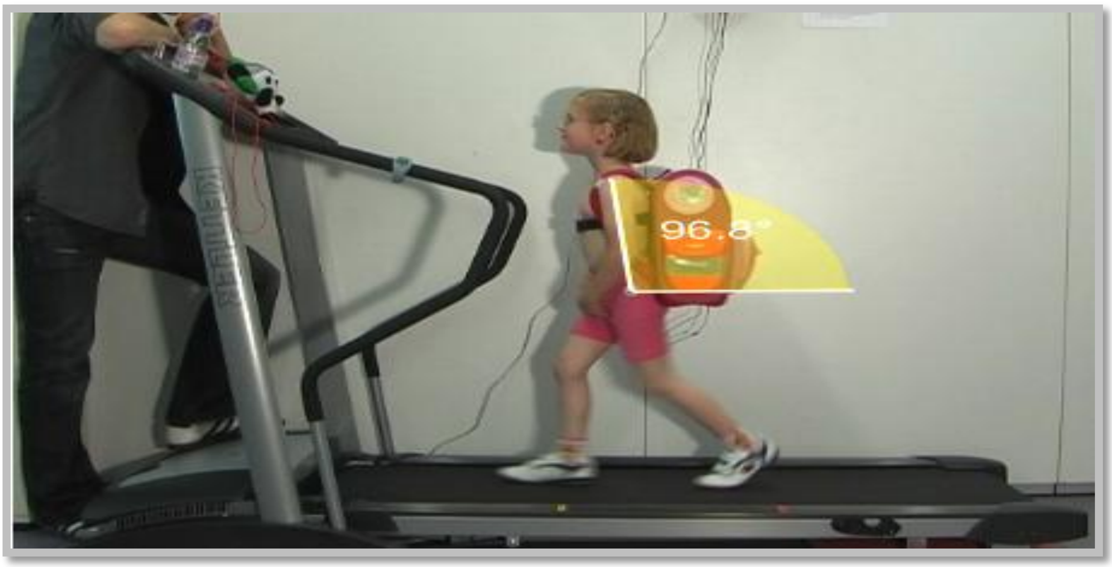


Figure 35: The trunk's motion range during two phases in a stride.

3.2.2.3.4 The distance from the floor to the earlobe joint (height)

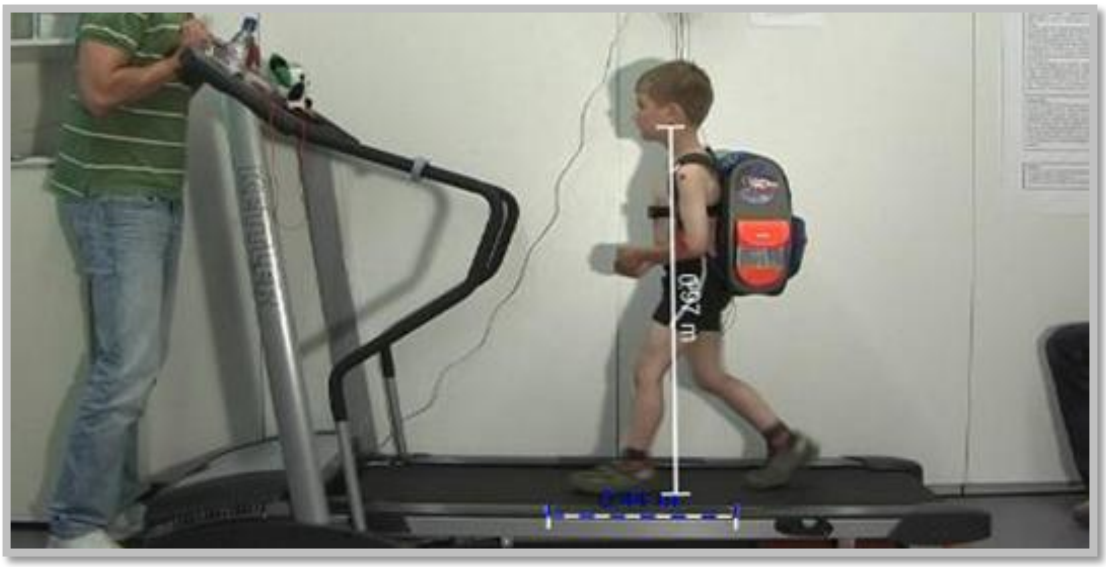
The distance (Entfernung) option from the right window was selected for earlobe to the floor. Reference to determine the distance should be specified. When children were walked on the treadmill, their earlobe joint's distance to the floor was measured three times in a stride (The three stride phases, when the left foot was in front, the mid stance, and when the right foot was in front).

Using the Dartfish analysis software, a marker point on the ear of the child along with another vertically perpendicular point at the height of the shoe soles were selected. The software determined the vertical distance between these points in centimeters. A previously defined length of track on the treadmill was used as reference.

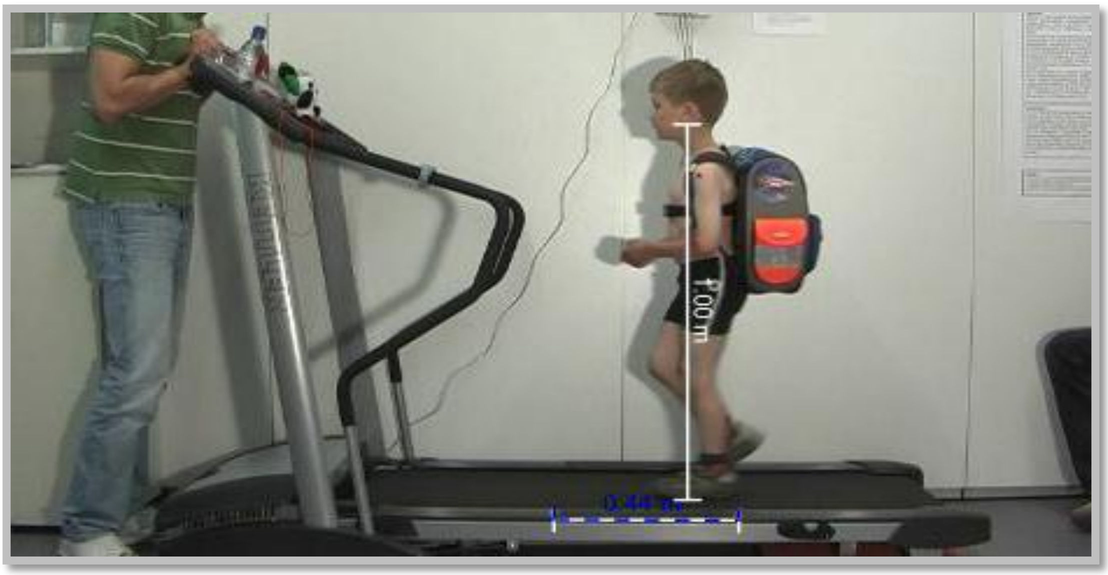
The distance from the floor to the earlobe joint was measured in three complete gait cycles (six step lengths) during the first ten seconds of the first minute and the last 10 seconds of the fifth minute of walking. This process was performed with four different backpack weights.

Figure 36: Screenshot from the distance from the floor to the earlobe joint of Dartfish analysis system.

Left foot (initial contact)



Mid stance



Right foot (terminal stance / pre swing)

Figure 37: The distance from the floor to the earlobe joint during the three-phases *in a stride.*

3.2.2.3.5 The step length

The distance (Entfernung) option from the right window was selected for step lenght. Reference to determine the distance should be specified (figure.33). The step length was measured when the children were walking (with back-packs) on a treadmill. The step length has been used in the distance between the tiptoe of the back foot till the beginning of the heel of the leading foot. This measurement was done for both of the steps in a stride. The step lengths were measured in three complete gait cycles (six step lengths) during the first ten seconds of the first minute and the fifth minute of walking. The whole process was repeated three more times, though each time with different backpack weights.

Figure 38: Screenshot from the step length of Dartfish analysis system.

Left foot (initial contact)

Right foot (terminal stance / pre swing)

Figure 39: The distance between the feet when either the left or right foot is leading.

Step length, trunk inclination angle and distance from earlobe to floor were simultaneously calculated for all four different load conditions at the beginning and end.

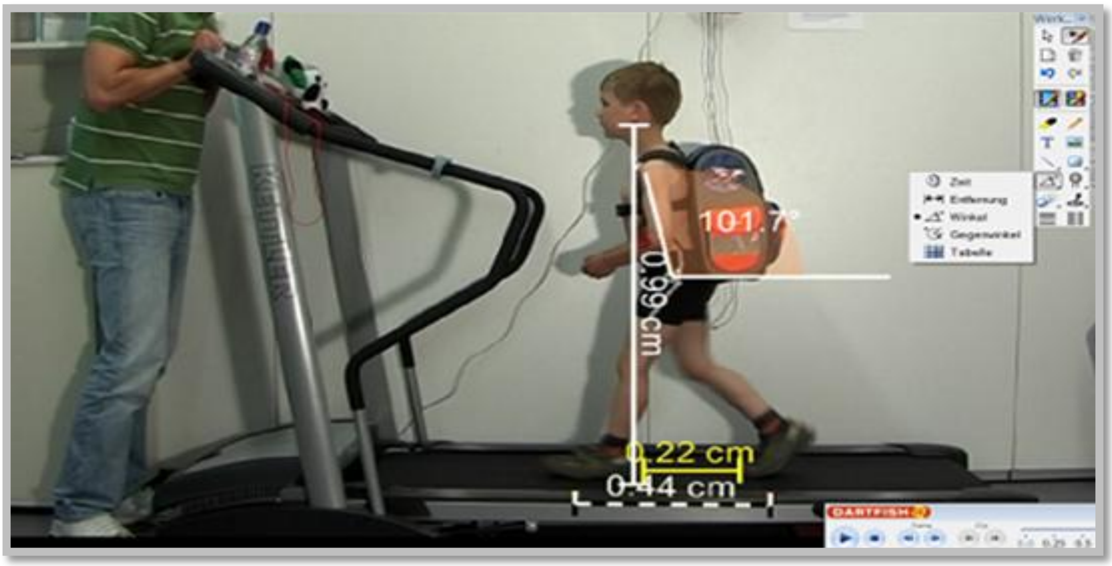


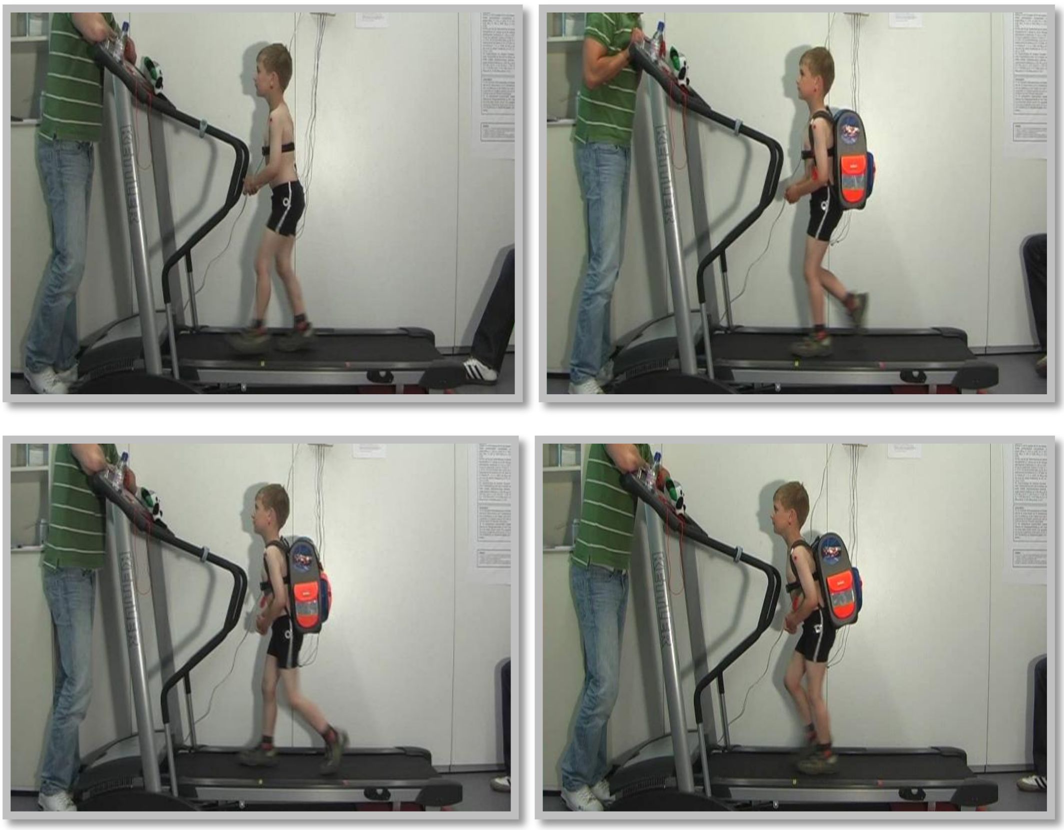
Figure 40: Screenshot from distance from the floor to the earlobe joint, the trunk's motion range and step length of Dartfish analysis system.

3.2.3 Treatment

Once the subjects were finished with the MVC tests, reflective markers were placed on four surfaces of the body for video analysis: joint earlobe, shoulder (acromion process), hip (greater trochanter) and ankle (lateral malleolus). The Polar device was fastened around the subject's chest to measure the frequency of the heartbeat. To record videos, a camera was placed laterally to the subject, 2.35 m away from the treadmill, with a height approximately at the subject's hip joint (90 cm). A two-strap „Scout Easy II" backpack with a weight of 1.25 kg was used by all subjects. Two points- 44 cm apart-were placed next to the treadmill for reference so that the subjects were aware of how much walking space they had to stay within the camera's picture while on the treadmill.

Each subject was required to walk on the treadmill at the speed of 3 km/h, with four different load conditions: walking without a backpack (0 % of body weight which is served as a control) and walking with a backpack load of 10 %, 20 % and 30 % of their body weight, using the data recorded when their weight was first taken. With each backpack load, the subjects were to walk for 5 minutes on the treadmill.

0 % BW *10 % BW*



20 % BW *30 % BW*

Figure 41: Four different load conditions: walking without a backpack and walking with backpacks that weigh 10 %, 20 % and 30 % of the child's total bodyweight.

A two-strap „Scout Easy II“ backpack with a weight of 1.25 kg was used by all subjects. Books were used to fill the backpack in place of usual school supplies.

With each backpack load, the subjects were to walk for 5 minutes on the treadmill. The EMG signals at the first and last 10 seconds of each five-minute walk were collected and video recordings were made at the same time intervals for analysis. A research assistant always stood in front of the treadmill and talked to the subjects to ensure that they did not get distracted by their surroundings and looked straight ahead to allow for more accurate video recording. Between each walk, the subjects were given a break while a research assistant added weight to the backpacks.

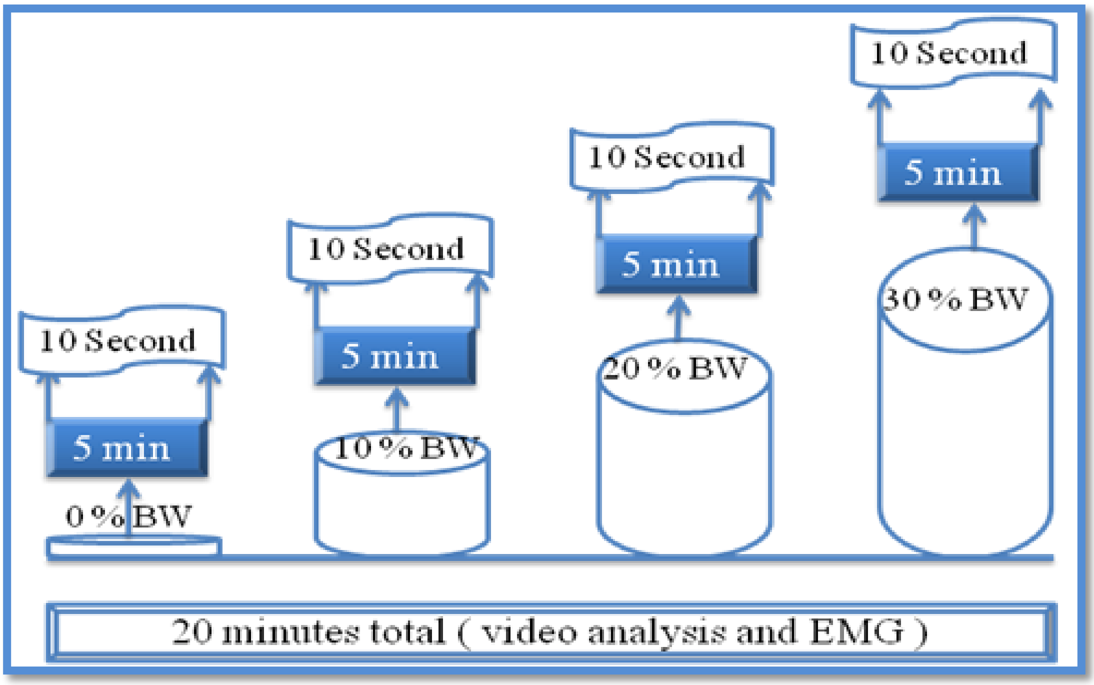


Figure 42: The chart shows how the physical investigation on the children was executed [Modified, Wydra, 2009, p. 23].

3.2.4 The research process

The investigation began during the spring of 2009. The subjects volunteered to participate from all across the state of Saarland through the Saarbrücker Zeitung. Of the total 76 subjects, 41 (23 girls and 18 boys) attended kindergarten while 35 (12 girls and 23 boys) attended the first grade in elementary school. Two subjects were tested every day over the course of nine weeks, starting April 11th 2009.

The investigation was made up of three parts: a questionnaire, EMG and video analysis of kinematic body posture.

Once the parents and volunteers arrived at the Institute for Pedagogics, the parents were asked to fill out a 10-minute questionnaire designed to investigate backpack carrying habits of their children. They were asked to answer regarding the following topics:

gender, age, distance travelled between home and school, method of transportation, backpack carrying behavior, backpack's weight, complaints from back pain, level of pain, the effect of backpack weight on the pain, daily physical exercise habits, attendance in sports clubs/activities, etc.

Once the questionnaire has been completed, the participants are taken to a room where they are asked to remove their shoes. Their weight is then measured and immediately 10, 20 and 30 % of their body weight is calculated to be used later during the treadmill walk.

Next their heights were measured by centimeter scale installed against a wall. Again, they were asked to remove their shoes and to stand in front of the measuring scale. Once their heights were recorded, they were moved on to fitness testing.

The tests included the following:

The Sorensen (straighten trunk), push-up and sit-up tests for a duration of 40 seconds each; the screening test in which the children picked up the bottle (1kg) and schoolbag (10 % of body weight) in a face-down position for as long as possible, as well as the flexibility test which tested the maximum stretch in both legs using the ishiocrurale muscle group.

Before entering the main phase of the investigation, the subjects were given a momentary break. Then they were moved to the main investigation room to prepare. Before beginning the main phase of the investigation, the subjects were allowed 3 minutes on the treadmill to adjust.

EMG electrodes were then placed to determine the MVC of the upper trapezius, the thoracic erector spinae at T12 and the lumbar erector spinae L3 muscle. Two MVC tests-lasting 10 seconds each-were then taken. Further markers were placed on four spots of the body for video analysis: the joint earlobe, the shoulder (acromion process), the hip (greater trochanter) and the ankle (lateral malleolus).

Once all markers and electrodes were placed, each subject was required to walk on a treadmill at a speed of 3 km/h, with four different load conditions which were recorded with video analysis and EMG. The loads were 0 %, 10 %, 20 % and 30 % of the child's body weight, carried in a backpack for 5 minutes each. The first and last 10 seconds of each walk were recorded by video as well as EMG signals.

Table 8: The design of the study (the progression of the study at a glance).

Children volunteered to become the test subjects for the investigation

↓

Two subjects were tested every day over the course of 9 weeks

↓

The parents were asked to fill out a 10-minute questionnaire about backpack carrying habits of their children

↓

Before beginning the investigation, the subjects were walked 3 minutes on the treadmill to adjust.

↓

EMG electrodes were placed to determine the MVC of the upper trapezius, the thoracic erector spinae at T12 and the lumbar erector spinae L3 muscle

↓

Marker placement

Markers were placed on four spots of the body for video analysis: the joint earlobe, the shoulder (acromion process), the hip (greater trochanter) and the ankle (lateral malleolus).

↓

Treadmill walking test

Each subject was required to walk on a treadmill at a speed of 3 km/h, with four different load conditions recorded with video analysis and EMG:

- 5 minutes of walking on a level treadmill without a backpack
- 5 minutes of walking on a level treadmill with 10 % of the child's total BW in backpack in a backpack
- 5 minutes of walking on a level treadmill with 20 % of the BW in a backpack
- 5 minutes of walking on a level treadmill with 30 % of the BW in a backpack

3.3 Statistical Hypothesis

The following are the specific hypotheses of this research effort:

H1: The trunk inclination angle increases significantly while children walk on a treadmill with 10, 20 and 30 % of the body weight in a backpack as compared to the children who walk without a backpack.

H2: There is a significant decrease in the trunk motion range while children walk on a treadmill with 10, 20 and 30 % of the body weight in a backpack, which will not be present when walking without a backpack.

H3: There is a significant decrease in the distance from the floor to the earlobe joint (height) when children walk on the treadmill while carrying a backpack with 10, 20 and 30 % of body weight which will not occur when walking without a backpack.

H4: With the increase of the weight of backpacks the step length significantly increase while children walk on a treadmill with a 10, 20 and 30 % load of body weight, when compared to walking without a backpack.

H5: There is a significant difference in muscle activity and fatigue muscle of the upper trapezius, thoracic erector spinae T12 and lumber erector spinae L3 muscle while children walk on treadmill without a backpack and with a backpack including 10, 20 and 30 % of body weight.

H6: With the increase of the weight of backpacks, there is a significant difference between kindergartener and primary schoolchild in kinematic body posture and electromyographic parameters.

H7: There is a relationship between body posture and EMG analysis while children walk on a treadmill with a 10, 20 and 30 % load of body weight, when compared to walking without a backpack.

3.4 Statistics

The data evaluation was achieved by statistica® software version 8.0 (stat soft Tulsa, Oklahoma, USA), SPSS 17.0 and Microsoft Excel 2007 for windows.

Descriptive statistics (mean, SD) for age, height, weight were calculated. All muscle activities (upper trapezius, thoracic erector spine at T12 and lumbar erector spinae at L3) were normalized and expressed as an MVC percentage. Integrated EMG signal (IEMG) was calculated to evaluate the muscle activity while power spectral frequency analysis was applied to evaluate muscle fatigue by the shift of median power frequency (MPF).

Accordingly at the two measuring time points under each of the four load conditions, a repeated ANOVA measurement [2 (time points) ×4 (loads)] was carried out to evaluate each data set achieved in body posture and EMG parameters. Analysis of variance assumes normal distributions and homogeneity of variance. If significant ($p<0.05$), a Tukey HSD post hoc test was used to find out the specific differences between loading conditions. To be precise about the results section, probability scores were expressed relative to $p<0.05$, $p<0.01$ or $p<0.001$. Furthermore, Spearman correlation nonparametric analysis was performed on the load conditions while Pearson correlation coefficients analysis was used to find the relationship between body posture and EMG analyses in kindergartners and primary school children.

To measure the strength of the relationship between variables in the study, an effect size was used (Leonhart, 2004, p. 398). These were calculated on the body posture and parameters EMG on the load conditions.

Effect size by Analysis of variance (ANOVA):

η^2 =.01 Small

η^2 =.06 Medium

η^2 =.14 Large

When showing P values on graphs, investigators commonly use a "Michelin Guide" scale.

$P < 0.05$ significant (*)

$P < 0.01$ significant (**)

$P < 0.001$ highly significant (***)

4 Results

The results are presented in three sections. The first section deals with the questionnaire. In the following illustrations, the results relate to the hypotheses. First of all, the alterations of body posture parameters - including the trunk inclination angle, trunk motion range, distance from the floor to the earlobe joint and step length - will be studied and compared for different load conditions. Then electromyographic alterations to back muscles which relate with muscle activity (IEMG), median power frequency (MPF) from the upper trapezius, thoracic erector spine at T12 and lumbar erector spinae at L3 in four load condition. The subjects were both boys and girls from primary school and kindergarten.

Descriptive statistics: A total of 76 children (41 boys and 35 girls) volunteered to participate in the investigation. There were 23 girls and 18 boys participating from kindergarten and 12 girls and 23 boys from Primary school.

4.1 Results of questionnaire

1) How far is the way for your child measuring from the house door to the school (e.g. kindergartener)?

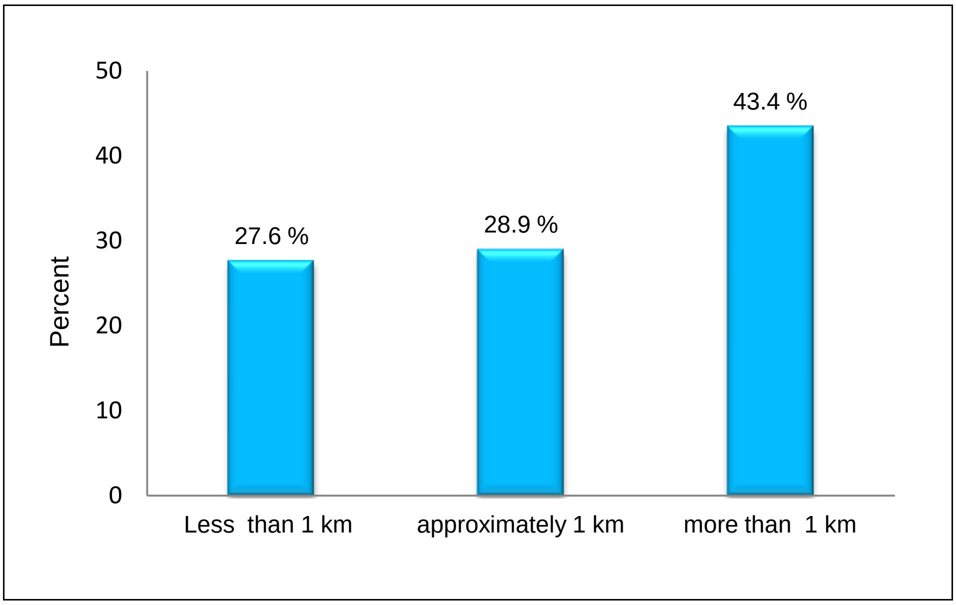


Figure 43: The distance from the child's house to school or kindergartener (n=76).

As indicated in figure 43, about 27.63 % of schoolchildren and kindergarteners walk less than 1 km from the house door to school, 28.95 % walk approximately 1 km, and 43.42 % walk more than 1 km.

2) What type of transportation is used for the majority of the way?

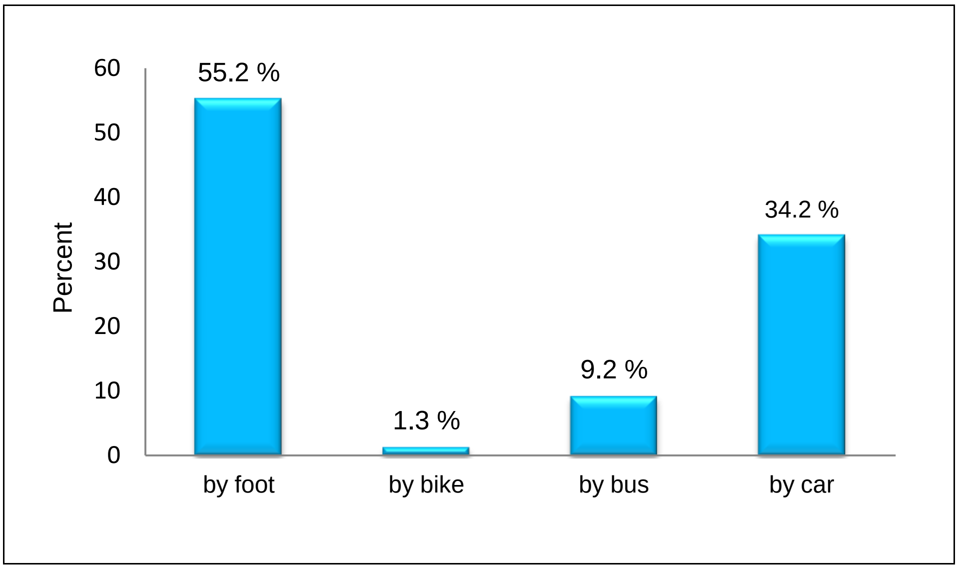


Figure 44: The type of transportation (by foot, bike, car, and bus, n=76).

As seen in figure 44, almost 55.26 % of the schoolchildren and kindergarteners walked, around 1.32 % went by bike, nearly 9.21 % used the bus and the remaining 34.21 % went by car.

3) Overall how many meters do you walk on way to school and back?

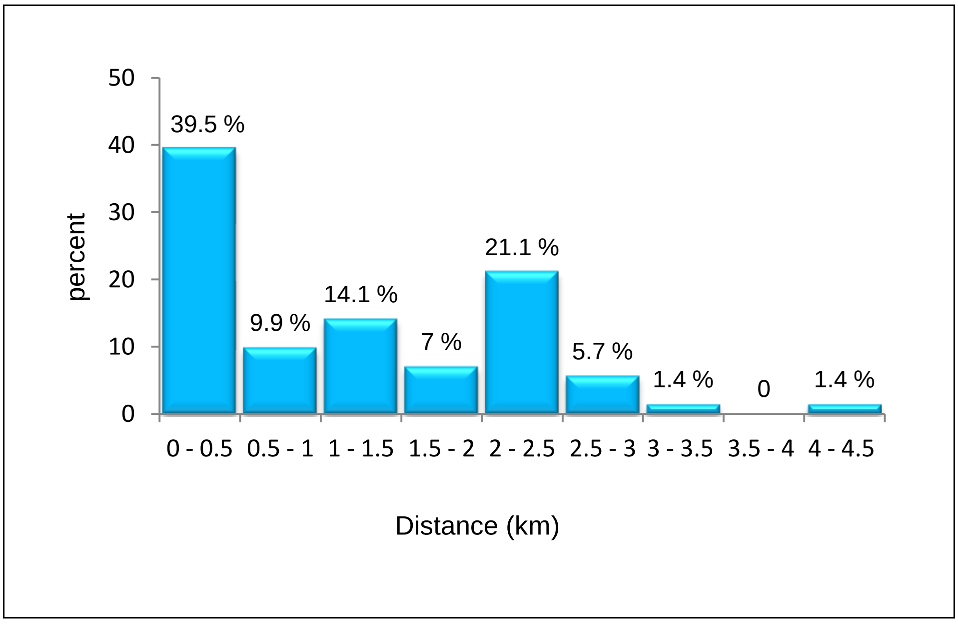


Figure 45: The distance (in kilometres) children walk on way to school and back (n=71).

As illustrated in figure 45, we can see that nearly 39.5 % of children walk less than 0.5 km, 9.9 % walk between 0.5 km and 1 km, 7 % between 1.5 km and 2 km, 21.2 % walk between 2 km to 2.5 km, 5.7 % of children walk between 25 km and 3 km, 1.41 % walk between 3 km and 3.5 km and the same percentage walk between 4 km to 45 km.

4) How long does your child have to carry his/her backpack?

Your child carries his or her schoolbag the whole way to school by him or her-self.

You carry your child’s schoolbag.

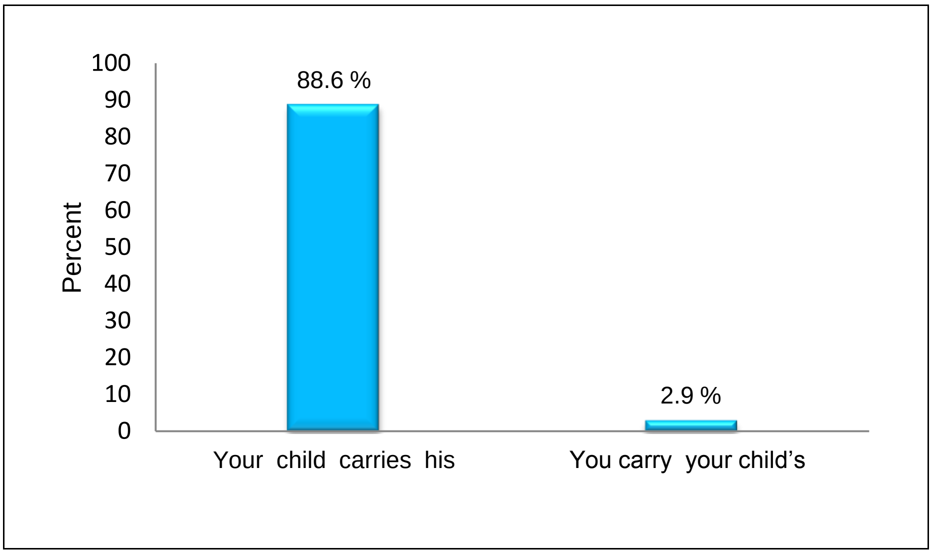


Figure 46: The children carrying backpack by themselves or their parents and 3 schoolchildren (8.6 %) did not answer the question (n=35).

As it can be observed in figure 46, out of 35 schoolchildren questioned, 31 (88.6 %) carried their backpacks by themselves and one schoolchild’s back-pack (2.9 %) was carried by parents or others. 3 participants did not answer the question.

5) Measure as accurately as possible the weight of the fully stuffed backpack (Meas-urement scale).

Weight of the stuffed backpack: ___________ kg

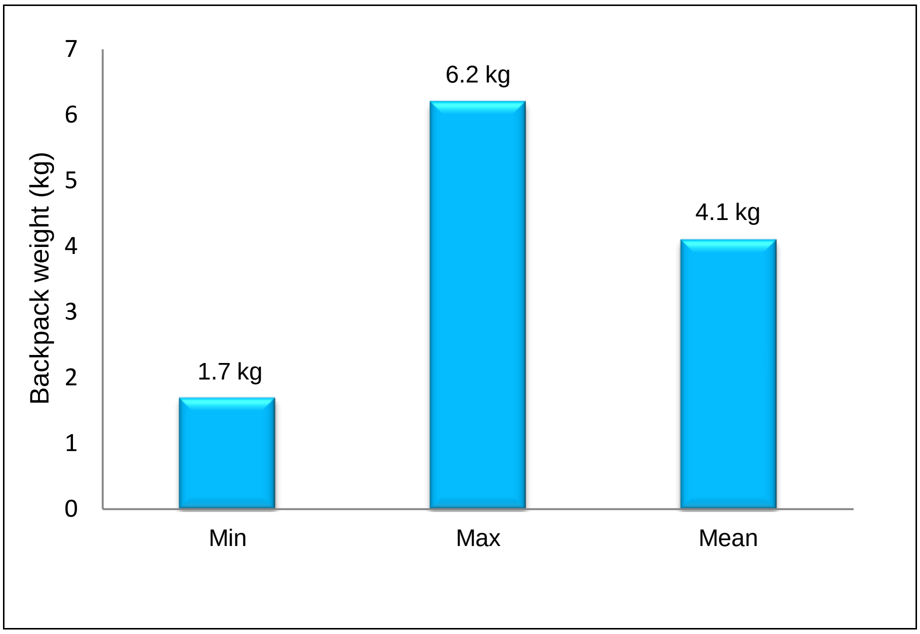


Figure 47: The weight of the fully stuff backpack (n=33).

As it can be seen in figure 47 and table 9, some of the children were carrying a minimum 10.2 % of their body weight. Others carried a maximum 26.6 % of body weight, making the average backpack weight 16.7 % of body weight (Modified, Wydra, 2009, p. 27).

Table 9: The percent of body weight with backpack weight.

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
In percent of body weight	33	10.2	26.6	16.7	4.05	16.4
Backpack weight (kg)	33	1.7	6.2	4.1	.90	.82

6) Does your child take any additional food or drink to school in the morning?

Yes ☐; No ☐

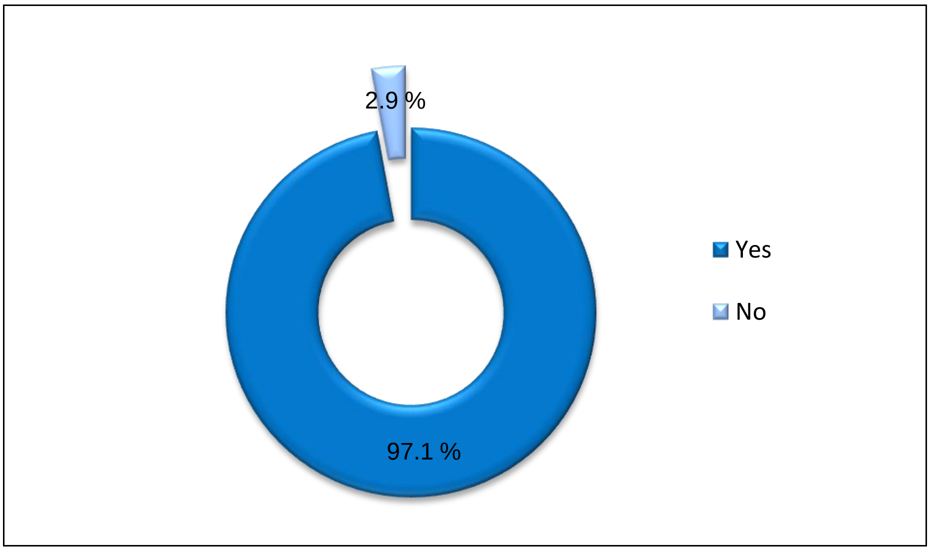


Figure 48: The children carrying food or drink at the morning to school (n=35)

As seen in figure 48, nearly 97.1 % of children took food and drink in the morning and almost 2.9 % did not.

Table 10: Carrying food or drink to school.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	34	97.2	97.2	97.2
	No	1	2,9	2,9	100

7) Please ask your child how heavy his backpack usually is:

rather very lighter □□□□□ rather very heavier

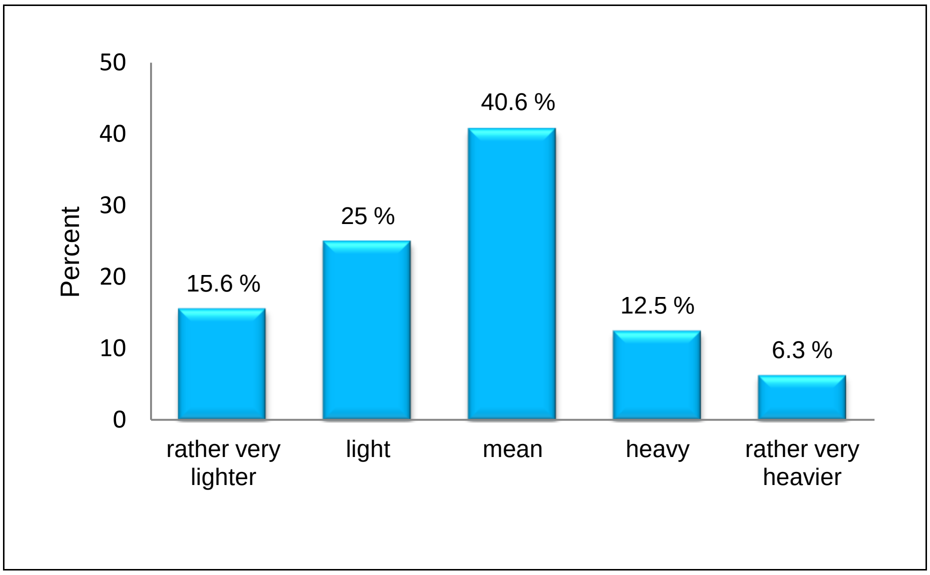


Figure 49: The weight of the backpack according to the subjects (n=35).

As indicated in figure 49, nearly 15.6 % of children answered “rather very light", 25 % answered to “light”, but 40.6 % answered “mean”, 12.5 % answered “heavy” and 6.3 % complained that the backpacks were “rather very heavy”.

8) Do you feel pain in your back while carrying your backpack?

Yes ☐; No ☐

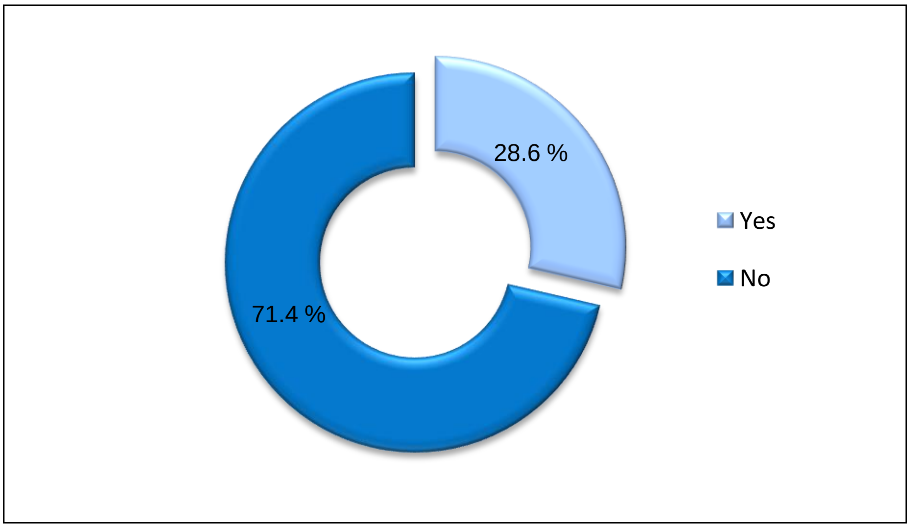


Figure 50: Fleeting pain on back while children carrying backpacks (n=35)

As it can be seen in Figure 50, nearly 28.6 % of the 35 subjects answered positively to the above question and 71.4 % answered negatively.

Table 11: Fleeting pain on back while children carrying backpacks.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	10	28.6	28.6	28.6
	No	25	71.4	71.4	100

9) If yes, where exactly?

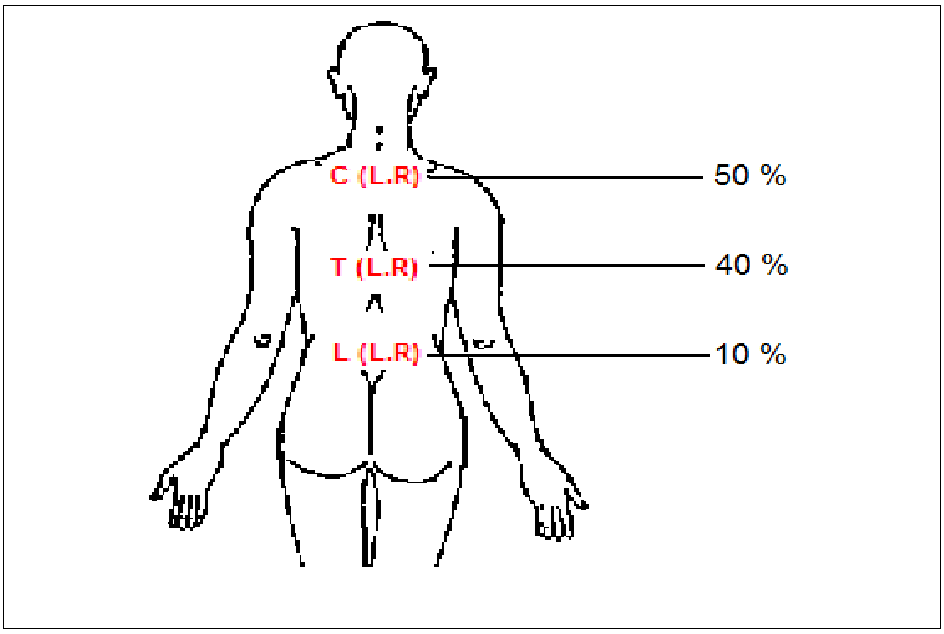


Figure 51: Exact location of back pain (n=11).

Pain localization in the lumbar spine was determined by the students as either in the shoulder spine, in the thoracic spine and in the lumbar spine. Of the 10 subjects who responded to the question, 40 % felt pain in thoracic spine T (L, R), 50 % felt it in the shoulder spine C (L, R) and 10 % in lumbar spine L (L, R).

10) How bad is the pain?

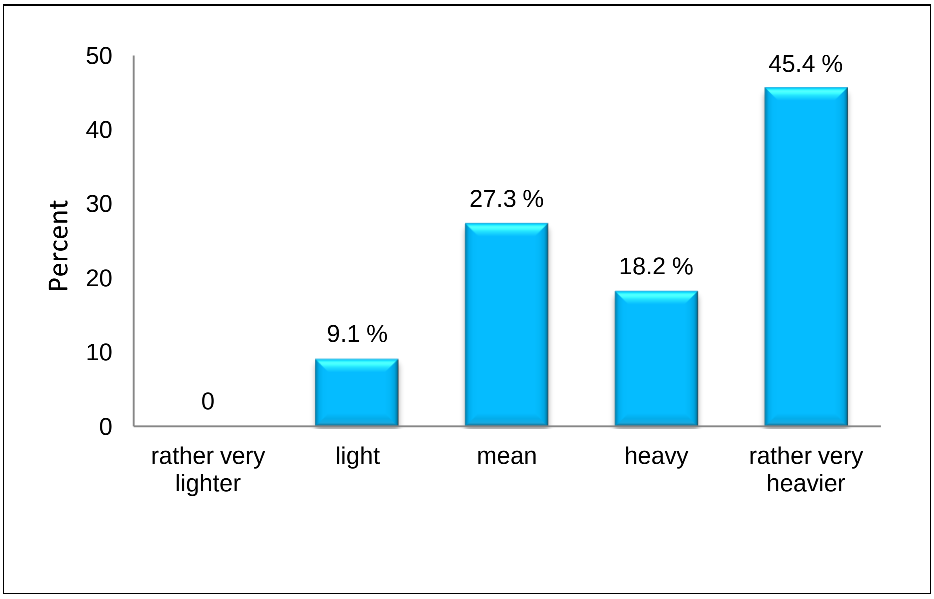


Figure 52: The intensity of pain in children (n=11).

As per the chart above, 18.2 % of the children said they felt heave pain, 27.3 % answered that their pain was average, another 9.1 % answered that it was light and 45.4 % said that it was very heavy.

11) If you take off your backpack, does the pain get better? Yes ☐; No ☐

90 % of children said the pain got better when they took off their backpack and for 10 % of children there was no difference.

Table 12: Change in pain after removing backpack (n=10).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	9	25.7	90	90
	No	1	2.9	10	100

12) Do you have any additional spinal pain? Yes ☐; No

As it can be observed in table 13, the majority of children (93 %) answered negatively and only 7 % answered positively.

Table 13: The back pain of the children (n=29).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	2	5.7	6.9	6.9
	No	27	77.1	93.1	100

13) How many days a week are they active for at least 60 minutes?

0 Day	1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐	☐

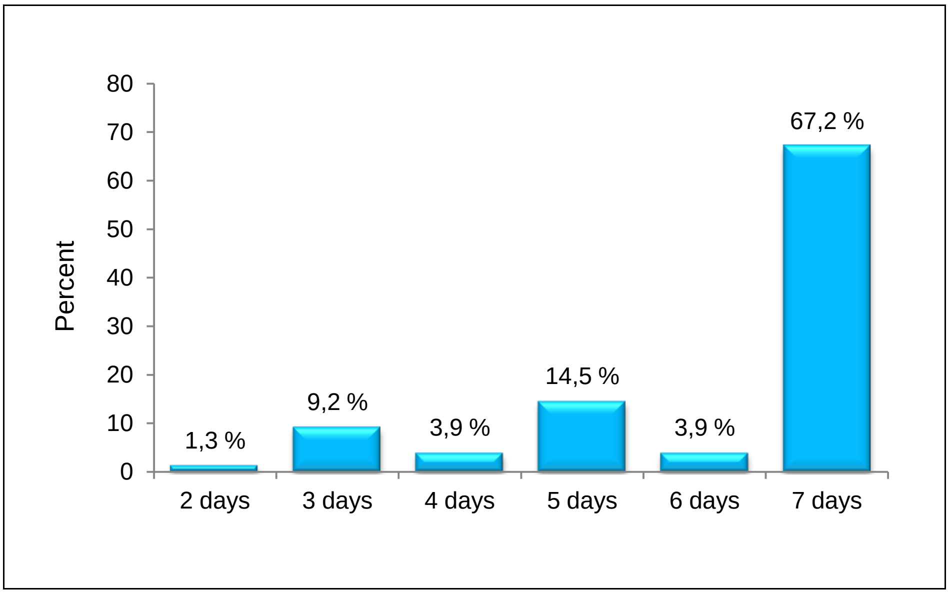


Figure 53: The activity of children for at least 60 minutes during the days of week (n=51).

The majority (67.2 %) of children answered that they were active at least 1 hour in a day, 14.5 % were active 5 days a week, 9.2 % answered 3 days a week, 3.9 % answered that they were active either 4 or 6 days and only 1.3 % of children answered that they were active just 2 days in the week.

14) How long do you spend being physically active in school or kindergarten during the day? (e.g. game during a big break).

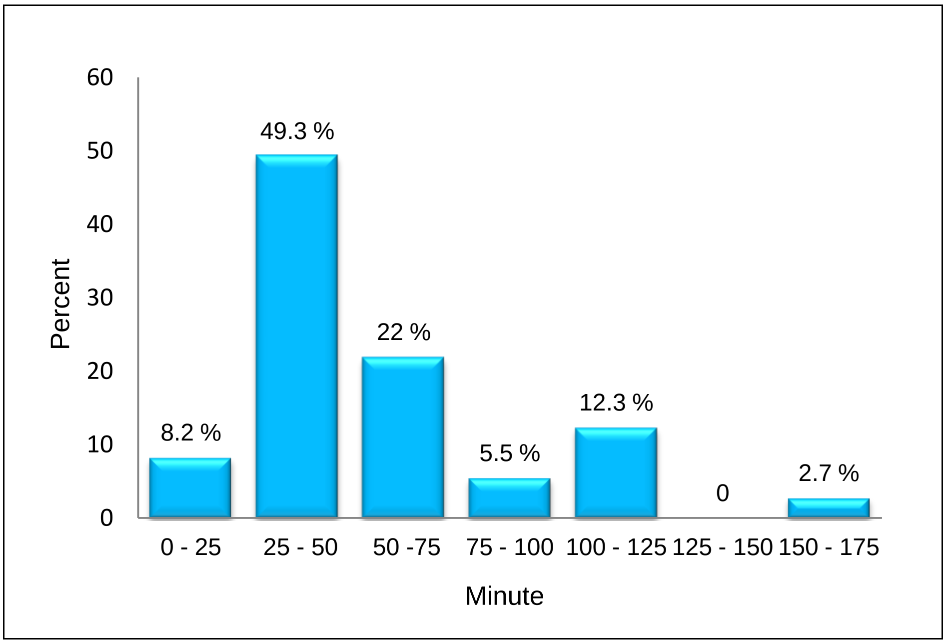


Figure 54: The physical activity of children in school or kindergarten (n=73).

With reference to above chart in figure 54, around 49.3 % answered that they had about 25 to 50 minutes of physical activity, 22 % replied around 50 to 75 minutes and 12.3 % answered that they were active nearly 100 to 125 minutes. But almost 8.2 % answered less than 25 minutes. The activity of only 5.5 % was 75 to 100 minutes and only 2.7 % of responses about the physical activity level at school or kindergarten were between 150 to 175 minutes.

15) How many days a week do you play outdoors?

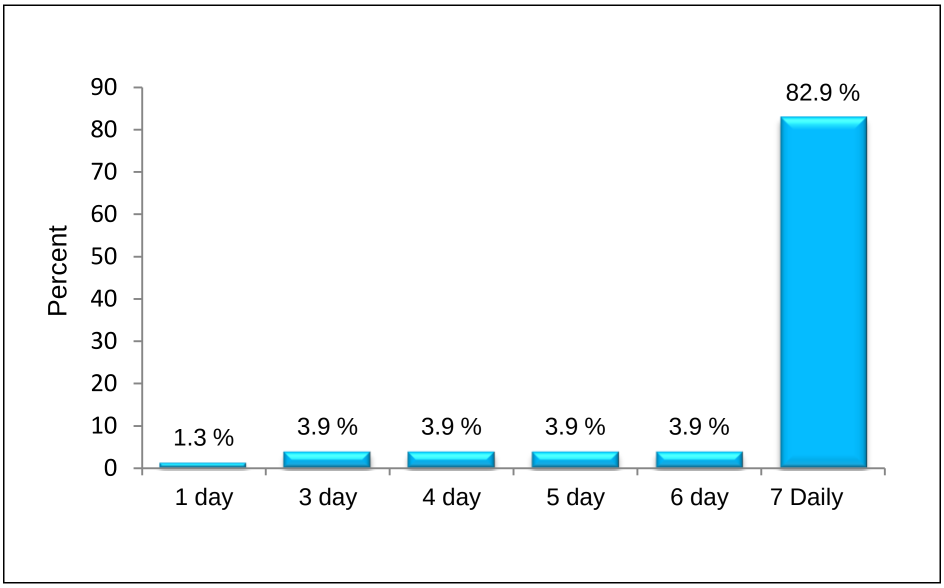


Figure 55: Number of days a week playing outdoors.

With reference to the above diagram 55, the majority of answers (82.9 %) said daily, 3.9 % of answers said 3, 4, 5 or 6 days a week and only 1.3 % of answers said one day in the week.

16) How long is the distance that you walk daily?

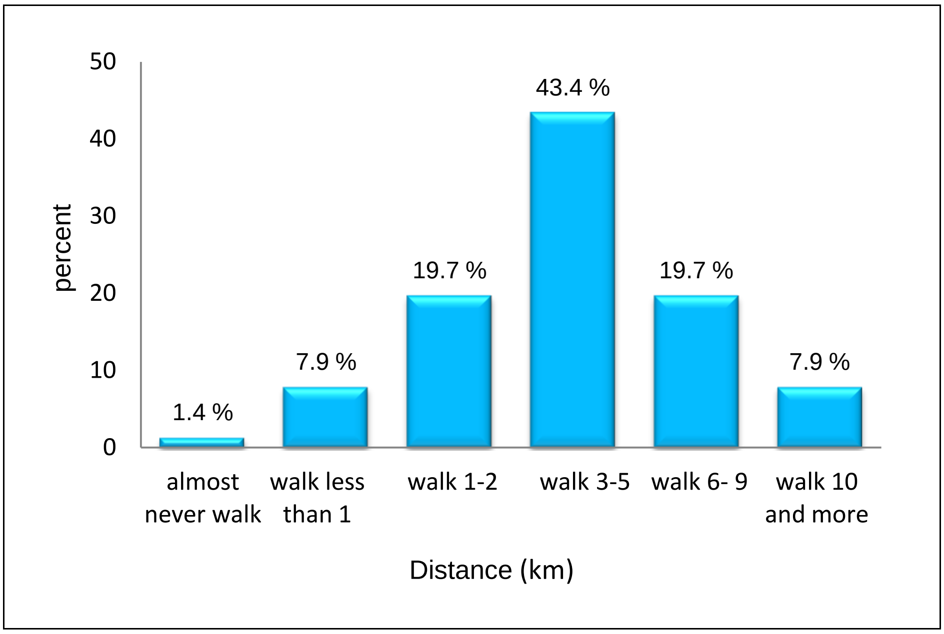


Figure 56: The distance which children walked daily (n=76).

As indicated in figure 56, 43.4 % of children walked about 3 to 5 km daily, 19.7 % walked about 6 to 9 km, same percentage walked about 1 to 2 km a day, 8 % walked less than 1 km and the same percent walked more than 10 km. Only 1.4 % of children answered that they almost never walk.

17) Are you a member of any sport clubs? (Please highlight only 1 answer).

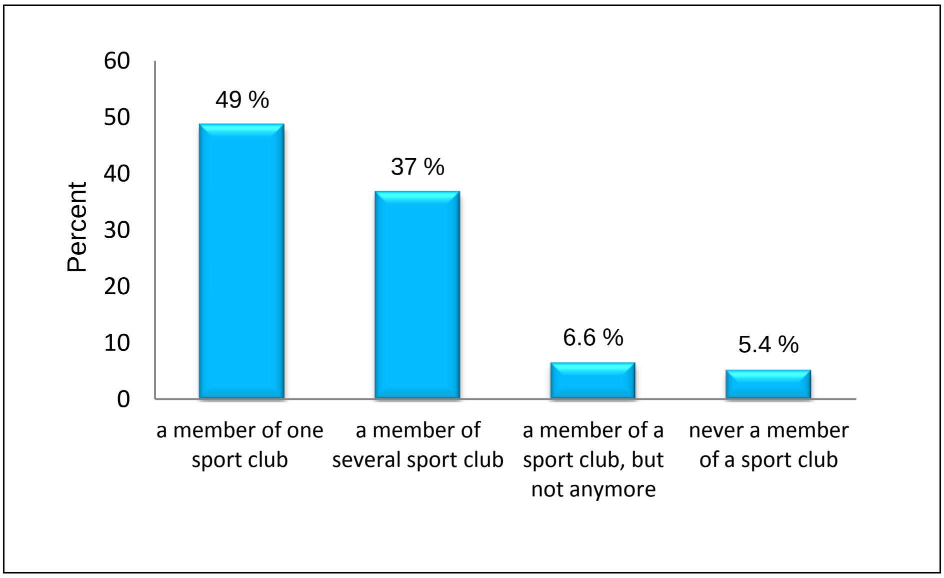


Figure 57: The children's membership in sports clubs (n=76).

As it can be seen in figure 58, 49 % of children were members of one sport club at the moment, 37 % of children were members of several sport clubs, 6.6 % of them used to be members of a sport club and 5.4 % of them have never been a member of a sport club.

4.2 Results of kinematics body posture

Table 14: Biomechanical measures for the first 10 s and the last 10 s of the 5 min of walking the children on the treadmill with different load conditions [mean (SD)] for kindergarten boys (n=18).

Variable	0 % BW		10 % BW		20 % BW		30 % BW	
	1min	5min	1min	5min	1min	5min	1min	5min
(M) Trunk inclination angle (°)	98.8	99.1	101.6	102.5	103.1	104.8	107.9	107.4
(SD)	3.4	4.2	3.9	3	2.9	3.5	4.6	4.5
(M) Trunk motion range (°)	3.6	3.4	2.	2.3	2.8	3.1	2.4	2.4
(SD)	1.9	2	2.1	1.8	2.3	1.2	1.8	2.6
(M) Step length (cm)	16.7	16.6	17.9	17.6	18.8	18.9	17.9	17.7
(SD)	2.3	2	2.2	2.3	2	1.9	2.3	2.5
(M) Distance the floor to the ear-lobe joint (cm)	98.5	98.6	97	96.7	96.1	95.9	94.3	93.8
(SD)	3.5	3.8	3.6	3.2	3.8	3.5	3.6	3.1

Table 15: Biomechanical measures for the first 10 s and the last 10 s of the 5-min of walking the children on the treadmill with different load conditions [mean (SD)] for kindergarten girls (n=23).

Variable	0 % BW		10 % BW		20 % BW		30 % BW	
	1min	5min	1min	5min	1min	5min	1min	5min
(M) Trunk inclination angle (°)	97.2	97.8	100.9	101.3	103	104.1	105.9	107.3
(SD)	2.6	2.9	3.8	3.3	2.8	3.5	3.7	3.6
(M) Trunk motion range (°)	4	4.1	2.9	2.5	3.4	2.8	3.1	2.5
(SD)	1.8	1.6	1.4	2.5	1.7	1.6	1.5	1.4
(M) Step length (cm)	18.9	18	19.7	18.9	20.4	20.6	21.1	20.1
(SD)	2.9	2.4	2.1	2.4	2.6	3	2.8	1.9
(M) Distance the floor to the ear-lobe joint (cm)	103.8	103.7	102.5	101.8	101.3	100.8	99.5	98.7
(SD)	4.9	4.6	4.5	3.9	4.3	3.8	4.3	4.4

Table 16: Biomechanical measures for the first 10 s and the last 10 s of the 5-min of walking the children on the treadmill with different load conditions [mean (SD)] for primary school boys (n=23).

Variable	0 % BW		10 % BW		20 % BW		30 % BW	
	1min	5min	1min	5min	1min	5min	1min	5min
Trunk inclination angle (°) (M)	97.2	97.7	100.9	101.3	103	104.2	105.9	107.3
Trunk inclination angle (°) (SD)	2.6	2.9	3.8	3.3	2.8	3.5	3.7	3.6
Trunk motion range (°) (M)	4	4.1	2.9	2.5	3.4	2.8	3.1	2.5
Trunk motion range (°) (SD)	1.8	1.6	1.4	2.5	1.7	1.6	1.5	1.4
Step length (cm) (M)	18.9	18	19.7	18.9	20.4	20.6	21.1	20.1
Step length (cm) (SD)	2.9	2.4	2.1	2.4	2.6	3	2.8	1.9
Distance the floor to the ear-lobe joint (cm) (M)	103.8	103.9	102.5	101.8	101.4	100.8	99.5	98.7
Distance the floor to the ear-lobe joint (cm) (SD)	4.3	4.6	4.5	3.9	4.3	3.8	4.3	4.4

Table 17: Biomechanical measures for the first 10 s and the last 10 s of the 5-min of walking the children on the treadmill with different load conditions [mean (SD)] for primary school girls (n=12).

Variable	0 % BW		10 % BW		20 % BW		30 % BW	
	1min	5min	1min	5min	1min	5min	1min	5min
(M) Trunk inclination angle (°)	98.8	98.4	101.2	105.5	103.2	105.2	107.2	109.3
(SD)	3.5	3.2	4.1	3.1	2.4	3	4.97	3.55
(M) Trunk motion range (°)	4.5	4.7	2.9	3.7	3	3.5	2.9	2.5
(SD)	1.8	2.2	1.5	1.6	1.9	1.5	1.3	2.1
(M) Step length (cm)	17.4	18	18.4	19.2	19.8	19.9	19.7	19.3
(SD)	2.4	2.1	1.8	1.9	1.1	1.9	1.3	2.4
(M) Distance the floor to the ear-lobe joint (cm)	104.9	105.5	104	104.2	102.8	102.1	100.7	100.5
(SD)	6.1	5.1	5.6	5.5	5.7	5.8	6.7	6.4

Table 18: A repeated ANOVA measurement [2 (time points)×4 (loads)] was performed to compare each data set obtained in body posture parameters at the two measuring time points under each of the four load conditions.

Variables	Effect	F	P
Step length (cm)	Gender	.52	.472
	Kinder-school	9.11	.004*
	Gender*Kinder-school	.90	.346
	Load conditions	48.73	0.000*
	Load conditions*Gender	.81	.489
	Load conditions*Kinder-school	1.38	.251
	Load conditions*Gender* Kinder-school	.05	.984
	2 (time points) the 1st and 5th min	4.38	.040*
	2 (time points)*Gender	4.79	.032*
	2 (time points)*Kinder-school	.02	.886
	2 (time points)*Gender*Kinder-school	.86	.358
	Load conditions*2 (time points)	1.93	.126
	Load conditions*2 (time points)*Gender	1.75	.159
	Load conditions*2 (time points)*Kinder-school	.17	.914
	Load conditions*2 (time points)*Kinder-school*Gender	.66	.580
Distance from the floor to the earlobe joint (cm)	Gender	.0	.841
	Kinder-school	24.2	.000*
	Gender* Kinder-school	.7	.392
	Load conditions	316.4	0.000*
	Load conditions*Gender	1.7	.166
	Load conditions*Kinder-school	2.8	.039*
	Load conditions*Gender*Kinder-school	.6	.609
	2 (time points) the 1st and 5th min	10.1	.002*
	2 (time points)*Gender	1.2	.276
	2 (time points)*Kinder-school	.5	.486
	2 (time points)*Gender*Kinder-school	2.6	.109
	Load conditions*2 (time points)	1.8	.145
	Load conditions*2 (time points)*Gender	.8	.515
	Load conditions*2 (time points)*Kinder-school	1.4	.231
	Load conditions*2 (time points)* Kinder-school* Gender	1.4	.259

Variables	Effect	F	P
Trunk inclination range (°)	Gender	. 2	.655
	Kinder-school	2.1	.157
	Gender*Kinder-school	5.9	.017*
	Load conditions	250.7	0.000*
	Load conditions*Gender	.5	.684
	Load conditions*Kinder-school	.5	.690
	Load conditions*Gender*Kinder-school	.05	.659
	2 (time points) the 1st and 5th min	21.6	.000*
	2 (time points)*Gender	.6	.439
	2 (time points)*Kinder-school	.0	.889
	2 (time points)*Gender*Kinder-school	.0	.885
	Load conditions*2 (time points)	2.0	.112
	Load conditions*2 (time points)*Gender	.7	.568
	Load conditions*2 (time points)*Kinder-school	.6	.592
	Load conditions*2 (time points)*Kinder-school*Gender	.8	.521
Trunk motion range (°)	Gender	2.10	.152
	Kinder-school	1.11	.297
	Gender* Kinder-school	.23	.639
	Load conditions	24.02	0.000*
	Load conditions*Gender	4.27	.006*
	Load conditions*Kinder-school	.32	.814
	Load conditions*Gender* Kinder-school	.98	.404
	2 (time points) the 1st and 5th min	.12	730
	2 (time points)*Gender	2.82	.098
	2 (time points)*Kinder-school	.84	.364
	2 (time points)*Gender*Kinder-school	1.37	.246
	Load conditions*2 (time points)	.89	.446
	Load conditions*2 (time points)*Gender	.29	.832
	Load conditions*2 (time points)*Kinder-school	.28	.837
	Load conditions*2 (time points)*Kinder-school*Gender	.89	.446

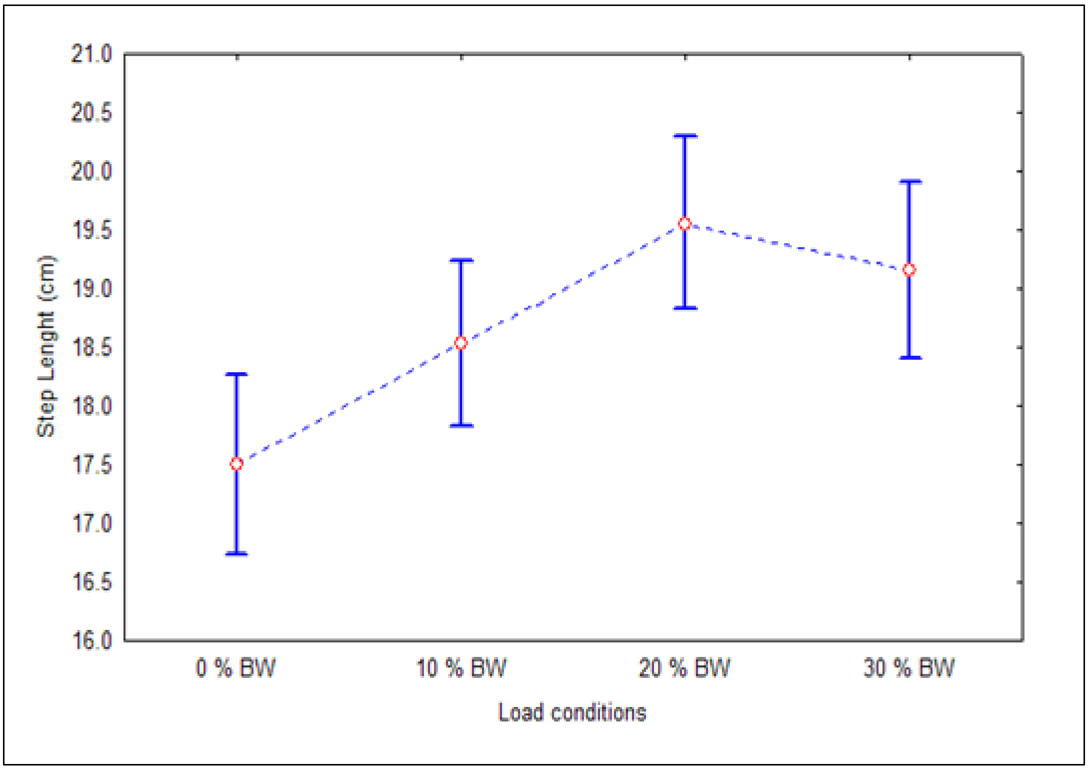


Figure 58: Changes in different load conditions with backpack during 20 minutes for gender, kindergartener and primary schoolchild by measuring of the step length.

As indicated in figure 58, there was a significantly high increase in step length (p<0.001) for boys, girls, kindergarteners and primary schoolchildren ($F=48.73$, $p=0.000$, $\eta^2=0.42$). However for comparing four different load conditions at the 20th min of (0, 10, 20, 30 % BW) the Post hoc with Tukey-HSD tests has been used. According to the ANOVA results (Tab. 19) with the increase of the weight of backpack between 0 %, 10 %, and 10 %, 20 % body weight (BW) while walking on the treadmill the step length increased. In other words, with the increase of the load of backpack approximately 10 % and 20 % BW, the step length has been increased. In 30 % BW the step length has been decreased.

Table 19: The Post hoc with Tukey-HSD test results for step length in different load conditions.

Load conditions	(1) 17.5	(2) 18.5	(3) 19.5	(4) 19.1
0 % BW		0.000	0.000	0.000
10 % BW	0.000		0.000	0.001
20 % BW	0.000	0.000		0.112
30 % BW	0.000	0.001	0.112	

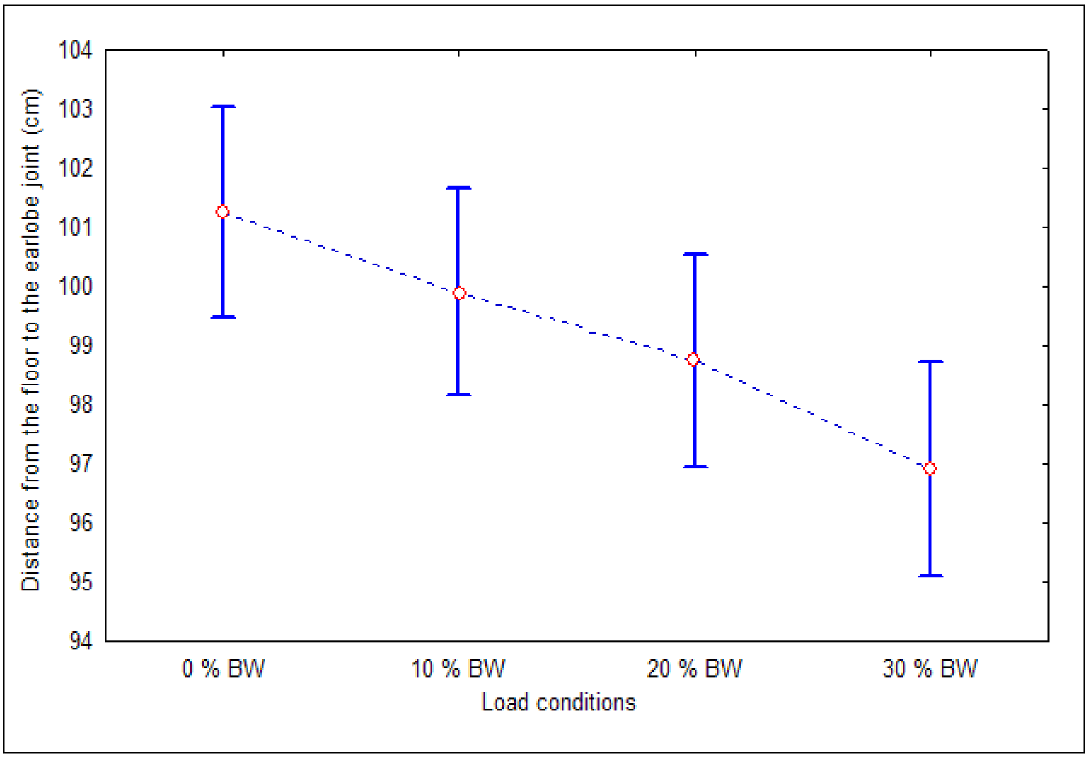


Figure 59: Changes in different load conditions with backpack during 20 minutes for gender (boys, girls), kindergartener and primary schoolchild in distance from the floor to the earlobe joint.

As it can be exemplified from figure 59, there was a highly significant decrease in distance from the floor to the earlobe joint (height) in all different groups ($F=316.37$, $p=0.000$, $\eta^2=0.82$). The ANOVA results (Tab. 20) indicated that while the children walking on the treadmill, with the increase of the backpack weight, the distance from the floor to the earlobe joint between 0 %, 10 %, and 10 %, 20 % and 20 %, 30 % body weight (BW) significantly decreased. On the other hand by increasing the backpack weight, the distance from the floor earlobe to the earlobe joint has been decreased.

Table 20: The Post-hoc with Tukey-HSD test results for distance from the floor to the earlobe joint in load conditions.

Load conditions	(1) 100.9	(2) 99.5	(3) 98.4	(4) 96.5
0 % BW		0.000	0.000	0.000
10 % BW	0.000		0.000	0.000
20 % BW	0.000	0.000		0.000
30 % BW	0.000	0.000	0.000	

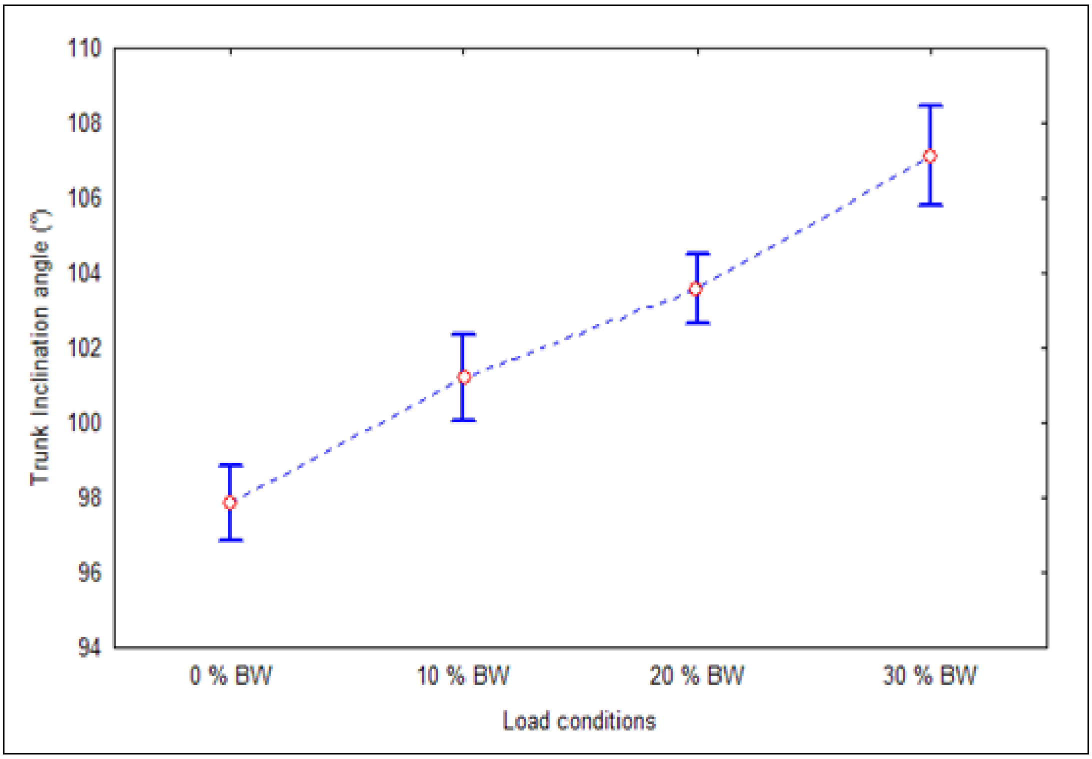


Figure 60: Changes in different load conditions with backpack during 20 minutes for boys and girls, kindergartener and primary schoolchild of trunk inclination angle.

As it has been shown above in figure 60, there was a significantly high increase in trunk inclination angle (*F=250.74, p=0.000,* η^2*=0.80*). Comparing the different load conditions of zero (Tab. 22) indicated that between 0 %, 10 %, and 10 %, 20 % and 20 %, 30 % of body weight (BW) significantly increased trunk inclination angle when children walked on the treadmill.

Table 21: The Post-hoc with Tukey-HSD test results for trunk inclination angle in load conditions.

Load conditions	(1) 97.6	(2) 101	(3) 103.4	(4) 106.8
0 % BW		0.000	0.000	0.000
10 % BW	0.000		0.000	0.000
20 % BW	0.000	0.000		0.000
30 % BW	0.000	0.000	0.000	

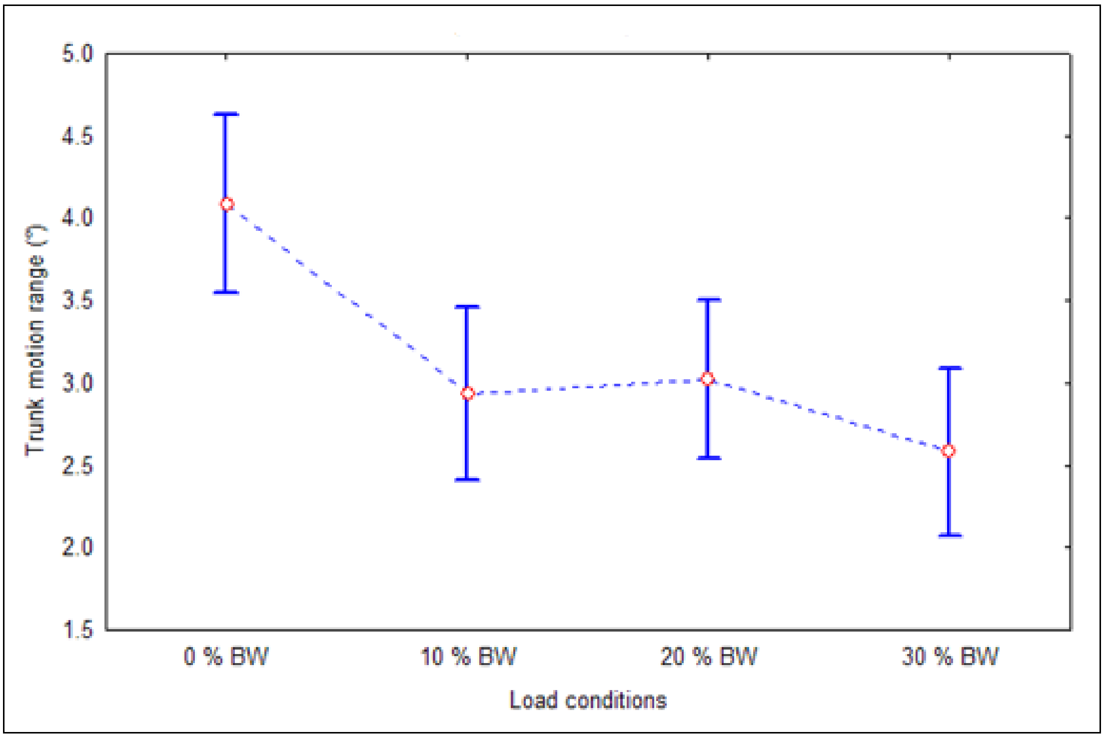


Figure 61: Changes *in different load conditions with backpack during 20 minutes for, boys, girls, kindergartener and primary schoolchild of trunk motion range.*

As it can be illustrated from figure 61, there was a highly significant decrease for all groups in trunk motion range ($F=24.01$, $p=0.000$, $\eta^2=0.26$). However, for comparing different load conditions the Post Hoc with Tukey-HSD tests were used. The ANOVA results (Tab. 22) indicated that between 0 %, 10 % body weight (BW) significantly decreased trunk motion range but it did not change significantly between 10 %, 20 % and 20 %, 30 % body weight (BW) while children walked on the treadmill. That is to say there was no significant change of trunk motion range with increase of the backpack.

Table 22: The Post hoc with Tukey-HSD test results for trank motion range in different load conditions.

Load conditions	(1) 4	(2) 2.9	(3) 2.9	(4) 2.5
0 % BW		0.000	0.000	0.000
10 % BW	0.000		0.986	0.244
20 % BW	0.000	0.986		0.123
30 % BW	0.000	0.244	0.123	

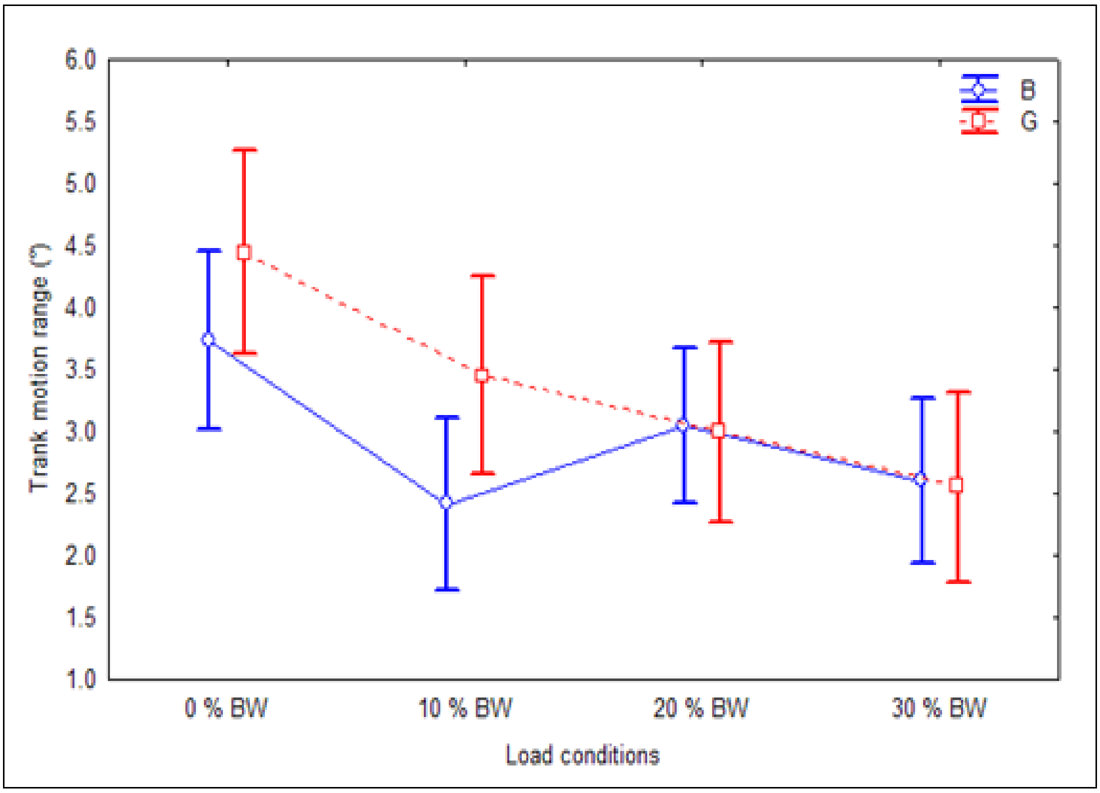


Figure 62: changes in different load conditions with backpack during 20 minutes for gender boys (B) and girls (G) of trunk motion range.

As it can be observed in figure 62, there was a significantly decrease for boys and girls in trunk motion range ($F=4.27$, $p=0.005$, $\eta^2=0.05$). The Tukey-HSD tests results for gender *(boys and girls)* (Tab. 23) revealed that between 0 %, 10 % body weight (BW) significant decreased trank motion range for boy and girl, but did not change significantly between 10 %, 20 % and 20 %, 30 % body weight (BW) between load conditions for both boys and girls. To be precise, the changes of trunk motion range did not increase in load conditions for gender *(boys and girls)*.

Table 23: The Post hoc with Tukey-HSD test results for trunk motion range in different load conditions for boys (B) and girls (G).

B-G	Load conditions	(B) 3.7	(B) 2.4	(B) 3	(B) 2.6	(G) 4.3	(G) 3.5	(G) 2.8	(G) 2.5
B	0 % BW		0.000	0.071	0.000	0.946	0.995	0.207	0.011
B	10 % BW	0.000		0.196	0.996	0.000	0.538	0.911	0.999
B	20 % BW	0.071	0.196		0.641	0.003	0.912	0.999	0.823
B	30 % BW	0.000	0.996	0.641		0.000	0.201	0.994	1
G	0 % BW	0.946	0.000	0.003	0.000		0.022	0.000	0.000
G	10 % BW	0.995	0.538	0.912	0.201	0.022		0.317	0.008
G	20 % BW	0.207	0.911	0.999	0.994	0.000	0.317		0.891
G	30 % BW	0.011	0.999	0.823	1	0.000	0.008	0.891	

Table 24: Results of ANOVA by analyze of variance with repeated measures in load conditionswith backpack for the alterations of body posture that following for distance from floor earlobe, trunk inclination angle in mid stance phase.

Variables	Effect	F	P
Distance from the floor to the earlobe joint (cm) in mid stance phase	Gender	.0	.827
	Kinder-school	27.1	.000*
	Gender*Kinder-school	.8	.386
	Load conditions	165.3	0.000*
	Load conditions*Gender	.81	.489
	Load conditions*Kinder-school	1.0	.399
	Load conditions*Gender*Kinder-school	2.5	.059
	2 (time points) the 1st and 5th min	1.2	.325
	2 (time points)*Gender	4.5	.037*
	2 (time points)*Kinder-school	1.2	.167
	2 (time points)*Gender*Kinder-school	2.0	.167
	Load conditions*2 (time points)	2.2	.140
	Load conditions*2 (time points)*Gender	1.0	.385
	Load conditions*2 (time points)*Kinder-school	1.5	.205
	Load conditions*2 (time points)*Kinder-school*Gender	.3	.790
Trunk inclination angle (°) in mid stance phase	Gender	.1	.948
	Kinder-school	24.2	.691
	Gender*Kinder-school	.7	.360
	Load conditions	316.4	0.000*
	Load conditions*Gender	1.7	.098
	Load conditions*Kinder-school	2.8	.309
	Load conditions*Gender*Kinder-school	.6	.998
	2 (time points) the 1st and 5th min	10.1	.005*
	2 (time points)*Gender	1.2	.148
	2 (time points)*Kinder-school	.5	.190
	2 (time points)*Gender*Kinder-school	2.6	.645
	Load conditions*2 (time points)	1.8	.017*
	Load conditions*2 (time points)*Gender	.8	.757
	Load conditions*2 (time points)*Kinder-school	1.4	.382
	Load conditions*2 (time points)*Kinder-school*Gender	1.4	.878

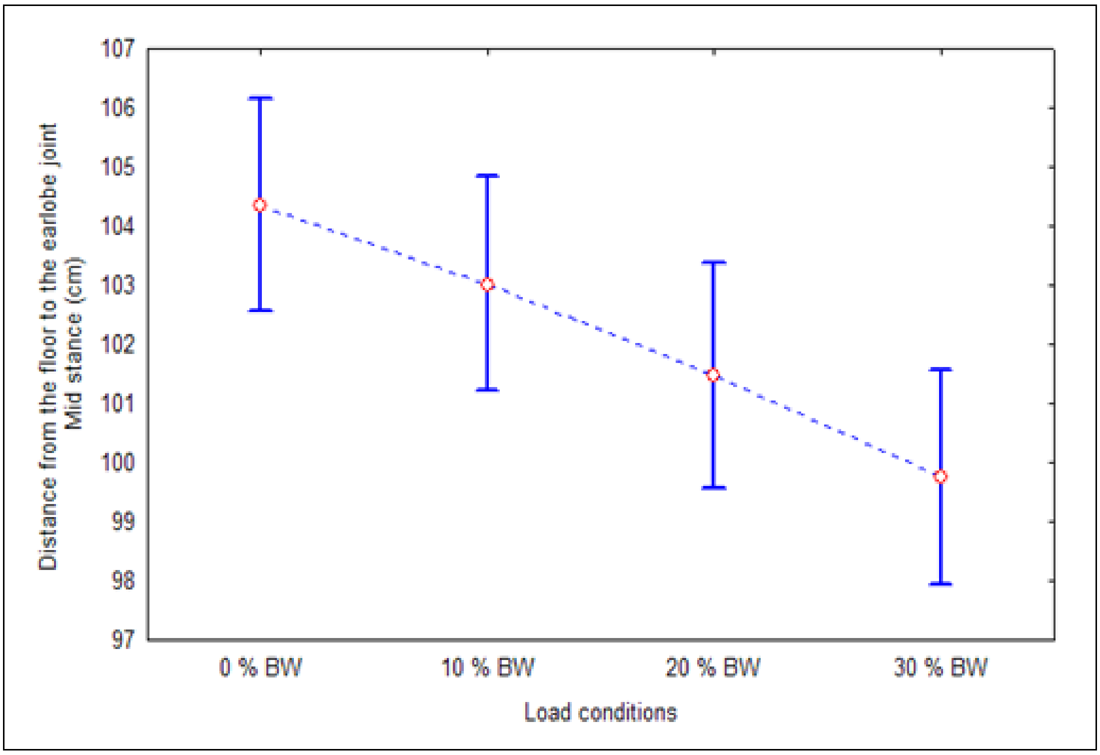


Figure 63: Changes in different load conditions with backpack during 20 minutes for boys, girls, kindergartener and primary schoolchild of distance from the floor to the earlobe joint for mid stance phase.

As it can be seen from figure 63, there was a highly significant decrease for all mentioned groups in distance from the floor to the earlobe joint for mid stance phase ($F=165.33$, $p=0.000$, $\eta^2=0.70$). The ANOVA results (Tab. 25) showed that throughout the 20 minutes of walking on treadmill between 0 %, 10 % and 10 %, 20 % and 20 %, 30 % body weight (BW) load, the distance from the floor to the earlobe joint for mid stance phase in load conditions decreased significantly.

Table 25: The Post hoc with Tukey-HSD test results for the distance from the floor to the earlobe joint for mid stance phase in different load conditions.

Load conditions	(1) 104	(2) 102.6	(3) 101.1	(4) 99.4
0 % BW		0.000	0.000	0.000
10 % BW	0.000		0.000	0.000
20 % BW	0.000	0.000		0.000
30 % BW	0.000	0.000	0.000	

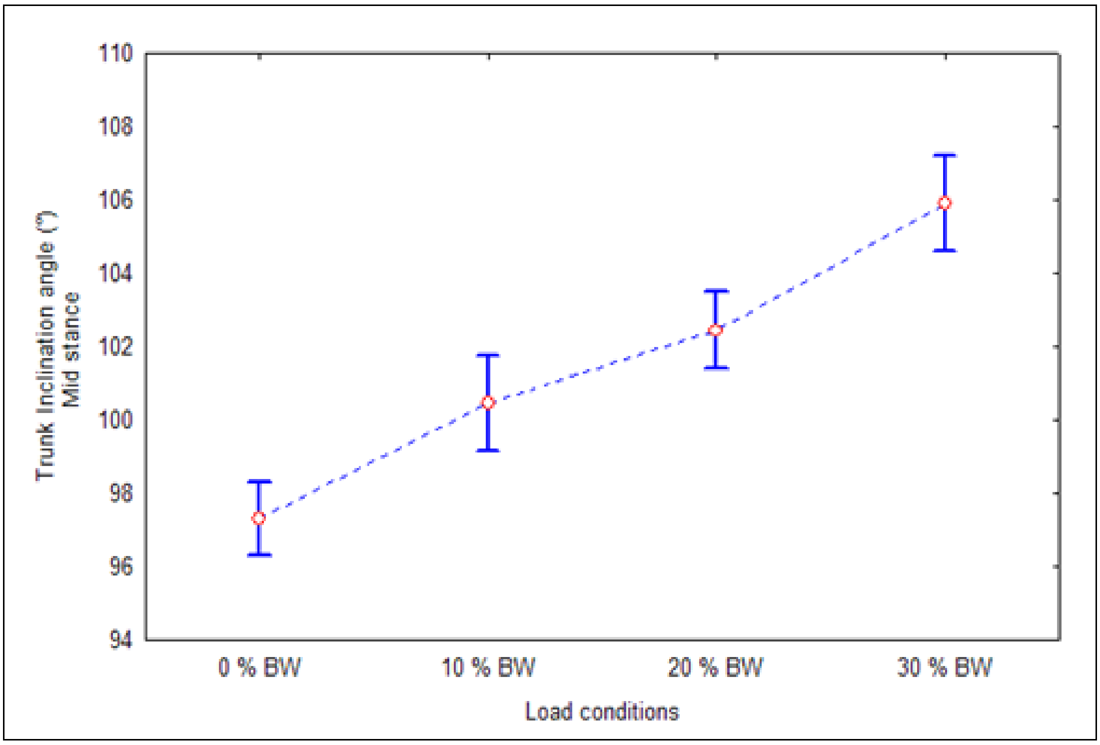


Figure 64: Changes in different load conditions with backpack during 20 minutes for gender (boys, girls), kindergartener and primary schoolchild of trunk inclination angle for mid stance phase.

As it is illustrated in figure 64, there was a significantly high increase in load conditions of trunk inclination angle ($F=195.55$, $p=0.000$, $\eta^2=0.74$).The ANOVA results (Tab. 26) denoted that during 20 minutes of walking on treadmill between 0 %, 10 %, and 10 %, 20 % and 20 %, 30 % body weight (BW) load, the trunk inclination angle for mid stance phase were also significant in different load conditions. On the other hand, with the increase of the weight of backpack the trunk inclination angle for mid stance phase increased.

Table 26: The Post-hoc with Tukey-HSD test trunk inclination angle for mid stance phases in different load conditions.

Load conditions	(1) 97.1	(2) 100.3	(3) 102.2	(4) 105.6
0 % BW		0.000	0.000	0.000
10 % BW	0.000		0.000	0.000
20 % BW	0.000	0.000		0.000
30 % BW	0.000	0.000	0.000	

A Spearman correlation analysis was performed in the step length and distance from the floor to the earlobe joint on the load conditions. Correlations are significant at $p<0.01$.

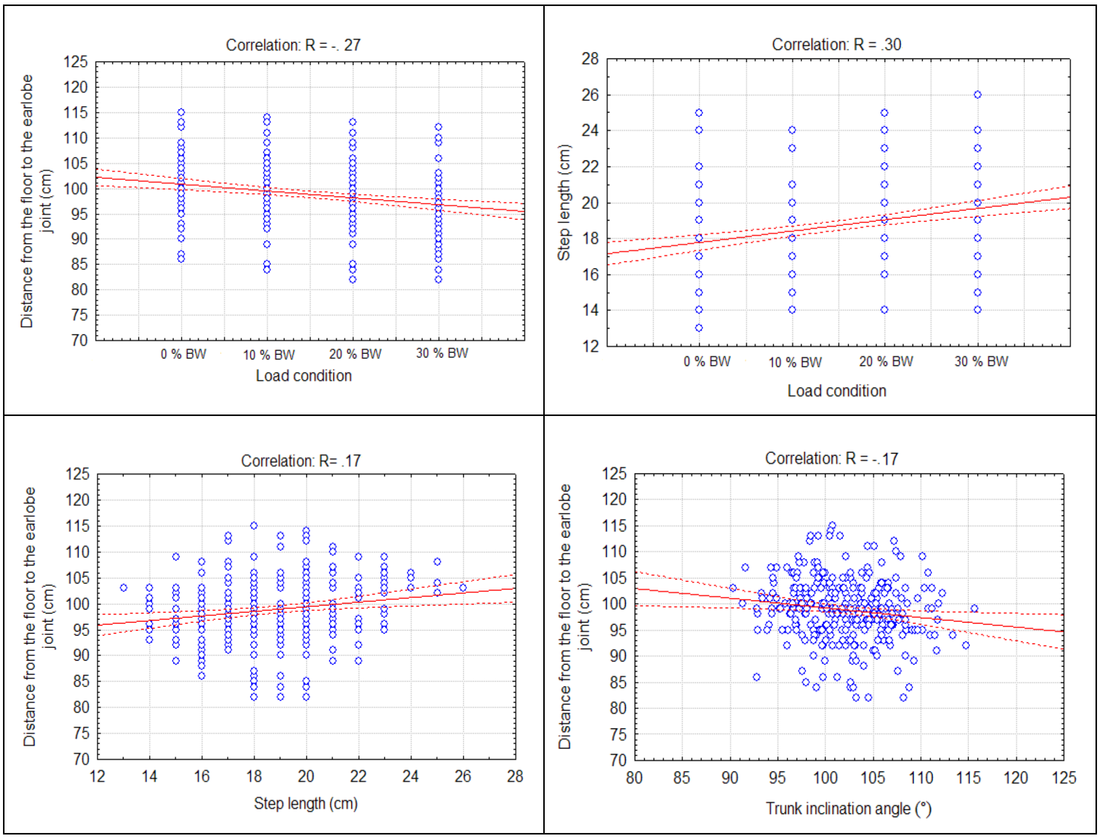


Figure 65: The correlation between the distance from the floor to the earlobe joint and step length, and the correlation between the trunk inclination angle and the distance from the floor to the earlobe joint.

Correlation analysis showed that the Spearman correlation nonparametric between the distance from the floor to the earlobe joint and the load conditions was (-0.27) significantly negative, between step length and the load conditions was (0.30) significantly positive, between the distance from the floor to the earlobe joint and step length was (0.17) significantly positive, and between the trunk inclination angle and the distance from the floor to the earlobe joint was (-0.17) significantly negative.

Table 27: Correlation is significant at the 0.01 level for the distance from the floor to the earlobe joint and the step length.

Variable	Spearman Correlation	Sig. (2-tailed)	N
Between load condition and the distance from the floor to the earlobe joint	-0.27*	.000	304
Between load condition and step length	0.30*	.000	304
Between the distance from the floor to the earlobe joint and step length	0.17*	.000	299
Between the distance from the floor to the earlobe joint and the trunk inclination angle	-0.17*	.004	299

A Spearman correlation analysis was performed in the trunk inclination angle and the trunk motion range on the load conditions. Correlations are significant at p<0.01.

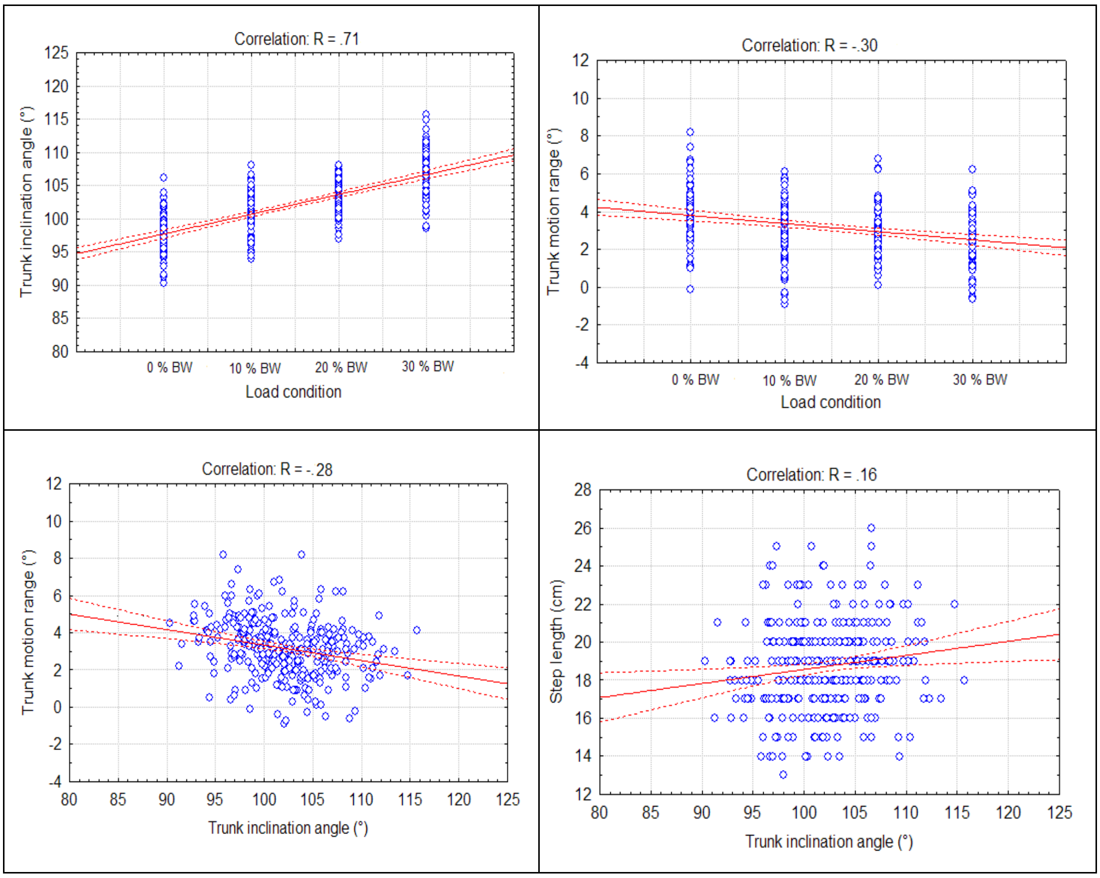


Figure 66: The correlation between the trunk inclination angle and the trunk motion range, and between step length and the trunk inclination angle.

The above correlation analysis showed that the Spearman correlation nonparametric between the trunk inclination angle and the load conditions, and between the trunk motion range and the load conditions, and between the trunk inclination angle and the trunk motion range and between the trunk inclination angle and step length, were (0.71), (-0.30), (-0.28) and (0.16) respectively, with a significant difference at the 0.01 level. Therefore, the present study represented that there was a significant positive correlation relationship between the trunk inclination angle, step length and the load conditions. In addition there was a significant negative relationship between the trunk motion range and the load conditions correlation and between the trunk inclination angle and trunk motion range.

Table 28: Correlation is significant at the 0.01 level for the trunk inclination angle and the trunk motion range.

Variable	Spearman Correlation	Sig. (2-tailed)	N
Between load condition and the trunk inclination angle	0.71*	.000	299
Between load condition and the trunk motion range	-0.30*	.000	300
Between the trunk inclination angle and the trunk motion range	-0.28*	.000	299
Between the trunk inclination angle and step length	0.16*	.012	299

4.3 Results of IEMG and MPF

Table 29: Physiological measures the 2nd, 3rd and 4.1th sec of each 10 sec at the 1st and 5th min of walking the children on the treadmill with different load conditions [mean (SD)] for kindergarten boys of IEMG and MPF(n=18).

Variable	0 % BW		10 % BW		20 % BW		30 % BW	
	1min	5min	1min	5min	1min	5min	1min	5min
(M) Upper trapezius, IEMG (mv)	13.7	13.2	19	19.4	25.7	20.9	33.9	26.7
(SD)	8.7	7	9	7.3	13.5	10.7	17.7	15
(M) Thoracic erector spinae, IEMG (mv)	29.7	27.9	26.2	25.3	24.2	23	24	24.1
(SD)	12.3	9.9	10.1	1.5	8.3	6.9	11	10.5
(M) Lumbar erector spinae, IEMG (mv)	31.8	27	27	27.5	26.4	24.6	27.2	29.1
(SD)	12	11.9	9.3	14	10.1	6.9	11.5	13.9
(M) Upper trapezius, MPF (Hz)	80.2	76.7	80.4	78.5	80.7	82.6	82.8	82.9
(SD)	8.8	7.1	8.1	9.2	12	11.3	10.4	10.5
(M) Thoracic erector spinae, MPF (Hz)	93	94.3	88.3	88.6	82.8	83.7	84.7	84.1
(SD)	12.4	10.8	13.1	13.3	17.1	10.6	10.8	12.6
(M) Lumbar erector spinae, MPF (Hz)	115.1	116.2	107.6	104.8	100.7	103.3	97.7	99.1
(SD)	10.7	13.2	8.6	11.5	15.5	9.8	11.4	9.2

Table 30: Physiological measures the 2nd, 3rd and 4.1th sec of each 10 sec at the 1st and 5th min of walking the children on the treadmill with different load conditions [mean (SD)] for kindergarten girls of IEMG and MPF (n=23).

Variable	0 % BW		10 % BW		20 % BW		30 % BW	
	1min	5min	1min	5min	1min	5min	1min	5min
(M) Upper trapezius, IEMG (mv)	22.7	19.7	26.5	25.9	35.3	31.1	37.4	36.3
(SD)	11.2	11.9	11.2	13.2	22.4	13.2	12.5	12.6
(M) Thoracic erector spinae, IEMG (mv)	28.9	28.2	25.2	25.9	24.1	24.6	26	28.3
(SD)	7.7	9.7	9.7	8.4	9.3	8.9	12.7	12.5
(M) Lumbar erector spinae, IEMG (mv)	31.8	29.6	27.7	26.9	25	24.8	23.2	25.9
(SD)	10.6	10.4	10	9	7.6	8.3	8	8.9
(M) Upper trapezius, MPF (Hz)	75.9	74.9	75.4	76.7	77.8	79.7	84.1	85.5
(SD)	6.7	7.3	6.4	7.4	8	6.7	6.1	6.5
(M) Thoracic erector spinae, MPF (Hz)	92.3	93.4	86.9	88.6	77.9	79.7	81.9	84.3
(SD)	9.6	10.3	10.4	10.2	8	6.7	10.1	7.3
(M) Lumbar erector spinae, MPF (Hz)	115.9	117.1	105.3	106.3	100.5	93.5	95.8	95.5
(SD)	12.5	11.5	12.5	12.3	13.4	12.8	12.9	14.3

Table 31: Physiological measures the 2nd, 3rd and 4.1th sec of each 10 sec at the 1st and 5th min of walking the children on the treadmill with different load conditions [mean (SD)] for primary school boys of IEMG and MPF(n=23).

Variable	0 % BW		10 % BW		20 % BW		30 % BW	
	1min	5min	1min	5min	1min	5min	1min	5min
(M) Upper trapezius, IEMG (mv)	14.9	13.7	12.7	15.1	18.7	19.1	27.1	27
(SD)	9.9	8.1	7.8	10.1	10.9	12.5	15.3	21.1
(M) Thoracic erector spinae, IEMG (mv)	26.9	26.2	22.8	24	22.1	22.2	21.8	22.7
(SD)	10.3	11.7	8.7	9.5	9.3	8.8	7.3	10.5
(M) Lumbar erector spinae, IEMG (mv)	30.1	28.8	24.9	25.6	22.1	23.5	23	25.5
(SD)	10.1	11.3	8.6	8	7.9	6.8	7.9	8.4
(M) Upper trapezius, MPF (Hz)	78.7	78.3	76.9	77	76.2	79.8	82.6	80.6
(SD)	7.9	9.3	10.6	10.1	11.6	11.5	11.1	11.3
(M) Thoracic erector spinae, MPF (Hz)	99.6	97.5	93.8	93.4	92.7	90.9	87.9	89.5
(SD)	9.4	9.5	8.8	7.9	10.1	8.5	7.4	7.7
(M) Lumbar erector spinae, MPF (Hz)	118.5	115	111.4	110.6	103.3	104.9	101	98
(SD)	14.2	11.8	12	10.5	12	9.7	8.7	10.3

Table 32: Physiological measures the 2nd, 3rd and 4.1th sec of each 10 sec at the 1st and 5th min of walking the children on the treadmill with different load conditions [mean (SD)] for primary school girls of IEMG and MPF(n=12).

Variable	0 % BW		10 % BW		20 % BW		30 % BW	
	1min	5min	1min	5min	1min	5min	1min	5min
(M) Upper trapezius, IEMG (mv)	19.1	15.6	18.8	23.1	21.6	24.7	33.3	33.5
(SD)	13.8	7.8	13.3	20.2	14.5	14.4	20.7	19.6
(M) Thoracic erector spinae, IEMG (mv)	19.7	19.8	18	17.2	15.3	17.1	16.6	19
(SD)	4.9	6.9	5.4	5.7	5.5	5.4	5.4	4
(M) Lumbar erector spinae, IEMG (mv)	25.6	22.8	21.2	21.6	18.9	20.2	19.8	20.1
(SD)	7.3	8.5	7.7	7.8	5.8	6.8	7.7	6.3
(M) Upper trapezius, MPF (Hz)	75.7	75.2	72.4	73.8	73.2	73.7	78.8	81.3
(SD)	5.4	7.7	9	8.5	6.6	4.5	8	5.2
(M) Thoracic erector spinae, MPF (Hz)	99.4	97.7	92.2	90	87.1	86.3	81.3	83.1
(SD)	11.8	10.9	9.2	8.2	9.6	9.4	5.2	8.1
(M) Lumbar erector spinae, MPF (Hz)	115.7	111.3	108.4	104.1	99.2	95.6	93.5	94.2
(SD)	9.8	6.6	6.2	10.4	8.8	8.1	8.3	7.7

Table 33: A repeated ANOVA measurement [2 (time points)×4 (loads)] was used to compare each data set obtained in trunk muscle activity parameters at the two measuring time points under each of the four load conditions.

Variables	Effect	F	P
Upper trapezius IEMG (% MVC)	Gender	5.68	.020*
	Kinder-school	1.12	.294
	Gender*Kinder-school	0.06	.814
	Load conditions	57.32	0.000*
	Load conditions*Gender	.38	.771
	Load conditions*Kinder-school	1.37	.252
	Load conditions*Gender* Kinder-school	.57	.636
	2 (time points) the 1st and 5th min	5.18	.026*
	2 (time points)*Gender	.18	.672
	2 (time points)*Kinder-school	7.21	.009*
	2 (time points)*Gender*Kinder-school	.17	.679
	Load conditions*2 (time points)	1.22	.303
	Load conditions*2 (time points)*Gender	1.41	.240
	Load conditions*2 (time points)*Kinder-school	.66	.575
	Load conditions*2 (time points)*Kinder-school*Gender	.41	.747
Thoracic erector spine at T12 IEMG (% MVC)	Gender	.03	.868
	Kinder-school	6.43	.014*
	Gender*Kinder-school	6.04	.017*
	Load conditions	11.14	0.000*
	Load conditions*Gender	.08	.969
	Load conditions*Kinder-school	.29	.829
	Load conditions*Gender*Kinder-school	.11	.955
	2 (time points) the 1st and 5th min	.87	.356
	2 (time points)*Gender	1.26	.267
	2 (time points)*Kinder-school	2.44	.124
	2 (time points)*Gender*Kinder-school	.14	.706
	Load conditions*2 (time points)	1.74	.162
	Load conditions*2 (time points)*Gender	.14	.938
	Load conditions*2 (time points)*Kinder-school	.12	.950
	Load conditions*2 (time points)*Kinder-school*Gender	.83	.477

Variables	Effect	F	P
Lumbar erector spinae at L3 IEMG (% MVC)	Gender	1.67	.202
	Kinder-school	2.47	.123
	Gender*Kinder-school	3.43	.070
	Load conditions	15.42	0.000*
	Load conditions*Gender	1.00	.397
	Load conditions*Kinder-school	1.06	.366
	Load conditions*Gender* Kinder-school	3.20	.025*
	2 (time points) the 1st and 5th min	.45	.505
	2 (time points)*Gender	.98	.328
	2 (time points)*Kinder-school	.96	.332
	2 (time points)*Gender*Kinder-school	.01	.753
	Load conditions*2 (time points)	4.03	0.009*
	Load conditions*2 (time points)*Gender	.34	.793
	Load conditions*2 (time points)*Kinder-school	.25	.864
	Load conditions*2 (time points)*Kinder-school*Gender	.17	.914

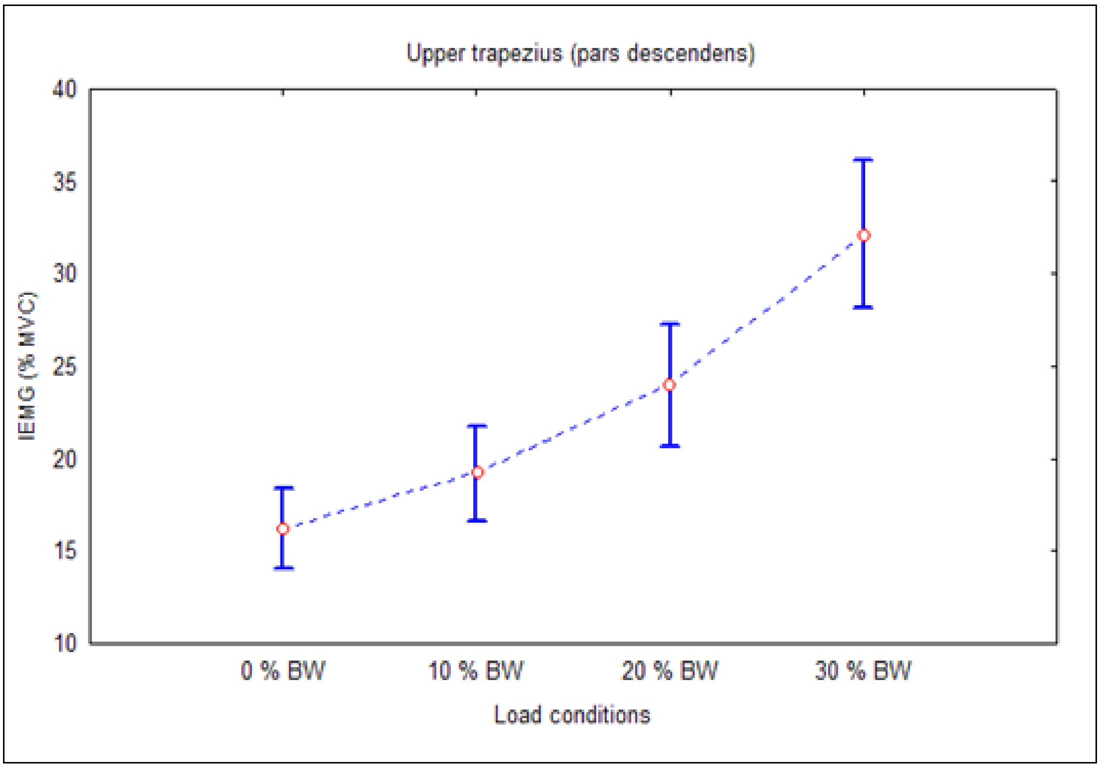


Figure 67: Changes in load conditions during 20 minutes for boys and girls in kindergarten and primary school of IEMG on the upper trapezius (Pars descendens).

As indicated in figure 67, there was a highly significant increase altogether in muscle activity at the upper trapezius ($F=57.31$, $p=0.000$, $\eta^2=0.48$). However, for comparing between different load conditions in (0 %, 10 %, 20 %, 30 % BW) the post hoc with Tukey-HSD tests has been used. The ANOVA results (Tab. 34) indicated that when children walked on the treadmill during 20 minutes, muscle activity of the upper trapezius increased with increased loading especially for 20 % and 30 % BW. In other words, with increase of the weight of backpack, consequently the muscle activity of the upper trapezius increased.

Table 34: The post hoc with Tukey-HSD test results for IEMG upper trapezius in different load conditions.

load conditions	(1) 16.1	(2) 18.8	(3) 24	(4) 31.7
0 % BW		0.123	0.000	0.000
10 % BW	0.123		0.000	0.000
20 % BW	0.000	0.000		0.000
30 % BW	0.000	0.000	0.000	

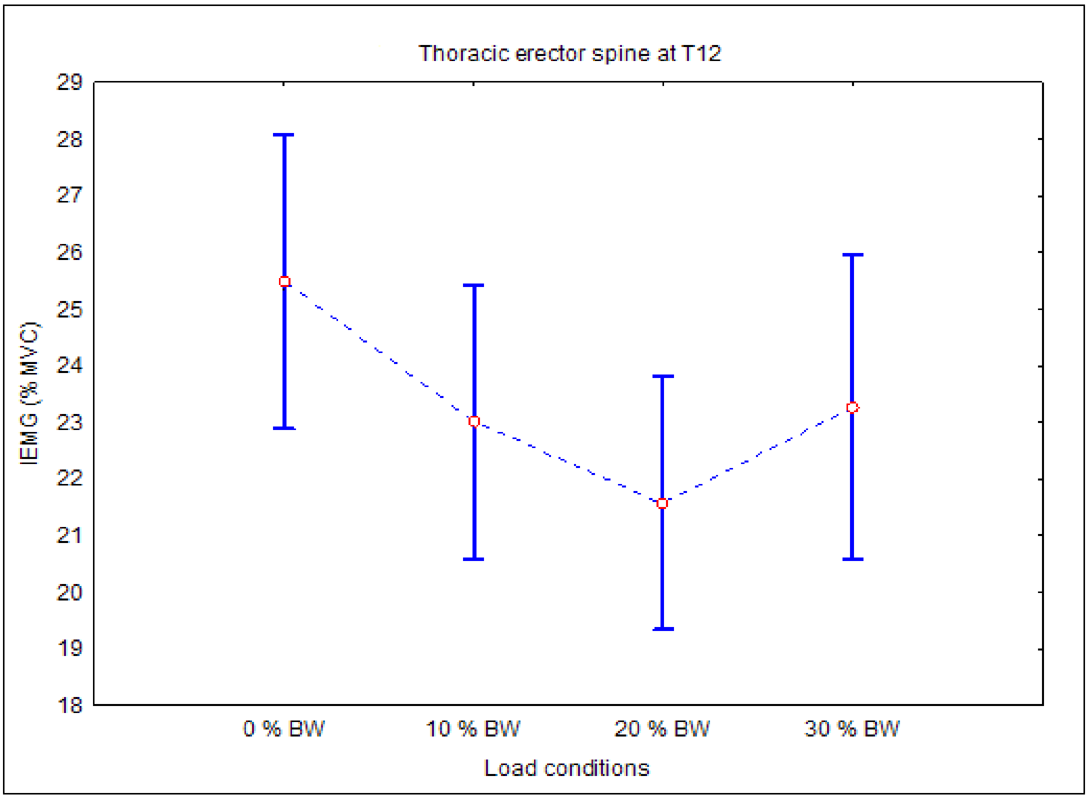


Figure 68: Changes in different load conditions during 20 minutes for boys and girls in kindergartener and primary school of IEMG on thoracic erector spine at T12.

As it can be seen in figure 68, there was a highly significant decrease altogether in mentioned groups in different load conditions of muscle activity at the thoracic erector spine at T12 ($F=11.14$, $p=0.000$, $\eta^2=0.19$). The ANOVA results (Tab. 36) showed that when the children walked during 20 minutes on the treadmill between 0 %, 10 % body weight (BW) load, the muscle activity of the thoracic erector spine at T12 decreased significantly, but it did not change significantly between 10 %, 20 % and 20 %, 30 % body weight (BW) load.

Table 35: The Post-hoc with Tukey-HSD test results for IEMG thoracic erector spine at T12 in different load conditions.

load conditions	(1) 26	(2) 23.5	(3) 21.1	(4) 23.7
0 % BW		0.000	0.000	0.001
10 % BW	0.000		0.135	0.986
20 % BW	0.000	0.135		0.060
30 % BW	0.001	0.986	0.060	

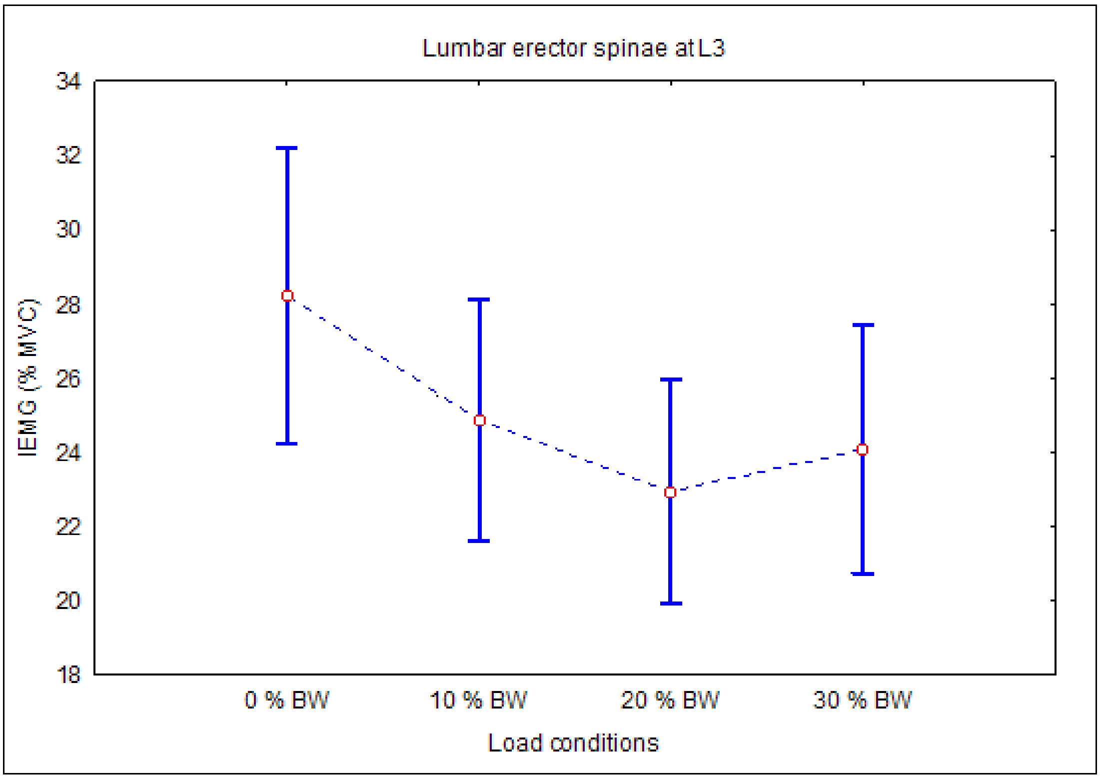


Figure 69: Changes in different load conditions during 20 minutes for boys, girls, kindergartener and primary schoolchild by means of IEMG on lumbar erector spinae at L3.

As it can be seen from figure 69, there was a significantly decrease in different load conditions of muscle activity at lumbar erector spinae at L3 ($F=15.42$, $p=0.000$, $\eta^2=0.25$). The ANOVA results (Tab. 36) indicated that in 0 %, 10 % and 10 %, 20 % body weight (BW) load the muscle activity of the lumbar erector spinae at L3 decreased significantly, but it did not change significantly in 30 % body weight (BW) load when the children were walking on the treadmill during 20 minutes. In other words, with the increase of the weight of backpack, the activity of the muscle at the lumbar erector spine at L3 between 20 %, 30 % has not changed significantly.

Table 36: The Post-hoc with Tukey- HSD test results for IEMG lumbar erector spinae at L3 in different load conditions.

load conditions	(1) 28.9	(2) 25.5	(3) 23.4	(4) 24.3
0 % BW		0.000	0.000	0.000
10 % BW	0.000		0.046	0.508
20 % BW	0.000	0.046		0.622
30 % BW	0.000	0.508	0.622	

Table 37: A repeated ANOVA measurement [2 (time points) ×4 (loads)] was used to compare each data set obtained in trunk muscle fatigue at the two measuring time points under each of the four load conditions.

Variables	Effect	F	P
Upper trapezius (MPF)	Gender	1.90	.173
	Kinder-school	4.30	.042*
	Gender*Kinder-school	.19	.666
	Load conditions	16.56	0.000*
	Load conditions*Gender	1.17	.322
	Load conditions*Kinder-school	4.13	.007*
	Load conditions*Gender*Kinder-school	.69	.556
	2 (time points) the 1st and 5th min	.31	.578
	2 (time points)*Gender	.35	.554
	2 (time points)*Kinder-school	.25	.616
	2 (time points)*Gender*Kinder-school	.21	.647
	Load conditions*2 (time points)	.95	.418
	Load conditions*2 (time points)*Gender	.53	.660
	Load conditions*2 (time points)*Kinder-school	.12	.950
	Load conditions*2 (time points)*Kinder-school*Gender	.24	.867
Thoracic erector spine at T12 (MPF)	Gender	1.74	.193
	Kinder-school	.50	.484
	Gender*Kinder-school	.63	.431
	Load conditions	68.60	0.000*
	Load conditions*Gender	3.07	.030*
	Load conditions*Kinder-school	.32	.810
	Load conditions*Gender*Kinder-school	.61	.610
	2 (time points) the 1st and 5th min	.00	.988
	2 (time points)*Gender	2.10	.153
	2 (time points)*Kinder-school	.75	.391
	2 (time points)*Gender*Kinder-school	1.35	.250
	Load conditions*2 (time points)	.67	.570
	Load conditions*2 (time points)*Gender	.16	.925
	Load conditions*2 (time points)*Kinder-school	.79	.501
	Load conditions*2 (time points)*Kinder-school*Gender	.37	. 775

Variables	Effect	F	P
Lumbar erector spinae at L3 (MPF)	Gender	2.8	.099
	Kinder-school	.0	.849
	Gender*Kinder-school	1.2	.288
	Load conditions	111.4	0.000*
	Load conditions*Gender	.8	.500
	Load conditions*Kinder-school	1.2	.315
	Load conditions*Gender*Kinder-school	.3	.800
	2 (time points) the 1st and 5th min	6.6	.013*
	2 (time points)*Gender	1.3	.262
	2 (time points)*Kinder-school	6.0	.018*
	2 (time points)*Gender*Kinder-school	.0	.869
	Load conditions*2 (time points)	.6	.607
	Load conditions*2 (time points)*Gender	2.2	.095
	Load conditions*2 (time points)*Kinder-school	.7	.568
	Load conditions*2 (time points)*Kinder-school*Gender	1.0	.409

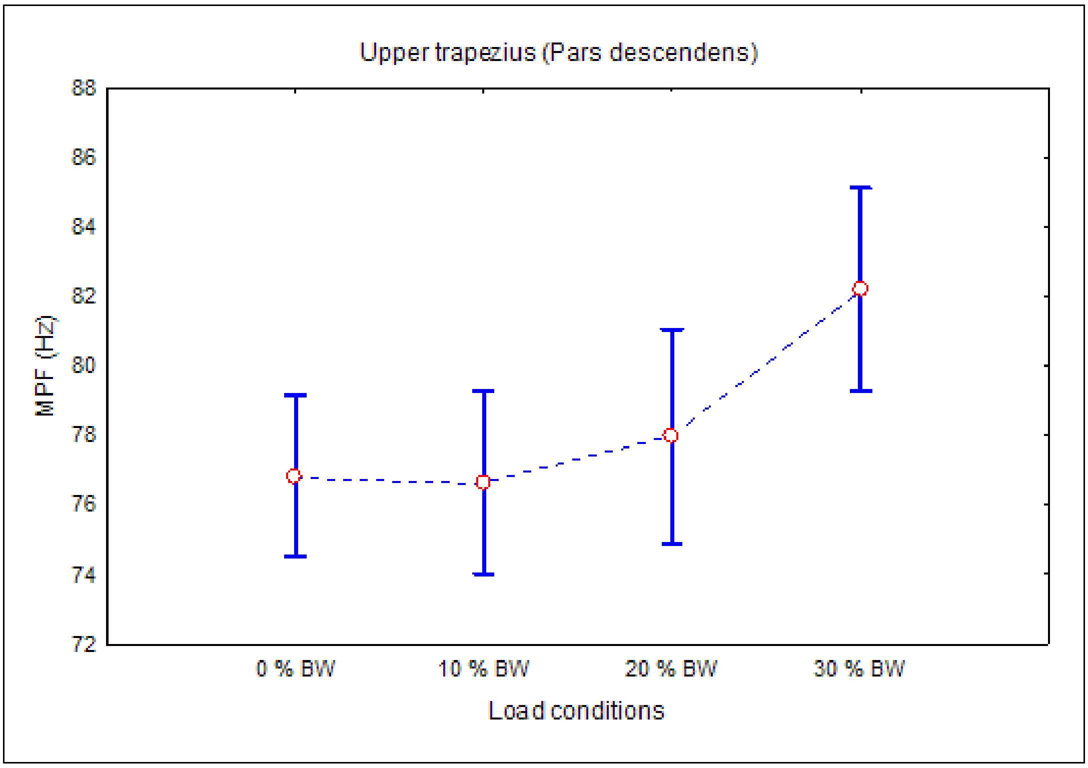


Figure 70: Changes in different load conditions during 20 minutes for boys, girls, kindergartener and primary schoolchild of MPF on the upper trapezius (Pars descendens).

As indicated in figure 70, there was a significantly high increase in median power frequency at the upper trapezius ($F=16.55$, $p=0.000$, $\eta^2=0.21$). However, for comparing the different load conditions during 20 minutes of (0 %, 10 %, 20 %, 30 % BW) the Post Hoc with Tukey-HSD tests is used. The ANOVA results (Tab. 38) indicated that between 20 %, 30 % body weight (BW) load, the median power frequency at the upper trapezius increased significantly while the children were walking on the treadmill. Moreover no difference was significant between 0 % and 10 % and between 10 %, 20 % BW.

Table 38: The Post hoc with Tukey-HSD test results for MPF upper trapezius (Pars descendens) in different load conditions.

load conditions	(1) 76.9	(2) 76.9	(3) 78.4	(4) 82.6
0 % BW		0.999	0.322	0.000
10 % BW	0.999		0.291	0.000
20 % BW	0.322	0.291		0.000
30 % BW	0.000	0.000	0.000	

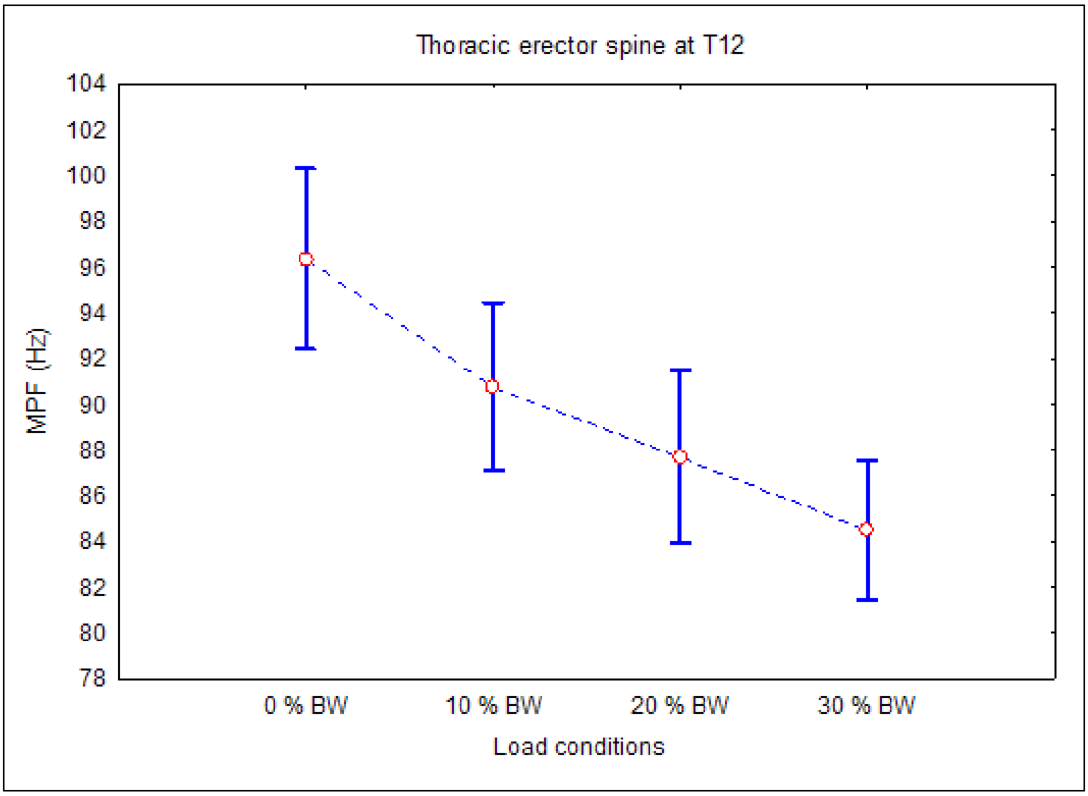


Figure 71: Changes in different load conditions during 20 minutes for boys, girls, kindergartener and primary schoolchild of MPF on the thoracic erector spine at T12.

As it can be observed in figure 71, there was a significantly high decrease in median power frequency at the thoracic erector spine at T12 ($F=68.59$, $p=0.000$, $\eta^2=0.54$). However, for comparing different load conditions during 20 minutes of (0 %, 10 %, 20 %, 30 % BW) the Post Hoc and Tukey-HSD tests were used. The ANOVA results (Tab. 39) indicated that between 0 %, 10 %, and 10 %, 20 % and 20 %, 30 % body weight (BW) load median power frequency at the thoracic erector spine at T12 significantly decreased when the children were walking on the treadmill. In other words, with the increase of the weight of backpack, the median power frequency at the thoracic erector spine at T12 significantly decreased.

Table 39: The Post hoc with Tukey-HSD test results for MPF thoracic erector spine at T12 in different load conditions.

load conditions	(1) 96.5	(2) 91.2	(3) 88.3	(4) 85.3
0 % BW		0.000	0.000	0.000
10 % BW	0.000		0.001	0.000
20 % BW	0.000	0.001		0.001
30 % BW	0.000	0.000	0.001	

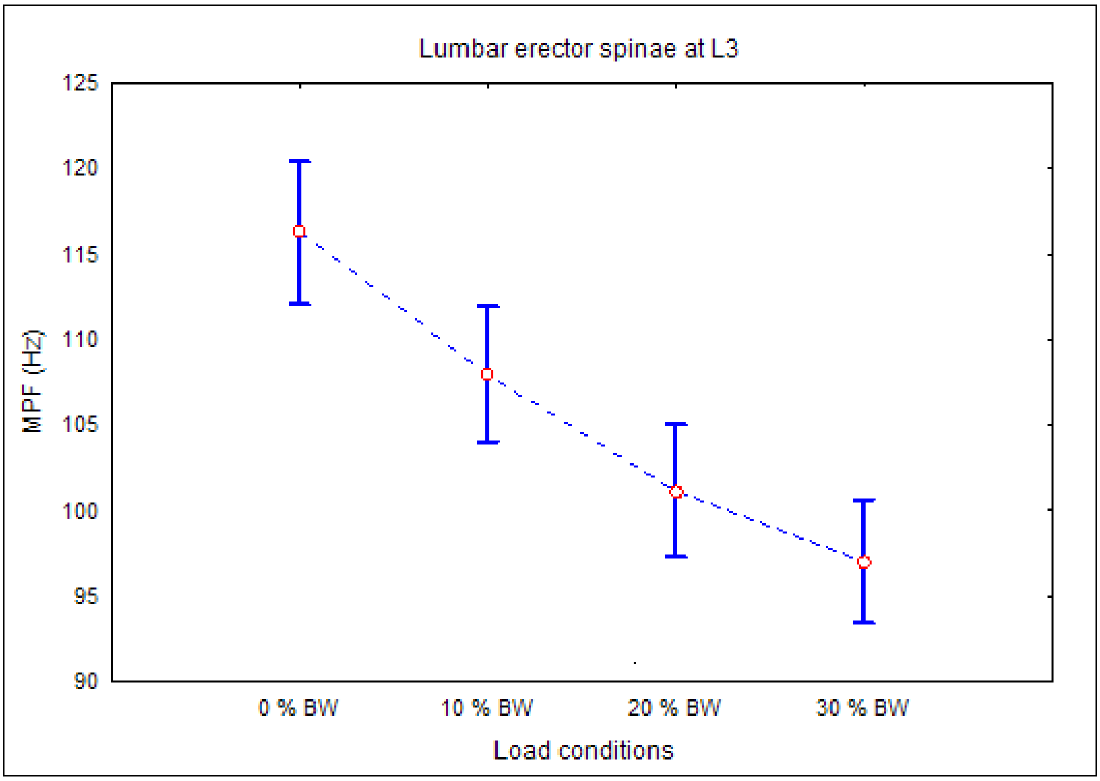


Figure 72: Changes in different load conditions during 20 minutes for boys, girls, kindergartener and primary schoolchildren of MPF on the lumbar erector spinae at L3.

As it can be observed in figure 72, there was a significantly high decrease for above groups in median power frequency at the lumbar erector spinae at L3 ($F=111.45$, $p=0.000$, $\eta^2=0.69$). However, for comparing different load conditions during 20 minutes of (0 %, 10 %, 20 %, 30 % BW) the Post Hoc with Tukey-HSD Tests were used. The ANOVA results (Tab. 40) indicated that between 0 %, 10 %, and 10 %, 20 % and 20 %, 30 % the body weight (BW) load median power frequency at the lumbar erector spinae at L3 significantly decreased when the children were walking on the treadmill. In other words, with the increase of the weight of backpack, median power frequency at the lumbar erector spinae at L3 significantly decreased.

Table 40: The Post hoc with Tukey-HSD test results for MPF the lumbar erector spinae at L3 in different load conditions.

load conditions	(1) 116.5	(2) 108.5	(3) 101.9	(4) 97.5
0 % BW		0.000	0.000	0.000
10 % BW	0.000		0.000	0.000
20 % BW	0.000	0.000		0.000
30 % BW	0.000	0.000	0.000	

A Spearman correlation analysis was performed in muscle activity and median power frequency at the upper trapezius on the load conditions. Correlations are significant at the p<0.01.

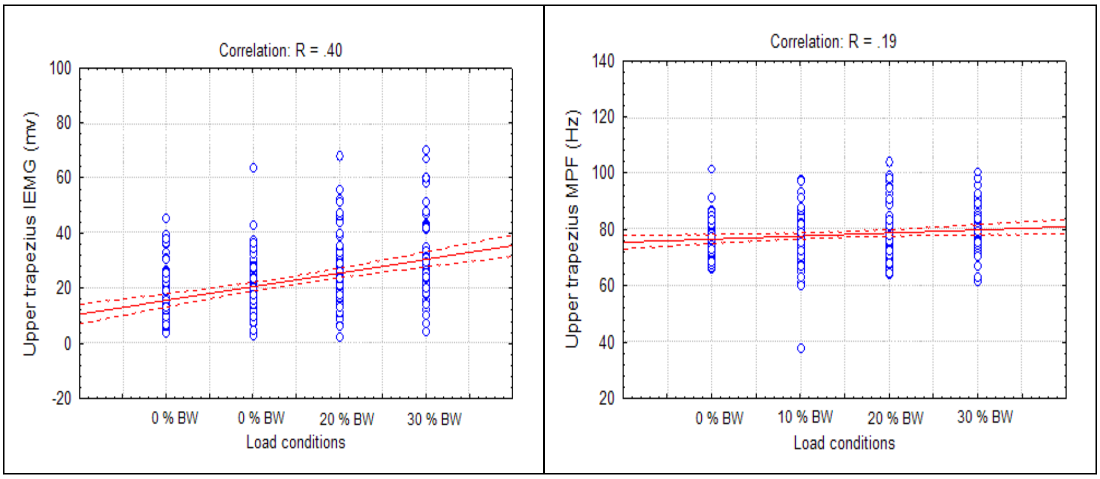


Figure 73: The correlation between the muscle activity and median power frequency on the load conditions.

The same analysis indicated that Spearman correlation nonparametric between load conditions and the muscle activity at the upper trapezius and between the median power frequency at the upper trapezius and the load conditions were (0.40) and (0.19) respectively, with a significant difference at the 0.01 level. Consequently a significant positive correlation relationship existed between them.

Table 41: Correlation is significant at the 0.01 level for both the muscle activity and the median power frequency at the upper trapezius.

Variable	Spearman Correlation	Sig. (2-tailed)	N
Between load condition and the muscle activity at the upper trapezius	0.40*	.000	298
Between load condition the median power frequency at the upper trapezius	0.19*	.000	298

As mentioned previously a Spearman correlation analysis was done in muscle activity and median power frequency at the thoracic erector spine at T12 on the load conditions. Correlations are significant at the p<0.01.

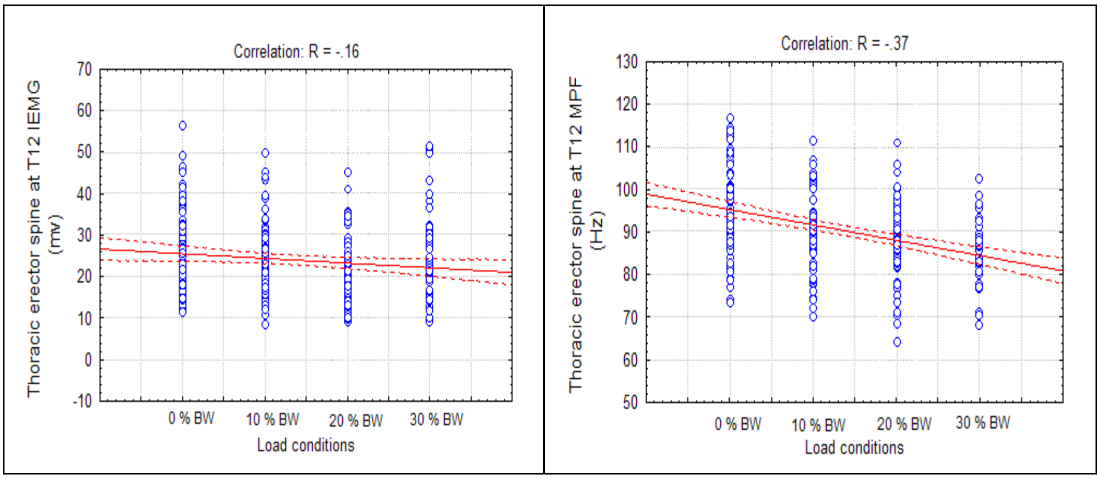


Figure 74: The correlation between the muscle activity and median power frequency on the load conditions.

As correlation analysis revealed, the Spearman correlation nonparametric between load conditions and the muscle activity at the thoracic erector spine at T12, and between the median power frequency at the thoracic erector spine at T12 and the load conditions, were (-0.16) and (-0.37) respectively, with a significant difference at the 0.01 level. As a result a significant negative correlation relationship existed between them.

Table 42: Correlation is significant at the 0.01 level for the muscle activity and the median power frequency at the thoracic erector spine at T12.

Variable	Spearman Correlation	Sig. (2-tailed)	N
Between load condition and the muscle activity at the thoracic erector spine at T12	-0.16*	.000	287
Between load condition the median power frequency at the thoracic erector spine at T12	-0.37*	.000	281

The analysis of muscle activity and median power frequency at the lumbar erector spinae at L3 on the load conditions was presented according to Spearman correlation analysis. Correlations are significant at the p<0.01.

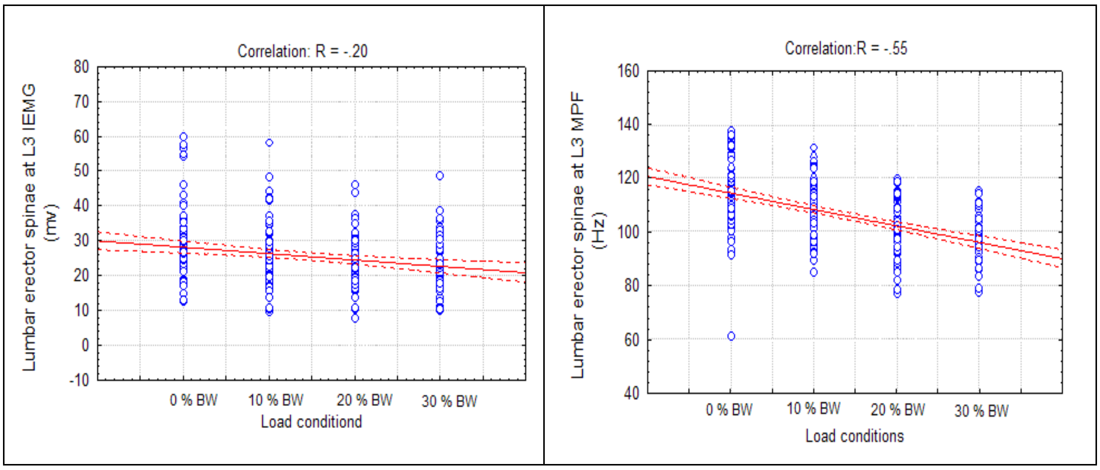


Figure 75: The correlation of the muscle activity and median power frequency at the lumbar erector spinae at L3 on the load conditions.

According to the correlation analysis, the Spearman correlation nonparametric between load conditions and the muscle activity at the lumbar erector spinae at L3, and between the median power frequency at the lumbar erector spinae at L3 and the load conditions, were (-0.20) and (-0.55), correspondingly. The present study showed a significant negative correlation between the muscle activity at the lumbar erector spinae at L3 and the load conditions, between the median power frequency at the lumbar erector spinae at L3 and the load conditions negative.

Table 43: Correlation is significant at the 0.01 level for the muscle activity and the median power frequency at the lumbar erector spinae at L3.

Variable	Spearman Correlation	Sig. (2-tailed)	N
Between load condition and the muscle activity at the lumbar erector spinae at L3	-0.20*	.000	268
Between load condition the median power frequency at the lumbar erector spinae at L3	-0.55*	.000	269

4.4 Differences between kindergartener and primary schoolchildren

Difference between kindergartener and primary schoolchildren in kinematic body posture and electromyographic parameters

In kinematic body posture, there was a significant difference between kindergartener and primary schoolchild in distance from the floor to the earlobe joint. It did not differ significantly between kindergartener and primary schoolchild in trunk inclination angle, the trunk motion range and step length in different load conditions (Tab. 18).

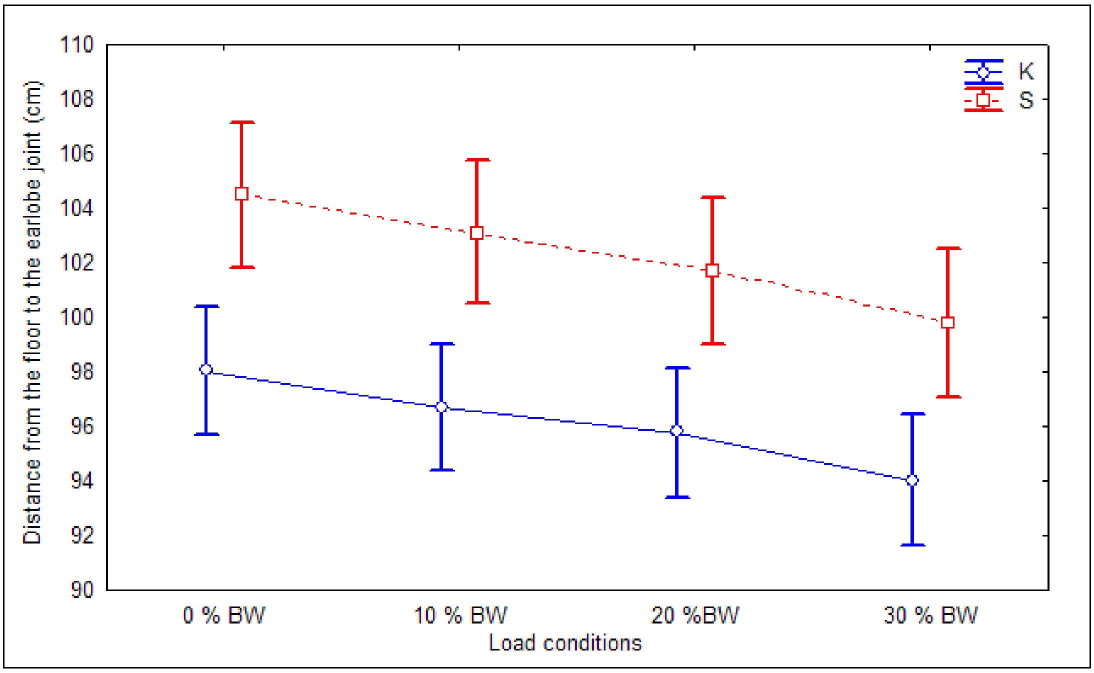


Figure 76: Changes in different load conditions with backpack during 20 minutes for kindergartener (K) and primary schoolchild (S) in distance from the floor to the earlobe joint.

As it can be observed in figure 76, there was a significant decrease altogether for both kindergarteners and primary schoolchildren in distance from the floor to the earlobe joint ($F=2.83$, $p=0.039$, $\eta^2=0.04$). The results of the Tukey-HSD tests for kindergartener child and primary schoolchild (Tab. 44) have been utilized. It indicated that between 0 %, 10 %, and 10 %, 20 % and 20 %, 30 % body weight (BW) significantly decreased in distance from the floor to the earlobe joint in kindergartener; it also indicated the same results for the primary schoolchild. In other words, with the increase of the backpack weight of both kindergartener child and primary schoolchild, the distance from the floor to the earlobe joint decreased.

Table 44: The Post-hoc with Tukey-HSD test results for distance from the floor to the earlobe joint in load conditions of kindergartener (K) child and primary schoolchild (S).

K-S	Load conditions	(k) 97.9	(k) 96.6	(k) 95.7	(k) 93.9	(s) 104.3	(s) 102.8	(s) 101.5	(s) 99.5
k	0 % BW		0.000	0.000	0.000	0.165	0.003	0.858	0.886
k	10 % BW	0.000		0.000	0.000	0.000	0.192	0.004	0.263
k	20 % BW	0.000	0.000		0.000	0.000	0.000	0.258	0.045
k	30 % BW	0.000	0.000	0.000		0.000	0.000	0.000	0.304
s	0 % BW	0.165	0.000	0.000	0.000		0.000	0.000	0.000
s	10 % BW	0.003	0.192	0.000	0.000	0.000		0.000	0.000
s	20 % BW	0.85	0.004	0.258	0.000	0.000	0.000		0.000
s	30 % BW	.886	0.263	0.045	0.304	0.000	0.000	0.000	

In electromyographic parameters (IEMG and MPF), there was a significant difference between kindergartener and primary schoolchild in IEMG and it did not differ significantly of the upper trapezius, thoracic erector spinae at T12 and the erector spinae at L3 in load conditions (Tab. 33).

Moreover there was a significant difference between kindergartener and primary schoolchild in MPF of the upper trapezius, and it did not differ significantly in MPF of the thoracic erector spinae at T12, the erector spinae at L3 in load conditions (Tab. 37).

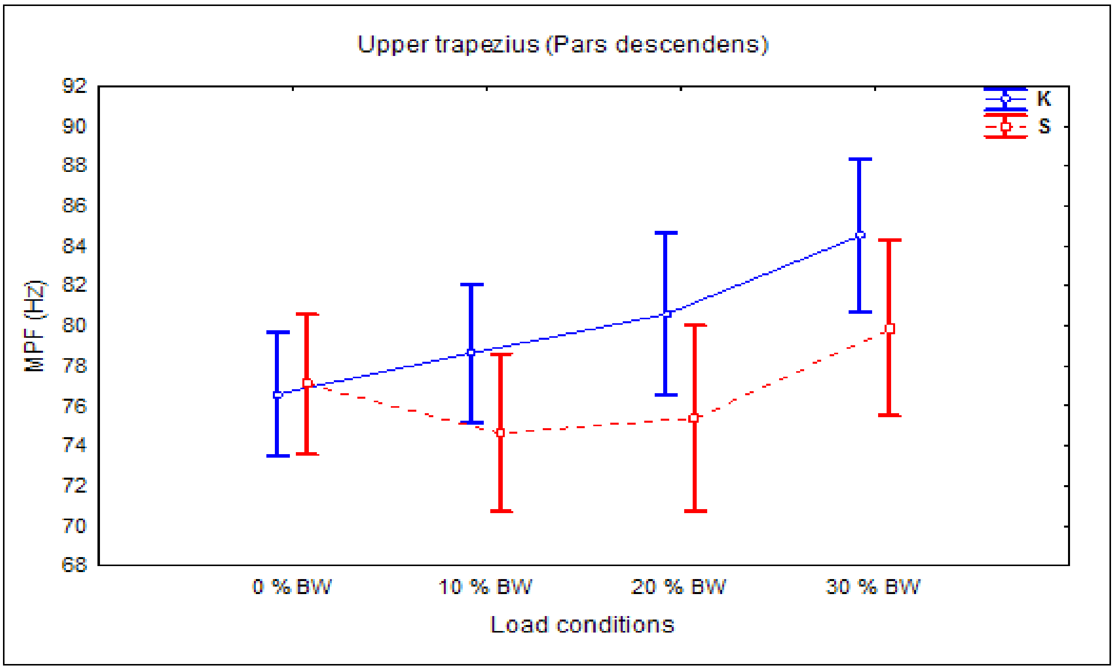


Figure 77: Changes in different load conditions during 20 minutes kindergartener (K) and primary schoolchild (S) of MPF on the upper trapezius (Pars descendens).

As it can be observed in figure 77, there was a significantly low increase for kindergarteners and primary schoolchildren in median power frequency at the upper trapezius ($F=195.55$, $p=0.007$, $\eta^2=0.06$). The Tukey-HSD tests results (Tab. 45) indicated that in different load conditions between 20 % and 30 %, body weight (BW) the median power frequency at the upper trapezius in kindergarteners significantly increased, and also between 20 % and 30 % body weight the median power frequency at the upper trapezius for primary schoolchildren significantly increased at the upper trapezius.

Table 45: The Post-hoc with Tukey-HSD test results for kindergartener and primary schoolchildren in median power frequency at the upper trapezius in different load conditions.

K-S	load conditions	(k) 76.5	(k) 78.4	(k) 80.4	(k) 84.6	(s) 77.4	(s) 75.1	(s) 76.1	(s) 80.3
k	0 % BW		0.999	0.019	0.000	1.000	0.819	0.999	0.693
k	10 % BW	0.999		0.692	0.000	0.999	0.971	0.996	0.824
k	20 % BW	0.019	0.692		0.010	0.277	0.091	0.713	0.998
K	30 % BW	0.000	0.000	0.010		0.003	0.000	0.000	0.870
s	0 % BW	1.000	0.999	0.091	0.003		0.339	0.997	0.303
s	10 % BW	0.819	0.971	0.005	0.000	0.339		0.785	0.018
s	20 % BW	0.999	0.996	0.713	0.000	0.997	0.785		0.018
s	30 % BW	0.693	0.824	0.998	0.870	0.133	0.001	0.018	

4.5 The relationship between body posture and EMG analysis

Further investigation into the relationship between body position and the parameters of EMG during the dynamic task was also conducted. Statistics reflect the results of the repeated measures on the 76 subjects. A Pearson correlation analysis was performed in the body posture and the parameters of EMG on the different load conditions. Correlations are significant at p<0.01.

The study found that according to the correlation analysis, the Pearson correlation coefficients between different trunk inclination angle (1-4) and different erector spinae at L3 (IEMG 1-4) was (-0.30) significantly negative.

The same analysis indicated that between different step length (1-4) and different upper trapezius (IEMG 1-4), different thoracic erector (IEMG 1-4), different erector spinae at L3 (IEMG 1-4),were (0.29), (0.32) and (0.33), correspondingly. The present study showed a significant positive correlation relationship existed between them.

Table 46: Correlation is significant at the 0.01 level for the body posture and EMG (IEMG, MPF).

	Difference upper trapezius (IEMG) 1-4	Difference thoracic erector (IEMG) 1-4	Difference erector spinae at L3 (IEMG) 1-4	Difference upper trapezius (MPF) 1-4	Difference thoracic erector (MPF) 1-4	Difference erector spinae at L3 (MPF) 1-4
Difference trunk inclination angle 1-4	0.143	-0.226	-0.298	0.009	-0.079	-0.039
Sig. (2-tailed)	0 .241 N=75	0.068 N=72	0.015 N=71	0.948 N=62	0.544 N=63	0.733 N=59
Difference step length 1-4	0.294	0.321	0.335	0.120	0.093	0.084
Sig. (2-tailed)	0.015 N=75	0.008 N=72	0.006 N=71	0.384 N=62	0.489 N=63	0.541 N=59
Difference distance from the floor to the earlobe joint 1-4	-0.203	-0.074	0.127	0.249	0.085	-0.065
Sig. (2-tailed)	0 .095 N=75	0.554 N=72	0.310 N=71	0.053 N=62	0.514 N=63	0.629 N=59
Difference trunk motion range 1-4	0.013	-0.126	0.062	0.029	-0.061	0.182
Sig. (2-tailed)	0 .924 N=75	0.359 N=72	0.646 N=71	0.840 N=62	0.668 N=63	0.211 N=59

5 Discussion and Conclusions

The present study evaluated recommendations for backpack weights. The study set out to measures the strain children receive from carrying heavy loads for after an extended period of time. In this investigation, combinations of physiological and biomechanical variables have been used. Although the previous reported studies' main focuses were on a selection of either physiological or biomechanical parameters, this study is unique because of its combination of data collection on all these parameters kinematic body posture and EMG activity.

5.1 Questionnaire responses

Questionnaire responses regarding the distance from the child's house to his/her school or kindergarten and back, transportation, carrying behavior, complaints about back pain, and daily physical activities in kindergarten/school.

Seventy-six parents of kindergarten and grade school children completed the questionnaire. The questionnaire itself can be categorized into four sections. The first section is regarding the distance children walked from their house to kindergarten/school and the method of transportation (by foot, bike, car, bus, etc) they used. The results showed that about 27.63 % of the children walked less than 1 km from their house door to kindergarten/school, 28.95 % walked approximately 1 km, and 43.42 % of the children walked more than 1 km. The findings of this study are similar to those of Dordel et al. (2007), in which it was reported that 48.4 % walked less than 1 km, 29.2 % walked approximately 1 km and 22.4 % walked more than 1 km.

The study by Dordel et al. also showed that in 6 year olds, 72 % walked, 11.5 % took the car and 1.3 % rode the bike while in 7 year olds, 75.6 % walked, 7.5 % took the car and 0.5 % rode the bike. In ages of 15±2 years, a total of 747 (59 %) students went to school on foot, 501 (40 %) were transported by bus or car, and 15 (1 %) by bicycle in a study by Korovessis et al. (2005). The results of our transportation question was that the majority of the children (55.26 %) walked, around 1.32 % rode by bike, nearly 9.21 % went by bus and remaining 34.21 % went by car.

The second sets of questions were related to backpack carrying behaviors including: carrying time (the whole way, part of the way) and backpack weight. Out of 35 students in our study, 31 (88.6 %) were carrying their backpacks by themselves, one student's backpack (2.9 %) was carried by others and 3 students (8.6 %) did not answer. The weights of the backpacks in our study were high, with an average of 4.1 kg, a minimum weight of 1.7 kg and a maximum weight of 6.2 kg.

The result of this study revealed the mean weight of the backpack carried by children to be 4.1 kg, which is 16.7 % of their body weight. Some of the children were carrying a minimum 10.2 % of their body weight. Other children carried a maximum 26.6 % of body weight, making the average backpacks weigh around 16.7 % of their body weight. Some studies suggest that children should carry no more than 10 % of their body weight (Guyer, 2001; Iyer, 2001) as excessive weight in a schoolbag can lead to health problems in children (Hong et al., 2000b; Staff, 1999; Grimmer & Williams, 2000). The results of the present study suggest that the backpacks maybe a causative factor. When a person carries a backpack there is a counter rotation of the pelvis and thorax (Lai & Jones, 2001). However, this counter rotation is decreased if the weight in the backpack is greatly increased. It can be estimated that the participants in our study were carrying an extra weight of nearly 4 to 6 % of their body weight.

The third set of questions was related to complaints regarding back pain: existence of pain, if yes the location and level of pain, improvements when removing the backpack and any additional complaints. These were only asked of grade school children.

Our results show that nearly 15.6 % of children said that their backpacks were “rather very light” and 25 % answered “light”. 40.6 % answered “average”, 12.5 % answered “heavy” and 6.3 % complained that the backpacks were “rather very heavy”.

Regarding fleeting back-pain, while carrying backpacks: nearly 28.6 % said that there was pain, while 71.4 % said that there was none.

The location of pain in the lumbar spine was determined by the students as either being in the shoulder spine, the thoracic spine or the lumbar spine. 10 subjects were questioned and 40 % felt pain in thoracic spine T (L, R), 50 % felt it in the shoulder spine C (L, R) and 10 % in lumbar spine L (L, R). Back pain rampancy with schoolchildren alters from country to country and assortment in the literature from 20 % to 51 % (Viry et al., 1999; Balague et al., 1995; Braitberg, 1994). According to this research, back pain in an adolescent plays an important role in possible back pain in adult life, examination and prevention of low back pain in adolescents and children is of great value.

Our report of both back pain and heavy backpacks approximately concur with those reported by Negrini and Carabalona (2002) who reported that the children’s backpacks were heavy (79 %) and caused back pain (46.1 %). In fact, Troussier et al. (1994) found that school children reported the least amount of back pain when carrying loads in backpacks (45 % pain) compared with carrying loads by hand (69 % pain) or over the shoulder (54 % pain). Numerous features could have interacted to cause pain for the school children. These factors could include the kind of schoolbag, the manner of carriage, the weight, the anthropometrical characteristics, and the age of the subjects (Linton, 2000; Niemi et al., 1997).

The fourth types of questions were associated with daily physical activities in school and asked whether he/she plays in the outdoors during the week, is he/she member in a sport club, what kind of sports he/she plays and how often? The majority (65.7 %) of children answered that they were active 7 days a week and only 1.3 % of children answered that they were active just 2 days in the week. Regarding to the daily outdoor activity, the majorities (82.9 %) of answers were positive and only 1.3 % of children answered that they almost never walk. Finally, nearly 48.7 % of children were members of one sport club, and 36.8 % of children were members of several, 6.6 % used to be the members of a sport club and 5.3 percent of them have never been a member.

According to the literature, schoolchildren included in competitive activities perform to report more LBP associated with those who contributed in sport activities on a regular basis (Kujala et al., 1999; Harreby et al., 1999). Watson et al. (2003) reported that LBP is compared with duration of exercise more than 4 hours in a week. In present study, 65.7 % of children had spent at least 1 hour a day for sport activities in a variety of types.

5.2 The kinematic body posture parameters

The kinematic body posture parameters including the trunk inclination angle, trunk motion range, distance from the floor to the earlobe joint and step length.

The changes of kinematic body posture in children who carrying backpacks have been reported by several studies. According to Grimmer et al. (2002) increased trunk flexion with increasing load has been identified as adaptation to bring the centre of gravity of the body and backpack further forward to maintain balance.

Hypotheses 1: The trunk inclination angle increases significantly while children walk on a treadmill with 10, 20 and 30 % of the body weight in a backpack as compared to the children who walk without a backpack.

Accordingly, the results of (Fig. 60) the trunk inclination angle significantly increased with the loads of 30 , 20 and 10 % of body weight when compared to the 0 % body weight load conditions ($p<0.001$). We also found significant changes between the trunk inclination angle of the 30 % and 20 % load conditions ($p<0.001$), and between the 20 % and 10 % load conditions, and between the 10 % and 0 % load conditions ($p<0.001$). Our results have shown that with each load on the trunk inclination angle, during the 1st and 5th min, significant differences occurred. Furthermore; the present study revealed that the correlation between load conditions and trunk inclination angle was significantly positive (0.709).

The findings of the trunk inclination angle of this research are consistent with previous studies (Malhotra & Sen Gupta, 1965; Li & et al., 2003; Rohlmannt et al., 2001; Goodgold et al., 2002a; Hong & Cheung, 2003; Hong & Brueggemann, 2000; Fiolkowski et al., 2006; Al-Khabbaz et al., 2008; Rahman et al., 2009). Malhotra and Sen Gupta (1965) which compared the trunk inclination angle using visual examination of six school boys (aged 9 to 15 years) wearing book bags weighing 2.6 kg (10-12 % of each subject's body weight) with different methods. They found that this level of load did not produce considerable trunk inclination angle. Li and Hong (2003) investigated the impact on children's trunk position and breathing pattern when carrying different weight of backpacks while walking on a treadmill for 20 min. The results showed that the 20 % load condition induced a significant increase in the trunk inclination angle, decreased trunk motion range and increased the respiratory frequency. In addition, another study has also proposed that carrying a backpack weighing 15 % of body weight had been showed to be too heavy and damaging for the youth (Chansirinukor et al., 2001).

Goodgold et al. (2002a) investigated the combined influences of increasing schoolbag load and task demand on trunk inclination angle on two boys, aged 11 and 9 years old. Their results observed that although trunk forward leans usually increased with the increases in backpack load and task demand, trunk inclination angle was not dependent.

Recently, Hong and Cheung (2003) also found that prolonged postural strain caused by the inclination angle of the trunk could top to lower back problem and muscular-skeletal disorder. Hong and Brueggemann (2000) examined the load carriage of schoolchildren during treadmill walking and showed that when the load increased from 10 % to 15 % body mass, significant trunk inclination angle was observed. Fiolkowski et al. (2006) found that there was less hip flexion and forward head positions when the backpack was carried interiorly and concluded that carrying a front pack resulted in a more upright posture during walking when compared with solely carrying a backpack with the same load. Moreover, another study on the effect of carrying backpacks on trunk posture was reported by Rahman et al. (2009) that carrying weighty load of 15 % and 20 % of body weight, during level walking induced a significant increase in trunk forward lean for children aged 6 years old. No significant difference in trunk forward lean was observed between 0 % and 10 % of body weight load condition.

In addition, Hong and Cheung (2003) reported that the trunk inclination can be explained by the motor control theory. One of the main functions of motor control is to orient the body with respect to the external world, which involves maintaining posture to minimize the disturbance of balance, thus stabilizing the whole body's center of gravity. When loaded with a backpack, the individual will attempt to change the center of gravity of the body-backpack system back to that of an unloaded condition. This can be attained by forward inclination (Bloom et al., 1987), and such regulation helps the body to reduce the energy expenses and increase the efficiency of walking with weight.

In the present investigation, the relative load of their backpack to the subject's body weight may have been adequate to cause a change in the body posture. Angle inclination of the trunk changed when an additional load is added to the back, which is a postural alteration, to gain body balance. Through the alternation of trunk posture, body balance was maintained. However this alternation was escorted by a higher demand placed on the trunk muscles.

The present and previous of the trunk inclination angle is quite dependable, progressively increasing as the load of the backpack increases. The further stress placed on the arrangement of the vertebral column due to the combination of load and trunk inclination angle products in an increased intradiscal pressure on the spine. The results of studies have indicated that intradiscal pressure increases as the forward bending degree of the trunk increases (Rohlmann et al., 2001).

The present study revealed that walking with a load of 30 % body weight resulted in a trunk inclination angle in primary schoolchildren for both boys and girls of 8.72° and 8.36° and kindergarten boys and girls of 8.59°and 8.39° respectively in the 1st min of walking and of kindergarten boys and girls of 9.63° and 10.97° and kindergarten boys and girls of 8.26°and 9.97° respectively in the 5th min. The results also observed that a load of 20 % body weight resulted in a trunk inclination angle of schoolchildren (boys and girls) of 5.84° and 4.4° and kindergarteners (boys and girls) of 4.38°and 5.68° respectively in the 1st min of walking and of schoolchildren (boys and girls) of 6.5° and 6.82° and kindergartener (boys and girls) of 5.66°and 6.06° respectively in the 5th min. The data reported in this examination confirm our hypothesis that with the increase of the weight of backpacks the trunk inclination angle increased linearly.

Hypotheses 2: There is a significant decrease in the trunk motion range while children walk on a treadmill with 10, 20 and 30 % of body weight in a backpack, which will not be present when walking without a backpack.

The present results indicate (Fig. 61) that the trunk motion range experienced a highly significant decrease for all load conditions ($p<0.001$). There are no significant differences between 10 %, 20 % and 20 %, 30 % of body weight (BW) on the trunk motion range. The results in addition have illustrated that with each load on trunk motion range, at the 1st and 5th min, no significant differences have been found. It can be found that the negative correlation between load conditions and trunk motion range, and between trunk inclination angle and trunk motion range, were (-0.301) and (-0.248) respectively. The minimal trunk motion range was related to the load conditions of 20 % BW was 2.82° and 3.51° for the schoolchildren (boys and girls), and for kindergarteners (boys and girls) it was 3.02°and 2.49° respectively. At 30 % BW for schoolchildren (boys and girls) it was 2.40° and 2.52° and for kindergartener (boys and girls) it was 2.49°and 2.493° respectively after 5 min walking. There are few studies about the effect of carrying loads on the trunk inclination angle in either adults or children. The increased load on the back would produce an extra pelvic instant and therefore contraction of the abdominal muscles would increase. In addition, a significant increase in the anterior-posterior swing of the trunk while carrying higher weights would force the abdominal, back and leg muscles to work quickly in order to keep dynamic balance. The decrease in trunk motion range shows that while walking with a weighty load product, the abdominal, back and leg muscles stiffen during greater contraction (Cook & Neumann, 1987; Hong & Brueggemann, 2000).

Consequently the hypothesis has been confirmed according to the reported data that with the increase of the load weight, the trunk motion range, progressively decreased.

Hypotheses 3: There is a significant decrease in the distance from the floor to the earlobe joint (height) when children walk on the treadmill while carrying a backpack with 10, 20 and 30 % of body weight which will not occur when walking without a backpack.

In harmony with (Fig. 59), in all different groups a highly significantly decrease in distance from the floor to the earlobe joint has been found. Our study concurs that with the increase of the backpack weight, the distance from the floor to the earlobe joint between 0 %, 10 % and 10 %, 20 % and 20 %, 30 % body weight (BW) has been significantly decreased. Additionally for each load, the distance from the floor to the earlobe joint at the 1st and 5th min significant differed. Besides, the results showed that for both kindergartener and primary schoolchildren the distance from the floor to the earlobe joint significantly increased, and there was a significantly negative correlation present between the load conditions and distance from the floor to the earlobe joint or height (-0.25).

The results of the study showed that walking with a load of 30 % body weight resulted in the distance from the floor to the earlobe joint (height) for schoolchildren to decrease for (boys and girls) -4.28 cm and -4.23 cm and for kindergarteners (boys and girls) for -4.2 cm and -3.43 cm respectively in the 1st min of walking. For schoolchildren (boys and girls) it reduced by -5.12 cm and -4.97 cm and for kindergarteners (boys and girls) by -4.67cm and -3.88cm respectively in the 5th min. It was as well demonstrated that with a load condition of 20 % body weight, the distance from the floor to the earlobe joint for schoolchildren (boys and girls) reduced by -2.44 cm and -2.12 cm and for kindergarteners (boys and girls) it reduced by -2.35 cm and -2.59 cm respectively in the 1st min of walking. For schoolchildren (boys and girls) it reduces by -2.95 cm and -3.42 cm and for kindergarteners (boys and girls) reduced by -2.57 cm and -1.93cm respectively in the 5th min.

The third hypothesis suggests that with the increase of the weight of the backpacks, the distance from the floor to the earlobe joint (height) significantly decreases linearly. A similar study of the distance from the floor to the earlobe joints in different load conditions when walking on the treadmill cannot be found in the previous research.

Hypotheses 4: With the increase of the weight of backpacks the step length significantly increase while children walk on a treadmill with a 10, 20 and 30 % load of body weight, when compared to walking without a backpack.

Our results also confirm (Fig. 58) that with the increase of the weight of the backpack (about 10 % and 20 % body weight (BW)) the step length increased significantly. However, there were no significant changes in step length between 20 % and 30 % BW. In opposition to this hypothesis, the step length decreased when under loading conditions of around 30 % body weight. The current study only examines the step length at the 1st and 5th min, so that significant differences were found between the measurements.

Similarly the correlation between load conditions and step length, and between distance from the floor to the earlobe joint and step length, were positive (0.22) and (0.432) respectively.

In a different investigation, Connolly et al. (2008) showed that the stride length reduced for either the right or the left leg when a backpack was put over either shoulder when compared with the foundation walk. On the other hand, the stride length increased for both legs when the backpack was put over both shoulders when compared with the foundation walk. Contrastingly, Chow et al. (2005) found that the increase in backpack load resulted in a significant decreases in step length, cadence, walking speed and single time. There were also significant increases in the double support time and stride time with increasing backpack load. However, no significant changes in step time or stride length were noted with increasing backpack load.

5.3 Electromyographic parameters

Electromyographic responses to back muscles including muscle activity (IEMG), median power frequency (MPF) from the Upper Trapeziu (Pars descendens), Thoracic Erector Spine at T12 and Lumbar Erector spinae at L3.

The purpose of this study was to characterise trunk muscle activity and have muscle fatigue for the control condition, comparing not carrying a backpack with carrying a backpack.

Hypotheses 5: There is a significant difference in muscle activity and fatigue muscle of the upper trapezius, thoracic erector spinae T12 and lumber erector spinae L3 muscle while children walk on treadmill without a backpack and with a backpack including 10, 20 and 30 % of body weight.

For the upper trapezius muscle, the results showed that the muscle activity of the UT increased significantly while carrying the backpack ($p \leq 0.001$). Our results have shown that the muscle activity of the upper trapezius increased when there of an increase of load especially between 10, 20 and 20 %, 30 % BW though the muscle activity did not differ significantly between 0 % and 10 % BW. It is crucial to note that the median power frequency at the upper trapezius increased in the 20 % and 30 % body weight (BW). Because the median power frequency increased at 20 % and 30 % body weight, we can conclude that this shows that there was no muscle fatigue in the upper body.

Previous researches in this field including Bobet and Norman (1984) who examined the EMG of the trapezius and erector spinae muscles. It indicated that the metabolic determines alone would not be sufficient to address the biomechanics' reply, and consequently several studies on trunk posture emerged. Cook and Neumann (1987) also reported that the muscle activity reduced in the lumber paraspinals muscles when a load was carried in the backpack posture as associated with a weight anterior to the chest carried by the arms. In addition, Hong and Cheung (2002) found out that the carrying load conditions significantly influenced the degree of fatigue and muscular activity in the upper trapezius. The upper trapezius is well illustrious to be the stabilizer of the shoulder, neck and head in order to limit their movement. Stabilizing the shoulder and keeping a comparatively straight head posture is important. Recently, Hong and Li (2008) also showed that in the 20-min of prolonged walking on a treadmill, the upper trapezius increase of muscle activity was not found. Though, muscle fatigue was found in 10 min.

In fact, in the present study there is a positive correlation between load conditions and EMG activity of upper trapezius and between load and median power frequency of upper trapezius, being (0.40) and (0.19) correspondingly. On the other hand at the 1st and 5th min, the EMG activity of upper trapezius was significant, but for median power frequency was not significant.

The findings of this study demonstrated that the EMG activity of the thoracic erector spine at T12 significantly decreased in all mentioned groups in different load conditions. The results recommend that the EMG activity of the thoracic erector spine at T12 between the 0 % and 10 % load conditions ($p<0.001$), as a significant change has been found, but it did not change significantly between 10 % , 20 % and 20 %, 30 % load conditions. In the current study the median power frequency at thoracic erector spine at T12 decreased significantly in the 10 % and 20 % and 30 % body weight (BW). Due to the fact that the median power frequency decreased, there was muscle fatigue found in all of the load conditions.

In a similar previous study, Hong and Cheung (2002) examined the long-lasting postural adjustment process during repetitive works, which obviously illustrious from the preparatory activation of the postural muscles. The erector spinae at T12 level did not find either a significant principal influence or interaction in the EMG responses.

In addition, the achieving results have shown the negative correlation between the load and the EMG activity of the thoracic erector spinae at T12, and between load and median power frequency of the erector spinae at T12, which were (-0.16) and (-0.37) respectively. The data reported in this investigation represented that at the 1st and 5th min EMG activity and median power frequency of the thoracic erector spinae at T12, no significant differences were found.

In this study the EMG activity of lumbar erector spinae at L3 significantly decreased in different load conditions. A significant changes in the EMG activity of lumbar erector spinae at L3 of between 0 %, 10 % and 10 %, 20 % load conditions can be found, but it did not change significantly between 20 % and 30 % body weight (BW). Our results also confirm that the median power frequency at the lumbar erector spinae at L3 decreased significantly at 10 % and 20 % and 30 % body weight (BW). There was muscle fatigue found in all load conditions as a result of the decrease in median power frequency.

As in the previous studies shown the EMG activity changes are highly dependent on the time factor, such as lifting frequency or distance rather than on the weight or mechanical work. Bobet and Norman (1984) reported that with no load, the back muscles must resist a trunk forward instant because the centre of gravity of the upper body is located rather forward of the lumbosacral joint. With a load on the back, the combined centre of gravity of the trunk with increase the backpack changes toward the back. This makes an extension instant. In order to counterbalance the load on the back, a forward trunk lean occurs (Pascoe et al., 1997; Filiaire et al., 2001). Cook and Neumann (1987) found a slight, but not significant, reduce in lumbar paraspinal EMG levels during the stance phase of each cycle of gait while adults carried a box of 10 % and 20 % BW. Hong and Cheung (2002) found that the EMG activity of lumbar erector spinae reduced as the load increased. The results show that muscle fatigue of the lumbar erector spinae relative on the distance walked overground.

In addition, this study revealed the negative correlation between the load and EMG activity of lumbar erector spinae at L3, and between load and median power frequency of lumbar erector spinae at L3, which were (-0.20) and (-0.55) respectively. Moreover at the 1st and 5th min on EMG activity no significant differences were found, but median power frequency of lumbar erector spinae at L3 was significant.

Against the hypothesis of 20 % and more loads for muscle fatigue, in this study the muscle fatigue of 10 % BW has been observed especially for the thoracic erector spine at T12 and lumbar erector spinae at L3. As a matter of fact, the main reason is that before the investigation has been started the participants performed fitness tests that included Sorensen, push-ups, sit-ups and screening tests. As stated by physiologists after fitness test the participants should rest completely for a few hours, then the MVC test can be taken. According to Hong et al. (2008) after MVC test, the children were asked to rest for 30-min to avoid any muscle fatigue, and also a 3-min rest between each exercise. Only then were the children allowed to practice walking on the treadmill. Unfortunately in this study the children weren't asked to rest due to lack of free time after school.

5.4 Difference between kindergartener and primary schoolchild

Hypotheses 6: With the increase of the weight of backpacks, there is a significant difference between kindergartener and primary schoolchild in kinematic body posture and electromyographic parameters.

The data collected showed significant changes in kinematic body posture and electromyographic parameters of kindergartener and primary schoolchild without any load and with loads above 10, 20 and 30 % of BW, therefore barely confirming the sixth hypothesis.

The kinematic data obtained from this study demonstrated that the trends of changing distance from the floor to the earlobe joint were also found in loads carried by the kindergartener and primary schoolchild. No significant difference was found in the trunk inclination angle, step lenght and trunk motion range during the walking for kindergartener and primary schoolchild in load conditions.

From table 37, by comparing the results of kindergartener and primary schoolchild in EMG parameters, it seems that children have significant difference among the four carrying conditions at MPF of the upper trapezius while carrying backpack load. The results of the study showed that when the loads increased from no load conditions to 10, 20 and 30 % of body weight conditions, significant changes in MPF of the upper trapezius is observed.

In this study (Tab. 33), IEMG of neither the thoracic erector spinae at T12 nor the erector spinae at L3showed significant difference in carrying different loads for kindergartener and primary schoolchild after walking.

There were no previous studies on children carrying a backpack while walking on a treadmill with which we could compare our results.

5.5 Relationship between body posture and EMG analyses

Hypotheses 7: There is a relationship between body posture and EMG analysis while children walk on a treadmill with a 10, 20 and 30 % load of body weight, when compared to walking without a backpack.

It was assumed that the kinematic body posture results would support the trends observed in the EMG data.

Furthermore, no or little discomfort was reported the relationship between body posture and EMG analyses, although the kinematics body posture showed most changes in the EMG.

In fact, in the present study the relationships of body posture and EMG activity showed significant changes from different step lengths (1-4) and different upper trapezius (IEMG 1-4), different thoracic erector (IEMG 1-4), different erector spinae at L3 (IEMG 1-4), were positive (0.29), (0.32) and (0.33) respective and between different trunk inclination angle (1-4) and different erector spinae at L3 (IEMG 1-4) was (-0.30) significantly negative.

On the other hand, the limited relation between the body posture and EMG parameters in the present study might have been too small to reveal significant changes.

No previous studies with which we could compare our hypothesis regarding the relationship between body posture and EMG parameters were available.

5.6 Discussion of the method study

Limitations

Our study has some limitations.

The first limitation of this study is that it was done in a laboratory.

The second limitation of this study is that the subjects performed dynamic activities (with backpacks) on a treadmill instead of walking on normal ground.

The third limitation of this study is that the subjects walked only 5 minutes (approximately 250 meters) with each different load condition.

The fourth limitation is this study is that only one camera was used during the experiments.

Finally, there was no rest between the experiment EMG (muscle activity and fatigue in children) and fitness tests.

Suggestions for future research

- Electromyographic measurements (EMG) of the muscle rectus abdominis during the backpack experiment.
- The test subjects should rest before starting the EMG experiment with a backpack.
- The test subjects should stay in the MVC for exactly 5 seconds for optimal results.
- The subjects could be walked longer than 5 minutes (20 minutes, 1 kilometer).
- The choices for the MVC exercises should be based on reliable and well-published sources.
- It would also be recommendable to use two cameras simultaneously during the experiments.

Suggestions for improving bad backpack conditions

- Encourage students to carry only materials that are necessary.
- Persuade students to wear appropriate, standard backpacks under 1.3 kg on both shoulders.
- Provide students with information on the different types of backpacks.
- Students' physical activity and well being must factor into the design of the school curriculum as well as personal recreation time.
- Select backpacks with numbers compartments for better weight distribution.
- For example, the backpacks should have a waist belt so that weight is off the shoulders and distributed on the hips.

6 Summary

This study used biomechanics (kinematic body posture), physiology (EMG) and a questionnaire to evaluate existing conditions and recommendations for carrying backpack load in children who walk to school. The treadmill was used as an experimental apparatus in this study. It accepted controlling the walking speed and facilitating utilize of biomechanical and physiological monitoring equipment thus as long as quantitative observation of carriage load in children. All of the participants in the study carried their backpack on two shoulders because they understood that that was the best way to do so. The weight on the back would force the subjects to change their body position to counteract the deviation from the normal kinematic pattern when body posture and balance were disturbed. However, the relative load of backpack to the subject’s body weight may have been insufficient to cause a shift in the body posture. This study suggests that body posture and electromyography parameters (IEMG, MPF) during walking with load carriage in children are affected by the load weight.

Other recommendations for load carriage in children are based on posture, gait analysis and cardiovascular/ metabolic efficiency. In 2000, Hong and Brueggemann found that at a load of 15 % or 20 % body weight, there was a significant increase of forward trunk lean compared with 0 % or 10 % loads. Trunk forward lean angle was significantly increased with loads of 15 % and 20 % bodyweight (BW) as compared to no load and 10 % BW (Hong & Cheung, 2003). Loads of 15 and 20 % BW were also shown to result in prolonged blood pressure recovery time. Heart rate was unchanged in carrying different loads. Chansirinukor et al. (2001) suggested that a backpack load of 15 % BW is too heavy for adolescents to maintain a prolonged standing posture. Low back pain was defined as pain in the lower back from 12th rib to the lumbar or lumbosacral area (Shehab et al., 2005). Goodgold et al. (2002a) stated that the incident of back pain in children approaching rates as seen in adults and backpacks are believed to contribute to back and other musculoskeletal problems in children. A summary of the results of the three-part investigation:

- With the increase of the backpack weight, the trunk inclination angle progressively increased and trunk motion range decreased linearly. There was a negative correlation between load conditions and trunk motion range, and between trunk inclination angle and trunk motion range.
- With the increase of the backpack weight, the distance from the floor to the earlobe joint (height) decreased. There was a negative correlation between load conditions and distance from the floor to the earlobe joint (height).

- With the weight of backpack at about 10 % and 20 % body weight (BW) step length increased and at 30 % BW decreased. The correlation between load conditions and step length, and between distance from the floor to the earlobe joint and step length, were positive.
- From a load of 30 % of body weight the changes in stride length and body height are reduced.
- There was an increase of muscle activity in the upper trapezius at 20 % and 30 % BW as well as median power frequency at 30 % BW. There was a positive correlation between load conditions, EMG activity and median power frequency in the upper trapezius. This shows that there was no muscle fatigue in the upper body.
- With the increase of the backpack weight, the muscle activity of the thoracic erector spine at T12 and lumbar erector spinae at L3 decreased and median power frequency existed for all load conditions. There was a negative correlation between load conditions, EMG activity and median power frequency at the thoracic erector spine at T12 and lumbar erector spinae at L3. There was muscle fatigue found in all load conditions in the thoracic erector spine at T12 and lumbar erector spinae at L3.
- With increasing load, children are increasingly inclined to the front and thus relieve the back muscles (spinae T12 and L3), meaning a decrease in EMG activity.
- There were differences between kindergartener and primary schoolchild's kinematic body posture and electromyographic parameters as well as significant changes in step length and the distance from the floor to the earlobe joint. There were also significant differences between IEMG of the thoracic erector spinae at T12 and MPF of the upper trapezius.
- The mean weight of the backpack carried by children was 4.1 kg, which is around 16.7 % of their body weight.
- 27.63 % of the children walked less than 1 km from their house door to kindergarten/school, 28.95 % walked approximately 1 km, and 43.42 % walked more than 1 km.
- The majority of the children (55.26 %) walked, around 1.32 % rode the bike, nearly 9.21 % went by bus and 34.21 % went by car.

While the effect of prolonged carriage of backpack loads on the spine is still unclear, until a universal load limit that everyone can understand is agreed upon, students, parents, teachers, and all others involved should become aware of the problem and things they can do on their own to help prevent injuries. Our recommend that children position the centre of a typical school backpack at approximately waist level, and that they actively decrease their backpack loads to minimise postural displacement. The strength and endurance are of the children more important for the upright posture and back health than the weight of the backpack.

7 Deutsche Zusammenfassung

Der Einfluss der Belastung von Schulranzen auf die Körperhaltung von Kindern am Beispiel der Rumpfmuskelaktivität beim Laufen auf einem Laufband

Einleitung

Es ist ein bekanntes Phänomen, dass die meisten Schulkinder sehr schwere Schultaschen für eine lange Zeit tragen. Der Hauptgrund liegt in erster Linie darin, dass sie gezwungen sind ihre Materialien für die Hausaufgaben zwischen Schule und zu Hause hin und her transportieren. Aus diesem Grund sollen die Einflüsse der Belastung durch die Schultaschen auf die Rückenmuskulatur von Grundschulkindern nachgewiesen werden.

In dieser Studie wurden Methoden der Biomechanik (kinematische Körperhaltung), der Physiologie (EMG) sowie ein Fragebogen zur Auswertung der Bedingungen im Alltag verwendet, um Vorschläge für das zu tragende Gewicht, welches Kinder auf ihrem Schulweg tragen sollen, zu machen. Das Laufband wurde als experimentelles Gerät in dieser Studie verwendet. Es erlaubte die Kontrolle über die Gehgeschwindigkeit und erleichterte den Einsatz von biomechanischen und physiologischen Überwachungsgeräten, mit denen eine quantitative Messung der Belastung bei den Kindern vorgenommen wurde. Das Gewicht, welches auf dem Rücken getragen wird, zwingt die Kinder, ihre Körperhaltung anzupassen, indem sie der Abweichung vom normalen kinematischen Muster entgegenwirken, in dem Moment, in dem die Körperhaltung und Balance durch das Tragen einer beträchtlichen zusätzlichen Last gestört wird. Dieser Untersuchung lag die Annahme zugrunde, dass die Körperhaltungs- und elektromyographischen Parameter (IEMG, MPF) bei Kindern sich verändern, wenn sie beim Laufen mit zusätzlichem Gewicht belastet werden.

Untersuchungen zur Veränderung der Körperhaltung durch die Belastung mit Schulranzen bei älteren Schulkindern sind in Zukunft noch durchzuführen. Ebenso sind weitere Untersuchungen bezüglich der Links- und Rechtsunterschiede, die sich in einigen Parametern gezeigt haben, und die Auswirkungen der Gewichtsbelastung auf den Unterkörper weiter zu untersuchen.

Fragestellung und Arbeitshypothesen

Die folgenden Fragen sollen in dieser Studie beantwortet werden:

1) Wie verändert sich der Rumpfwinkel bei einer zusätzlichen Belastung des Rückens mit Gewicht in Form von Schulranzen?
2) Ist die Abnahme des Bewegungsausmaß evident, nachdem dem Schulranzen Gewicht hinzugefügt wurde?
3) Welche Veränderungen ergeben sich in der Schrittlänge, sobald das Schulranzengewicht zunimmt?
4) Welche Auswirkungen sind auf die Körperhöhe nach der Zugabe des Schulranzengewicht bemerkbar?
5) Gibt es signifikante Veränderungen der Muskelaktivität (IEMG) und der Muskelermüdung (MPF) des Upper trapezius , Thoracic spinae T12 und Lumber spinae L3 Muskel mit der Zunahme des Schulranzengewichts?
6) Was ist der Unterschied in der kinematischen Körperhaltung und der elektromyografische Parameter der Kindergartenkinder gegenüber den Schulkindern, wenn das Schulranzengewicht erhöht wird?
7) Welcher Zusammenhang besteht zwischen der Körperhaltung und der EMG-Analyse, während die Kinder auf einem Laufband mit verschiedenen Lastbedingungen laufen?

Untersuchungsmethodik

Die Untersuchung begann im Frühjahr 2009. Die Probanden, aus dem gesamten Saarland stammend, beteiligten sich freiwillig nach einem Aufruf in der Saarbrücker Zeitung. Von den insgesamt 76 Probanden gingen 41 (23 Mädchen und 18 Jungen) in den Kindergarten, während 35 (12 Mädchen und 23 Jungen) die erste Klasse in der Grundschule besuchten. Bei allen Probanden wurde ein Schulranzen des Typs „Scout Easy II" mit einem Eigengewicht von 1,25 kg verwendet.

Nachdem alle Markierungen und Elektroden gelegt wurden, wurde jeder Proband gebeten, auf einem Laufband bei einer Geschwindigkeit von 3 km/h zu laufen. Sie wurden mit vier verschiedenen Lastbedingungen per Videoanalyse und EMG aufgezeichnet. Die zusätzlichen Lasten des Schulranzen betrugen 0 %, 10 %, 20 % und 30 % des Körpergewicht des Kindes. Jede Belastungsstufe wurde für 5 Minuten durchgeführt. Die ersten und letzten 10 Sekunden eines jeden Belastungszustandes wurden per Video sowie EMG-Signale aufgezeichnet.

Die Untersuchung bestand aus drei Teilen: einem Fragebogen, einer EMG-Analyse und einer Video-Analyse der kinematischen Körperhaltung.

Fragebogen

Vorab der Untersuchung wurden die Eltern gebeten, einen auf 10 Minuten konzipierten Fragebogen zu beantworten, der Auskunft über die Schulranzentrage-gewohnheiten ihrer Kinder geben sollte. Befragt wurden folgende Themen: Geschlecht, Alter, Schulweg, Transportmittel, Schulranzentrageverhalten, Ranzengewicht, Rückenbeschwerden, Körperliche Aktivität im Alltag, Mitgliedschaft in Sportvereinen/ Aktivitäten in der Freizeit, usw.

Die kinematische Körperhaltung

Das aufgezeichnete Video wurde digitalisiert und durch das Bewegungs-Analyse-System (Dartfish Software Version 5.5) analysiert. Untersucht wurden drei komplette Gang-Zyklen bzw. sechs Schrittlängen zu einen Zeitpunkt. Die gemessene Schrittlänge bezog sich auf den Abstand zwischen den Zehenspitzen des hinteren Fußes bis zum Beginn der Ferse des vorderen Fußes. Während die Kinder gingen, wurde ihre Körperhöhe zweimal innerhalb eines Schrittzyklus gemessen (Die beiden schreiten Phasen, wenn jeweils der linke Fuß bzw. der rechte Fuß vorne war). Außerdem wurden die Veränderungen des Rumpfwinkels und des Bewegungsausmaß analysiert. Der Rumpfwinkel bezieht sich auf den Winkel der Verbindungslinie zwischen den Schultern (acromion) und der Hüfte (trochanter Major) in Bezug auf die horizontale Linie über die Hüften. Das Bewegungsausmaß bezieht sich auf die Veränderungen im Bereich des Rumpfwinkel innerhalb eines Schrittzyklus. (Es umfasst den maximalen Rumpfwinkel abzüglich des minimalen Rumpf Bereich innerhalb der beiden Schritte).

Electromyography (MVC, IEMG and MPF)

Es wurden zur Elektromyographie ein Gerät mit 16 Kanälen (DSYLAB 10, Deutschland) sowie Oberflächen-EMG-Elektroden (Ambu Blue Sensor N, Malaysia) verwendet. Die EMG-Elektroden wurden so angebracht, um das MVC des Upper trapezius, der Thoracic erector spinae bei T12 und der Lumbar erector spinae L3 Muskel zu bestimmen. Zwei MVC-Tests–mit je einer Laufzeit von 10 Sekunden - wurden durchgeführt.

Das integrierte EMG-Signal (IEMG) wurde berechnet, um die Muskelaktivität zu bewerten. Das integrierte IEMG (aus der zweiten., dritten und 4,1ten Sekunde der Zehn-Sekunden-Aufnahme) wurde verwendet, um die Muskelaktivität des Upper trapezius, des Thoracic erector spinae bei T12 und des Lumbar erector spinae bei L3 als Absolute während Belastung darzustellen. Die Medianfrequenz (MPF) wurde berechnet, um Muskelermüdung innerhalb des Amplitudenspektrum zu bewerten. Zudem wurde Fast

Fourier Transform (FFT) verwendet, um die EMG spektrale Leistungsdichte für die zweite, dritte und 4,1te Sekunde von der Zehn-Sekunden-Aufnahme zu berechnen.

Ergebnisdarstellung und Diskussion

Mit der Zunahme des Schulranzengewichts nimmt der Rumpfwinkel schrittweise zu, das Bewegungsausmaß nimmt hingegen linear ab. Es gab eine negative Korrelation zwischen der zunehmenden Belastung und des Bewegungsausmaßes, sowie zwischen dem Rumpfwinkel und des Bewegungsausmaßes. Mit der Zunahme des Schulranzengewicht nahm die Körperhöhe (Abstand vom Boden zu den Ohrläppchen) ab. Es gab eine negative Korrelation zwischen den Belastungsstufen und der Körperhöhe. Bei der Gewichtszunahme des Schulranzen auf 10 % und 20 % des Körpergewichts hat die Schrittlänge zugenommen, bei einer Belastung mit 30 % des Körpergewichts hat sie hingegen abgenommen. Die Korrelationen zwischen den Belastungsstufen und Schrittlänge, sowie zwischen der Körperhöhe und der Schrittlänge waren positiv.

Es gab eine Zunahme der Muskelaktivität beim oberen Trapezius bei 20 % und 30 % Belastung sowie die Medianfrequenz bei 30 % Belastung. Es gab eine positive Korrelation zwischen den Belastungsstufen, der EMG-Aktivität und die Medianfrequenz beim oberen Trapezius. Dies zeigt, dass es keine Muskelermüdung im Upper trapezius gibt. Mit der Zunahme des Schulranzengewichts nahm die Medianfrequenz des Thoracic erector spinae bei T12 und der Erector spinae lumbar bei L3 ab und eine mediane Frequenz lag für alle Belastungsstufen vor. Es gab eine negative Korrelation zwischen den Belastungsstufen, der EMG-Aktivität und die Medianfrequenz am Thoracic erector spinae bei T12 und am Erector spinae lumbar bei L3. Es wurde eine Muskelermüdung in allen Belastungsstufen im thoracic erector spine bei T12 und im lumbar erector spinae bei L3 festgestellt.

Das Mittelwert Schulranzengewicht der Kindern betrug 4,1 kg, was durchschnittlich 16,7 % ihres Körpergewichts entsprech. 27,6 % der Kinder hatten einen Weg von der Haustür bis zur Schule/zum Kindergarten, der weniger als 1 km betrug, bei 28,9 % betrug er ungefähr 1 km und bei 43,4 % war er länger als 1 km. Die Mehrheit der Kinder (55,3 %) kam zu Fuß, nur 1,3 % fuhren mit dem Fahrrad, 9,2 % kamen mit dem Bus und 34,2 % wurden mit dem Auto gebracht.

- Bei einer Belastung von 20 % und 30 % des Körpergewichts kommt es zu bedeutsamen Veränderungen der Körperhaltung: Rumpfwinkel, Bewegungsausmaß, Körperhöhe und Schrittlänge.
- Ab einer Belastung von 30 % des Körpergewichts reduzieren sich die Veränderungen der Schrittlänge und der Körperhöhe.
- Mit ansteigender Belastung neigen sich die Kinder immer mehr nach vorne und entlasten somit die Rückenmuskulatur (Spinae T12 und L3), so dass die EMG-Aktivität abnimmt.
- Die Angst vor einer Überlastung scheint bis zu einer Belastung in der Höhe von 20 % des Körpergewichts somit unbegründet zu sein!

Während die langfristigen Auswirkungen des Tragens von Schulranzen auf die Wirbelsäule immer noch unklar sind, empfiehlt sich doch eine universelle Belastungsgrenze, die jeder verstehen kann und die eingehalten wird, einzuführen. Schüler, Eltern, Lehrer und alle anderen Beteiligten sollten sich des Problems bewusst sein und sie sollten wissen, was sie selbst tun können, um Spätschäden vorzubeugen. Unsere Position ist zu empfehlen, dass Kinder das zentrale Gewicht eines durchschnittlichen Schulranzens etwa auf Hüfthöhe positionieren sollten, und dass sie aktiv das Gewicht der Schulranzen verringern sollen, um Haltungsschäden zu minimieren. Die Kraft und Ausdauer sollten die Kinder besser für eine aufrechte Haltung und Gesundheit des Rückens einsetzen, als zum Tragen des Gewichts des Schulranzen.

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Appendix 1

Universität des Saarlandes
Sportwissenschaftliches Institut
Arbeitsbereich Gesundheits- und Sportpädagogik

Anamnesebogen

Untersuchungsdatum: ___________________

Allgemeine Angaben

Name: _______________________________

Geburtsdatum: ________________________ (Alter in Monaten: _____)

Geschlecht: männlich ☐; weiblich ☐

Anschrift:

____

Telefon_________________________; E-Mail: ___________________________

Angaben zum Schulweg bzw. Weg zum Kindergarten

1) Wie weit ist der Weg ihres Kindes von der Haustür bis zur Schule (bzw. Kindergarten)?

kürzer als 1 km ☐
ungefähr 1km ☐
länger als 1 km ___________

2) Wie wird der größte Teil dieser Strecke zurückgelegt?

zu Fuß ☐
mit dem Fahrrad ☐
mit dem Bus ☐
mit dem Auto ☐
anders: ______________

3) Wie viele Meter legst du bei Hin- und Rückweg insgesamt zu Fuß zurück?
____

Trageverhalten (nur Schulkinder)

Tragedauer

4) Wie lange muss Ihr Kind den Ranzen tragen?

Ihr Kind trägt seine Schulranzen auf dem gesamten Schulweg selbst ☐

Sie tragen den Schulranzen für Ihr Kind ☐

5) Sonstiges:____

Ranzengewicht

6) Gewicht des gefüllten Ranzen wird möglichst genau gemessen (Messgenauigkeit Waage)

Gewicht des gefüllten Ranzens: ____ kg

7) Nimmt Ihr Kind morgens noch etwas zu essen und zu trinken mit?

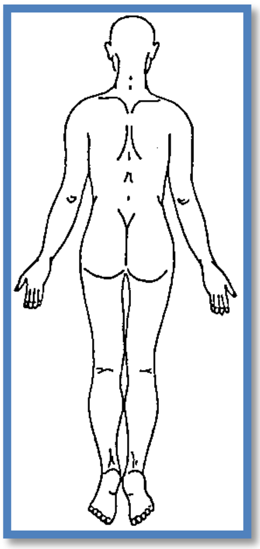
ja ☐; nein ☐

8) Frage an Kind: Fühlt sich dein Ranzen eher sehr leicht oder eher sehr schwer an?

eher sehr leicht ☐☐☐☐☐ eher sehr schwer

Fragen zu Rückenbeschwerden (nur Schulkinder)

9) Hast Du beim Tragen des Ranzens Rückenschmerzen? ja ☐; nein ☐
Wenn ja, Wo genau?



Links **Rechts**

10) Wie schwer sind diese Schmerzen?

eher sehr schwer ☐☐☐☐☐ eher sehr leicht

11) Werden die Schmerzen besser, wenn du den Ranzen abnimmst?

ja ☐; nein ☐

12) Hast du sonst Rückenschmerzen? ja ☐; nein ☐

MoMO Aktivitätsfragebogen für Kinder von 4 - 10 Jahren

I. Körperlich-sportliche Aktivität allgemein

Körperliche Aktivitäten schließen alle Tätigkeiten ein, bei denen das Herz schneller schlägt und für einige Zeit die Atmung erhöht ist. Zu den körperlichen Aktivitäten zählen beispielsweise Sport, Spielen mit Freunden oder den Fußweg zur Schule. Einige Beispiele hierfür sind: Laufen, anstrengendes Wandern, Rollschuh fahren, Rad fahren, Tanzen, Skateboarden, Schwimmen, Fußball spielen …

Frage 14 bezieht sich auf die gesamte Zeit, die du jeden Tag körperlich aktiv bist. Zähle die gesamte Zeit zusammen, die du jeden Tag mit körperlichen Aktivitäten verbringst, (<u>die Bewegungszeit in der Schule (Kindergarten) nicht miteingeschlossen</u>).

13) An wie vielen der letzten sieben Tage warst du für mindestens 60 Minuten am Tag körperlich aktiv?

0 Tage	1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐	☐

II. Sportliche Aktivität im Kindergarten bzw. der Schule

14) Wie viele Minuten bewegst du dich aktiv im Kindergarten bzw. der Schule? (z. B. Fangspiele in der großen Pause) _______________

III. Körperliche Aktivität im Alltag

15) Wie häufig spielst du pro Woche in der Regel im Freien

Täglich	6x	5x	4x	3x	2	1x	<1x	nie
☐	☐	☐	☐	☐	☐	☐	☐	☐

16) Wie groß ist die Entfernung, die du täglich zu Fuß gehst?

☐ Ich gehe fast nie zu Fuß

☐ Ich gehe weniger als einen km/Tag zu Fuß (nur im Haus)

☐ Ich gehe 1 - 2 km/Tag zu Fuß (15 bis 30 min pro Tag)

☐ Ich gehe 3 - 5 km/Tag zu Fuß (30 bis 60 min pro Tag)

☐ Ich gehe 6 - 9 km/Tag zu Fuß (1 bis 2 h pro Tag)

☐ Ich gehe 10 km und mehr am Tag zu Fuß (mehr als 2 h pro Tag)

V. Sportliche Aktivität in der Freizeit organisiert im Verein

17) Bist du Mitglied in einem Sportverein? *(Bitte kreuze nur eine Antwort an)*

☐ Ja, ich bin derzeit Mitglied in einem Sportverein.

☐ Ja, ich bin derzeit Mitglied in mehreren Sportvereinen. _______ (Anzahl).

☐ Ich war früher Mitglied in einem Sportverein, aber jetzt nicht mehr.

☐Nein, ich war noch nie Mitglied in einem Sportverein.

Appendix 2

List of publications from thesis

Babakhani, F. (2011). The effect of backpack load on the posture of primary schoolchildren and while walking on a treadmill. XIth International Scientific Conference „Perspectives in physical education and sport", 20-21 of May, 2011, Constanta, Romania.

Babakhani, F. Cárcamo, J. (2011). The effect of backpack load on posture of schoolchildren while walking on a treadmill. International Symposium on "Science based Prevention" 30th June-1st July 2011; Center for Sports Science and Sports Medicine Berlin, Germany.