

BACK FUNCTIONING :

THE EFFECTIVENESS OF AN INTERVENTION

PROMOTING GOOD BODY MECHANICS

IN ELEMENTARY SCHOOLCHILDREN

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DIT PROEFSCHRIFT KWAM TOT STAND ALS ONDERDEEL VAN DE OPDRACHT VAN HET STEUNPUNT SPORT, BEWEGING EN GEZONDHEID, VERRICHT MET DE STEUN VAN DE VLAAMSE GEMEENSCHAP.

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SUMMARY

While back pain in childhood is a common condition, at young age symptoms are generally mild, do not often lead to restrictions of daily activities and represent little health consequences. However, the predictive value of back pain at young age for back pain as an adult, stresses the need for primary prevention.

The multi-factorial nature of the risk for developing back pain in childhood is widely accepted. On the other hand, the causative mechanisms for back pain occurrence at young age remain largely undetermined. Based on epidemiological evidence in relation to the biomechanical concept suggesting a U-shaped relationship for optimal loading, several correlates may influence children's back function. In this way, environmental factors that may counterbalance optimal spinal loading of children's young body structures may be present at school, which is the workplace of the young.

In this line, children's postural behavior in the Flemish class environment was pictured. This pilot study was grounded because sitting is the most reported factor in relation to back pain reporting at young age and due to the reality that standard school managements prescribe long sitting periods. The study findings pointed out that prolonged static kyphotic sitting without use of the backrest is common in Flemish elementary schoolchildren and children who spend more time sitting with a flexed trunk reported significantly more thoraco-lumbar pain.

The school is considered as an ideal setting for back pain prevention since it has the opportunity of optimizing environmental conditions in relation to spinal loading and giving education and feedback regarding good body mechanics, reaching a large percentage of the population. Since pain is highly subjective and mainly correlated with psychosocial factors primary back education programs should focus on good back functioning, instead of being focused on figures of back pain prevalence. The promotion of good back function in the elementary school environment seems useful because of the promising results of previous research with respect to improved postural behavior and increased back posture knowledge. The present intervention study attempted to eliminate some restrictions from previous intervention studies regarding sparse post-intervention measurements, small study samples, short duration of post-intervention follow-up, and non-randomized controlled trials. The intervention was a comprehensive multi-factorial program to optimize the daily load on young spinal structures during two school-years with additional focus on sitting in the school context and with involvement of class teachers.

The present optimized back posture program seemed to be an effective way to improve elementary schoolchildren's back posture knowledge and made them conscious of a healthy lifestyle related to good back functioning. Additionally, postural behavior during material handling was improved. Better material handling in an unconstrained situation suggested that the learned skills became generalized. Moreover, the multi-factorial program may have reduced some exposure in the school environment since elementary schoolchildren's classroom postures were improved using traditional furniture after the two-school-year promotion of good body mechanics. Moreover, back posture education was favorable for children's back functioning with respect to trunk muscle endurance. However, the promotion of good body mechanics had no effect on children's leg muscle capacity or neutral spinal curvature in a test condition. Finally, the promotion of good body mechanics had no effect on back pain reporting and did not increase fear avoidance beliefs. A broader-spectrum finding was that our two-school-year back posture program seemed to be feasible for teachers and pleasant for children.

Further, the intensity of the two-school-year promotion of good body mechanics within the school curriculum between the 4th and the 6th grade provided stable intervention effects at 1-year and 2-year follow-up regarding back posture knowledge and postural skills. These positive findings encourage the promotion of good body mechanics at young age. If schoolchildren could start the growth spurt with a sound dose of back posture knowledge being motivated to function in a biomechanical favorable way, the typically mechanical load in the critical adolescent phase could possibly be decreased.

Besides, the doctoral thesis incorporated some reliability measurements for back function parameters in an elementary school-aged population. The study findings indicated in 8 to 11 year old children a range between poor to fair to good and even excellent reliability values for all the assessments used in our research, i. e. measurement of static back curvatures (two variables represented poor reliability while two demonstrated fair reliability values), trunk muscle endurance (a good and an excellent reliability value) and postural stability (a poor reliability value, three fair to good reliability reports and an excellent reliability value for the composite parameters).

In conclusion, the present study findings provide evidence to encourage the promotion of good body mechanics through the mandatory elementary school curriculum. However, follow-up investigation on the impact of early school-based back posture programs in relation to the lifelong integration of back posture principles according to a biomechanical favorable lifestyle and back pain reporting later in life is essential.

SAMENVATTING / DUTCH SUMMARY

Ook al is het optreden van rugpijn in de kindertijd een algemeen gegeven, op jonge leeftijd zijn de symptomen meestal mild, ze leiden niet dikwijls tot beperkingen in dagdagelijkse activiteiten en gaan zelden gepaard met ernstige gezondheidsgevolgen. Toch wijst de dwingende relatie tussen het optreden van rugpijn op jonge en op volwassen leeftijd op de noodzakelijkheid van primaire preventie.

Het risico op het ontwikkelen van rugpijn bij kinderen heeft een multi-factorieel karakter, terwijl er grote onduidelijkheid blijft bestaan over de onderliggende mechanismen. Op basis van epidemiologische studies en de biomechanische concepten die een U-vormig verband suggereren voor een optimale belasting van de rugstructuren, werd vastgesteld dat verschillende factoren het functioneren van de rug bij kinderen kunnen beïnvloeden. Zo kunnen verschillende schoolomgevingsfactoren opgesomd worden die bij kinderen de optimale belasting op de jonge structuren van de rug uit balans brengen.

In dit kader werd in een pilootstudie het posturaal gedrag tijdens het zitten in de klas in kaart gebracht bij kinderen in Vlaamse lagere scholen. Dit onderzoeksopzet was onderbouwd door het feit dat zitten de meest gerapporteerde factor is in relatie tot rugpijn bij kinderen en dat standaard schoolsystemen kinderen lange periodes van zitten opleggen. De studieresultaten tonen aan dat langdurig statisch zitten zonder gebruik te maken van de rugleuning gangbaar is bij Vlaamse lagereschoolkinderen en dat kinderen die meer tijd spenderen in een houding met een gebogen rug significant meer thoraco-lumbale rugpijn rapporteren.

De school is een ideale setting voor rugpijnpreventie aangezien deze de mogelijkheid heeft omgevingsfactoren te optimaliseren en aan een grote groep jongeren vorming en feedback te geven omtrent biomechanisch verantwoord bewegen. Aangezien pijn een zeer subjectieve ervaring is en hoofdzakelijk gecorreleerd is met psychosociale factoren, is men tot het inzicht gekomen dat primaire rugscholingsprogramma's zich best focussen op het goed functioneren van de rug, in plaats van op prevalentiecijfers voor rugpijn op jonge leeftijd. De promotie voor het goed functioneren van de rug in de lagere school blijkt nuttig door de veelbelovende resultaten van voorgaand onderzoek met betrekking tot verhoogde kennis en verbeterd posturaal gedrag. Binnen dit doctoraatsonderzoek, werd geprobeerd om enkele beperkingen van voorgaande onderzoeken weg te werken, zoals weinig postinterventie-evaluaties, kleine proefgroepen, korte duur voor de postinterventie follow-up, en een niet-gerandomiseerde gecontroleerde proefneming. De interventie was een geoptimaliseerd

multi-factorieel programma dat gedurende twee jaar geïmplementeerd werd om de dagelijkse belasting op de jonge rugstructuren te optimaliseren met een extra focus op zitten in de schoolcontext en interactieve betrokkenheid van de klasleerkrachten.

Het geoptimaliseerde programma leek een effectieve manier om de posturale kennis van lagere schoolkinderen te verhogen en hen bewust te maken van een gezonde levensstijl aangaande een goede rugfunctie. Bovendien was het hef- en tilgedrag tijdens het hanteren van gebruiksvoorwerpen verbeterd. Het betere hef- en tilgedrag in een ongedwongen situatie suggereerde dat de geleerde vaardigheden gegeneraliseerd werden. Overigens zou het rugscholingsprogramma de blootstelling in de schoolomgeving enigszins kunnen gereduceerd hebben aangezien na de tweejarige promotie voor biomechanisch verantwoord bewegen de houdingen van lagereschoolkinderen in de klas verbeterd waren. Bovendien was het rugscholingsprogramma bevorderlijk voor het functioneren van de rug bij kinderen, met betrekking tot de uithouding van de rompspieren. De promotie had geen effect op de capaciteit van de beenspieren en de neutrale curvatuur in de zithouding tijdens een testsituatie. Tenslotte had het rugscholingsprogramma geen effect op het rapporteren van rugpijn en waren de overtuigingen van kinderen omtrent pijnvermijding niet toegenomen. Een ruimere en belangrijke bevinding was dat het twee schooljaren durende programma haalbaar was voor leerkrachten en dat kinderen het programma fijn vonden.

De intensiteit van de tweejarige promotie voor biomechanisch verantwoord bewegen binnen het schoolcurriculum van het 4^{de} tot het 6^{de} leerjaar, leverde bij het follow-up onderzoek na één en twee jaar stabiele interventie-effecten op met betrekking tot posturale kennis en rugvriendelijke vaardigheden. Deze positieve bevindingen moedigen vroegtijdige promotie voor biomechanisch verantwoord bewegen aan. Als schoolkinderen de groeispurt zouden kunnen aanvangen, met een behoorlijke dosis posturale kennis en gemotiveerd om op een biomechanisch verantwoorde wijze te functioneren, zou de typische mechanische belasting in de kritische fase van de adolescentie misschien kunnen worden verminderd.

In het kader van deze thesis werden enkele betrouwbaarheidsmetingen gedaan om bepaalde parameters met betrekking tot rugfunctionering te evalueren bij lagereschoolkinderen. Voor alle meetinstrumenten die in dit onderzoek bij 8- tot 11-jarige kinderen geëvalueerd werden, werden betrouwbaarheidswaarden gerapporteerd binnen een marge van lage tot excellente betrouwbaarheid. Voor de statische meting van de rugcurvatuur vertoonden twee variabelen lage betrouwbaarheid en twee voldoende. Voor de uithouding van de rompspieren was de betrouwbaarheidswaarde voor één variabele goed en voor één excellent. Voor posturale stabiliteit was de betrouwbaarheidswaarde voor één

samengestelde variabele laag, voor drie samengestelde variabelen voldoende tot goed en voor één samengestelde variabele excellent.

Men kan besluiten dat de huidige onderzoeksresultaten bewijsgrond leveren om de promotie voor biomechanisch verantwoord bewegen via het lagere schoolcurriculum aan te moedigen. Verder onderzoek naar de impact van vroegtijdige promotie voor rugvriendelijk bewegen via de lagere school in relatie tot de levenslange integratie van posturale principes conform een biomechanisch verantwoorde levensstijl en rugpijn prevalentie op volwassen leeftijd is echter aangewezen.

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SECTION 1

GENERAL INTRODUCTION

PART 1: LITERATURE REVIEW

1. Back functioning: theoretical framework

Functional stability

The skeletal system and the spinal column in particular are the primary supporting structures of the body. Mechanical stability of the spinal column, especially in dynamic conditions and under heavy loads, is provided by the spinal column and the precisely coordinated surrounding muscles. The stabilizing system of the spine was conceptualized by Panjabi (1992) and consisted of three subsystems: the spinal column, the spinal muscles and the neural control unit (figure 1).

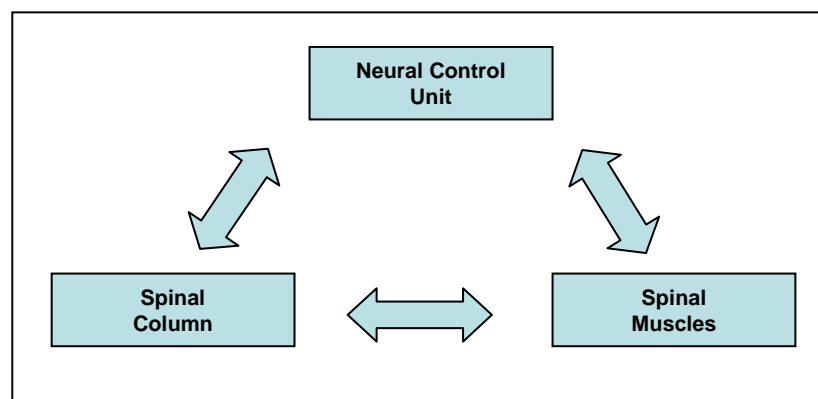


Figure 1: The stabilizing system (Panjabi 1992).

With respect to the concept of Panjabi (1992), the spinal column provides intrinsic stability. The spinal column carries the loads and provides information about the position, the motion and the loads of the spinal column. The information of the spinal column is transferred into action by the neural control unit. The neural control unit determines the requirements for stability and coordinates the muscle response. The trunk muscles surrounding the spinal column provide dynamic stability, including the fascia and ligaments which originate and insert on these bone structures. The fascia and the ligaments act as mediators supporting muscle activity. The activity of the trunk muscles must take into consideration the stabilizing function of spinal column, but also the dynamic changes in the spinal postures and loads. Danneels (2001) proposed to modify Panjabi's model of the stabilizing system towards a more general concept of functional spinal stability (figure 2). According to this definition of spinal stability, the neural control unit was divided into the subsystems neuromuscular control and postural control. Neuromuscular control provides a concerted action between the afferent input (proprioception) and the efferent output of the nervous system (coordination),

and allows the muscles to contract with the required strength and at the appropriate time. Postural control is the capacity to keep the projection of the body's center of gravity within the base of support. So, the passive structures (cfr Panjabi's subsystem 'spinal column'), muscular characteristics (cfr Panjabi's subsystem 'spinal muscles'), and postural and neuromuscular control constantly interact to offer adequate stability to the spine during changes of postures and static and dynamic loading (Danneels et al. 1999).

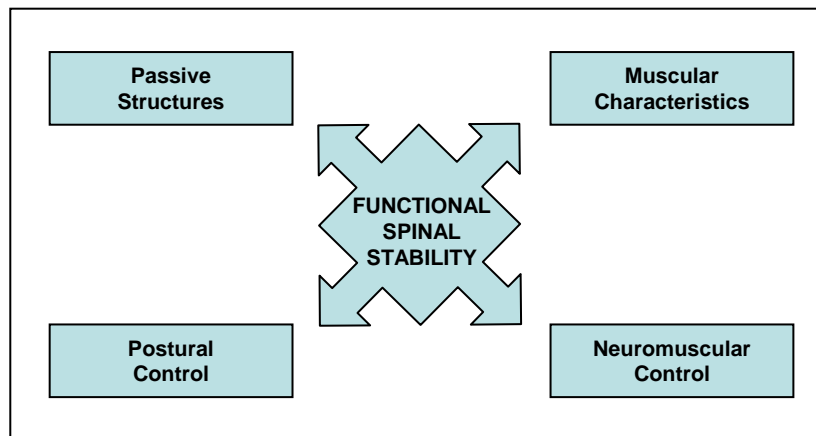


Figure 2: Functional spinal stability (Danneels 2001).

In summary, mechanical stability refers to functional stability. This means that the spinal column has to unite two, sometimes conflicting functions, namely intrinsic stability and dynamic stability (mobility). Under normal conditions, the subsystems work in harmony to provide the needed intrinsic and dynamic stability.

The role of motor control in functional stability

Motor control plays an important part in order to coordinate the recruitment of muscles during functional and daily life activities, which is described in the lumbar bracing concept of McGill (2002). Muscle contractions should be adequately coordinated in order to stiffen the joints and ultimately determine joint stability. Therefore, the motor control system coordinates the activation of the trunk muscles to ensure sufficient stability allowing the spine to withstand load and sustain postures and activities. On the other hand, the joints possess inherent stiffness by passive capsules and ligaments, particularly at the end range of motion. Thus the motor control system has to ensure that the passive structures become not overloaded.

In conclusion, the lumbar bracing concept of McGill (2002) suggests that the motor control system is able to control stability of the joints through coordinated muscle activation and to a lesser degree by placing joints in positions that modulate passive stiffness contribution. Accordingly, the synchronicity of balanced stiffness produced by the motor control system is

absolutely critical. Hence, the activation of synergistic and antagonistic muscle groups in an optimal way is crucial since they have to work harmoniously to ensure (1) stability, (2) generation of the required moment and (3) desired joint movement.

Spinal loading and the linkage to back pain

Referring to McGill (2002), spinal loading stands for to the mechanical load on the spinal column. Basically, mechanical load corresponds to the joint reaction forces. Joint reaction forces are created by compression (forces generated in the direction of the Y-as) and shear force (forces generated in the direction of the X-as). Stress, refers to the intensity of loading, equal to the force exerted divided by the area over which it is applied.

The joint positions of passive spinal structures in addition to muscular activity of all muscles that originate and insert on spinal structures generate spinal loading. The basic principle to load the spine optimally is to preserve a neutral spinal posture (the natural spinal curvature including cervical lordosis, thoracic kyphosis and lumbar lordosis) because of the equally distributed compression on the spinal structures in a neutral position. Additionally, in a neutral spinal curvature the impact of the shear forces is optimal because of muscular anti-shear components. As the spine flexes, extends, lateral bends or axially twists, the orientation between the vertebrae and other spinal structures changes, which results in an unequally distributed stress on the spinal structures.

The literature provides no evidence for the direct relationship between spinal loading and back pain. Though, there is conclusive evidence that mechanical tissues overload causes damage (McGill 2002). However, definitive large-scale studies in order to explore whether tissue damage causes pain are non-existent due to ethical issues (McGill 2002). In the same line, Adams et al. (2002) reported that the linkage between spinal loading, injury and pain is found to be an undoubtedly complex relationship. Accordingly, based on the available literature, McGill (2002) and Adams et al. (2002) suggested that the relationship between loading the back and back pain might be a U-shaped curve. According to the U-shaped model, there would be a moderate optimal loading zone and two problematic regions representing too little and too much loading which include a risk for pain or injury (figure 3). As a consequence, sufficient loading seems to be necessary to cause strengthening and toughening of the tissues, but excessive levels may result in weakening.

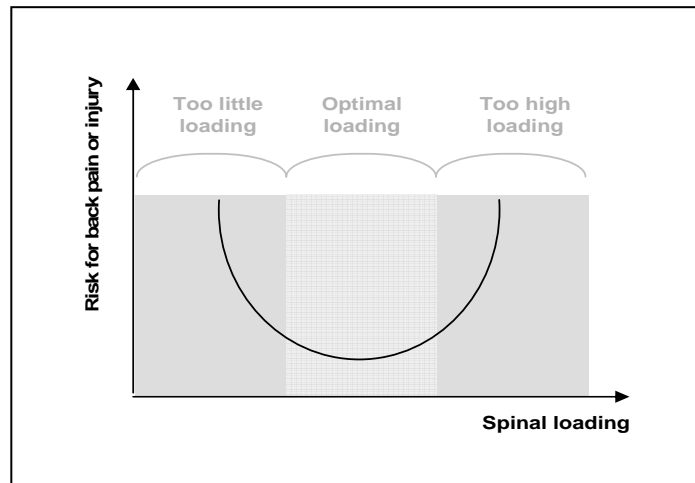


Figure 3: U-shaped curve for the relationship between spinal loading and back pain (McGill 2002).

2. Back functioning in children: epidemiological evidence

Reviewing the epidemiological literature, we were faced with a methodological-related complexity. A variety of definitions for back pain over and above different study concepts are investigated which complicates comparison between studies. In this line, prevalence and incidence, in addition to cross-sectional, longitudinal and prospective study methods, are key concepts within the epidemiologic research focusing back pain. The latter and other essential terms as well as the way the terms are used in this doctoral thesis are described below.

Terminology

Back pain prevalence refers to the percentage of individuals in a given population who are experiencing back pain during a specified period of time, such as *month prevalence* evaluating back pain for the time span of a month or *point prevalence* referring to the percentage of individuals with back pain at a given moment in time (Adams et al. 2002, Burton et al. 1996). *Cumulative or lifetime back pain prevalence* is the proportion that has ever experienced back pain (Burton et al. 1996). *Back pain incidence* is the percentage of individuals in a given population who develop back pain for the first time during a specified period of time (Adams et al. 2002, Burton et al. 1996).

Discussing different epidemiological research methods, cross-sectional studies typically investigate *ongoing back pain* in relation to possible influencing factors and longitudinal studies usually focalize on *ongoing or recurrent back pain*. Further, incidence of back pain is basically investigated in a prospective design focalizing on the *onset of back pain*.

Additionally, different categorizations of back pain are investigated within the epidemiological field. Some studies reported prevalence rates focalizing 'back pain' where other studies focused on precise zones of the back, such as 'low back pain' or 'neck pain'. In our following 'literature review' we did not intend to focus on specific zones of pain. As a result, study findings on pain prevalence are reported as originally described in the involved studies. In addition, our synopsis of possible risk factors for back pain at young age included studies presenting non-specific back pain reports in children.

Questioning pain, recall bias cannot be excluded. However, the recall period can be reduced reasonably. Burton et al. (1996) found that 60% of the adolescents could not remember the periods of pain that occurred in the previous year. Accordingly, Staes et al. (2003) showed that time scales longer than a month resulted in unreliable information. Therefore, this doctoral thesis intended the evaluation of *back pain prevalence within the last week*. The one-week prevalence for back and/or neck pain was defined as the occurrence of pain or discomfort, continuous or recurrent, at some point in the past week. The children were told that pain or discomfort due to fatigue related to a single exercise was not considered as a back or neck pain problem.

In the literature, different study populations were investigated comprising schoolchildren with age ranges between 6 to 18 years. In the current thesis, the term *elementary schoolchildren* refers to children aged between 6 to 12 years. In case of studies with a mixed study population consisting of both elementary (6-12 years) and secondary (13-18 years) schoolchildren, the term *schoolchildren* is used.

Finally, in the literature 'risk factors for back pain' are largely discussed. We preferred to talk about '*correlates influencing back function*' since we did not want to stress back pain. To generalize the back pain problem the expressions *back function* and *back functioning* are introduced. These terms refer to the underlying mechanisms for postural behavior based on the functional spinal stability concept. In the evaluation of postural behavior, muscle activity and spinal curvature are important aspects among the functional stability components due to their determinative role on spinal load distribution.

Back pain prevalence in schoolchildren

Epidemiological evidence establishes in schoolchildren a lifetime prevalence rate for back pain of approximately 30% (Çakmak et al. 2004). Estimates of life-time prevalence for back pain in children vary from 13% to 51% whereas point prevalence ranges from 1% to 31% (Harreby et al. 1999, Jones et al. 2004). In Flanders, back pain prevalence rates in the elementary school population are evaluated by two research groups. In the study of Gunzburg et al. (1999) the lifetime prevalence in 9 year olds was 36%. Further, 14% of the 9

year olds complained of back pain the day before testing, 25% had already had to miss school because of pain, 10% had had to interrupt sport activities because of pain and 23% had already sought medical care. Cardon et al. (2002) measured back pain prevalence four times in 9-12 year old children. At all measurements, the week prevalence for back and neck pain varied between the ranges of 24% to 30%.

For the majority of the children, back pain experiences are mostly non-specific, mild in nature, do not represent a self-limiting character (Jones et al. 2005) and do not lead to functional restrictions in daily living (Jones et al. 2004, Staes et al. 2003). However, in a subgroup of children the occurrence of back pain is yet recurrent (Brattberg 2004). Research has indicated a range from 7% to 27% for the prevalence of recurrent low back pain in children. Furthermore, Harreby et al. (1999) demonstrated that children with recurrent or continuous low back pain utilize increased medical attention, consume more painkillers, and experience reduced quality of life. Along the same lines, there are coherent indications that suffering from recurrent low back pain in childhood included a higher risk for a chronic evolution of back pain (Harreby et al. 1999). Accordingly, Feldman et al. (2001) demonstrated that the beginning of back pain in childhood is one of the major reasons for chronic low back pain in adulthood.

In summary, although most back pain cases are acute episodes that represent little health consequences, low back pain is a common complaint during childhood. Furthermore, some children experience at their young age recurrent low back pain which can lead to disabling consequences.

Measuring back pain in children

Measuring back pain in children is a debatable topic. In epidemiological research, self-reports for back and/or neck pain are commonly used. However, a wide range of prevalence percentages and conflicting information in relation to possible risk factors are reported in the literature owing to methodological differences and diverse definitions for back pain.

Furthermore, feeling pain is a subjective phenomenon. Accordingly, self-reported pain reflects one's perception of pain (Wadell 1998). At young age, children are in the middle of a learning process experiencing their body and reporting their aches. Perceived back pain has not necessarily a clinically apparent cause. Pain reports in children are for the greater part an expression of internal and external aspects such as pain beliefs, coping with pain, illness behavior and social interactions (Balagué et al. 2003).

Although self-reporting is considered to be subjective, the test-retest results of the study by Staes et al. (1999) showed that their evaluated questionnaire provided reproducible documentation regarding self-reported pain in schoolchildren. However, two longitudinal

studies pointed out that reports of back pain showed inconsistent patterns during childhood and that nearly 60% of the pain episodes at baseline were forgotten later (Burton et al. 1996, Sjolie 2004).

As a result, efforts were made to purify self-reported back pain in children. As a first attempt, parental reporting was introduced asking for their children's possible back pain experience. In the study by Watson et al. (2002) 95% of parental responses agreed with their child's report as the child did not report pain. However, when a child reported pain the agreement between child and parental pain reporting was only 33%. This may suggest that children's perceived back pain is of such a nature that they did not alert their parents (Balagué et al. 2003). A second challenge for measuring back pain in children more objectively was to evaluate the consequences of back pain. It was demonstrated by Staes et al. (1999) that self-reports in children provided valuable information about the consequences of pain, such as level of medical consultation and limitations during sporting and recreational activities. However, the potential functional consequences during childhood (like absence from school because of back pain, limitations during sport activities) are less considerable when compared to back pain related consequences in adults (like work absenteeism, work incapacity). A third alternative for measuring back pain more objectively comprised face to face interviews. In the studies of Staes et al. (2000) and Wedderkopp et al. (2001) children were interviewed with respect to back pain related questions (onset, severity, localization, functional limitations) in a standardized manner. Self-administration of a questionnaire was compared to oral administration (interview) in 16- to 18-year olds by Staes et al. (2000). The study findings revealed no differences in item completion between self-administration and oral administration. A final attempt for objective back pain assessment included a clinical diagnosis or a doctor's visit. However, a medical contact doesn't seem an ideal option taking into account the potential risk of medicalizing back pain.

In conclusion, an inherent limitation of all studies on back pain is the subjective nature of back pain and the need to rely on subject recall. However, since pain is a subjective phenomenon, personal recall is the only way to assess pain (Goodman and McGrath 1991). The reality that back pain can not be validated against a golden measure (Wedderkopp et al. 2003) complicates research and interpretation of study results on back pain.

Risk factors in relation to early back pain

The multi-factorial nature of the risk for back pain in childhood is widely accepted. Although risk factors for back pain are investigated intensively, the role of most factors seems to be controversial and the causative mechanisms for back pain occurrence at young age remain largely undetermined (Cardon and Balagué 2004).

In the literature, risk factors for back pain were grouped in various ways (Adams et al. 2002). In the current doctoral thesis the risk factors for back pain in children and adolescents will be discussed based on the following comprehensive list of categorized risk factors (figure 4). However, we do not pretend that this list, neither the classification of the risk factors, is conclusive. The term ‘intrinsic risk factors’ was used to categorize the factors belonging to ‘individual’, while ‘extrinsic risk factors’ describe the factors originating from outside, thus arising from the environment.

Below, we will resume the literature concerning possible risk factors for back pain at young age. Risk factors are discussed separately by referring to the study findings of diverse researches including that specific risk factor. Since the risk for developing back pain at young age is multi-factorial, the presupposed interrelationship between multiple risk factors is lost in case of isolating risk factors. However, in the literature numerous combinations of possible risk factors were investigated in relation to a large variation of definitions for back pain.

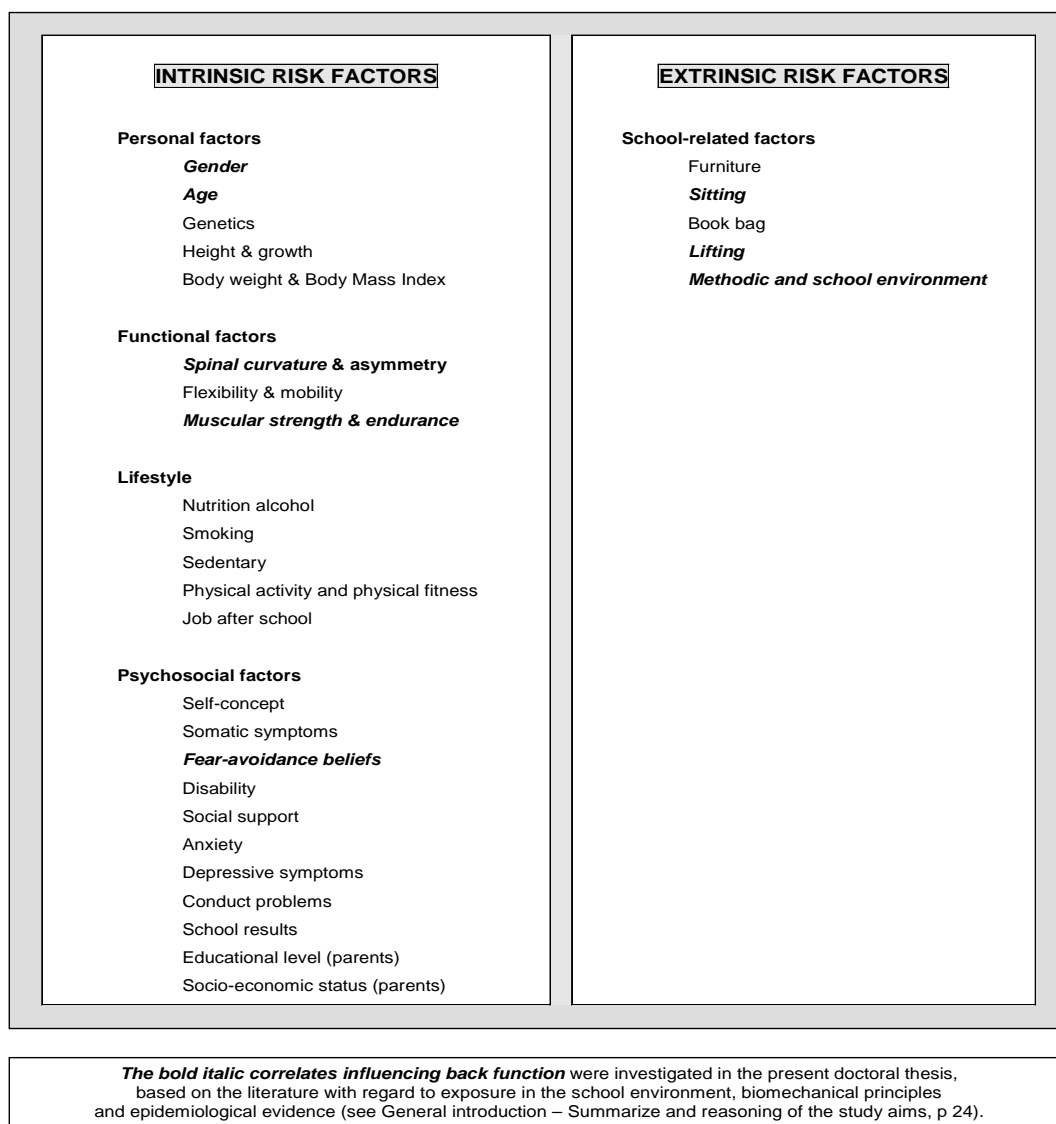


Figure 4: The risk for back pain at young age is multi-factorial.

Personal factors

Gender. Multiple studies observed a higher prevalence of back pain reported by girls compared to boys (Balagué et al. 1998, Balagué et al. 1999, Duggleby et al. 1997, Harreby et al. 1999, Korovessis et al. 2004, Kovacs et al. 2003, Salminen 1984, Salminen et al. 1992, Watson et al. 2002). Some other studies reported no gender difference in relation to reporting patterns of back pain (Kristjansdottir and Rhee 2002, Newcomer and Sinaki 1996, Staes et al. 2003, Taimela et al. 1997, Wedderkopp et al. 2001) while Burton et al. (1996) reported a higher prevalence of back pain in boys.

Age. In the literature, there is consensus about increasing back pain prevalence relative to chronological age (Balagué et al. 1994, Balagué et al. 1999, Brattberg 1994, Burton et al. 1996, Duggleby et al. 1997, Grimmer and Williams 2000, Harreby et al. 1999, Kristjansdottir and Rhee 2002, Panagiotopoulou et al. 2004, Salminen 1984, Troussier et al. 1994, Vikat et al. 2000, Watson et al. 2002, Wedderkopp et al. 2001). Furthermore, a significant increase of back pain prevalence at age 12-13 is a consistent finding in the literature (Burton et al. 1996, Mierau et al. 1989, Olsen et al. 1992, Troussier et al. 1994). In support of this, some authors have pointed out that the onset of back pain roughly corresponds with the adolescent growth spurt (Balagué et al. 1999). It was demonstrated that youngsters with a high growth spurt (i. e. more than 5 cm in six months) were three times more likely to report low back pain than their peers (Balagué et al. 1999).

Height & growth. A positive relationship between height and back pain has been reported (Salminen et al. 1992) demonstrating that boys with back pain were on average 4 cm taller compared to the control group. Furthermore, the longitudinal study of Poussa et al. (2005) showed that the body height growth between 11 to 14 years was a predictor for back pain incidence until the age of 22 years. However, the majority of studies did not demonstrate any relationship between body height and back pain (Balagué and Nordin 1992, Jones et al. 2003, Kujala et al. 1992). Discussing an additional anthropometric aspect, some studies have shown a positive relationship between leg length discrepancy of more than 2.5 cm and having back pain (Giles and Taylor 1981, Kovacs et al. 2003), but Fairbank et al. (1984) found no such association in schoolchildren.

Body weight & Body Mass Index (BMI). With exception of the studies performed by Harreby et al. (1995), Sheir-Neiss et al. (2003) and Hestbaek et al. (2006) which revealed in schoolchildren a positive association between BMI and low back pain, no association was established by nearly all others (Cardon et al. 2004, Grimmer and Williams 2000, Jones et al. 2003, Korovessis et al. 2004, Kovacs et al. 2003, Vikat et al. 2000, Watson et al. 2003, Wedderkopp et al. 2003). Only one prospective study (Salminen et al. 1995) has demonstrated that weight at follow-up was greater in children with recurrent or continuous back pain, although weight at baseline was not predictive for future back pain.

Family history of back pain. A variety of studies demonstrated a significant relationship between non-specific back pain reports among parents and their children (Balagué et al. 1994, Balagué et al. 1999, Duggleby 1997, Gunzburg et al. 1999, Lebouef-Yde 2004, Salminen 1984,). Contrary, one study could not confirm an association between non-specific back pain reports among parents and their children (Kovacs et al. 2003). Different aspects, such as genetic components, environmental influence and psychosocial factors may affect this relationship. The possible familial and genetic influence on children's self-reported back pain was supported by the twin study of Hestbaek et al. (2004). The latter study demonstrated that the shared environment plays an important part until age 15. As adolescents become adults, the effect of the non-shared environment increases and the genetic factors become more imperative.

Basically, agreement is found for an increase of back pain prevalence relative to chronological age. Along this line, Kristjansdottir and Rhee (2002) mentioned that older children may be more exposed to physical and environmental insults owing to their increasing range of activity in terms of frequency and intensity in comparison to younger children. Furthermore, family history of back pain seems to play a part in children's self-reported pain. On the other hand, there is only limited evidence to suggest that height, growth, weight or BMI are associated with ongoing back pain in childhood and adolescence. The underlying mechanisms for a possible relationship between height or weight and back pain or injury may be increased forces and torques regarding humans' spinal biomechanics. One may presume that taller and heavier persons may create greater torques because of greater lever arms and greater upper body mass respectively (Adams et al. 2002). With regard to the relationship between gender and back pain reports, controversial findings are reported.

Functional factors

Spinal curvature & asymmetry. Salminen (1984) investigated in 11 to 17 year olds postural changes in the saggital plain and found functional postural changes in about 30% of this study population. Additionally, youngsters who had a hyperlordotic curve reported pain more frequently (Salminen 1984). On the other hand, in the studies by Harreby et al. (1995) and Widhe (2001) back pain was not related to children's spinal curvature. Correspondingly, Poussa et al. (2003) found that children's spinal curvature at age 11-14 did not predict back pain at age 22 years. With respect to postural changes in the frontal plain, some studies have shown that the presence of scoliosis was a risk factor for back pain (Kovacs et al. 2003, Michel et al. 1997) while others have found no association (Fairbank et al. 1984, Grundy and

Roberts 1984). Again, the literature can not present conclusive evidence on the relationship between postural changes in the spine and back pain reports.

Flexibility & mobility of muscles and joints. The literature reports conflicting evidence about the relationship between spinal mobility or joint flexibility and back pain in children and adolescents. When focusing on flexibility of the hip muscles, Feldman et al. (2001) found that stiffness of both hip flexors and hip extensors was associated with the development of back pain. Correspondingly, tight hip flexors correlated with increased frequency of back pain in the studies of Salminen et al. (1995) and Kujala et al. (1997). Additionally, Mierau et al. (1989) found an association of decreased flexibility of the hip extensors with back pain among boys aged 14 -18 years. Contrary, Harreby et al. (1999) and Widhe (2001) did not point out an association between tight hip extensors and back pain. With respect to spinal mobility, three studies identified decreased spinal mobility as a risk factor for back pain (Fairbank et al. 1984, Jones et al. 2005, Salminen et al. 1995). Consistent with these finding, Salminen et al. (1992) observed decreased mobility in 15 year old adolescents reporting back pain when they performed lumbar extension and increased mobility when lumbar flexion was performed. In contrast to the suggested relationship between spinal mobility and pain, no association between spinal mobility measurements and the development of back pain was found by Burton et al. (1996), Feldman et al. (2001) and Sjolie and Ljunggren (2001). As a last aspect with regard to mobility Payne et al. (2000) discussed back health in 15-70 year olds. They observed that a higher score for spinal mobility was positively related to back health. However, this finding was based on analyses in the total group without a distinction for youngsters.

Muscular strength & endurance. A recent study by Jones et al. (2005) pointed out that low endurance of trunk flexors was a risk indicator for recurrent and nonspecific back pain in a group of adolescents. In the same line, the study findings of Sjolie and Ljunggren (2001) indicated that insufficient trunk extensor endurance and lack of stability were important aspects for both present and future low back pain in adolescents. Consistent with these findings, Salminen et al. (1995) found in their cross-sectional study a decreased isometric endurance of trunk extensors and flexors among low back pain sufferers at the age of 15 years. Conversely to the consistent study findings on trunk muscle endurance, research on the relationship between trunk muscle strength and back pain reports in adolescents revealed conflicting findings. Newcomer et al. (1997) found that back pain was associated with trunk muscle strength in 10-19 year olds. In contrary, Balagué et al. (1993) could not establish a relation between isokinetic trunk muscle strength and history of low back pain in 10-16 year olds. Corresponding results were found by Feldman et al. (2001) who demonstrated that poor isometric trunk flexor strength was not a risk factor for the development of low back pain in adolescents. Furthermore, an imbalance in trunk muscle

strength was identified as a risk factor for low back pain in 15-19 year olds. It was demonstrated that a reduced development of trunk extensors compared to trunk flexors was a predictor for future low back pain (Lee et al. 1999).

Basically, the literature reports conclusive findings with regard to a negative relationship between endurance of the trunk extensors and trunk flexors and back pain reports in schoolchildren. For all other functional parameters, findings in the literature are contradictory and recommend future research on functional parameters in schoolchildren. A theoretical explanation by Mikkelsen et al. (2006) for the association between functional correlates and back pain or injury included that modifications in the spinal curvature, low muscle flexibility, decreased joint mobility and insufficient capacity of the stabilizing muscles may change the biomechanics of the spine in an inopportune way (by increasing spinal loading).

Lifestyle factors

Physical activity. Based on the literature review by Duggleby and Kumar (1997) and Ebbehoj et al. (2002), it was concluded that intensive sport exposure and inactivity are both possible risk factors for low back pain in schoolchildren. Corresponding with these findings, studies among an athletic population of schoolchildren found conclusive results. Kujala et al. (1992) found that the duration of training was higher in children with low back pain reports. The study of McMeeken et al. (2001) added that the incidence and magnitude of pain was higher in young athletes when compared to controls. Furthermore, Korrovesssis et al. (2004) demonstrated with respect to athletic activities that sports exposure was significantly related to low back pain, but only in girls. Consistent with studies in athletic populations, competitive sports were explored with regard to back pain in schoolchildren. According to the study of Balagué et al. (1988), there was a positive relationship between competitive sport activities and back pain. Additionally, Balagué et al. (1999) revealed in their review that the risk for back pain in children and adolescents depends on the type of sport, the level of competition, the intensity of physical training and acute spinal trauma. In contrast, Harreby et al. (1999) found a positive association between competitive sports and back pain for boys only, while Sjolie et al. (2004) found no association between low back pain and participation in competitive sport activities.

Besides the studies exploring the possible risk of physical activity for low back pain in young athletes, the risk of physical activity was evaluated in non-athletic populations. In non-athletic children, consistent results were found with regard to the risk of being not physically active. Accordingly, Sjolie et al. (2004) indicated that being physically active less than three times weekly was associated with low back pain during the preceding year. In the same line,

Salminen et al. (1993 and 1995) showed in their prospective 3-year follow-up study that schoolchildren with initial low back pain and back pain at follow-up were characterized by a low frequency of leisure time physical activity. Besides, research on the relationship between physical activity and low back pain in schoolchildren reveals contradictory evidence. On the one hand, three studies reported that increased physical activity (Newcomer and Sinaki 1996), such as practice of sports more than two times a week (Kovacs et al. 2003) or frequent participation in a high level of physical exercise (Jones et al. 2003), increased the risk for back pain. Additionally, Burton et al. (1996) found a positive association between sports participation and back pain, but only for boys. On the other hand, Grimmer and Williams (2000) reported that regularly participation in organized sports had just a protective effect for low back pain in schoolchildren. Along the same lines, Gunzburg et al. (1999) demonstrated no difference in reported low back pain between children actively involved in sports activities and those who were not. Finally, Feldman et al. (2001), Watson et al. (2003), Cardon et al. (2004) found no associations between physical activity and low back pain in schoolchildren. Furthermore, the first study making use of objectively measured physical activity with accelerometers in relation to back pain did not demonstrate an association between any of the accelerometer measures and schoolchildren's pain reports (Wedderkop et al. 2001). As a final interesting point, study findings of a recent 25-year follow-up study (Mikkelsen et al. 2006) showed that men who were physically active in adolescence were at lower risk for development of recurrent low back pain. Women showed a similar but insignificant trend. It was hypothesized by Mikkelsen et al. (2006) that being physically active during childhood and adolescence may modify the sensory perception of the central nervous system, which could be one possible underlying mechanism for the fewer pain reports in subjects who have been physically active at young age.

Sedentary activity in leisure time. Grimmer and Williams (2000) reported consistent indications for an increased risk of low back pain in young people who were sitting for long periods of time after school. Along the same lines, four studies (Balagué et al. 1988, Kristjansdottir and Rhee 2002, Sheir-Neiss et al. 2003, Troussier et al. 1994) showed that schoolchildren with back pain spent significantly more hours watching TV and/or using computers than those without back pain. In contrast, three studies did not identify a relationship between the amount of time spent sitting during leisure time and back pain (Harreby et al. 1999, Kovacs et al. 2003, Watson et al. 2003). In the same line, Jones et al. (2003) demonstrated prospectively that the extent of sedentary activities did not have any effect on the future onset of pain in schoolchildren. Finally, two studies reported conflicting results when evaluating simultaneously different facets of sedentary activity. Accordingly, Sjolie (2004) found that low back pain was positively associated with television or computer use, but not with the time spent reading, whereas Gunzburg et al. (1999) observed

significantly more low back pain in children who reported playing video games for more than two hours per day, but this was not so for television watchers. Based on children's reporting, sitting is found to be the most reported provoking factor in the literature associated with back pain (Balagué et al. 1999). However, there is no persuasive evidence to explain whether this finding is a result of the sitting activity and posture related aspects or because of the inactivity in itself (Cardon and Balagué 2004).

Job after school. Discussing schoolchildren's work-related activities during off-school hours brings up obvious evidence. Three studies focusing on having a job in leisure time consistently reported that having a job during off-school hours, certainly a heavy job, increased the risk for back pain reporting (Feldman et al. 2001, Harreby et al. 1999, Watson 2003). The prospective study of Jones et al. (2003) emphasized this finding demonstrating in schoolchildren that having a job at baseline increased the risk of low back pain at follow-up. However, a difference between job type, number of hours worked per week or whether the job required the lifting of heavy loads was not found (Jones et al. 2003).

Nutrition & alcohol. Kristjansdottir and Rhee (2002) found in schoolchildren aged 11-12 and 15-16 years a positive relationship between back pain and poor eating habits regarding irregular meal intake, eating fast food, snacking and coffee drinking. However, the latter associated factors only explained a small proportion of the total variance in back pain. With respect to alcohol consumption, Kovacs et al. (2003) did not find an association between low back pain and alcohol consumption. Kristjansdottir and Rhee (2002) reflected on children with irregular eating habits and alcohol intake in relation to back pain. They speculated that children with poor eating and drinking habits may be at risk for overall malnutrition, or at best for an inappropriate nutritional state, in which there is a deficit of nutrients and minerals essential to musculoskeletal functioning and strength.

Smoking. Recently, the cohort study of Mustard et al. (2005) demonstrated in 4-16 year old schoolchildren who were resurveyed 13 years later, that the risk for development of back pain was associated with smoking. The relationship between smoking and back pain was confirmed in the review articles by Duggleby and Kumar (1997), Balagué et al. (1999), Rozenberg and Bourgeois (1999) and Ebbelohj et al. (2002). Correspondingly, six of the seven original studies in schoolchildren aged 7-18 years pointed out consistently that smoking was a significant risk in relation to back pain (Balagué et al. 1988, Brattberg et al. 1994, Feldman et al. 1999, Harreby et al. 1999, Kristjansdottir and Rhee 2002, Vikat et al. 2000). Only one study did not find an association between cigarette smoking and low back pain (Kovacs et al. 2003). According to the review of Leboeuf-Yde (1999) and Goldberg et al. (2000), it remains unclear whether the relation between smoking and back pain onset is causal. However, in the recent mixed cross-sectional and prospective study by Hestbaek et al. (2006), smoking was positively associated with low back pain including evidence for a

causal link between smoking and low back pain. Potential mechanisms which may underlie this causal role for smoking in the risk of back pain include effects on the cardiovascular system, mechanical effects arising from coughing, and nicotine effects in the neuromuscular system (Goldberg et al. 2000, Power et al. 2001).

Basically, it can be concluded that working during off-school hours is associated with reported back pain in schoolchildren. Further, intensive sports exposure and being physically non-active are consistently identified as risk factors for back pain reports in schoolchildren. On the other hand, further study is necessary to explore whether sedentary activities are a risk for developing back pain in schoolchildren, and particularly the role that prolonged sitting and seating postures may play. Along the same lines, the study findings on smoking and eating habits in relation to back pain in children remain controversial. However, the discourse regarding the relationship between lifestyle factors in relation to back pain in children has to deal with some hindrances. Questioning life-style factors, the risk that children may underreport undesirable habits (such as alcohol intake, smoking, eating fast food, snacking) can not be excluded. Social desirability is a typical confounding factor using self-administered questionnaires. In the same line, children's daily habits belonging to their lifestyle may indirectly reflect psychosocial distress and social problems (parental educational level, socio-economic status), which are recognized as main sources in reporting back pain. So, both under reporting of lifestyle factors and the characteristic of the latent psychosocial variables being interrelated with back pain reports may play an important part in the complexity of identifying the relationship between lifestyle factors and back pain.

Psychosocial factors

Negative psychosocial characteristics. Based on the vast amount of literature investigating psychosocial factors in relation to back pain reports in schoolchildren, there is conclusive evidence supporting a relationship between psychosocial factors and reported back pain. In the study by Balagué et al. (1995) a distinction was made between positive and negative psychosocial factors. The latter study demonstrated that negative psychosocial factors were associated with increased back pain reports in schoolchildren while positive factors were associated with a reduction of self-reported pain (Balagué et al. 1995). These findings were in agreement with multiple studies emphasizing in schoolchildren the association between back pain and negative psychosocial characteristics, such as low psychological profile with regard to sleep quality and health perception (Spalzki et al. 2002, Vikat et al. 2000), a higher degree of somatising (Jones et al. 2003, Staes et al. 2003, Van

Gent et al. 2003), increased fear-avoidance beliefs (Burton et al. 1996), diminished self-esteem (Staes et al. 2003), augmented negative affect (Staes et al. 2003), poor well-being (Sjolie 2002), dislike of going to school (Storr-Paulsen 2002), low life quality (Harreby et al. 1999), poor mental health (Feldman et al. 2001), conduct problems (Watson et al. 2003, Jones et al. 2003), anger (Jones et al. 2003), disobedience and violence (Jones et al. 2003), lower perceived social support (Kristjansdottir and Rhee 2002, Staes et al. 2003) and poor school performances (Balagué et al. 1994, Salminen 1984). In addition, Gunzburg et al. (1999) demonstrated that general well-being in 9-year-old schoolchildren was inversely related with back pain. Furthermore, the prospective study by Jones et al. (2003) concluded that in children who were initially free of pain, adverse psychosocial factors and the presence of conduct problems and high levels of hyperactivity were predictive for future low back pain.

Parental educational level and socio-economic status. In the studies of Sjolie (2002) and Siambanes et al. (2004) socio-economic status was not related to the prevalence of back pain. However, Vikat et al. (2000) observed socio-economic background of the family of origin as a predictor for back and neck pain. Additionally, Leboeuf-Yde et al. (2002) demonstrated a significant negative association between the level of parental education and back pain in children. Along the same lines, the cohort study by Mustard et al. (2005) reported an association between low parental socio-economic status and incidence of back pain in early adulthood.

Basically, the literature indicates that children with negative psychosocial experiences are more likely to report back pain. Additionally, there is some evidence to support the hypothesis that socio-economical influence during childhood is predictive for future back pain. With reference to the underlying mechanism of possible psychosocial correlates for back pain, an interaction between physical and psychosocial risk factors was identified in adult populations (Devereux et al. 1999). It was hypothesized that psychosocial stress may increase spinal loading due to muscle tension, suggesting a mechanical explanation for a part of the related back pain report (Marras et al. 2000).

School-related factors

Furniture. All studies focusing on school furniture in relation to children's anthropometric characteristics (Limon et al. 2004, Milanese and Grimmer 2004, Panagiotopoulou et al. 2004, Parcels et al. 1999) demonstrated a mismatch between the dimensions of school furniture and anthropometrics. It was observed that nearly 80% of 6-13 years old schoolchildren cannot find appropriate chair desk combinations in the class, particularly due to chairs with seats that are too high and too deep and desks that are too high. On the other hand, traditional school furniture itself is frequently taken to be the reason

for posture problems and back complaints (Milanese and Grimmer 2004, Salminen et al. 1992, Troussier et al. 1999). Though, the possible beneficial effects of the use of ergonomically designed chair-desk combinations on elementary schoolchildren's back pain were not shown (Troussier et al. 1999). On the other hand, Candy et al. (2004) showed that the use of a seat wedge was associated with a reduction of back pain reports.

Sitting. With respect to sitting in the school environment, prolonged static sitting and poor posture were identified as possible risk factors for back pain in children (Knight and Noyes 1999, Murphy et al. 2004). Furthermore, the static class organizations usually applied in traditional schools seemed to stimulate prolonged sitting (Cardon et al. 2004, Storr-Paulsen and Aagaard-Hansen 1994). Regrettably, children seemingly spent these required periods of prolonged sitting in poor postures (Murphy et al. 2002).

Book bag related factors. The ambiguous relationship between book bags and back pain in children was emphasized in a review of Cardon and Balagué (2004). Korovessis et al. (2005) demonstrated that back pack carrying resulted in asymmetric postures and frontal trunk shifts which were both associated with high intensity of pain. Based on the literature, the majority of studies could not provide evidence for the association between back pain and either type of school bag, method of carrying or the percentage of body weight carried (Goodgold and Nielsen 2003, Jones et al. 2003, Korovessis et al. 2004, Van Gent et al. 2003, Watson et al. 2003). On the other hand, two studies demonstrated that schoolchildren's perceived book bag weight was related to their reported back pain (Negrini and Carabalona 2002, Szpalski et al. 2002). This finding was in agreement with the study of Sheir-Neiss et al. (2003) reporting that schoolchildren with back pain carried heavier school bags representing a greater percentage of their body weights when compared to controls. In contrast, Watson et al. (2003) established that children with a higher relative book bag weight reported pain less frequently.

Lifting. A study that focused on the possible risk for back pain in children related to lifting activities in the school environment could not be located. However, lifting is included as a school-related correlate since schools autonomously determine the kind and amount of lifting activities, such as the daily organization of refreshment consumption and lunch using storages in each classgroup. Additionally, lifting activities are subsistent to the mandatory lessons physical education of both the elementary and secondary timetables. Furthermore, grammar schools may present vocational directions typically including lifting tasks. So, lifting and especially excessive lifting and twisting have been associated with back pain reports in adolescent athletes (Harvey and Tanner 1991). Furthermore, evaluation of the risk of lifting in the adult occupational setting revealed conclusive evidence indicating lifting as a risk factor for back pain (Frymoyer et al. 1983).

Basically, there is a mismatch between dimensions of school furniture relative to children's anthropometric characteristics. Prolonged static sitting and poor postures are common in the school environment and are related to back pain reports. Backpack loading may act as an aspect within the multi-factorial risk for back pain considering the U-shaped function for optimal loading, but persuasive evidence for a causative relationship with back pain is missing. Little is known about the possible risk of lifting for back pain at young age (in a non-occupational setting). The mechanical exposure of the school environment was acknowledged as underlying mechanism for the school-related factors in relation to back pain by Jones et al. (2003). The daily load by the school environment may help to counterbalance the optimal daily loading of children's young body structures (carrying loads, poor postures, prolonged sitting) considering the believed U-shaped function (too much exposure is harmful).

Summarizing the discussion on risk factors for back pain at young age, the comment on the multi-factorial nature of the risk for back pain at young age (Jones et al. 2005) needs to be repeated. Based on our literature review, the study findings on risk factors showed for the major part inconsistent findings when they were evaluated separately. Since different researches for a specific risk factor demonstrated other results when that factor was investigated in another arrangement of risk factors, the multi-factorial nature of the risk for back pain in childhood and the interrelationship between risk factors may be assumed. As a result, a multidimensional approach is recommended in order to study correlates influencing back function and in an attempt to determine preventive measures for back pain in childhood.

3. Interventions to promote good back function in children

Because of the considerable prevalence figures for back pain at young age and the tendency for increased back pain reports in youngsters, school-based intervention studies entered the last decennia in the scientific field in the scope of back pain prevention at young age. However, till now most of the modifiable risk factors for back pain in childhood and adolescence remain unclear due to conflicting study results of widespread research.

It is widely accepted that the schools are in charge for health promotion among children (Johnson and Despande 2000). Furthermore, based on epidemiologic evidence and biomechanical concepts, one may assume exposure of the school environment related to the potential loading factors regarding prolonged poor sitting and absence of appropriate furniture. In consequence, the school is an ideal setting for primary prevention with regard to optimal loading since it has the potential of optimizing environmental conditions and giving

prolonged feedback reaching a large percentage of the population. Moreover, the school setting allows parental involvement throughout information sessions, meetings and deliverance of educational material.

Different approaches have been used to optimize the daily load on children's body structures through the school environment. Primarily, one has attempted to modify school furniture. In this line, the introduction of ergonomically designed furniture was not convincing since children did not automatically sit properly on ergonomically designed furniture (Troussier et al. 1999). On the other hand, Candy et al. (2004) found that the use of a sitting wedge was effective and associated with a reduction of back pain reports. Besides modification of the school furniture, back education programs have been used to promote good back function through the school curriculum by increasing children's postural knowledge in order to alter their postural behavior. A back education program in order to promote a biomechanical favorable lifestyle usually contains a series of lessons about anatomy, biomechanics and recommended postural behavior. Back education is frequently integrated in the school curriculum.

Recently the effectiveness and quality of school-based interventions to promote good back function in children were discussed in two review studies. The review by Cardon and Balagué (2004) focused on the effects of multi-component school-based interventions while Steele et al. (2006) included both *uni- and multi-component* interventions to discuss effectiveness, as presented in figure 5. In the recent review of Steele et al. (2006) the following twelve school-based intervention studies were evaluated in terms of knowledge, postural behaviors and pain prevalence as summarized below in figure 5.

(1) Balagué et al. (1996) aimed to decrease prevalence of low back pain in elementary schoolchildren by implementing the principles of Swedish back school during two sessions of 90 minutes and two annual sessions. The 3-year intervention study resulted in an overall reduction of low back pain prevalence.

(2) (3) (4) The intervention study by Cardon et al. (2001, 2002, 2002) was designed in order to improve body mechanics and postural behavior in elementary schoolchildren. A controlled pre-post design with a 1-year follow up was used to evaluate the effects of a six-week back education program. The multi-factorial program had a significant impact on the use of back education principles up to one year. However, a transfer of postural principles into the daily unconscious sitting behavior of the child was not found. In a supplementary study (Cardon et al. 2001), extra support formulating specific guidelines for class teachers in order to enhance the implementation of learned principles turned out to be efficacious.

(5) In the intervention study by Feingold and Jacobs (2002) a 30 minutes educational session was implemented in order to improve children's back-pack wearing posture.

After the intervention the children's postures had not significantly improved, but their back pain reports were decreased.

(6) The intervention study performed by Mendez and Comez-Conesa (2001) aimed to prevent the occurrence of low back pain. A postural hygiene program was applied to elementary schoolchildren. The 8-week postural program resulted in increased back-care-related knowledge and improved general postural habits.

(7) (8) The interventions by Goodgold (2003) and Goodgold and Nielsen (2003) were developed in order to improve the safety of back pack carriage in schoolchildren through education as part of the physical activity school curriculum. After schooling, 42% of the children had changed the way to use their back pack and 93% felt knowledgeable about back pack safety, which was an increase of 24%.

(9) Robertson and Lee (1990) investigated the effects of back care education that was structured in the school curriculum to teach acceptable sitting postures, safe lifting techniques and sports injury prevention procedures. The results indicated that back education had an immediate impact on children's sitting and lifting behavior.

(10) Schwartz and Jacobs (1992) aimed to train children in making appropriate and safe decisions with regard to the use of their body in order to prevent the onset of back pain. Children's knowledge was improved after the intervention when compared to pre-intervention results.

(11) In the study by Sheldon (1994) schoolchildren were trained in safe lifting techniques teaching back care principles. After the informative session, children's knowledge and postural behavior with respect to safe lifting was improved.

(12) The study by Spence et al. (1984) compared two teaching methods in order to educate safe lifting techniques. No differences were found between the two methods. Further, the study results did not indicate improved lifting behavior after the intervention while children's knowledge was increased.

School-based intervention studies	Intervention characteristics			Study characteristics			Outcome
	PURPOSE	IMPLEMENTATION TIME	CONTENT	SAMPLE SIZE	AGE OF PARTICIPANTS	TIME BETWEEN IMPLEMENTATION AND EFFECT EVALUATION	
School-based intervention studies	To minimize back pain complaints by increasing schoolchildren's body-consciousness	A theoretical session for the class teacher	Body consciousness awareness program through increased awareness among teachers	532	6-15 years	1 year	The intervention had no effect on pupils' back pain prevalence
	To decrease low back pain prevalence	Two sessions of 90 minutes and two annual sessions	Swedish back school principles	1715	11.7 years	3 years	The intervention resulted in an overall reduction of low back pain prevalence
	To improve body mechanics and postural behavior	A six-week back education program, six sessions one per week	Back school including spinal care principles and exercise	120	11 years	11 weeks	Postural behavior was improved and extra support formulating specific guidelines turned out to be efficacious
				706	10 years	1 year	A transfer of postural principles into daily unconscious sitting behavior was not found
				706 / 363 / 69	10 years	1 year	Intervention children scored better on all practical test items and reported lower self-reported pain
Multi-factorial school-based intervention	To improve children's posture and back-pack wearing method	One 30-minutes session	Educational lecture including good back pack related principles	17	13 years	1 week	Children's postures were not significantly improved, but their back pain reports were decreased
	To prevent low back pain occurrence	A 8-week postural hygiene program, 11 sessions	Exercise, behavioral intervention and self-monitoring	106	9 years	1 year	The postural program resulted in increased back-care-related knowledge and improved general postural habits
Uni-factorial school-based intervention	To improve the safety of back pack carriage	One session within physical education curriculum	Lecture about good back pack related guidelines	252	ns	Few months	After schooling, 42% of the children had changed the way to use their back pack and 93% felt knowledgeable about back pack safety, which was an increase of 24%
	To teach acceptable sitting postures, safe lifting techniques and sports injury prevention procedures	Three sessions	Back care education	91	ns	Immediate	Back education had an immediate impact on children's sitting and lifting behavior
	To train children to make appropriate and safe decisions with regard to the use of their body in order to prevent the onset of back pain	A 60-minutes session	Lecture on anatomy, biomechanics and risks for injury	141	ns	1 month	Children's knowledge was improved after the intervention when compared to pre-intervention results
	To train children safe lifting techniques	One session	Lecture on back care principles and risk factors	70	6 th to 8 th graders	6 weeks	Children's knowledge and postural behavior with respect to safe lifting was improved
	Comparison of two teaching methods to educate safe lifting techniques	One session	Lecture on safe lifting techniques including demonstration	76	11-14 years	2 months	The study did not result in improved lifting behavior while children's knowledge was increased

* Multi-factorial intervention study included in the review of Cardon and Balmués (2004)

** Uni-factorial intervention studies included in the review of Steele et al. (2006)

*** Multi-factorial intervention studies included in the review of Cardon and Balmués (2004) and Steele et al. (2006)

ns: not specified

Figure 5: Overview of school-based intervention studies focalizing on back function.

Analyzing the findings of the 12 school-based intervention studies, it was demonstrated that back health promotion was effective in increasing knowledge and decreasing back pain prevalence (Steele et al. 2006). Additionally, the majority of the intervention studies demonstrated beneficial effects on postural behavior. However, the quality of all intervention studies was questioned owing to one or more shortcomings with regard to small sample sizes, uncontrolled study designs, lack of considering confounding factors or poor data collection methodologies (Steele et al. 2006). Therefore, the reviewers advocated further research before the effectiveness of school-based interventions regarding promotion of good back function should be quantified. Though, remarkable differences in the quality of the intervention studies were reported by Steele et al. (2006). Accordingly, the authors mentioned that the quality appraisal tool for their systematic review was based on the method as prescribed by the Cochrane Health Promotion and Public Health Field, evaluating literature with different study designs. The authors designated that a different tool, directly concentrated on the evaluation of intervention-study's characteristics, might have been more sensitive in differentiating the quality discrepancy of the 12 included interventions studies.

In the recent review of Cardon and Balagué (2004) focusing on *multi-componential* school-based interventions, only five school-based intervention studies could be included. In agreement with the findings of Steele et al. (2006), Cardon and Balagué (2004) concluded that school-based intervention studies are promising but too limited to formulate evidence-based guidelines.

4. Summarize and reasoning of the study aims

Back pain in childhood is a common condition but symptoms are generally mild, non-specific and do not lead to restrictions of daily activities. At young age back pain represents little health consequences. An epidemiological review reported that the life time prevalence in adulthood reaches 80% (Walker 2000). This high prevalence of back pain implies a high social and economic charge and restrains a considerable part of the population in their personal psychosocial and functional functioning.

The predictive value of back pain at young age for back pain as an adult, stresses the need for primary prevention (Brattberg 2003, Feldman et al. 2001, Harreby et al. 1999). However, a critical point in the prevention-intervention discourse includes the lack of evidence for the direct impact of primary prevention on back pain prevalence (Linton and Van Tulder 2001), certainly in children (Cardon and Balagué 2004). One could question whether self-reported back or neck pain is the right outcome of a back education program in elementary schools. In the scope of early interventions, evaluation of the possible change of correlates influencing

back function in the school environment seems ambitious in respect to the possible change of back pain prevalence in the longer term. Thus, back pain prevalence might better be approached as a long term effect while the evaluation of back education programs should focus on the direct effects like better back posture knowledge and modifications in factors influencing spinal loading in the school environment. Based on the literature, high fear-avoidance beliefs and misconceptions about pain are persistent in adults playing a significant part in the development of long-term disability (Goubert et al. 2004). Given the 80% life time prevalence for back pain in adulthood (Wadell 1998), it is important that early back education in children does not result in increased fear-avoidance beliefs. Therefore, it is relevant to examine in an intervention study whether children's fear-avoidance beliefs and self-reported pain increase as a potential consequence of the attention for pain.

Notwithstanding, primary prevention should focus on good back functioning, instead of being focused on back pain prevalence. Based on epidemiologic evidence and the biomechanical concept suggesting a U-shaped relationship for optimal loading, several correlates may influence children's back function. Accordingly, the school environment seems to expose children to prolonged poor sitting (Murphy et al. 2004) and the use of inappropriate furniture (Panagiotopoulou et al. 2004). Along the same lines, children spend much time in school and spend much time sitting (Storr-Paulsen and Aagaard-Hansen 1994).

As a result, sitting behavior in elementary schoolchildren was an important issue in this doctoral thesis exploring classroom postures in 8 to 12 year olds (Chapter 1) and creating our intervention to promote good back functioning (following paragraph).

Further, the promotion of good back function in the elementary school environment seemed useful because of the promising results of preceding research with regard to improved postural behavior and increased back posture knowledge. However, the preceding school-based intervention studies were for the most part too limited considering intervention characteristics as well as study characteristics (Cardon and Balagué 2004, Steele et al. 2006).

Therefore, the present doctoral investigation aimed to optimize the promotion of good body mechanics based on the qualities and limitations of preceding school-based intervention studies (Chapter 3).

- Since multiple correlates seemed to affect mechanical loading within the school environment demanding for a multi-factorial approach to promote good back function, the present intervention was *multi-factorial*.

- Further, the multi-factorial intervention was a more intensive program with respect to *implementation time* and *program intensity* in comparison to five preceding multi-factorial school-based intervention studies (see summarizing table - figure 5).
- Accordingly, it was demonstrated that sitting habits are more favorable in a 'Moving School', which encourages movement during lessons through work organization and circumstantial and behavioral influences (Cardon et al. 2004). Along the same lines, Murphy et al. (2004) found that less movement during lessons and longer lessons were related to the likelihood of back and neck pain occurring in schoolchildren. Moreover, in a previous intervention study promoting good body mechanics the sitting postures during lesson times were not improved (Cardon et al. 2002). Based on the study findings of the latter studies, the present promotion included an additional *focus on sitting in the school context* during daily class activities. Therefore, two basic principles were elaborated to *increase postural dynamism in the class*: stimulation of dynamical sitting and prevention of prolonged static sitting. 'Postural dynamism' stands for frequent posture changes in addition to variable and dynamical activities
- Cardon et al. (2002) demonstrated that extra support formulating specific guidelines for class teachers in order to enhance the implementation of learned principles turned out to be efficacious. As a result, the current back posture program provided *didactic material* and presented *intervention guidelines for teachers* in order to increase postural dynamism and to optimize the integration of learned back posture principles.
- Final optimizations of the present intervention included that intervention effects were studied in a *pretest posttest design over two school-years* using an *experimental and a control group* with *randomization* at school level. In addition, the study design incorporated a *1-year and a 2-year follow-up* measurement.

Summarizing the characteristics optimized intervention, the present intervention was a comprehensive *multi-factorial* program to optimize the daily load on young spinal structures during *two school-years* with additional focus to *increase postural dynamism in the class* and with *involvement of class teachers*. Further, the present intervention study attempted to eliminate restrictions regarding sparse *post-intervention measurements*, small *study samples*, short *duration of post-intervention follow-up*, and non-*randomized controlled trials*.

Furthermore, epidemiologic and biomechanical evidence indicated that adequate back functioning in young individuals could possibly play a part in the multidimensional approach to prevent back pain. However, till now the possible effects of a school-based intervention program on children's back function were never evaluated.

Therefore, the current doctoral thesis intended to evaluate intervention effects on the school-related correlates 'classroom postures' and 'postural behavior during material handling' (Chapter 3 - Part 1) as well as on the functional correlates 'trunk muscle endurance', 'leg muscle capacity' and 'spinal curvature' (Chapter 3 - Part 2), in addition to 'back posture knowledge', 'fear-avoidance beliefs', 'self-reported pain' (Chapter 3 - Part 1, 3 & 4) and 'self-reported postural behavior' (Chapter 3 - Part 4).

The evaluation of back function parameters in 9- to 12-year olds constituted a problem. Measuring back function is only useful when reliability is determined. However, most studies on the reliability of functional test methods with respect to muscular endurance have been carried out in adults (Alaranta et al. 1994, Biering-Sørensen 1984, Essendorp et al. 2002, Hyytiainen et al. 1991, Latimer et al. 1999, Nordin et al. 1987) while a minority has been carried out in secondary school aged children (Oksanen and Salminen 1996, Salminen et al. 1992). Besides, the present doctoral investigation selected the Zebris® system for spinal assessment since this system allows the objective assessment of static curvatures. This system was never used to evaluate spinal curvatures in children.

As a result, an important objective of the current doctoral thesis was to test trunk muscle endurance performance and the Zebris® technique for reliability in children at elementary school-age (Chapter 3 - Part 2).

Finally, postural stability is considered to be an important indicator of musculoskeletal health and therefore could be of importance in view of clinical issues. The literature has identified disturbed postural control as a risk factor among the many risk factors for back pain in adults (Kuukkanen and Malkia 2000). In this line, postural control might also be a potential underlying mechanism among the multi-factorial risk for back pain at young age. However, based on the literature, reliability reports and normative data for bilateral stance assessments in elementary schoolchildren are limited. Only when reliability for stability assessments in elementary school-age children is established, reference data can be determined and the possible association with back pain can be investigated at an early stage of the problem.

Therefore, this doctoral thesis attended to determine test-retest reliability and reference values for postural stability in 9 to 10 years old schoolchildren using the Balance Master® System (Chapter 2).

Ending our ‘literature review’ with reference to back functioning in children, the central research aims of the present doctoral thesis are summarized in figure 6.

Central research questions	
To study the possible association between class-room postures and self-reported pain (Chapter 1)	To describe the effectiveness of promoting good body mechanics (Chapter 3)
<p>To portray children’s postural behavior in the class during lesson activities</p> <p>To evaluate the relationship between children’s self-reported pain and their postural behavior in the class</p>	<ol style="list-style-type: none"> 1. To evaluate intervention effects on: children’s postural knowledge, postural behavior in the class (sitting) and during material handling (lifting), fear-avoidance beliefs and self-reported pain To investigate children’s and teachers’ perceptions with regard to the 2-year promotion of good body mechanics 2. To evaluate intervention effects on correlates influencing children’s back function (muscular endurance, spinal curvature and leg muscle capacity) To study the reliability of measurements to evaluate correlates influencing back function (muscular endurance and spinal curvature) in an elementary school-aged population 3. To evaluate the stability of intervention effects on: postural knowledge, fear-avoidance beliefs and self-reported pain at 1-year follow-up To investigate whether class teachers persist in the promotion of good body mechanics post-intervention 4. To evaluate the stability of intervention effects on: postural knowledge, self-reported postural behavior, fear-avoidance beliefs and self-reported pain at 2-year follow-up
To evaluate the objective measurement of functional factors (Chapter 2)	
<p>To report test-retest reliability and reference values for the objective measurement of postural stability using the Neurocom Balance Master System in an elementary school-aged population</p>	

Figure 6: Central research aims.

PART 2: METHODS

1. Study aims & hypotheses

In the present doctoral thesis three central research aims were incorporated to evaluate correlates influencing postural behavior and back functioning at young age (figure 6 & 7). Back functioning refers to the underlying mechanisms for postural behavior focusing on muscle activity and spinal curvature due to their determinative role on spinal load distribution.

Three central research aims to study back functioning at young age	
I. Detection of school-related correlates	III. Evaluation of intervention effects
Association between classroom postures and self-reported pain in children <ul style="list-style-type: none"> ◦ <i>class room postures</i> ◦ <i>self-reported pain</i> 	Intervention effects on: 1. knowledge 2. correlates influencing children's back function a. school-related correlates ◦ <i>class room postures</i> ◦ <i>postural behavior during material handling</i> b. functional correlates ◦ <i>muscular endurance</i> ◦ <i>spinal curvature</i> ◦ <i>leg muscle capacity</i> 3. fear-avoidance beliefs 4. self-reported pain Stability of intervention effects 1. knowledge 2. fear-avoidance beliefs 3. self-reported pain 4. self-reported postural behavior
II. Measuring functional correlates	
Reliability study measuring functional factors influencing back function in children <ul style="list-style-type: none"> ◦ <i>postural stability</i> ◦ <i>muscular endurance</i> ◦ <i>spinal curvature</i> 	

Figure 7: Three central research aims to study back functioning at young age.

In one respect, the purpose of the doctoral thesis was to obtain specific information regarding biomechanical exposure in the elementary school environment and the possible relationship with back functioning at young age. In this line, the relationship between classroom postures and self-reported pain was evaluated in 8 to 11 year olds.

The hypothesis with regard to the detection of school-related correlates included that children's postural behavior during lesson time was poor and associated with back and/or neck pain reports.

Based on the literature there is a lack of reliability reports for functional measurement in the elementary school-aged population. Therefore, a second purpose was to gain insight in the objective measurement of functional factors in elementary schoolchildren. Therefore, test-

retest reliability for postural stability, trunk muscle endurance and spinal curvature assessment was investigated in an elementary school-aged population. Test-retest measurement for leg muscle capacity was not investigated since the reliability for measuring trunk muscle capacity is well documented in children (Deighan et al. 2003).

Finally, the major purpose of this doctoral thesis was to evaluate intervention effects on school-related and functional correlates in elementary schoolchildren (see also figure 4 - p 9). Therefore a comprehensive evidence-based multi-factorial intervention was conceived by optimizing a prior intervention program (Cardon et al. 2002). Accordingly, the effects of the optimized 2-year multi-factorial back education program on school-related and functional correlates were evaluated in elementary schoolchildren. Therefore, the children who followed the multi-factorial back education program with focus on postural dynamism in the school context were compared to the control group. An additional purpose was to evaluate the effects of the intervention promoting good body mechanics on children's back pain prevalence and fear-avoidance beliefs. As a result, elementary schoolchildren's classroom postures, postural behavior during material handling, back posture knowledge (school related correlates), trunk muscle endurance, leg muscle capacity, spinal curvature (functional correlates), in addition to self-reported pain and fear-avoidance beliefs were explored in a pre-post quasi-experimental study design. Furthermore, the stability of 2-year intervention effects was investigated in a 1-year follow-up study focusing on knowledge, fear-avoidance beliefs, self-reported pain and the role of the elementary school class teacher. As a final point the effectiveness of back posture promotion was discussed investigating stability of 2-year intervention effects two years after the intervention was finished. Children's knowledge, self-reported postural behavior, fear-avoidance beliefs and self-reported pain were addressed.

With respect to the evaluation of 2-year intervention effects, it was hypothesized that intervention children showed better back posture knowledge, improved fear-avoidance beliefs, better use of back posture principles, healthier back functioning and less back pain reports compared to a control group. In correspondence, the hypotheses for the follow-up studies incorporated that the 2-year intervention effects of the multi-factorial back education program remained stable both one and two years after the intervention was finished.

2. Study sample with respect to a broader experimental design & randomization

The present doctoral thesis was part of a broader research project entitled “Sport, Physical activity and Health” (Sport, Beweging en Gezondheid), carried out by the Policy Research Centre, a consortium of researchers from KULeuven, Ghent University, and VUBrussel. This Policy Research Centre was funded by the Flemish Government together with 12 other Policy Research Centers for the time span of 2002 to 2006. The main purpose of the Policy Research Centre “Sport, Physical activity and Health” was to provide scientific support to the Flemish Government with regard to sports participation, physical activity, fitness and health. Besides gaining more insight into the current status of and the relationship between sports participation, physical activity, fitness and health in the Flemish population, an important aim of the Policy Research Centre was to evaluate effects of intervention programs promoting physical activity, sports participation and health in different populations of the Flemish community. As part of this last aim, an intervention study was executed, investigating the effects of the promotion of physical activity and good body mechanics in elementary schoolchildren. Therefore, 16 Flemish elementary schools were selected by simple randomization.

In Flanders, education is regulated and for the largest part financed by one of three communities. The schools can be divided in three groups based on their educational system: (1) schools owned by the communities (gemeenschapsonderwijs), (2) subsidized public schools organized by provinces and municipalities (officieel gesubsidieerd onderwijs), (3) subsidized free schools mainly organized by an organization affiliated by the catholic church (vrij gesubsidieerd onderwijs). The three communities have a unified school system, with only small differences between the three educational systems.

The simple randomization with respect to the broad experimental design (promotion of physical activity and promotion of good body mechanics) was conducted considering a priori a single inclusion factor (province East-Flanders) and two exclusion criteria (city center of Ghent, education for groups with special needs). Additionally, the randomization was stratified for educational system taking the actual distribution of the three educational systems into account. The province East-Flanders was selected because of practical implications reaching the schools from the housing of our department (Ghent, the provincial capital town). Schools in the city center of Ghent were excluded due to over demand for participation in various researches within the broad scientific field, performed by the multiple departments at the Ghent University. A posteriori, analyzes showed that no differences between conditions were found for parental education levels, type of school furniture,

children's anthropometrical characteristics (length, weight, BMI), gender and chronological age.

An overview of all schools is annually published in Flanders by the Ministry of Education. Different volumes present school lists for each of the five Flemish provinces, discriminating between common education and education for groups with special needs as well as between elementary and secondary education. In each volume, the schools are categorized by educational system. The province East-Flanders counted 421 elementary schools associated to common education and outside the city center of Ghent. The schools were presented over 81 pages. The 2nd school on every 10th odd page was selected and contacted for participation (every 5th page, every 3rd page). Sixteen elementary schools were selected (4 community schools, 4 subsidized official schools, 8 subsidized free schools). No school refused to participate.

The total study sample comprised 810 elementary schoolchildren (mean age at baseline: 9.7 ± 0.7 years). The 4th and 5th grade children of the 16 elementary schools were randomly assigned at school-level into one of the four conditions, taking the actual distribution of the educational systems into account (in each condition a community school, a subsidized official school and 2 subsidized free schools): the experimental group promoting physical activity (PA, 4 schools), the experimental group promoting good body mechanics (BACK, 4 schools) the experimental group promoting good body mechanics in addition to physical activity (BACK+PA, 4 schools) and the control group (CONTROL, 4 schools).

The present doctoral thesis was a part of the intervention study investigating the effects of the promotion of physical activity and good body mechanics in elementary schoolchildren. However, the major purpose of this thesis was to evaluate the effects of the promotion of good body mechanics focusing on elementary schoolchildren's back function. Since the role of physical activity as part of a back education program is unclear in the literature, the experimental schools promoting physical activity were not integrated in the data analysis of the current doctoral thesis. Therefore, the 2x2 factorial design was reduced to a controlled design including two conditions: the intervention group which received promotion of good body mechanics (BACK, 4 schools) and the control group (CONTROL, 4 schools). The experimental part of the present doctoral thesis included thus at baseline participants of eight Flemish elementary schools (figure 8).

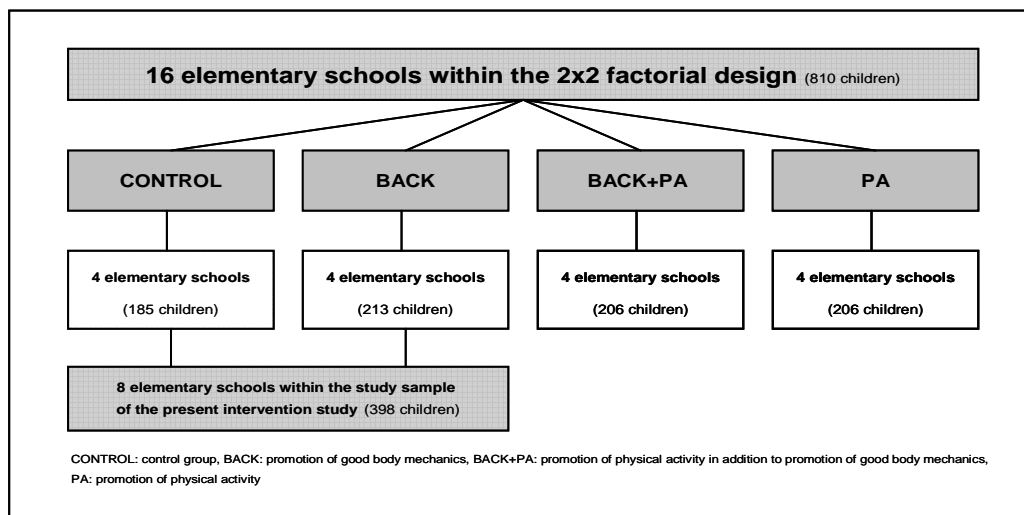


Figure 8: Study sample with respect to a broader experimental design .

The interaction of physical activity promotion and promotion for good body mechanics in elementary schoolchildren by comparing the BACK group, the BACK+ PA group and the CONTROL group was reported by Cardon et al. (2006). In the general conclusions (Section 3), the effects of adding a physical activity promotion program to a multi-factorial back education program in elementary schoolchildren will be discussed.

3. Participants

3.1 Relationship between sitting behavior and self-reported pain (cross-sectional study)

In the scope of this doctoral thesis evaluating correlates of back function at young age, the possible relationship between children's sitting behavior and self-reported pain was focused. The latter relationship was investigated at baseline in elementary schoolchildren out of the broader research project (n=810). In each class, two to three children were selected by simple randomization for the observation of their sitting behavior during a regular lesson. As a result, the class room observations of 105 children were evaluated using a cross-sectional study design (54 boys, 51 girls; mean age 9.9 ± 0.8 years), as presented in figure 9.

3.2 Reliability of trunk muscle endurance, spinal curvature assessment and postural stability

The reliability of back function measurements in children was evaluated in a separate sample. The participants were 4th and 5th grade children out of an elementary school, which was selected by simple randomization. The study sample comprised 47 children for test-retest reliability of trunk muscle measurement (23 boys, 24 girls; mean age 10.1 ± 0.5 years), 40 children for test-retest reliability of the spinal curvature assessment (19 boys, 21 girls; mean age 10.2 ± 0.7 years) and 20 children for test-retest reliability of postural stability (10 boys, 10 girls; mean age 10.1 ± 0.7 years).

3.3 Evaluation of intervention effects (intervention and follow-up studies)

Effects on school-related correlates

As mentioned above, eight Flemish elementary schools were selected by simple randomization. The total study sample comprised 398 elementary schoolchildren (mean age at baseline: 9.9 ± 0.8 years). All schools were comparable with regard to geographic location and parental educational levels. The 4th and 5th grade children of the eight elementary schools were simply randomized at school-level into the intervention group (BACK) and the control group (CONTROL). During the second intervention year, 33 children dropped out as they changed school or because they were not present at the days of data collection. The total drop-out of 8.5% was equally distributed in the intervention group (9.7%) compared to the controls (7.1%). At post-testing, the intervention group consisted of 193 participants (93 boys, 100 girls; mean age 11.3 ± 0.8 years) and the control group included 172 children (82 boys, 90 girls; mean age 11.4 ± 0.8 years), as presented in figure 9.

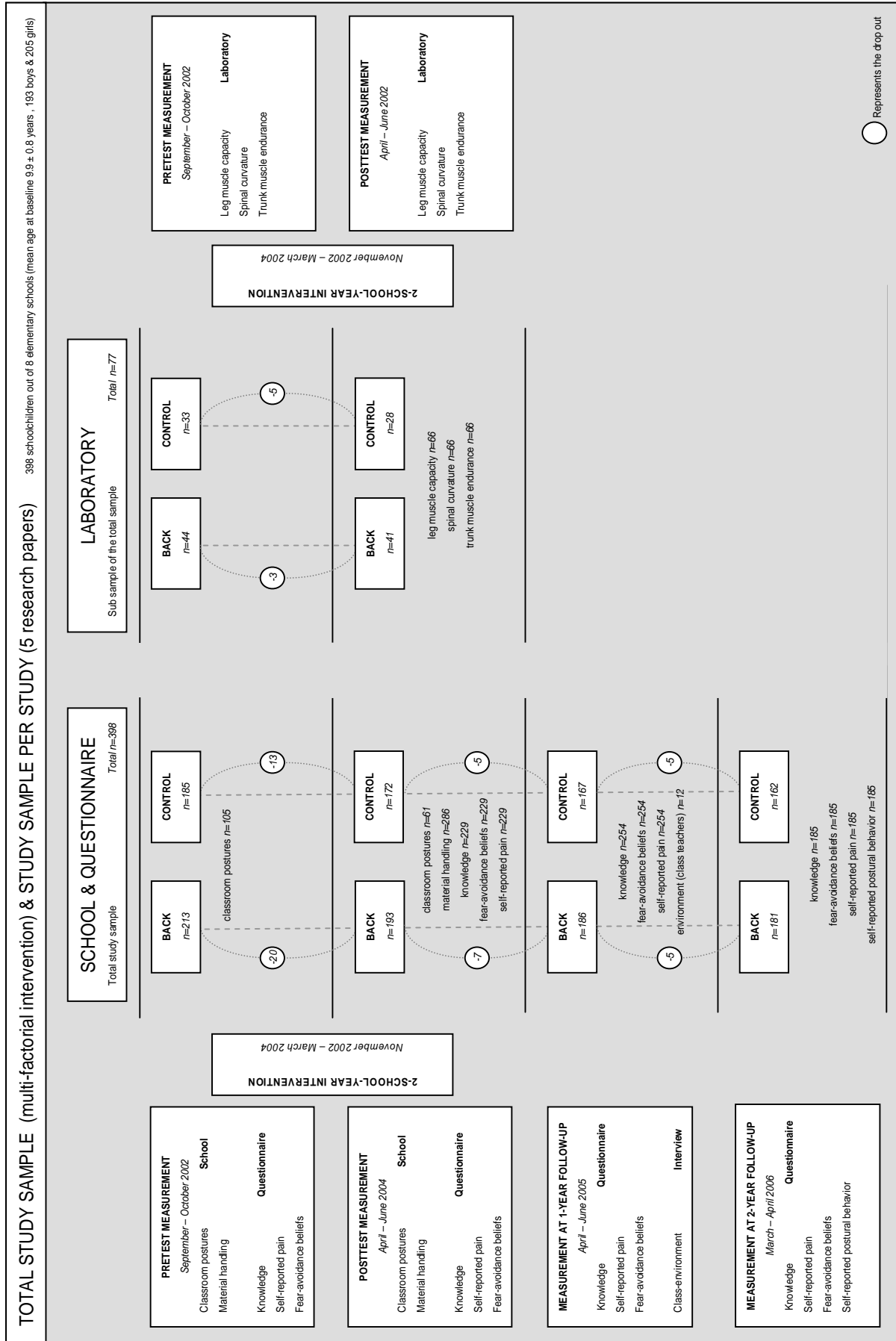


Figure 9: Composition of the study samples.

Effects on back functioning

In a sub sample of the total study sample (n=398), 77 children were at baseline tested for in depth measurements in the Centre for Sports Medicine at the Ghent University Hospital (figure 9). Eight children dropped out as they changed school (n=5) or because they were absent on the testing day (n=3). As a result, at posttest evaluation the intervention group consisted of 41 participants (19 boys, 22 girls; mean age 11.2 ± 0.9 years) and the control group included 28 children (11 boys, 17 girls; mean age 11.4 ± 0.6 years).

1-year follow-up study

Between post-test evaluation and follow-up testing, eight 6th grade children (5 intervention children and 3 controls) dropped out as they changed school and the addresses of four 7th grade pupils (2 intervention pupils and 2 controls) were missing according to a change of address. The total study sample at 1-year follow-up consisted of 353 children (figure 9) including 266 responders (119 boys, 147 girls; mean age 12.1 ± 0.7 years) which represented a response rate of 75.4%. From 12 participants, the questionnaire-based data could not be included in the statistical analyses at 1-year follow-up due to non-response at pre- and/or post-test evaluation.

2-year follow-up study

Between 1-year and 2-year follow-up evaluation, ten children dropped out due to a change of address. At 2-year follow-up, the intervention group consisted of 94 secondary schoolchildren in the 7th or 8th grade (43 boys, 51 girls; mean age at 2-year follow-up 13.3 ± 0.8 years) and the control group included 101 children in secondary schools (45 boys, 56 girls; mean age at 2-year follow-up 13.2 ± 0.7 years). Considering the study sample at 2-year follow-up, there was a return rate of 56.8% (195/343). The response rate in relation to the total study sample over the four years was 49.0% (195/398). In the statistical analyses at 2-year follow-up, 10 participants could not be included because of non-response at one of the three earlier testing moments (pre, post or 1-year follow-up evaluation).

4. Intervention

The optimized multi-factorial intervention was a comprehensive intervention based on prior studies (Cardon et al. 2000, Cardon et al. 2001, Cardon et al. 2002, Cardon et al. 2004) and consisted of a back education program and the stimulation of postural dynamism through support and environmental changes, as presented in figure 10. 'Postural dynamism' stands for frequent posture changes in addition to variable and dynamical activities.

Class teachers were involved in the promotion of good body mechanics integrating intervention guidelines during two school-years. Teacher's application of guidelines was not encouraged externally. However, during the two intervention school-years six activities related to good body mechanics were organized by the main test leader for the class teachers and the children (a quiz, a picture contest, a tinker contest, a repetition lesson, a 'weight your book bag' action and an 'incline your work surface' action). During the follow-up school-years, class teachers were not encouraged to promote good body mechanics.

In the course of the first intervention-school-year, all parents of the intervention children were informed about the program through an information session and a brochure.

4.1 Back education

The basic program consisted of six back education lessons at one-week interval, taught by a physical therapist to one class group at a time. The same physical therapist taught all children anatomy and pathology of the back and the basic principles of biomechanical favorable postures through a teaching method based on guided discovery. To allow an easy understanding of the 'back posture principles' two comic characters were introduced: 'Fit Fred', who does everything right, and 'Lazy Leo', who 'makes his disks very unhappy' by being very lazy and doing everything wrong. Besides back posture theory, skills related to good body mechanics were taught and practiced. This part of the intervention study was identical to the intervention evaluated in previous research (Cardon et al. 2000). The current intervention supplementary included intensifying components in order to optimize the integration of the back posture principles into the daily classroom routine. Therefore, teachers were asked to be present during all back education sessions and received a comprehensive manual including the six lessons and back ground information. Besides, didactic material was provided and guidelines were presented in order to stimulate integration of the back posture principles. Each class teacher received ten large pictures representing the back posture principles presented by 'Fred Fit' and 'Lazy Leo'. Teachers were instructed to implement the 'principle of the day' and later on the 'principle of the week'. Therefore, during the day and afterwards during the week, one back posture principle was

discussed in the class group and the concerning picture was posted in the class environment, encouraging the pupils to pay extra attention to application of the principle.

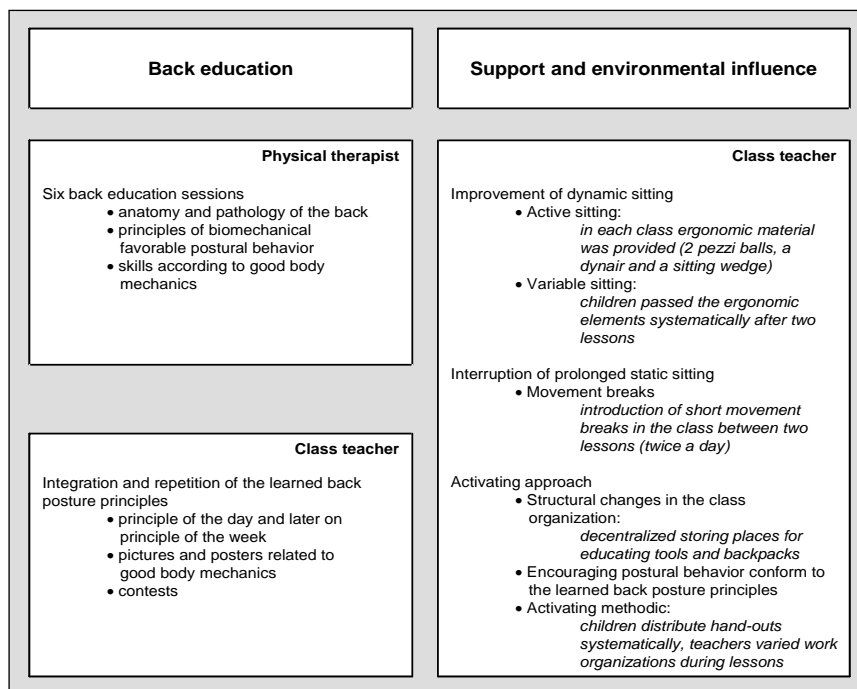


Figure 10: Components of the multi-factorial back posture program.

4.2 Support and environmental influence

Another optimization compared to the intervention evaluated in previous research (Cardon et al. 2000), included the focus on postural dynamism during daily class activities. Based on the German project 'Bewegte Schule' (Breithecker 2000, Cardon et al. 2004), encouraging movement into the lesson through work organization, and through environmental and behavioral influence, two basic principles were elaborated to increase postural dynamism in the class: stimulation of dynamical sitting and prevention of prolonged static sitting. Stimulating dynamical sitting, active and variable sitting were reinforced by providing two pezzi balls, a dynair and a wedge in each classroom. The children passed the ergonomic elements systematically at recess. Furthermore, in order to interrupt prolonged static sitting, short movement breaks between the lessons were introduced. Twice a day the movement breaks were organized in the class, supplementary to the recess. A large picture illustrating the movement break was posted in the classroom. On a repetitively four-week interval there was a different movement break for every day of the week. Finally, class teachers were encouraged to teach following an activating approach (e. g. distribution of handouts systematically through children, variable work organizations like a stand-desk, use of sitting alternatives) and to change structural class organizations, (e. g. decentralized storing places for educational tools, textbooks and school bags).

5. Evaluation Instruments

5.1 Evaluation of school-related correlates

Observation of class room postures

Observation in the classroom environment in order to record children's postural behavior during lesson time was considered the most suitable method to apply in schools (Murphy et al. 2002). The Portable Ergonomic Observation (PEO) method was selected since literature on the PEO method showed acceptable validity and high intra- and inter-observer reliability (Cardon et al. 2004, Fransson-Hall et al. 1995, Murphy et al. 2002).

Focusing children's postural behavior in the class, the following 'class room postures' were evaluated: trunk flexion over 45°, trunk rotation over 45°, neck flexion over 20° and neck rotation over 45°, sitting with or without use of the back rest and arm supports. Additionally, the following postural 'activities' were observed: static sitting, dynamic sitting, writing and reading, standing, walking, being active and lying on the floor. The percentages of the observed time interval (duration to the nearest 1 second) and how many times the postures and activities occurred (frequency) were recorded by the PEO computer software package.

Observation of material handling

In order to evaluate children's use of back posture principles in an unconstrained situation, postural behavior was observed during a movement session, based on previous research (Cardon et al. 2002). The movement sessions were organized during recess and presented as an evaluation of throwing and catching skills. Children were not told that the use of back posture principles was being tested. Postural behavior during lifting, transferring and putting down a bench, picking up a light object from the floor (shuttle) and moving a heavy object (medicine ball) were encoded qualitatively (0-4) with high scores representing performances conform to the learned back posture principles.

5.2 Evaluation of functional correlates

A sub sample (n=77) of the total sample (n=398) was tested more extensively at the Ghent University laboratories in order to evaluate back function parameters. All the tests were strictly non-invasive.

Capacity of the leg muscles (Biodex)

A calibrated isokinetic testing machine (Biodex System 3 Pro, Biodex Corp., Shirley, NY) was used for bilateral leg muscle capacity. The 'Isokinetic Bilateral – Knee (extension/ flexion) – Conc/Conc 60/60 180/180' test was selected to measure children's knee extensor and knee flexor capacity of both legs. This test assessed each leg at two velocities, evaluating children's maximal strength of the leg muscles at low speed (60°/sec, 5 repetitions, high resistance) and endurance at high speed (180°/sec, 15 repetitions, low resistance). The outcome parameters were 'maximal torque/body weight' (%), 'total work' (Joule) and 'average power' (Watt). Validity and reliability with regard to the use of the Biodex System 3 Pro for isokinetic testing of the knee flexors and knee extensors is well established in adult populations (Drouin et al. 2004) and reliability is documented in children as well (Deighan et al. 2003).

Static back curvatures (Zebris® and BioAnalysis v2)

An ultrasound analysis system (Zebris® CMS70P, Isny, Germany) was selected for the objective assessment of static back curvatures. The Zebris® system consisted of a basic unit which was connected with a computer, a pointer and a sensory unit. The ultrasound pointer was used to define surface reference points on the back of the child (the processi spinosi of thoracic and lumbar vertebrae were palpated and marked with a pen) and comprised two markers that sent ultrasound pulses. The sensory unit received signals from the transmitters located in the measuring unit. By means of triangulation, the markers' absolute three-dimensional coordinates were calculated. Based on these data, the children's thoracic kyphosis and lumbar lordosis were calculated with use of a soft-ware algorithm (BioAnalyse v2), as presented in figure 11. The children's back curvatures were measured three times for both a standing and a seating position. Previous research in adult samples reported sufficient reproducibility, accuracy and validity for use of the Zebris® technique (Malmstrom et al. 2003)

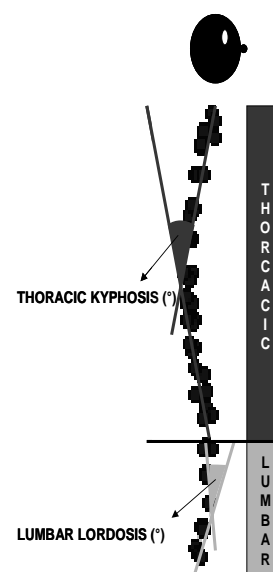


Figure 11: Calculation of thoracic kyphosis and lumbar lordosis using the Zebris® System and BioAnalyse v2.

Isometric trunk extensor and flexor endurance (Sørensen test and static curl)

Good validity of the Sørensen test was established in adult populations (Demoulin et al. 2006). In addition, the reliability for trunk extensor and trunk flexor endurance testing was found to be good in adolescents (Newcomer and Sinaki 1996, Oksanen and Salminen 1996).

Trunk extensor endurance testing



Figure 12: Trunk extensor endurance test.

for trunk extensor endurance was the endurance time, measured with a stopwatch.

Based on the method of Sørensen (1984), children's isometric endurance of the trunk extensors was evaluated (figure 12). Therefore, the child was lying prone with extended legs, fixed with two belts. The child had to bring the head and the upper part of the body unsupported through a horizontal position with the arms in a 'wing position'. This position was kept until exhaustion. The score

Trunk flexor endurance testing



Figure 13: Trunk flexor endurance test.

as long as possible. The endurance time was recorded with a stopwatch.

Based on the literature (Newcomer and Sinaki 1996, McGill 1999, McIntosh et al. 1998, Salminen et al. 1992), the static curl was used to determine trunk flexor endurance (figure 13). Therefore, the subjects were in a supine position on a research table with the legs fixed by a belt proximal to the knee-joint. With the arms crossed on the shoulders, the subjects had to curl up and to maintain this flexed position

Static and dynamic postural balance (Neurocom Balance Master® System)

Children's postural stability was tested using the Balance Master® System (NeuroCom, Clackamas, Ore., USA). This system offers the technology for an objective assessment and comprehensive documentation of postural control (Cambier et al. 2001). The Balance Master® consisted of a portable force platform connected to a computer including a software program that calculated the center of pressure relative to the platform coordinates. Based on those center of pressure data and the subject's body height, the position and displacement of the center of gravity (COG) were sampled.

Static standing balance

The modified Clinical Test of Sensory Interaction on Balance (mCTSIB) quantified postural sway velocity of the children standing quietly on the force platform. This test consisted of four different sensory conditions including three consecutive trials of 10 seconds: (1) standing with eyes open on a firm surface, (2) standing with eyes closed on a firm surface, (3) standing with eyes open on a foam surface, (4) standing with eyes closed on a foam surface. Performing these static postural tasks, the relative absence of sway was an outcome measure for static standing balance (COG sway velocity).

Dynamic standing balance

The test for the Limits of Stability (LOS) quantified several movement characteristics associated with the subject's ability to voluntary sway towards various locations in space, and briefly maintain stability at those positions. The LOS test measured the child's volitional (intentional) control of the COG. A limit of stability is the maximum distance a person can lean in a given direction (measured as angular distance from vertical) without losing balance, stepping, or reaching. Therefore, the children had to move a cursor (their projection of their center of gravity on the monitor) as close as possible to eight targets (their limits of stability projected on the monitor). Performing these dynamic postural tasks, accuracy was indicated by (1) whether or not the subject reached the target (maximal excursion), (2) whether the target was reached on the initial attempt (endpoint excursion), and (3) whether or not progress towards the target was smooth and consistent (directional control).

5.3 Evaluation of back posture knowledge, self-reported postural behavior, fear-avoidance beliefs and back pain prevalence

Children completed a questionnaire at school under supervision of the class teacher. The



Figure 14: Bodily picture for localisation of the pain.

questionnaire was based on previous research in 9 to 11 year olds, representing good test-retest stability (Cardon et al. 2002). One part evaluated specific back posture knowledge and included 10 questions directly corresponding to the content of the back education program. Another part evaluated general back posture knowledge and consisted of a multiple-choice quiz including 11 items related to general principles of good body mechanics. Additionally, fear-avoiding beliefs were evaluated analyzing five questions on a 5-point-scale (definitely yes to definitely no on questions related to physical activity; for example 'When your back

hurts it is dangerous to swim'). Furthermore, the questionnaire evaluated prevalence of back and neck pain within the last week. Severity of back or neck pain was indicated on a 5-point-scale (a little bit pain, a bit pain, modest pain, much pain, very much pain) and frequency on a 4-point-scale (once, several times, frequently, continuous). Children with back pain were asked to draw the corresponding localization of their pain on a bodily picture (figure 14).

After intervention completion, the questionnaire integrated an additional part for children of the intervention group asking in which degree they could remember the back education sessions (4-point-scale from nothing to everything) and how frequently they used the back posture principles in their current daily live (5-point-scale from never to ever). Furthermore, at 2-year follow-up, 20 supplemental questions on children's postural behavior were included considering the use of back posture principles during daily live, postural behavior in the class during lesson time and during studying at home, spinal loading during regularly sitting on a chair as well as the use of ergonomically designed material in the class and at home.

5.4 Evaluation of teachers' perceptions about the intervention program and control for possible interference

Meeting with the experimental class teachers

At the end of the first intervention year, a personal meeting with all experimental teachers was organized to evaluate the multiple components of the intervention (figure 15). All experimental teachers (n=10) were interviewed with regard to intensity and frequency of the intervention prescriptions considering the different aspects of the promotion of good body mechanics (like the intensifying components for the back posture principles, interruption of prolonged sitting, movement breaks, use of ergonomic material). The experiences and concerns of class teachers were used to optimize the back posture program of the second intervention year (data not presented in this doctoral thesis).

Questionnaire for all class teachers

At the end of the second intervention year, all teachers (5th and 6th grade class teachers, n=20) completed a questionnaire (figure 15). The experimental class teachers were asked in which degree they found the implementation of back posture education and movement breaks and the use of ergonomic elements useful (4-point-scale). Further, the experimental teachers were asked if they understood the intervention guidelines explained in the oral presentation and the manual (definitely yes to definitely no on a 5-point-scale). Controlling for

possible interference, both control and experimental teachers were asked whether or not the class had participated in activities related to good body mechanics. To control for the intervention variable and evaluating implementation, experimental class teachers were asked to rate on a 5-point-scale how frequently they applied the intervention guidelines. The control teachers were asked the same questions, in the framework of class teachers' use of didactical principles.

Interview with all class teachers

At the end of the first follow-up year, an interview with the 6th grade class teachers (n=12) was organized (figure 15). All class teachers were asked whether ergonomic material was available for the pupils during the follow-up school-year and whether or not the class had participated in events related to good body mechanics. Furthermore, teachers within intervention schools (n=6) were asked if they had integrated the intervention guidelines increasing postural dynamism in the class during the follow-up school-year. When teachers answered positively, they were asked to rate how frequently they applied the intervention guidelines (17 questions answering never to always on a 5-point-scale) based on the questionnaire for experimental class teacher at post-test.

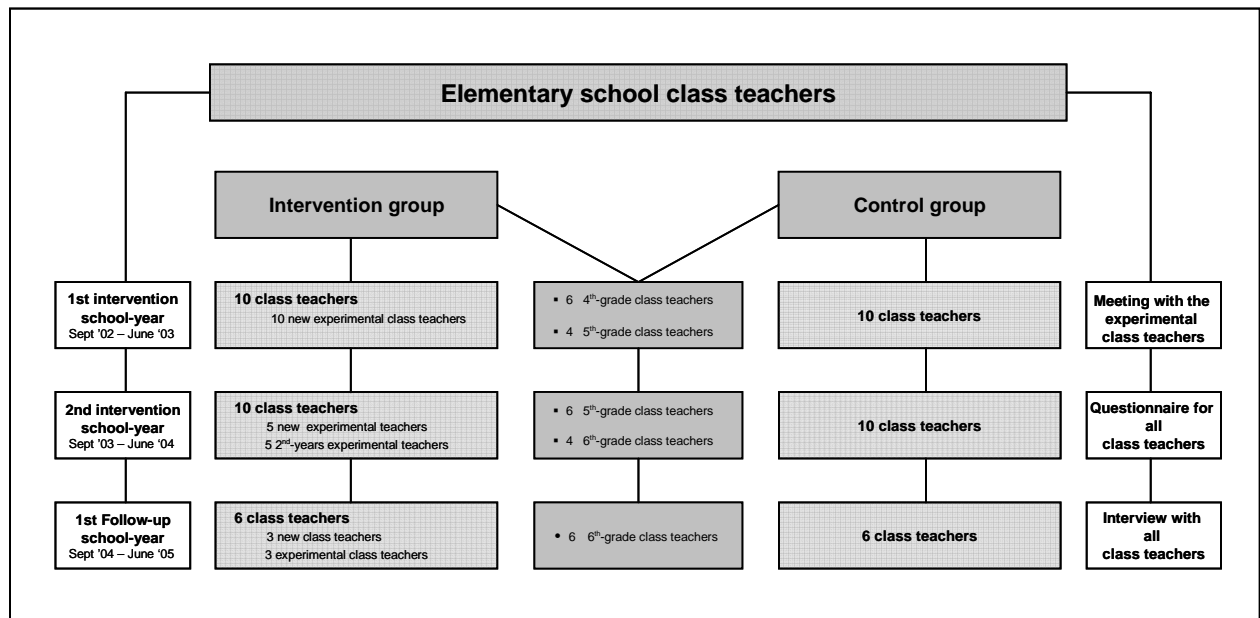


Figure 15: Flow chart of class teachers within the participating elementary schools.

6. Procedure

In the experimental schools, the comprehensive intervention in order to promote good body mechanics was considered to be a part of the health education program. Before the start of the intervention, all parents of both the intervention and the control children signed an informed consent form for the observations of postural behavior at school. The study protocol with respect to the central research aims was approved by the ethical committee of the Ghent University.

Pre-testing occurred during September and October 2002. The baseline data with regard to the observation of children's class room postures were used for the detection of school related correlates influencing back function (cross-sectional study).

The intervention to promote good body mechanics started in November 2002.

In February 2003, the reliability of functional parameters was evaluated in 4th and 5th grade children from another randomly selected school. The parents of all 153 4th and 5th grade children were notified by a letter and asked for the participation of their child in the reliability study for back function measurements. Test and retest measurements for the assessment of the children's spinal curvature, trunk muscle endurance and postural stability were used to evaluate reliability of back function parameters in an elementary school-aged population (reliability study + separate study within the study about intervention effects on functional correlates).

Post-testing was performed from April until June 2004. For the total sample, pre- and post-test evaluation included a questionnaire and an observation of material handling. Additionally, in each class group three children were selected by simple randomization in order to observe postural behavior in the classroom pre- and post-intervention. After the two years of intervention all teachers were asked to fill out a questionnaire about implementation, possible interference with other programs and perceptions related to the promotion of good body mechanics. The latter data were used to evaluate intervention effects with regard to school-related correlates influencing back function (effects on school-related correlates). Furthermore, a sub sample of the children was tested pre- and post-intervention in the Centre for Sports Medicine at the Ghent University Hospital. Therefore, parents who confirmed participation were asked by phone to make an appointment on a Wednesday afternoon or a Saturday morning, when Flemish children do not attend school. On one of the 10 proposed testing days, the children performed the back function measurements taking

about one hour. The evaluations of back function measurements with regard to trunk muscle endurance, leg muscle capacity and spinal curvature were used to investigate intervention effects on functional correlates influencing children's back function (effects on functional correlates).

In April 2005, a 1-year follow-up evaluation was performed to evaluate stability of 2-year intervention effects (1-year follow-up study). Follow-up questionnaires were identical to the evaluations at pre- and post-test. At pre- and post-test, children filled out the questionnaire under supervision of the class teacher. Contrary, at follow-up the questionnaires were completed at home. Therefore, 6th grade elementary schoolchildren received the questionnaire at school and were asked to fill it out at home independently. For all 7th grade pupils, the questionnaire was sent to their private address. A letter was enclosed with the request to return the independently completed questionnaire in a stamped and addressed envelope. In addition, all 6th grade teachers (n=12) were interviewed at the end of the follow-up school-year.

The 2-year follow-up evaluation was organized in March 2006, two years after the back posture program was finished (2-year follow-up study). All children were reached by mail to complete the questionnaires independently at home. They were asked to return the questionnaires in the provided stamped and addressed envelopes.

PART 3: OUTLINE OF THE THESIS

The following section, Section 2, consists of six original research papers including three central research aims to evaluate correlates influencing back function in schoolchildren.

Chapter 1 describes the association between classroom postures and self-reported pain in 8-12 year old elementary schoolchildren, using a cross-sectional study design. Children's classroom postures were observed using the Portable Ergonomic Observation method. Back and neck pain prevalence within the last week was evaluated through self-reporting.

In Chapter 2, the objective measurement of functional factors in elementary schoolchildren is investigated (reliability study). Test-retest reliability and reference values for postural stability in 9 to 10 years olds using the Balance Master® System are reported.

In Chapter 3, the effects of a comprehensive two-school-year multi-factorial back education program on school-related and functional correlates influencing back function in elementary schoolchildren are evaluated by means of a quasi-experimental study design. Part 1 evaluates the effects on school-related correlates with regard to back posture knowledge, postural behavior, fear-avoidance beliefs and self-reported pain. Children's postural behavior was objectively observed both during lesson time and during material handling in a play situation. Back posture knowledge, fear-avoidance beliefs and self reported pain were administered pre- and post-intervention by use of a questionnaire. Part 2 describes the effects of the multi-factorial back education program on functional correlates influencing back function in elementary schoolchildren. Children's trunk muscle endurance, leg muscle capacity and spinal curvature were evaluated in a pre-post design. A separate study was enclosed in this research paper to establish test-retest reliability for the back function parameters that were evaluated as intervention effects. Part 3 used a follow-up design to evaluate the stability of intervention effects in 10-14 year old schoolchildren following the two-school-year back education program. In this part, class teachers' efforts to promote good body mechanics were evaluated 1-year after the structured back education program was finished. Therefore, teachers were interviewed at the end of the follow-up school-year. In addition, Part 3 describes the stability of intervention effects on schoolchildren's back posture knowledge, fear-avoidance beliefs and back pain reports at 1-year follow-up. Correspondingly, Part 4 describes the stability of intervention effects on back posture knowledge, self-reported postural behavior, fear-avoidance beliefs and back pain reports in 11-15 years old schoolchildren at 2-year follow-up. Therefore, children completed the usual

questionnaire with regard to back function for the fourth time at the end of the second follow-up school-year.

Finally, in Section 3, general conclusions are formulated. An overview of the main findings will be presented at first. Subsequently, limitations of the doctoral thesis, general concerns, suggestions for further research and practical implications will be reflected in line of the literature and the present study findings.

REFERENCES

- Adams M, Bogduk N, Burton K, Dolan P (2002) The biomechanics of back pain. Edinburgh : Churchill Livingstone
- Alaranta H, Hurri H, Heliövaara M, Soukka A, Harju R (1994) Non-dynamometric trunk performance tests - reliability and normative data. *Scand J Rehabil Med* 26 : 211-215
- Balagué F, Dutoit G, Waldburger M (1988) Low back pain in schoolchildren. An epidemiological study. *Scand J Rehabil Med* 20 :175-179
- Balagué F, Nordin M (1992) Back pain in children and teenagers. *Baillieres Clin Rheumatol* 6 : 575-593
- Balagué F, Damidot P, Nordin M, Parnianpour M, Waldburger M (1993) Cross-sectional study of the isokinetic muscle trunk strength among school-children. *Spine* 18 : 1199-1205
- Balagué F, Nordin M, Skovron ML, Dutoit G, Yee A, Waldburger M (1994) Nonspecific low-back-pain among schoolchildren - A field survey with analysis of some associated factors. *Journal Spinal Disord Tech* 7 : 374-379
- Balagué F, Skovron ML, Nordin M, Dutoit G, Pol LR, Waldburger M (1995) Low back pain in schoolchildren. A study of familial and psychological factors. *Spine* 20 : 1265-1270
- Balagué F, Nordin M, Dutoit G, Waldburger M (1996) Primary prevention, education, and low back pain among school children. *Bull Hosp Jt Dis* 55 : 130-134
- Balagué F, Troussier B, Salminen JJ (1999) Non-specific low back pain in children and adolescents: risk-factors. *Eur Spine J* 8 : 429-438
- Balagué F, Dudler J, Nordin M (2003) Low-back pain in children. *Lancet* 36 : 1403-1404
- Biering-Sörensen F (1984) Physical measurement as risk indicators for low back trouble over a one-year period. *Spine* 9 : 143-148

- Brattberg G (1994) The incidence of back pain and headache among Swedish school children. *Qual Life Res* 3 : 27-31
- Brattberg G (2004) Do pain problems in young school children persist into early adulthood? A 13-year follow-up. *Eur J Pain* 8 : 187-199
- Breithecker D (2000) Enjoying school: fun in learning. More health and well being in the school as place of work, A project report. *Haltung und Bewegung* 4
- Burton AK (1996) Low back pain in children and adolescents: to treat or not. *Bull Hosp Jt Dis* 55 : 127-129
- Burton AK, Clarke RD, McClune TD, Tillotson KM (1996) The natural history of low back pain in adolescents. *Spine* 21 : 2323-2328
- Cakmak A, Yucel B, Ozyalcin SN, Bayraktar B, Ural HI, Duruoz MT, Genc A (2004) The frequency and associated factors of low back pain among a younger population in Turkey. *Spine* 29 : 1567-1572
- Cambier D, Cools A, Danneels L, Witvrouw E (2001) Reference data for 4- and 5-year-old-children on the Balance Master: values and clinical feasibility. *Eur J Pediatr* 160 : 317-317
- Candy E, Shepstone L, Watts R (2004) Does the introduction of a simple wedge to school seating reduce adolescent back pain? *Int J Theor Rehabil* 11 : 462-466
- Cardon G, De Bourdeaudhuij I, De Clercq D (2000) Effects of back care education in elementary schoolchildren. *Acta Paediatr* 89 : 1010-1017
- Cardon G, De Bourdeaudhuij I, De Clercq D (2001) Back care education in elementary school: a pilot study investigating the complementary role of the class teacher. *Patient Educ Couns* 45 : 219-226
- Cardon G, De Bourdeaudhuij I, De Clercq D (2001) Generalization of back education principles by elementary schoolchildren: evaluation with a practical test and a candid camera observation. *Acta Paediatr* 90 : 143-150
- Cardon G, De Bourdeaudhuij I, De Clercq D (2002) Back education efficacy in elementary schoolchildren: a one year follow-up study. *Spine* 27 : 299-305
- Cardon G, De Bourdeaudhuij I, De Clercq D (2002) Knowledge and perceptions about back education among elementary school students, teachers, and parents in Belgium. *J Sch Health* 72 : 100-106
- Cardon G, De Clercq D, De Bourdeaudhuij I, Breithecker D (2004) Sitting habits in elementary schoolchildren: a traditional versus a 'Moving school'. *Patient Educ Couns* 54 : 133-142
- Cardon G, Balagué F (2004) Low back pain prevention's effects in schoolchildren. What is the evidence? *Eur Spine J* 13 : 663-679

- Cardon GM, De Clercq DL, Geldhof EJ, Verstraete S, De Bourdeaudhuij IM (2006) Back education in elementary schoolchildren: the effects of adding a physical activity promotion program to a back care program. *Eur Spine J*: Epub ahead of print
- Danneels L, De Cuyper H, Vanderstraeten G, Cambier D, Witvrouw E (1999) Spierreëducatie bij lage rugklachten. *Vlaams Tijdschrift voor Sportgeneeskunde en Wetenschappen* 81 : 32-7
- Danneels L (2001) Evaluation and rehabilitation of functional spinal stability. *Doctoral thesis*.
- Demoulin C, Vanderthommen M, Duysens C, Crielaard JM (2006) Spinal muscle evaluation using the Sorensen test: a critical appraisal of the literature. *Joint Bone Spine* 73 : 43-50
- Drouin JM, Valovich-mcLeod TC, Shultz SJ, Gansneder BM, Perrin DH (2004) Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque and position measurements. *Eur J Appl Physiol* 91 : 22-9
- Deighan M, Croix M, Armstrong N (2003) Reliability of isokinetic concentric and eccentric knee and elbow extension and flexion in 9/10 year old boys. *Isokinet Exerc Sc* 11 : 109-115
- Duggleby T, Kumar S (1997) Epidemiology of juvenile low back pain: a review. *Disabil Rehabil* 19 : 505-512
- Ebbehoj NE, Hansen FR, Harreby MS, Lassen CF (2002) Low back pain in children and adolescents. Prevalence, risk factors and prevention. *Ugeskr Laeger* 164 : 755-758
- Essendorp M, Schibye B, Hey-Knudsen C (2002) Intra-abdominal pressure increases during exhausting back extension in humans. *Eur J Appl Physiol* 87 : 167-173
- Fairbank JC, Pynsent PB, Van Poortvliet JA, Phillips H (1984) Influence of anthropometric factors and joint laxity in the incidence of adolescent back pain. *Spine* 9 : 461-464
- Feingold AJ, Jacobs K (2002) The effect of education on backpack wearing and posture in middle school population. *Work* 18 : 287-294
- Feldman DE, Rossignol M, Shrier I, Abenhaim L (1999) Smoking. A risk factor for development of low back pain in adolescents. *Spine* 24 : 2492-2496
- Feldman DE, Shrier I, Rossignol M, Abenhaim L (2001) Risk factors for the development of low back pain in adolescence. *Am J Epidemiol* 154 : 30-36
- Fransson-hall C, Gloria R, Kilbom A, Winkel J (1995) A Portable Ergonomic Observation method (PEO) for computerized on-line recording of postures and manual handling. *Appl Ergon* 26 : 93-100
- Frymoyer JW, Pope MH, Clements JH, Wilder DG, MacPherson B, Ashikaga T (1983) Risk factors in low-back pain. An epidemiological survey. *J Bone Joint Surg Am* 65 : 213-218
- Giles LG, Taylor JR (1981) Low-back pain associated with leg length inequality. *Spine* 6 : 510-521

- Goldberg MS, Scott SC, Mayo NE (2000) A review of the association between cigarette smoking and the development of nonspecific back pain and related outcomes. *Spine* 25 : 995-1014
- Goodgold SA (2003) Backpack intelligence: implementation of a backpack safety program with fifth grade students. *Orthop Pract* 15 : 15-20
- Goodgold SA, Nielsen D (2003) Effectiveness of a school-based backpack health promotion program: Backpack Intelligence. *Work* 21 : 113-123
- Goodman JE, McGrath PJ (1991) The epidemiology of pain in children and adolescents: a review. *Pain* 46 : 247-264
- Goubert L, Crombez G, De Bourdeaudhuij I (2004) Low back pain, disability and back pain myths in a community sample: prevalence and interrelationships. *Eur J Pain* 8 : 385-394
- Grimmer K, Williams M (2000) Gender-age environmental associates of adolescent low back pain. *Appl Ergon* 31 : 343-360
- Grundy PF, Roberts CJ (1984) Does unequal leg length cause back pain? A case-control study. *Lancet* 2 : 256-258
- Gunzburg R, Balagué F, Nordin M, Szpalski M, Duyck D, Bull D, Melot C (1999) Low back pain in a population of school children. *Eur Spine J* 8 : 439-443
- Harreby M, Neergaard K, Hesseloe G (1995) Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low back pain in adults? *Spine* 20 : 2298-2302
- Harreby M, Nygaard B, Jessen T, Larsen E, Storr-paulsen A, Lindahl A, Fisker I, Laegaard E (1999) Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. *Eur Spine J* 8 : 444-450
- Harvey J, Tanner S (1991) Low back pain in young athletes. A practical approach. *Sports Med* 12 : 394-406
- Hestbaek L, Iachine IA, Leboeuf-Yde C, Kyvik KO, Manniche C (2004) Heredity of low back pain in a young population: a classical twin study. *Twin Res* 7 : 16-26
- Hestbaek L, Leboeuf-Yde C, Kyvik KO, Manniche C (2006) The course of low back pain from adolescence to adulthood: eight-year follow-up of 9600 twins. *Spine* 31 : 4468-72
- Hestbaek L, Leboeuf-Yde C, Kyvik KO (2006) Are lifestyle-factors in adolescence predictors for adult low back pain? A cross-sectional and prospective study of young twins. *BMC Musculoskelet Disord* 7 : 1-27
- Hyttiainen K, Salminen JJ, Suvitie T, Wickstrom G, Pentti J (1991) Reproducibility of nine tests to measure spinal mobility and trunk muscle strength. *Scand J Rehabil Med* 23 : 3-10

- Johnson J, Deshpande C (2000) Health education and physical education: disciplines preparing students as productive, healthy citizens for the challenges of the 21st century. *J School Health* 70 : 66-68
- Jones GT, Watson KD, Silman AJ, Symmons DP, Macfarlane GJ (2003) Predictors of low back pain in British schoolchildren: A population-based prospective cohort study. *Pediatrics* 111 : 822-828
- Jones GT, Silman AJ, Macfarlane GJ (2004) Parental pain is not associated with pain in the child: a population based study. *Ann Rheum Dis* 63 : 1152-1154
- Jones GT, Macfarlane GJ (2005) Epidemiology of low back pain in children and adolescents. *Arch Dis Child* 90 : 312-316
- Jones MA, Stratton G, Reilly T, Unnithan VB (2004) A school-based survey of recurrent non-specific low-back pain prevalence and consequences in children. *Health Educ Res* 19 : 284-289
- Jones MA, Stratton G, Reilly T, Unnithan VB (2005) Biological risk indicators for recurrent non-specific low back pain in adolescents. *Br J Sports Med* 39 : 137-140
- Knight G, Noyes J (1999) Children's behaviour and the design of school furniture. *Ergonomics* 42 : 747-760
- Korovessis P, Koureas G, Papazisis Z (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. *J Spinal Disord Tech* 17 : 33-40
- Korovessis P, Koureas G, Zacharatos S, Papazisis Z (2005) Backpacks, back pain, sagittal spinal curves and trunk alignment in adolescents: a logistic and multinomial logistic analysis. *Spine* 30 : 247-255
- Kovacs FM, Gestoso M, Gil del Real MT, Lopez J, Mufraggi N, Mendez JI (2003) Risk factors for non-specific low back pain in schoolchildren and their parents: a population based study. *Pain* 103 : 259-268
- Kristjansdottir G, Rhee H (2002) Risk factors of back pain frequency in schoolchildren: a search for explanations to a public health problem. *Acta Paediatr* 91 : 849-854
- Kujala UM, Salminen JJ, Taimela S, Oksanen A, Jaakkola L (1992) Subject characteristics and low-back-pain in young athletes and nonathletes. *Med Sci Sport Exer* 24 : 627-632
- Kujala UM, Taimela S, Oksanen A, Salminen JJ (1997) Lumbar mobility and low back pain during adolescence. A longitudinal three-year follow-up study in athletes and controls. *Am J Sports Med* 25 : 363-368
- Kuukkanen T and Malkia E (2000) Effects of a three-month therapeutic exercise programme on flexibility in subjects with low back pain. *Physiother Res Int* 5 : 46-61

- Latimer J, Maher CG, Refshauge K, Colaco I (1999) The reliability and validity of the Biering-Sorensen test in asymptomatic subjects and subjects reporting current or previous nonspecific low back pain. *Spine* 24 : 2085-2089
- Leboeuf-Yde (1999) Smoking and low back pain. A systematic literature review of 41 journal articles reporting 47 epidemiologic studies. *Spine* 24 : 1463-1470
- Leboeuf-Yde C, Wedderkopp N, Andersen LB, Froberg K, Hansen HS (2002) Back pain reporting in children and adolescents: the impact of parents' educational level. *J Manipulative Physiol Ther* 25 : 216-220
- Lebouef-Yde C (2004) Back pain - Individual and genetic factors. *Electromyogr Kinesiol* 14 : 129-133
- Lee JH, Hoshino Y, Nakamura K, Kariya Y, Saita K, Ito K (1999) Trunk muscle weakness as a risk factor for low back pain - A 5-year prospective study. *Spine* 24 : 54-57
- Limon S, Valinsky LJ, Ben-Shalom Y (2004) Children at risk - Risk factors for low back pain in the elementary school environment. *Spine* 29 : 697-702
- Linton S, van Tulder MW (2001) Preventive interventions for back and neck pain problems. What is the evidence? *Spine* 26 : 778 - 787
- Malmstrom EM, Karlberg M, Melander A, Magnusson M (2003) Zebris versus Myrin: a comparative study between a three-dimensional ultrasound movement analysis and an inclinometer/compass method: intradevice reliability, concurrent validity, intertester comparison, intratester reliability, and intraindividual variability. *Spine* 28:433-440
- McGill SM, Childs A, Liebenson C (1999) Endurance times for low back stabilization exercises: Clinical targets for testing and training from a normal database. *Arch Phys Med Rehab* 80 : 941-944
- McGill S (2002) *Low Back Disorders*. Champaign, IL : Human Kinetics
- McIntosh G, Wilson, Affleck M, Hall H (1998) Trunk and lower extremity muscle endurance: normative data for adults. *J Rehabil Outcomes Meas* 2 : 20-39
- McMeeken J, Tully E, Stillman B, Nattrass C, Bygott IL, Story I (2001) The experience of back pain in young Australians. *Man Ther* 6 : 213-220
- Mendez FJ, Gómez-Conesa A (2001) Postural hygiene program to prevent low back pain. *Spine* 26 : 1280-1286
- Michel A, Kohlmann T, Raspe H (1997) The association between clinical findings on physical examination and self-reported severity in back pain. Results of a population-based study. *Spine* 22 : 296-304
- Mierau D, Cassidy JD, Yong-Hing K (1989) Low-back pain and straight leg raising in children and adolescents. *Spine* 14 : 526-528
- Mikkelsen LO, Nupponen H, Kaprio J, Kautiainen H, Mikkelsen M, Kujala UM (2006) Adolescent flexibility, endurance strength, and physical activity as predictors of adult

- tension neck, low back pain, and knee injury: a 25 year follow up study. *Br J Sports Med* 40 : 107-113
- Milanese S, Grimmer K (2004) School furniture and the user population: an anthropometric perspective. *Ergonomics* 47 : 416-426
- Murphy S, Buckle P, Stubbs D (2002) The use of the portable ergonomic observation method (PEO) to monitor the sitting posture of schoolchildren in the classroom. *Appl Ergon* 33 : 365-370
- Murphy S, Buckle P, Stubbs D (2004) Classroom posture and self-reported back and neck pain in schoolchildren. *Appl Ergon* 35 : 113-120
- Mustard CA, Kalcevich C, Frank JW, Boyle M (2005) Childhood and early adult predictors of risk of incident back pain: Ontario Child Health Study 2001 follow-up. *Am J Epidemiol* 162 : 779-786
- Negrini S, Carabalona R (2002) Backpacks on! Schoolchildren's perceptions of load, associations with back pain and factors determining the load. *Spine* 27 : 187-195
- Newcomer K, Sinaki M (1996) Low back pain and its relationship to back strength and physical activity in children. *Acta Paediatr* 85 : 1433-1439
- Newcomer K, Sinaki M, Wollan PC (1997) Physical activity and four-year development of back strength in children. *Am J Phys Med Rehabil* 76 : 52-58
- Nordin M, Kahanovitz N, Verderame R, Parnianpour M, Yabut S, Viola K, Viola K, Greenidge N, Mulvihill M (1987) Normal trunk muscle strength and endurance in women and the effect of exercises and electrical-stimulation. Part 1: Normal endurance and trunk muscle strength in 101 women. *Spine* 12 : 105-111
- Oksanen A, Salminen JJ (1996) Tests of spinal mobility and muscle strength in the young: Reliability and normative values. *Physiother Theor Pract* 12 : 151-160
- Olsen T, Anderson R, Dearwater SR, Kriska AM, Cauley JA, Aaron DJ (1992) The epidemiology of low-back-pain in an adolescent population. *Am J Public Health* 82 : 606-608
- Panagiotopoulou G, Christoulas K, Papanckolaou A, Mandroukas K (2004) Classroom furniture dimensions and anthropometric measures in primary school. *Appl Ergon* 35 : 121-128
- Panjabi MM (1992) The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *J Spinal Disord* 5 : 383-389
- Panjabi MM (1992) The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. *J Spinal Disord* 5 : 390-396
- Parcells C, Stommel M, Hubbard R (1999) Mismatch of classroom furniture and student body dimensions. *J Adolescent Health* 24 : 265-273

- Payne N, Gledhill N, Katzmarzyk PT, Jamnik V (2000) Health-related fitness, physical activity, and history of back pain. *Can J Appl Physiol* 25 : 236-249
- Poussa MS, Heliövaara MM, Seitsamo JT, Kononen MH, Hurmerinta KA, Nissinen MJ (2005) Anthropometric measurements and growth as predictors of low-back pain: a cohort study of children followed up from the age of 11 to 22 years. *Eur Spine J* 14 : 595-598
- Poussa MS, Heliövaara MM, Seitsamo JT, Kononen MH, Hurmerinta KA, Nissinen MJ (2005) Predictors of neck pain: a cohort study of children followed up from the age of 11 to 22 years. *Eur Spine J* 14 : 1033-1036
- Power C, Frank J, Hertzman C, Schierhout G, Li L (2001) Predictors of low back pain onset in a prospective British study. *Am J Public Health* 91 : 1671-1678
- Robertson HC, Lee VL (1990) Effects of back care lessons on sitting and lifting by primary students. *Aust J Physiother* 36 : 245-248
- Rozenberg S, Bourgeois P (1999) Are children also fated to develop back pain? *Rev Rhum Engl Ed* 66 : 365-366
- Salminen JJ (1984) The adolescent back. A field survey of 370 Finnish schoolchildren. *Acta Paediatr Scand* 315 : 1-122
- Salminen JJ, Maki P, Oksanen A, Pentti J (1992) Spinal mobility and trunk muscle strength in 15-year-old schoolchildren with and without low-back-pain. *Spine* 17 : 405 - 411
- Salminen JJ, Pentti J, Terho P (1992) Low back pain and disability in 14-year-old schoolchildren. *Acta Paediatr* 81 : 1035-1039
- Salminen JJ, Oksanen A, Maki P, Pentti J, Kujala UM (1993) Leisure time physical activity in the young. Correlation with low-back pain, spinal mobility and trunk muscle strength in 15-year-old school children. *Int J Sports Med* 14 : 406-410
- Salminen JJ, Erkintalo-Tertti MO, Paajanen HE (1993) Magnetic resonance imaging findings of lumbar spine in the young: correlation with leisure time physical activity, spinal mobility, and trunk muscle strength in 15-year-old pupils with or without low-back pain. *J Spinal Disord* 6 : 386-391
- Salminen JJ, Erkintalo M, Laine M, Pentti J (1995) Low-back-pain in the young - a prospective 3-year follow-up-study of subjects with and without low-back-pain. *Spine* 20 : 2101-2107
- Schwartz RK, Jacobs K (1992) Body basics, a cognitive approach to body mechanics training in elementary school back pain prevention programs. *Work* 2 : 53-60
- Sheir-Neiss GI, Kruse RW, Rahman T, Jacobson LP, Pelli JA (2003) The association of backpack use and back pain in adolescents. *Spine* 28 : 922-930
- Sheldon MR (1994) Lifting instruction to children in an elementary school. *J Orthop Sports Phys Ther* 19 : 105-110

- Siambanes D, Martinez JW, Butler EW, Haider T (2004) Influence of school backpacks on adolescent back pain. *J Pediatr Orthop* 24 : 211-217
- Sjolie AN, Ljunggren AE (2001) The significance of high lumbar mobility and low lumbar strength for current and future low back pain in adolescents. *Spine* 26 : 2629-2636
- Sjolie AN (2002) Psychosocial correlates of low-back pain in adolescents. *Eur Spine J* 11 : 582-588
- Sjolie AN (2004) Persistence and change in non-specific low back pain – A 3-year prospective study. *Spine* 29 : 2452-2457
- Spence SM, Jensen GM, Shepard KF (1984) Comparison of methods of teaching children proper lifting techniques. *Phys Ther* 64 : 1055-1061
- Staes F, Stappaerts K, Vertommen H, Everaert D, Coppieters M (1999) Reproducibility of a survey questionnaire for the investigation of low back problems in adolescents. *Acta Paediatr* 88 : 1269-1273.
- Staes F, Stappaerts K, Vertommen H, Nuyens G, Coppieters M, Everaert D (2000) Comparison of self-administration and face-to-face interview for surveys of low back pain in adolescents. *Acta Paediatr* 89 : 1352-1357
- Staes F, Stappaerts K, Lesaffre E, Vertommen H (2003) Low back pain in Flemish adolescents and the role of perceived social support and effect on the perception of back pain. *Acta Paediatr* 92 : 444-451
- Steele EJ, Dawson AP, Hiller JE (2006) School-based interventions for spinal pain: a systematic review. *Spine* 31 : 226-233
- Storr-paulssen A, Aagaard-Hensen J (1994) The working positions of schoolchildren. *Appl Ergon* 25 : 63-64
- Storr-Paulsen A (2002) The body-consciousness in school - A back pain-school. *Ugeskr Laeger* 165 : 37-41
- Szpalski M, Gunzburg R, Balague F, Nordin M, Melot C (2002) A 2-year prospective longitudinal study on low back pain in primary school children. *Eur Spine J* 11 : 459-464
- Taimela S, Kujula UM, Salminen JJ, Viljanen T (1997) The prevalence of low back pain among children and adolescents - A nationwide, cohort-based questionnaire survey in Finland. *Spine* 22 : 1132-1136
- Troussier B, Davoine P, de Gaudemaris R, Fauconnier J, Phelip X (1994) Back pain in school children. A study among 1178 pupils. *Scand J Rehabil Med* 26 : 143-146
- Troussier B, Tesniers C, Fauconnier J, Grison J, Juvin R, Phelip X (1999) Comparative study of two different kinds of school furniture among children. *Ergonomics* 42 : 516-526
- Van Gent C, Dols JJ, de Rover CM, Hira Sing RA, de Vet HC (2003) The weight of schoolbags and the occurrence of neck, shoulder, and back pain in young adolescents. *Spine* 28 : 916-921

- Vikat A, Rimpela M, Salminen JJ, Rimpela A, Savolainen A, Virtanen SM (2000) Neck or shoulder pain and low back pain in Finnish adolescents. *Scand J Public Health* 28 : 164-173
- Wadell (1998) *The Back Pain revolution*. Edinburgh/London : Churchill Livingstone
- Walker BF (2000) The prevalence of low back pain: a systematic review of the literature from 1966 to 1998. *J Spinal Disord* 13 : 205-217
- Watson KD, Papageorgiou AC, Jones GT, Taylor S, Symmons DP, Silman AJ, Macfarlane GJ (2002) Low back pain in schoolchildren: occurrence and characteristics. *Pain* 97 : 87-92
- Watson KD, Papageorgiou AC, Jones GT, Taylor S, Symmons DP, Silman AJ, Macfarlane GJ (2003) Low back pain in schoolchildren: the role of mechanical and psychosocial factors. *Arch Dis Child* 88 : 12-17
- Wedderkopp N, Leboeuf-Yde C, Andersen LB, Froberg K, Hansen HS (2001) Back pain reporting pattern in a Danish population-based sample of children and adolescents. *Spine* 26 : 1879-1883
- Wedderkopp N, Leboeuf-Yde C, Andersen LB, Froberg K, Hansen HS (2003) Back pain in children: no association with objectively measured level of physical activity. *Spine* 28 : 2019-2024
- Widhe T (2001) Spine: posture, mobility and pain - A longitudinal study from childhood to adolescence. *Eur Spine J* 10 : 118-123

SECTION 2

ORIGINAL RESEARCH

OVERVIEW OF ORIGINAL RESEARCH

Chapter 1: Association between classroom postures and self-reported pain (cross-sectional study)

Classroom Postures of 8 to 12 year old children

Chapter 2: Objective measurement of functional factors in children at elementary school-age (reliability study)

Static and dynamic standing balance: test-retest reliability and reference values in 9 to 10 year old children

Chapter 3: Effectiveness of promoting good body mechanics in elementary schoolchildren (intervention study)

Part 1: Effects of back education on school-related correlates

Effects of a two-school-year multi-factorial back education program in elementary schoolchildren

Part 2: Effects of back education on functional correlates

Effects of back posture education on elementary schoolchildren's back function

Part 3: Intervention effects following back posture education: 1-year stability

Back posture education in elementary schoolchildren: stability of 2-year intervention effects

Part 4: Intervention effects following back posture education: 2-year stability

Back posture education in elementary schoolchildren: a 2-year follow-up study

CHAPTER 1

CLASSROOM POSTURES OF 8 TO 12 YEAR OLD CHILDREN

E. GELDHOF, G. CARDON, I. DE BOURDEAUDHUIJ AND D. DE CLERCQ

ERGONOMICS, ACCEPTED FOR PUBLICATION

CLASSROOM POSTURES OF 8 TO 12 YEAR OLD CHILDREN

Abstract. *The study aim was to examine classroom postures of 8 to 12 year olds in Flanders and to relate the outcomes to self-reported back or neck pain. Using the Portable Ergonomic Observation (PEO) method, postural behaviors were studied in 105 children from 41 different class groups. Additionally, self-reported one-week back and neck pain was evaluated. Pupils sat statically for 85% of the time, 28% of which the trunk was bent. For 9% of the time children were sitting dynamically and for 36% they used a back rest. Children who spent more time sitting with a flexed trunk reported significantly more thoraco-lumbar pain compared to pain-free children and to children with cervical pain ($P < .05$). Moreover, children reporting pain stood for a longer period of time than pain-free children ($P < .05$). It is concluded that prolonged static kyphotic sitting without use of the backrest is common in elementary schoolchildren in Flanders.*

Keywords: sitting posture, schoolchildren, ergonomic observation.

1. INTRODUCTION

Recent studies report increasing back pain prevalence among youngsters of school age [Harreby et al. 1999, Watson et al. 2002, Jones et al. 2003]. Back pain occurrence in childhood may be a risk factor for low back pain in adults [Harreby et al. 1999] and indicates a need for research into the early stages of the problem. Epidemiological research associates sitting with back pain in adults as well as in children and adolescents [Balagué et al. 1999, Sjölie and Ljunggren 2001]. However, due to the multi-factorial nature of the risk for back pain and the lack of longitudinal studies, the evidence for a causal relationship between sitting and pain is limited.

Sitting causes the pelvis to rotate backwards resulting in a reduction of lumbar lordosis, attended with an increase in muscle effort and disc pressure [Harrison et al. 1999]. Biomechanical research in adults has shown increased spinal loads while sitting poorly for long periods, indicating that poor and prolonged sitting could be risk factors for back or neck pain. Prolonged passive posture is proposed as a possible mechanical risk factor due to the excessive intra-disc compression caused by sustained spinal loading and ineffective load sharing [Wilke et al. 1999, Vleeming et al. 2000]. Poor posture is understood to

mean postures deviating from neutral spinal curvature. The literature indicates that in adult populations a seated posture with a twisted trunk, kyphotic sitting and sitting with a flexed neck can result in increased disc compression [Dvorak et al. 1991, McGill et al. 1994, Boden and Oberg 1998, Wilke et al. 2001]. In addition, mechanically favorable postures have been investigated. Supported arms and using a back rest tended to decrease intra-disc pressure because part of the load is transferred [Chaffin et al. 1999, Wilke et al. 1999].

Based on biomechanical studies of adult samples and epidemiological evidence suggesting an association between pain and sitting conditions at a young age, it can be reasonably postulated that similar spinal loading mechanisms related to poor and prolonged sitting might act in children whose spine is not fully matured. Moreover, a recent cross-sectional study among youngsters indicated prolonged sitting and poor posture as possible risk factors for back pain [Murphy and Buckle, 2003]. However, the school environment seems to expose children to the possible loading factors of prolonged sitting. Storr-Paulsen and Aagaard-Hansen (1994) reported that 8 and 9 year old children were required to sit for more than 60 minutes in any 90 minute period. Additionally, according to a recent pilot

study of Cardon et al. (2004), in one class of a traditional elementary school, pupils spent on average 97% of the lesson time sitting statically and in poor postures. Consistent with the latter study, Murphy et al. (2002) observed poor sitting postures during lesson times in 18 children in elementary school.

Furthermore, the literature indicates that prolonged and poor postures not only produce negative biomechanical and musculoskeletal effects, like strains on muscles and ligaments, but also involve physiological effects, like impeded blood circulation, and psychosocial consequences, such as emotional strains and low comfort perception [Marshall et al. 1995]. Thus, schoolchildren may be at particular risk for suffering negative mechanical, physiological and psychosocial effects since they spend long periods seated in the classroom, frequently in poor static postures. In addition, children undergo these possibly negative effects just at the time of decisive sensitive growth, determining maturity and development [Illi et al. 1998].

Inadequate school furniture is frequently taken to be the reason for posture problems and back complaints [Salminen et al. 1992b, Troussier et al. 1999]. Recent literature in the school environment demonstrated a mismatch between the body dimensions of pupils and the dimensions of the school furniture available to them [Parcells et al. 1999, Panagiotopoulou et al. 2004]. Therefore there have been attempts to eliminate or reduce the risk for back pain at a young age by modifying school furniture. However, it seems that pupils do not automatically sit 'properly' on ergonomically designed furniture. Therefore, at the very best only a limited part of the posture problem can be solved by optimizing the furniture [Troussier et al. 1999]. Moreover, the potential protective effects of using ergonomically designed workstations against back pain have not been demonstrated [Troussier et al. 1999].

Back education has also been used in attempts to reduce back pain in schoolchildren. Cardon et al. (2002) demonstrated that the implementation of a

back education program had a significant impact on the use of back care principles. However, a transfer of postural principles to the daily unconscious sitting behavior of the child was not found. As an alternative approach, it was argued that preventive action should include frequent position changes, since Murphy and Buckle (2003) found, in 66 children aged 11 to 14 years, that less movement during lessons and longer lessons were related to the likelihood of back and neck pain occurring. In a prior study [Cardon et al. 2004] it was found that sitting habits were more favorable in the 'Moving School', which encourages movement during lessons through work organization and circumstantial and behavioral influences.

In summary, poor sitting postures and prolonged sitting may increase spinal load and possibly the risk for back pain at a young age. Moreover, it was shown by Salminen et al. (1999) that individuals with disc degeneration at a young age not only have an increased risk of recurrent low back pain at this young age, but also a long-term risk of recurrent pain up to early adulthood. Furthermore, the literature indicates that poor postures and prolonged sitting are common in the classroom. However the number of studies evaluating ergonomics in the classroom is limited and the sample sizes of the available studies are small. Moreover, the existing literature mainly includes pupils from secondary schools. Finally, a comparison of classroom postures in different countries and hence different pedagogical cultures is of interest. The main purpose of the current study is to portray postural behaviors of 8 to 12 year olds in elementary school classrooms in Flanders. An additional objective is to relate the postures of elementary schoolchildren to self-reported back or neck pain.

2. METHODS

2.1 Participants

The participants were elementary schoolchildren of 41 fourth and fifth grade classes from sixteen randomly selected schools. In each class two to three

children were selected by simple randomization, to be filmed. Thus, postural behavior was evaluated in 54 boys and 51 girls (mean age 9.9 years, SD 0.8, range 8.5-12.5 years). In all classrooms traditional school furniture as presented in figure 1 was used.

The study was considered to be part of the psychosocial, medical and social counseling provided by the school, for which all parents signed an informed consent form. The study protocol was approved by the Ethical Committee of the University Hospital of Ghent University.

Figure 1: An image of the traditional school furniture in Flanders.



2.2 Instruments

Portable Ergonomic Observation (PEO) method with video tape.

Observation in the classroom environment in order to record the sitting posture of children in the classroom was considered the most suitable method to apply in schools [Murphy et al. 2002]. The Portable Ergonomic Observation (PEO) method was therefore selected to record postural behavior in the classroom. According to the literature the PEO method showed acceptable validity and high intra- and inter-observer reliability [Fransson-Hall et al. 1995, Murphy et al. 2002, Cardon et al. 2004].

In the current study, the body postures and class activities of children were recorded with unmanned cameras in the classrooms. The cameras were set to the side of the classroom, depending on the furniture organization, between 1.5 and 2.5 meters from the subject in the

sagittal view. The video tapes were analyzed afterwards. The current PEO screen listing categorizing postures and activities was based on the risk factors identified in the literature [Fransson-Hall et al. 1995], on the study of Murphy et al. (2002) and on a recent ergonomic investigation by Cardon et al. (2004).

As a result the following postures were evaluated: trunk flexion over 45°, trunk rotation over 45°, neck flexion over 20° and neck rotation over 45°. With a focus on postural responses to school furniture, sitting with and without use of the back rest and arm supports were included. The category 'activities' contained the following aspects: static sitting, dynamic sitting, writing and reading, standing, walking, being active and lying on the floor. Dynamic sitting was defined as sitting with continuous movement around the centre of gravity, like tipping on a chair.

The percentages of the observed time interval (duration to the nearest 1 second) and how many times the postures and activities occurred (frequency) were recorded by the computer software package. In the current qualitative description, frequencies provided less relevant information about the ergonomic observation of postures. Therefore, frequencies were only reported for standing, static sitting and dynamical sitting.

The PEO-registration of the video tapes was executed by two graduate students, who had been trained for 15 hours.

To evaluate intra-tester reliability, the 30-minute tapes of thirty randomly selected participating children were evaluated twice by the two observers with a one-week interval. To evaluate the inter-observer reliability of the PEO set-up, video tapes of thirty randomly selected participating pupils were evaluated by two observers on an individual basis.

Questionnaire on self-reported back and neck pain. To evaluate self-reported one-week prevalence of back and neck pain a reliable questionnaire from previous research in 9 to 11 year olds was used [Cardon et al. 2002]. The questionnaire evaluated prevalence of

back and neck pain within the last week, including severity (5-point-scale), frequency (4-point-scale) and localization of the pain (bodily picture). One-week prevalence was defined as the occurrence of pain or discomfort, continuous or recurrent, at some point in the past week. The children were told that pain or discomfort due to fatigue related to a single exercise was not considered as a back or neck pain problem.

2.3 Procedure

The PEO evaluation consisted of an observation in the classroom during a regular lesson in the normal school curriculum. To minimize disturbance of the classes, unmanned video registrations replaced the direct observations. The camera evaluations with three unmanned digital video cameras (type Sony DCR-TRV730E) recorded in one time the observation of three children. The cameras were positioned in the class before the beginning of the lessons or during a break. Each child was recorded for a period of 30 minutes during a language or mathematics lesson. Since the presence of a camera may alter behavior [Cardon et al. 2001], the children were not told the purpose of the video recordings. A verbal awareness check after filming showed that pupils were not aware of the purpose of the observations.

Within a month after video recording, the children completed a questionnaire on self-reported back and neck pain in school under the supervision of their class teacher.

2.4 Statistical analysis

Data analysis was performed using SPSS 11.0 for Windows. Intra-class correlation coefficients were used to evaluate the inter-tester and intra-observer reliability for the durations and frequencies of six postures and seven activities. To reproduce the output of the 13 variables, defined by the PEO set up, descriptive statistics were executed.

Only five children with back or neck pain reported 'very much pain'. All other children reported 'very little' or 'little pain'.

Therefore the intensity of back and neck pain was recoded from a 5-point-scale to a 2-point-scale (children reporting pain and children not reporting pain).

A One Way ANOVA test with a priori contrasts was executed to determine group differences for PEO outcomes and age (dependent variables) for children reporting back or neck pain versus pain-free children (independent variables). To detect group differences in PEO outcomes between the children reporting only neck pain, the children with back pain only and the children not reporting pain, a One Way ANOVA test was used. Results were defined as significant at $P < .05$.

3. RESULTS

The intra-class correlation coefficients to measure intra-observer agreement for the PEO registrations of durations and frequencies varied for the two observers between 0.92 ($P < .001$) and 0.98 ($P < .001$). The intra-class correlation coefficients for inter-observer agreement of the two observers varied for 8 of the 13 categorized variables between 0.83 and 0.94 ($P < .001$). Lower but still acceptable intra-class correlation coefficients were found for the frequency 'reading and writing' (0.65, $P < .001$), the duration of 'reading and writing' (0.76, $P < .001$), the frequency of 'walking around' (0.57, $P < .05$), the duration of 'walking around' (0.61, $P < .05$) and the duration of 'trunk rotation over 45°' (0.65, $P < .001$).

The observed durations of the categorized postures and activities are presented in table 1. The prevalence of self-reported back and neck pain in the last week was 21%, with no gender difference ($\chi^2 = .46$, ns). Seven children reported experiencing back or neck pain once, sixteen children experienced pain 'several times' or 'frequently' and one subject reported continuous pain. Children reporting back and neck pain showed a tendency to be older than children not reporting pain ($t = 1.90$, $P = .06$). As seen in table 1, no statistical differences were found in the durations of postures and activities between children reporting back or neck pain and pain free children ($t < 1.57$, ns), except that children reporting

pain stood for a longer period of time ($t=2.14$, $P<.05$). Fifty-five percent of the pain-reporting children were found to experience cervical pain ($n=12$) while 45% indicated pain in the thoraco-lumbar zone ($n=10$). None of the children reported simultaneous cervical and thoraco-lumbar pain. Analysis showed that children who spent more time sitting with the trunk flexed over 45° reported significantly more thoraco-lumbar pain compared to pain-free children and children with cervical pain ($F=3.43$, $P<.05$).

Cardon et al. 2004], the present study found that the PEO method evaluated postural activity of schoolchildren in the classroom with high reliability. However, when interpreting the variables 'reading and writing', 'walking' and 'trunk rotation', caution is recommended because of the low but still acceptable reliability.

The principal finding of the present study was that elementary schoolchildren in Flanders were sitting statically for 85% of the time, while the trunk was bent over 45° for 28% of the lesson time. Dynamic

Table 1: PEO outcomes of observed activities and postures with statistical analyses in relationship with self-reported back and neck pain.

PEO registered 30 minute observations	Total group ($n=105$)			Children not reporting pain ($n=83$)		Children reporting back or neck pain ($n=22$)				Statistical Analysis			
						Neck pain ONLY ($n=12$)		Back pain ONLY ($n=10$)		One Way ANOVA		Contrasts	
Duration (%)	Mean	SD	#	Mean	SD	Mean	SD	Mean	SD	F	P	t	P
Writing and reading	62.9	29.5	105	63.4	28.7	56.1	33.7	66.6	32.8	.41	ns	.30	ns
Static sitting	85.1	11.5	105	85.7	10.8	82.4	11.4	82.7	16.9	.66	ns	1.14	ns
Dynamic sitting	9.1	6.5	102	9.2	6.6	10.9	6.1	6.2	4.8	1.51	ns	.42	ns
Standing	4.0	8.1	50	3.2	6.0	5.4	10.3	9.1	16.1	2.71	ns	2.14	.04*
Walking	1.6	2.3	50	1.5	2.4	1.2	1.3	1.3	1.9	.09	ns	.40	ns
Active	0.1	0.6	2	0.1	0.6	0.0	0.0	0.0	0.0	.23	ns	.69	ns
Lying at the floor	0.1	0.5	3	0.1	0.5	0.0	0.0	0.0	0.0	.47	ns	.96	ns
Trunk flexion > 45°	28.4	25.3	97	29.9	25.5	11.7	10.1	36.4	29.2	3.43	.04*	1.05	ns
Trunk rotation > 45°	4.3	6.6	75	4.2	5.9	5.6	9.1	4.2	9.2	.24	ns	.50	ns
Use of back rest	35.6	27.9	105	36.7	28.5	32.0	24.0	30.1	29.9	.32	ns	.79	ns
Arm supports	84.7	13.4	105	85.7	12.8	82.6	15.4	78.8	15.9	1.38	ns	1.57	ns
Neck flexion > 20°	44.5	21.1	105	44.8	20.2	44.9	22.2	41.5	28.1	.11	ns	.31	ns
Neck rotation > 45°	13.9	9.9	105	13.8	10.3	16.8	9.9	11.4	5.1	.82	ns	.13	ns
Age (years)	9.8	0.8	105	9.7	0.8	10.1	0.8	10.1	0.6	1.80	ns	1.90	.06

4. DISCUSSION

The main purpose of the current study was to portray classroom postures of 8 to 12 year old children in Flanders. An additional objective was to relate observed postures of elementary schoolchildren to self-reported back or neck pain. One of the strengths of the current study was the inclusion of a large sample population covering numerous classes and schools.

In line with the literature [Fransson-Hall et al. 1995, Murphy et al. 2002,

sitting was observed for only 9% of the time and recorded only 13 times. The general sitting pattern showed that pupils interrupted their static sitting posture with short moments of dynamic sitting, and then returned to prolonged static sitting. Furthermore, only half of the children walked around or stood up during the class observations and this for 2 to 4% of the lesson time. These findings indicate that prolonged sitting is very common amongst schoolchildren in Flanders. This pattern is probably encouraged by the

traditional style of education. A possible biomechanical consequence may be increased intra-disc pressure resulting in decreased nutrition to the discs as found in adults by Wilke et al. (1999 and 2001).

This study also showed that the children spent the majority of the sitting periods in poor postures. During lesson times, they were sitting over 25% of the time with the trunk bent over 45° and nearly half of the time with a flexed neck. It is plausible that while children were sitting with a flexed trunk, the lumbar lordotic curve was flattened or even positioned in a kyphotic curvature. Wilke et al. (2001) demonstrated that kyphotic sitting in adults increases disc compression. Neck flexion is known to increase the cervical spinal load [Chaffin and Andersson 1991] and according to Breithecker (2000), is related to headaches in elementary school-age children.

The current PEO outcomes were generally in line with the PEO findings of Murphy et al. (2002) and Cardon et al. (2004). However, the time spent in neck flexion in the present study was twice as long compared to the time observed in the United Kingdom [Murphy et al. 2002]. One of the PEO studies in the United Kingdom stated that children performed work at desks for only 38% of the time [Murphy and Buckle 2003], i.e. half as long as in the child population surveyed for this study (64% of time). A possible explanation could be that children bent their neck performing reading and writing tasks. It is also possible that the educational organization which may vary between countries, causes a different output. A third explanation could relate to the study design. The study among sitting postures in the United Kingdom observed children aged 11 to 14 years in a secondary school. The school culture of a secondary school may be fundamentally different from that in elementary schools.

In the current study children spent respectively 4% and 14% of the time with the trunk and the neck rotated. In two studies including adult populations, sitting with a twisted trunk has been shown to require a high effort of the trunk musculature resulting in increased disc compression [McGill et al. 1994, Boden

and Oberg 1998]. In the United Kingdom, similar trends were reported for rotated postures in the classroom observations, i.e. children spent 3% in trunk rotation and 13% in neck rotation [Murphy et al. 2002]. However, the time span of rotated postures differed from the recent study findings of Cardon et al. (2004) in Flemish children, reporting 14% trunk rotation and 44% neck rotation. The reason for these differences might be that in the latter study [Cardon et al. 2004] only one class group was observed. In the observed classroom, desks were organized in small groups face to face, with the teacher staying in front of the classroom, forcing the children to twist around. In contrast, 41 class groups were evaluated in the present study and as a result many different classroom layouts were included.

Finally, a positive finding of the present study was that the children were sitting on traditional school furniture without arm rests, but supported their arms on their desks or thighs during 85% of the time and used their back rest during 36%. The current study findings were in line with the studies of Murphy et al. (2002) and Cardon et al. (2004), which respectively reported that children supported their arms on their desks for 91% of the time and used their back rest during 31% of the lesson time. According to Knight (1999) and Chaffin (1999), using a back rest and arm support may decrease the spinal load because part of the weight is transferred to a support reducing forces and flexion moments on the lumbar spine.

A general remark is that the individual differences were relatively smaller for activities than for postures. Possibly this is caused by the limited freedom of pupils to choose their activity during lessons, whereas postures are determined to a smaller extent by class organization and structures. As a consequence, changes in classroom layout might make a difference for postural dynamic in the classroom.

The postural pattern of elementary schoolchildren in Flanders was commonly prolonged sitting with a poor posture was common. This could be a risk factor for early degenerative changes and possibly

for back or neck pain. In line with earlier research [Olsen et al. 1992, Salminen et al. 1992a, Balagué et al. 1993, Balagué et al. 1994, Nissinen et al. 1994, Taimela et al. 1997], the present study revealed that 21% of the 8 to 12 year old children reported back or neck pain at some point in the last week. The association between observed postures and back or neck pain was weak, most likely because the effects of spinal loading do not occur until at an older age. Children were questioned at the age before or just starting growth spurt, when most back or neck complaints occur [Taimela et al. 1997, Leboeuf-Yde and Ohm Kyvik 1998]. The current study findings indicated some support for this hypothesis since there was a trend that older children reaching the onset age of growth spurt reported more back and neck complaints.

An important limitation of the present study was the cross-sectional design, which prevented an evaluation of the relationship between cause and effect. On the one hand it was found that thoraco-lumbar pain reports were more numerous in children sitting with their trunk bent over 45° during a higher percentage of the lesson time. On the other hand, it was observed that pain reporting children were standing for longer periods of time during lessons. The cross-sectional design made it impossible to explain this behavior as a cause or a consequence of back pain.

Furthermore, the low association between the PEO class observations and pain reports could be ascribed to the use of a questionnaire to evaluate pain. The use of a questionnaire is not incontestable because feeling pain is a subjective phenomenon and at a young age children are in the middle of a learning process concerning experiencing and reporting pain [Balagué et al. 2003]. Therefore, any findings related to self-reported back and neck pain complaints should be interpreted with caution.

An important consideration regarding disc compression in the immature spinal column must be reported. Adult population studies were considered in order to discuss the mechanical effects of possible loading factors. Similar effects

on the spinal column of children can only be assumed since no study could be located that evaluated disc loading responses in children. Therefore cautious interpretation is required and further study on this topic is advocated.

5. CONCLUSIONS

Prolonged static sitting with a poor posture is common in elementary schoolchildren in Flanders and from a biomechanical point of view, a supplementary spinal load may be assumed. Although the association with back pain at this young age is limited, modifications seem necessary to prevent future back pain. In consequence further longitudinal research is required to evaluate whether the stress on young growing body structures, associated with prolonged poor postures, has an impact later in life.

Moreover it seems that the postural behavior of young individuals partly depends on components of the class environment such as school furniture, teaching method, organizational class structures, the pedagogic concept and school management. The current study shows that dynamic sitting is very uncommon in the actual class environment in Flanders. According to this finding and to the literature it would seem useful to create and evaluate a multidimensional primary prevention program, implementing movement breaks, alterations of class organization and time structures. Moreover, the development of dynamic sitting habits in school-age children may help to improve sitting habits into adulthood. It is therefore recommended that future studies should investigate optimization of classroom environmental design.

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REFERENCES

1. Balagué, F., Damidot, P., Nordin, M., Parnianpour, M. and Waldburger, M., 1993, Cross-sectional study of the isokinetic muscle trunk strength among schoolchildren. *Spine*, 18, pp. 1199-1205.
2. Balagué, F., Nordin, M., Skovron, M.L., Dutoit, G., Yee, A. and Waldburger, M., 1994, Nonspecific low-back-pain among schoolchildren - A field survey with analysis of some associated factors. *Journal of Spinal Disorders*, 7, pp. 374-379.
3. Balagué, F., Troussier, B. and Salminen, J.J., 1999, Non-specific low back pain in children and adolescents: risk-factors. *European Spine Journal*, 8, pp. 429-438.
4. Balagué, F., Dudler, J. and Nordin, M., 2003, Low-back pain in children. *Lancet*, 361, pp. 1403-1404.
5. Boden, A. and Oberg, K., 1998, Torque resistance of the passive tissues of the trunk at axial rotation. *Applied Ergonomics*, 29, pp. 111-118.
6. Breithecker, D., 2000, Lust auf Schule: Lust auf Lernen. Mehr Gesundheit und Wohlbefinden am Arbeitsplatz Schule, Ein Projectbericht (Enjoying school, fun in learning: more health and well being in the school as place of work, A project report). *Haltung und Bewegung*, pp. 4.
7. Cardon, G., De bourdeaudhuij, I. and De clerq, D., 2001, Generalization of back education principles by elementary schoolchildren: evaluation with a practical test and a candid camera observation. *Acta Paediatrica*, 90, pp. 143-150.
8. Cardon, G., De bourdeaudhuij, I. and De clerq, D., 2002, Back education efficacy in elementary schoolchildren: a one year follow-up study. *Spine*, 27, pp. 299-305.
9. Cardon, G., De clerq, D., De bourdeaudhuij, I. and Breithecker, D., 2004, Sitting habits in elementary schoolchildren: a traditional versus a 'Moving school'. *Patient Education and Counseling*, 54, pp. 133-142.
10. Chaffin, D.B. and Andersson, G.B.J., 1991, *Occupational biomechanics*. (New York: Willey).
11. Chaffin, D.B., Andersson, G.B.J. and Bernard, J.M., 1999, *Occupational biomechanics*. (New York: Willey).
12. Dvorak, J., Panjabi, M.M., Novotny, J.E. and Antinnes, J.A., 1991, In vivo flexion/extension of the normal cervical spine. *Journal of Orthopaedic Research*, 9, pp. 828-834.
13. Fransson-hall, C., Gloria, R., Kilbom, A. and Winkel, J., 1995, A Portable Ergonomic Observation method (PEO) for computerized on-line recording of postures and manual handling. *Applied Ergonomics*, 26, pp. 93-100.
14. Harreby, M., Nygaard, B., Jessen, T., Larsen, E., Storr-paulsen, A., Lindahl, A., Fisker, I. and Laegaard, E., 1999, Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. *European Spine Journal*, 8, pp. 444-450.
15. Harrison, D.D., Harrison, S.O., Croft, A.C., Harrison, D.E. and Troyanovich, S.J., 1999, Sitting biomechanics part I: review of the literature. *Journal of manipulative and physiological therapeutics*, 22, pp. 594-609.
16. Illi, U., Breithecker, D. and Mundigler, S., 1998, *Bewegte Schule, Gesunde Schule* (Zurich: Eigenverlag).
17. Jones, G.T., Watson, K.D., Silman, A.J., Symmons, D.P.M. and Macfarlane, G.J., 2003, Predictors of low back pain in British schoolchildren: A population-based prospective cohort study. *Pediatrics*, 111, pp. 822-828.
18. Knight, G. and Noyes, J., 1999, Children's behaviour and the design of

- school furniture. *Ergonomics*, 42, pp. 747-760.
19. Leboeuf-yde, C. and Ohm kyvik, K., 1998, At what age does low back pain become a common problem. *Spine*, 23, pp. 228-234.
 20. Marschall, M., Harrington, A.C. and Steele, J.R., 1995, Effect of work station design on sitting posture in young children. *Ergonomics*, 38, pp. 1932-1940.
 21. McGill, S., Seguin, J. and Bennett, G., 1994, Passive stiffness of the lumbar torso in flexion, extension, lateral bending, and axial rotation - effect of belt wearing and breath-holding. *Spine*, 19, pp. 696-704.
 22. Murphy, S., Buckle, P. and Stubbs, D., 2002, The use of the portable ergonomic observation method (PEO) to monitor the sitting posture of schoolchildren in the classroom. *Applied Ergonomics*, 33, pp. 365-370.
 23. Murphy, S. and Buckle, P., 2003, Back pain amongst school children and physical risk factors in schools, Proceedings of the 'Back pain in schoolchildren - Causes and Solutions' conference, Robens Centre for Health Ergonomics, United Kingdom.
 24. Nissinen, M., Heliovaara, M., Seitsamo, J., Alaranta, H. and Poussa, M., 1994, Anthropometric measurements and the incidence of low-back-pain in a cohort of pubertal children. *Spine*, 19, pp. 1367-1370.
 25. Olsen, T., Anderson, R., Dearwater, S.R., Kriska, A.M., Cauley, J.A. and Aaron, D.J., 1992, The epidemiology of low-back-pain in an adolescent population. *American Journal Of Public Health*, 82, pp. 606-608.
 26. Parcels, C., Stommel, M. and Hubbard, R., 1999, Mismatch of classroom furniture and student body dimensions. *Journal of Adolescent Health*, 24, pp. 265-273.
 27. Panagiotopoulou, G., Christoulas, K., Papanckolaou, A. and Mandroukas, K., 2004, Classroom furniture dimensions and anthropometric measures in primary school. *Applied Ergonomics*, 35, pp. 121-128.
 28. Salminen, J.J., Maki, P., Oksanen, A. and Pentti, J., 1992a, Spinal mobility and trunk muscle strength in 15-year-old schoolchildren with and without low-back-pain. *Spine*, 17, pp. 405-411.
 29. Salminen, J.J., Pentti, J. and Terho, P., 1992b, Low back pain and disability in 14-year-old schoolchildren. *Acta Paediatrica*, 81, pp. 1035-1039.
 30. Salminen, J.J., Erkintalo, M.O., Pentti, J., Oksanen, A. and Kormanen, M.J., 1999, Recurrent low back pain and early disc degeneration in the young. *Spine*, 24, pp. 1316-1321.
 31. Sjölie, A.N. and Ljunggren, A.E., 2001, The significance of high lumbar mobility and low lumbar strength for current and future low back pain in adolescents. *Spine*, 26, pp. 2629-2636.
 32. Storr-paulssen, A. and Aagaard-hensen, J., 1994, The working positions of schoolchildren. *Applied Ergonomics*, 25, pp. 63-64.
 33. Taimela, S., Kujula, U.M., Salminen, J.J. and Viljanen, T., 1997, The prevalence of low back pain among children and adolescents - A nationwide, cohort-based questionnaire survey in Finland. *Spine*, 22, pp. 1132-1136.
 34. Troussier, B., Tesniers, C., Fauconnier, J., Grison, J., Juvin, R. and Phelip, X., 1999, Comparative study of two different kinds of school furniture among children. *Ergonomics*, 42, pp. 516-526.
 35. Vleeming, A., Lee, D., and Van wingerden, J.P., 2000, Joint function: development of an integral model for diagnosis and treatment, Proceedings of the 2000 IFOMT meeting, Perth Australia, pp. 118-123.
 36. Watson, K.D., Papageorgiou, A.C., Jones, G.T., Tayler, S., Symmons, D.P.M, Silman, A.J. et al., 2002, Low back pain in schoolchildren: occurrence and characteristics. *Pain*, 97, pp. 87-92.
 37. Wilke, H.J., Neef, P., Caimi, M., Hoogland, T. and Claes, L.E., 1999, New in vivo measurements of pressures in the intervertebral disc in daily life. *Spine*, 24, pp. 755-762.
 38. Wilke, H.J., Neef, P., Hinz, B., Seidel, H. and Claes, L., 2001, Intradiscal pressure together with anthropometric

data - a data set for the validation of models. *Clinical Biomechanics*, 16 (Suppl 1), pp. 111-126.

CHAPTER 2

STATIC AND DYNAMIC STANDING BALANCE: TEST-RETEST RELIABILITY AND REFERENCE VALUES IN 9 TO 10 YEAR OLD CHILDREN

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STATIC AND DYNAMIC STANDING BALANCE: TEST-RETEST RELIABILITY AND REFERENCE VALUES IN 9 TO 10 YEAR OLD CHILDREN

Abstract. Background. Based on the literature, reliability reports and normative data for bilateral stance assessments in elementary schoolchildren are limited. The present study was designed to report test-retest reliability and reference values for postural stability in 9 to 10 year old schoolchildren using the Balance Master® System. **Methods.** Twenty children participated in the reproducibility study (mean age 10.1 ± 0.7) including test and retest measurement with a one-week interval. The modified Clinical Test of Sensory Interaction on Balance (mCTSIB) quantified children's static standing balance. The test for the Limits of Stability (LOS) measured dynamic standing balance. The study sample to determine reference values consisted of 99 children (mean age 9.8 ± 0.5). **Results.** The ICC's for inter-item reliability of the four sensory conditions of the mCTSIB showed fair to excellent reliability (ICC's between 0.62 and 0.80). The reproducibility between test and retest was non-significant for the condition 'firm surface with eyes closed' (ICC of 0.37), fair to good for the three other sensory conditions (ICC's between 0.59 and 0.68), and excellent for the composite sway velocity (ICC of 0.77). For all LOS parameters, the significant ICC's showed fair to good reproducibility (ICC's between 0.44 and 0.62), with the exception of the non-significant ICC for the composite Reaction Time. The ICC's for the separate LOS parameters showed fair to good and excellent reliability for nine parameters (ICC's between 0.46 and 0.81), while 11 separate LOS scores did not demonstrate significant ICC's. Analyzing reference values, girls performed better on all the composite balance parameters compared to boys, with the exception of Reaction Time and Movement Velocity. No differences were found on standing balance scores between 9 and 10 year olds. **Conclusion.** The Balance Master® showed fair to good reliability for most postural parameters in 9 to 10 year olds. The current data on postural control in children aged 9 to 10 years are relevant for research in other domains within the clinical field, like obesitas and developmental coordination disorder or in relation to back pain prevalence at early age.

Keywords: children, standing balance, reliability, reference values.

1. INTRODUCTION

Postural stability is considered to be an important indicator of musculoskeletal health and therefore could be of importance in view of clinical issues. Postural stability refers to the inherent ability of a person to maintain, achieve or restore a specific state of balance and not to fall [16].

The most frequently used technique to evaluate postural stability, both static and dynamic, is the measurement of the position and displacement of the centre of pressure (COP) using a force plate form. Force plate measurements for postural assessment are widely used in adults and the reliability is well documented in this

population [3, 4, 11]. Based on the literature, reliability reports and normative data for bilateral stance assessments in elementary schoolchildren are limited. Children's development of postural stability using bilateral force plate measurements was earlier described in a number of studies [5, 10, 12, 13, 15, 18, 19]. However, the latter studies did not incorporate reliability reports on the evaluation method of force plate measurements for a childhood population. In contrast, reliability was investigated in childhood and adolescence with respect to other postural assessment techniques. Accordingly, the study of Atwater et al. [1] investigated reliability for the one-leg stance and a tilt board balance test in 4 to 9 year olds, Gabriel and colleagues [9]

evaluated in 5 to 9 year olds test-retest for the Neurocom VSR, Emery et al. [6] evaluated test-retest for the one-leg stance in 14 to 19 year olds and Mc Evoy and Grimmer [14] described repeated testing of upright posture evaluation using sagittal plane photography in 5 to 12 years. Further, Baker et al. [2] assessed in 2 to 12 year olds the reliability of two systems assessing to static standing balance, but test-retest reliability of the separate systems was not measured. Only when test-retest reliability for postural stability assessments using force plate measurements in elementary school-aged children is established, reference data can be determined and possible associations to impairments within the clinical field could be investigated in early stages of the potential problems.

According to Rival et al. [18] investigating developmental changes of postural control in children with respect to standing balance, a transition phase should occur around 7-8 years. In 9 to 10 year olds standing balance appeared to be adult-like [18], however not fully matured [17]. Therefore, the present study was designed to report test-retest reliability and reference values for postural stability in 9 to 10 years old schoolchildren using the Balance Master® System.

2. METHODS

2.1 Subjects

The reliability of the Balance Master® System was evaluated in 4th and 5th grade children from a randomly selected school. The parents of all 153 4th and 5th grade children were notified by a letter and asked for their child's participation in the reliability assessment for postural stability using the Balance Master® System. This invitation was accepted by 47 parents who signed the Informed Consent Form for their child. Out of this group, 20 children aged 9-10 years were selected by simple randomization to participate in the reproducibility study for postural stability (10 boys and 10 girls, mean age 10.1 ± 0.7).

In order to determine reference values for postural stability in elementary

schoolchildren, a sample of 4th and 5th grade children from 10 simply randomized selected schools was drawn. The parents of all 379 children were contacted to ask for their child's participation in the reliability assessment of postural stability. A total of 99 parents signed the Informed Consent form. The study sample in order to determine reference values consisted of 99 children between 9 and 10 years old (41 boys, 58 girls, mean age 9.8 ± 0.5).

2.2 Procedure

The reliability study for postural stability using the Balance Master® System in 9 to 10 year olds included test and retest measurement with a one week interval. Both the test and retest measurements and the assessments for reference values were performed by the same researcher, according to the following standardized test-setting. Children were barefoot for all measurements. Before performing the balance tests, the children's age and basic anthropometrical data were registered. Weight was assessed to the nearest 0.1 kg (Seca, max 200 kg). Height to the nearest 1 mm was measured using a wall-mounted stadiometer (Siber Hegner). The balance tests took place in a discrete room free from external distractions. Starting the assessment, the researcher positioned the children's feet following the appropriate alignments on the force platform for the medial malleolus and the outside border of the heel. All children started with the assessment of static balance, which was followed by the dynamic balance test. For each condition of the static balance test and before the dynamic balance test, one training trial was allowed before data collection. A side-view and frontal positioned camera registered the children performing both the static and dynamic standing balance tests. The study was approved by the Ethical Committee of the University Hospital of Ghent University.

2.3 Instruments

The Neurocom Basic Balance Master® System (NeuroCom, Clackamas,

Ore., USA) was used to measure children's postural stability with respect to standing balance. The Balance Master® consisted of a portable force platform connected to a computer including a software program that calculated the center of pressure relative to the platform coordinates. An estimation of the position and displacement of the center of gravity (COG) was sampled at 100 Hz, based on a simple inverted pendulum approximation using the sampled center of pressure data and the subjects' body height.

Static standing balance. The modified Clinical Test of Sensory Interaction on Balance (mCTSIB) quantified postural sway velocity of the children standing quietly on the force platform. This test consisted of four different sensory conditions including three consecutive trials of 10 seconds: (1) standing with eyes open on a firm surface, (2) standing with eyes closed on a firm surface, (3) standing with eyes open on a foam surface, (4) standing with eyes closed on a foam surface. The test sequence of the conditions was identical for all children.

Children were instructed to stand upright as steady as possible with the arms by their sides. In the conditions 'eyes open', the children were requested to keep the eyes open and look straight ahead. In the conditions 'eyes closed' they were blindfolded and asked to stand upright as steady as possible with eyes closed. The relative absence of sway was a measure for static stability (COG sway velocity).

Dynamic standing balance. The test for the Limits of Stability (LOS) quantified several movement characteristics associated with the subject's ability to voluntarily sway towards various locations in space, and briefly maintain stability at those positions. The LOS test measured the child's volitional (intentional) control of the COG. A limit of stability is the maximum distance a person can lean in a given direction (measured as angular distance from vertical) without losing balance, stepping, or reaching. The limits of stability were calculated individually, based on the children's body height. Performing the dynamic standing balance task, the location of the child's

COG was displayed on the computer screen as a cursor providing continuous visual feedback. Cursor control occurred by weight-shifting. The children had to move the cursor (their projection of their center of gravity) as close as possible to eight targets (their limits of stability). The eight targets were arranged in an ellipse, separated by an angle of 45° (forward, forward-right, right, backward-right, backward, backward-left, left, forward-left). They started at the midline and held the cursor at the target as long as the target remained highlighted. After eight seconds, the cursor disappeared and the child returned to the midline. The same procedure was repeated clockwise for all the targets.

Therefore, the children were instructed to "move as quickly and accurately as possible" to each of the eight targets, without displacing the feet, bending the trunk or moving the arms. Children were instructed to move like a 'piece of wood', to emphasize a neutral hip position performing the LOS. When a child lost the correct posture, the test leader stopped the test. Accuracy was indicated by (1) whether or not the subject reached the target (maximal excursion), (2) whether the target was reached on the initial attempt (endpoint excursion), and (3) whether or not progress towards the target was smooth and consistent (directional control).

2.4 Data analysis

Outcome measures of standing balance assessment: the standing balance parameters. According to the mCTSIB, the COG Sway Velocity was calculated as a ratio of distance traveled by the COG (expressed in degrees) to the time of the trial (10 seconds). The *Mean COG Sway Velocity* was the average of the COG Sway Velocity scores from the combined trials of any one condition; the sum of scores divided by the number of trials. The *Composite Mean COG Sway Velocity* was the average of the mean COG Sway Velocity scores for all conditions; the sum of the four means divided by the number of conditions.

The COG Sway Velocity scores indicated how well the subject accomplished the objective to stand as still as possible. Small scores reflected little movement, and are “good”. Large scores reflected more movement, and are “worse”.

The measured parameters of the LOS test were: reaction time (RT), movement velocity (Sway), endpoint excursion (EXE), maximal endpoint excursion (m-EXE) and directional control (CD). *Reaction Time* (RT) is the time in seconds between the signal to move and the initiation of movement. *Movement Velocity* (MVL) is the average speed of COG movement, expressed in degrees per second, between 5% and 95% of the distance to the primary endpoint. *Endpoint Excursion* (EPE) is the distance traveled by the COG on the primary attempt to reach the target, expressed in % LOS. *Maximal Endpoint Excursion* (MXE) is the furthest distance traveled by the COG during the trial. This may be larger than the Endpoint Excursion if the subject makes additional corrective attempts. *Directional Control* is a comparison of the amount of movement in the intended direction (towards the target) to the amount of extraneous movement (away from the target). In addition to the composite score, the LOS scores from the eight transitions were combined to provide a separate average score for each of the four main directions (forward – backward - right – left).

Statistical Analysis. Statistical analyses were conducted using SPSS 11.0 for Windows. The level of statistical significance was set at $P < .05$. Using Single Measure Intra-class Correlation Coefficients (ICC's), trial-to-trial (inter-item) and test-retest (inter-session) reliability evaluation for the Balance Master® was performed. The ICC values were interpreted according to the general guidelines of Fleiss [8] : ICC's > 0.75 were labeled 'excellent', > 0.40 'fair to good', < 0.40 'poor'.

To determine reference values in 9 to 10 year olds ($n=99$), Independent Samples T-tests were executed in order to analyze gender differences for age and anthropometrics (height, weight and BMI). Furthermore, the study sample ($n=99$) was divided into a group of 9 year olds ($n=52$) and a group of 10 year olds ($n=47$). Using Univariate Analysis of Variance, the standing balance parameters were separately analyzed as dependent variables. In addition, gender and age were included as between-subjects factors and BMI as a covariate.

3. RESULTS

3.1 Test-retest reliability

The ICC's representing intra-session reliability and inter-session stability for the use of the mCTSIB in the current study sample ($n=20$) are shown in table 1. The ICC's for inter-item reliability

Table 1: ICC's for static standing balance (mCTSIB).

Intratest Reliability: inter-item (3 trials)		Average Measure ICC	95% Confidence interval
COG Sway Velocity (°/sec)			
Test (n=20)	firm surface eyes open	0.62	0.20 - 0.84
	firm surface eyes closed	0.73	0.40 - 0.90
	foam surface eyes open	0.62	0.15 - 0.85
	foam surface eyes closed	0.74	0.44 - 0.81
COG Sway Velocity (°/sec)			
Retest (n=20)	firm surface eyes open	0.70	0.35 - 0.88
	firm surface eyes closed	0.77	0.50 - 0.90
	foam surface eyes open	0.80	0.55 - 0.92
	foam surface eyes closed	0.79	0.53 - 0.91
Inter-test Reliability: inter-session (mean score)		Single Measure ICC	95% Confidence interval
Mean COG Sway Velocity (°/sec)			
Test-retest (n=20)	firm surface eyes open	0.59	0.21 - 0.82
	firm surface eyes closed	0.37	-0.09 - 0.70
	foam surface eyes open	0.68	0.35 - 0.87
	foam surface eyes closed	0.63	0.33 - 0.87
	composite	0.77	0.47 - 0.91

ICC: Intraclass Correlation Coefficient

** $P < .01$; * $P < .05$

of the four sensory conditions of the mCTSIB showed fair to excellent reliability (ICC's between 0.62 and 0.80). The reproducibility between test and retest was non-significant for the condition 'firm surface with eyes closed' (ICC of 0.37), fair to good for the three other sensory conditions (ICC's between 0.59 and 0.68), and excellent for the composite sway velocity (ICC of 0.77). The ICC's representing inter-session stability for the LOS are presented in table 2. For all composite LOS parameters, the ICC's showed fair to good reproducibility (ICC's between 0.44 and 0.62), with the exception of the non-significant ICC for the composite *Reaction Time* (Confidence Interval: -0.4 – 0.71). The ICC's for the separate LOS parameters showed fair to good and excellent reliability for nine parameters (ICC's between 0.46 and 0.81), while 11 separate LOS scores did not demonstrate significant ICC's.

3.2 Reference values

The study sample to determine reference values showed no gender differences for age and anthropometrical values (age: $t=.447$, $df=104$, ns, height: $t=.825$, $df=104$, ns; weight: $t=1.026$, $df=104$, ns; BMI: $t=1.028$, $df=104$, ns).

The reference values for static and dynamic standing balance using the Neurocom Balance Master® in boys and girls aged 9-10 are presented in table 3. Girls performed better on all the composite balance parameters compared to boys, with the exception of *Reaction Time* and *Movement Velocity* according to the LOS (see table 3). No gender differences were found for the separate dynamic standing balance parameters towards the four main directions, with the exception of a better performance on *Endpoint Excursion Backwards* in girls. Further, no differences were found on standing balance scores between 9 and 10 year olds (for all

Table 2: ICC's for dynamic standing balance (LOS).

Intertest Reliability: inter-session (mean score 4 directions)		Single Measure ICC	95% Confidence Interval	
Test-retest (n=20)	Reaction Time (sec)			
	transition forward	0.21	-0.25 - 0.60	
	transition backward	0.18	-0.30 - 0.59	
	transition right	0.43	-0.01 - 0.73	
	transition left	0.10	-0.34 - 0.51	
	Movement Velocity (°/sec)			
	transition forward	0.09	-0.37 - 0.51	
	transition backward	0.81	0.58 - 0.92	
	transition right	0.47	0.04 - 0.75	
	transition left	0.62	0.26 - 0.83	
	Endpoint Excursion (% LOS)			
	transition forward	0.43	-0.01 - 0.74	
	transition backward	0.69	0.35 - 0.87	
	transition right	0.29	-0.16 - 0.64	
	transition left	0.46	0.04 - 0.75	
	Max. Endpoint Excursion (% LOS)			
	transition forward	0.53	0.11 - 0.79	
	transition backward	0.78	0.50 - 0.91	
	transition right	0.09	-0.36 - 0.50	
	transition left	0.70	0.38 - 0.87	
	Directional Control (%)			
	transition forward	0.57	0.17 - 0.81	
	transition backward	0.43	-0.03 - 0.74	
	transition right	0.36	-0.09 - 0.68	
	transition left	0.16	-0.30 - 0.55	
	Intertest Reliability: inter-session (composite mean score)		Single Measure ICC	95% Confidence Interval
	Test-retest (n=20)	Reaction Time (sec)	0.40	-0.04 - 0.71
		Movement Velocity (°/sec)	0.46	0.30 - 0.74
Endpoint Excursion (% LOS)		0.62	0.23 - 0.82	
Maximal Endpoint excursion (% LOS)		0.46	0.04 - 0.75	
Directional Control (%)		0.44	0.04 - 0.71	

ICC: Intraclass Correlation Coefficient

parameters: $F < 2.978$, $df=1$, $P > .088$).

No gender by age interaction effects were found for the balance parameters of both tests revealing that the effect of sex was the same at each age (for all parameters: $F < 3.150$, $df=1$, $P > .081$). Consequently, a distinction between 9 and 10 year olds was not made to present the reference values.

Measuring static standing balance, BMI was only a significant covariate for the foam conditions (foam eyes open: $F=6.581$, $df=1$, $P < .01$; foam eyes closed: $F=11.091$, $df=1$, $P < .01$) and the composite sway velocity ($F=4.860$, $df=1$, $P < .05$) of the mCTSIB. In the evaluation of dynamic standing balance, BMI was not a confounding factor.

4. DISCUSSION

The aim of the present study was to examine the reliability of static and dynamic standing balance testing in 9 to 10 year olds and to report reference values in this young population.

Intra-session and test-retest reliability. The intra-session reliability measuring static standing balance in 9 to 10 year olds using the Balance Master® demonstrated fair to excellent intra-session reliability for the four conditions of the mCTSIB. Further, mCTSIB stability parameters showed fair to excellent test-retest reliability for three sensory conditions and the composite sway velocity was the most reliable variable considering inter-session stability.

Table 3: Reference values for static and dynamic standing balance in girls and boys aged 9-10.

Balance Master® parameters	Total (n=99)	Girls (n=58)	Boys (n=41)	Statistics° (df=1)
	Mean ± SD	Mean ± SD	Mean ± SD	F
mCTSIB				
Composite Mean COG Sway Velocity (°/sec)	.712 ± .181	.679 ± .186	.783 ± .155	7.654**
firm surface eyes open	.323 ± .095	.303 ± .085	.351 ± .101	6.877**
firm surface eyes closed	.424 ± .137	.395 ± .127	.469 ± .142	8.140#
foam surface eyes open	.686 ± .183	.641 ± .184	.751 ± .162	9.572**
foam surface eyes closed	1.463 ± .408	1.376 ± .412	1.591 ± .370	6.313*
LOS				
Composite Reaction Time (sec)	.702 ± .157	.710 ± .160	.602 ± .155	.129#
transition forward	.753 ± .220	.750 ± .237	.757 ± .194	.230#
transition backward	.652 ± .236	.679 ± .233	.609 ± .237	2.123#
transition right	.747 ± .218	.751 ± .225	.740 ± .211	.025#
transition left	.689 ± .183	.677 ± .180	.707 ± .189	.852#
Composite Movement Velocity (°/sec)	5.916 ± 1.683	5.944 ± 1.603	5.876 ± 1.813	.014
transition forward	6.352 ± 2.178	6.375 ± 2.237	6.316 ± 2.117	.010#
transition backward	3.471 ± 1.290	3.559 ± 1.284	3.336 ± 1.306	.605
transition right	7.108 ± 2.752	6.867 ± 2.479	7.481 ± 3.136	.978
transition left	6.752 ± 2.360	6.808 ± 2.247	6.669 ± 2.553	.057
Composite Endpoint Excursion (% LOS)	78.25 ± 14.43	81.53 ± 12.30	73.50 ± 16.06	7.674**
transition forward	88.25 ± 16.64	90.56 ± 16.87	84.50 ± 15.78	2.641#
transition backward	55.12 ± 19.26	58.78 ± 18.69	49.45 ± 19.02	7.152**
transition right	86.30 ± 17.17	89.08 ± 17.41	82.00 ± 16.11	3.305#
transition left	82.92 ± 19.48	85.34 ± 16.56	79.26 ± 22.98	2.236
Composite Maximal Endpoint excursion(%LOS)	98.04 ± 10.63	99.95 ± 9.18	95.29 ± 12.05	4.472
transition forward	108.73 ± 13.38	110.37 ± 13.37	106.06 ± 12.55	1.983
transition backward	73.57 ± 18.01	75.19 ± 19.69	71.06 ± 15.01	1.225
transition right	107.10 ± 13.43	108.88 ± 12.40	104.35 ± 14.67	2.238#
transition left	103.34 ± 15.12	104.45 ± 12.17	101.66 ± 18.81	.749
Composite Directional Control (%)	70.31 ± 8.63	71.67 ± 8.11	68.34 ± 9.08	4.089
transition forward	81.20 ± 8.08	81.58 ± 8.45	80.59 ± 7.52	.333
transition backward	57.65 ± 16.30	58.24 ± 17.14	56.76 ± 15.12	.584#
transition right	73.62 ± 10.38	75.19 ± 9.24	71.19 ± 11.68	2.803#
transition left	70.34 ± 10.20	71.77 ± 9.24	68.17 ± 11.31	2.784#

SD= standard deviation

° Univariate Analysis of Variance: main effect of gender

** $P < .01$; * $P < .05$

Non-significant test-retest value (see tables 1 and 2)

However, the level of agreement between the two sessions at one-week interval showed poor reliability for the 'firm surface eyes closed' condition. Measuring inter-session reliability of dynamic standing balance, the stability was fair to good for all composite stability parameters, with the exception of the non-significant 'reaction time' parameters. Focalizing on children's performance on the four main transitions of the LOS, none of the 'reaction time' parameters were significant. Further, 'movement velocity' and 'maximal endpoint excursion' parameters showed fair to good reliability for two main directions and excellent reliability for the backward transition. The 'endpoint excursion' parameters showed fair to good reliability for transitions backward and left whereas 'directional control' parameters demonstrated only for the forward transition fair to good reliability. The present reproducibility data established more significant and in general better inter-session test-retest reliability values for the composite scores in comparison to the separate scores, both for the static and dynamic standing balance parameters. The study of Lafond et al. [11] pointed out that the reliability of COP measures increased by increasing the trial duration. Along the same lines, based on our study findings, a sufficient number of trials may be an important factor in order to ascertain reliable postural stability assessments.

Like many biological measurements, postural stability has an intrinsic variability influenced by physical, biomechanical, metabolic and psychosocial factors [11]. Consequently, many factors affect the reproducibility of postural outcomes, such as motivation, concentration, fatigue, emotional state, time of the test and relationship with the tester. Therefore, in the current study measurement order, testing sequence, tester and surrounding factors were identical during the two sessions in order to minimize variations between tests and retest measurements. So, the modest reproducibility in the current study may be attributed to the inherent variability in children's balance performances and not to the test protocol. The variable balance

performances may be supported by the higher reliability scores for the evaluation of children's stability recordings at one moment (intra-test reliability) when compared to the evaluation of stability scores at two moments (inter-test reliability). On the other hand, the Neurocom Balance Master®'s protocol measuring stability has to deal with the complexity to guarantee the exact same foot positioning on the force plate. Despite the strict prescriptions for foot placement, the chance for possible variation in positioning the feet seems to be a potential danger affecting reproducibility. Finally, the non-significant reliability values of the LOS parameters regarding the separate scores for the main directions may be caused by the calculation of the COG path by the inverted pendulum approximation. Based on the qualitative observation of children's videotaped stability performances and the standardized test protocol demanding a neutral hip position one may assume that a hip strategy was not used. However, small hip flexion and extension movements may have occurred since minor hip strategy movements are not detectable by eye. Accordingly, a limited part of variation in reliability might also be due to the inverted pendulum principle which doesn't take into account the possible use of a hip strategy.

Taking the latter into account, it can be concluded that the one-week reproducibility for standing balance assessments using the Balance Master® in 9 to 10 year olds pointed out fair to good and even excellent reliability for most parameters, which is in accordance to a study in adults aged 20 to 32 years [4]. However, when interpreting the 'Firm surface with eyes closed' sensory condition of the mCTSIB and some separate sway parameters for the main directions of the LOS in 9 to 10 year olds, caution is recommended.

Reference values. The current study found significantly lower sway velocities in girls compared to boys for the composite and separate sway parameters of static standing balance, indicating a better postural control in girls at age 9 to 10 years. Analyzing the composite scores

of dynamic standing balance in 9 to 10 year olds, girls moved at the same velocity towards the targets, but in comparison to boys their initial attempts were better and they hold their COG closer to their LOS in a more consistent progression. None of the separate stability scores for the four transitions towards the main directions of the LOS established significant differences between boys and girls, with the exception of the 'endpoint excursion' backwards. The absent gender effect on the separate stability parameters of the LOS could possibly be explained by the lack of reliable measurements for these parameters. The effect of gender on the separate 'endpoint excursion' score of the backward direction in relation to the excellent reliability value for this parameter may support this hypothesis. Otherwise, the composite scores are an evaluation of eight trials in comparison to the evaluation of three trials determining the separate stability scores for the main directions. Based on the presented reference data, the composite scores of the LOS seem to include a summation of slightly different separate stability scores between boys and girls. This may explain the significant difference between boys and girls on the total composite stability scores of the LOS. Further, the current study showed no significant age by gender interactions for postural parameters, which corresponded to the developmental study findings of Figura et al. [7] assessing the static balance in children aged 6 to 10 years old. In this line, the current study findings showed that being 9 or 10 years old did not influence the performance on standing balance measurements. One could suppose that the difference in children's anthropometrics at the same chronological age might confound the possible effect of age. However, in the current study BMI was only a significant covariate for the measurements on a compliant surface and for composite sway velocity and not for any other parameter. In this line, the reliance of BMI on the balance assessments on a soft surface seems reasonable since BMI directly determines the extent of foam compression. Accordingly, different body weights vary

the challenge of the balance task provided by the foam surface.

The present study's findings about gender differences in standing balance assessment in 9-10 year old children corresponded to the study results of Nolan et al. [15], who examined sex and age differences for postural control in 9 to 10 year olds. This development-orientated investigation for standing posture in children supported our finding with regard to the independency of anthropometrics. Nolan et al. [15] demonstrated that a relation between anthropometric measurements and balance parameters was non-existent, whereas height and weight differed with age. The authors suggested that while postural control may be partly affected by changes in stature as children grow, the development of visual, vestibular, and somatosensory systems may account for age-related changes in balance control to a greater extent. Accordingly, one might presume that boys at age 9-10 years use another control strategy compared to girls of this age group.

Coming to a conclusion, the portable Neurocom Balance Master® System is easy to transport and as such extremely useful in the school setting. In the present study, the elementary schoolchildren were volunteers out of a group randomly selected elementary schools and they did not have any specific background in balance testing or training. Additionally, the present study showed in general fair to good reliability for postural measurements using the Balance Master® System. Therefore, the postural parameters presented in the current study can be generalized to other elementary schoolchildren aged 9 to 10 years old. However, force plate measurements using the portable Balance Master® System in children should be further investigated, as well as the strategies for improving reliability such as by increasing the numbers or durations of the trials. At any rate, the current data on postural control in 9 to 10 year olds are relevant for research in other domains within the clinical field, like obesitas and developmental coordination disorder or in relation to back pain prevalence at early age.

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REFERENCES

1. Atwater SW, Crowe TK, Deitz JC, Richardson PK (1990) Interrater and test-retest reliability of two pediatric balance tests. *Phys Ther* 70 : 79-87
2. Baker CP, Newstead AH, Mossberg KA, Nicodemus CL (1998) Reliability of static standing balance in nondisabled children. *Pediatr Rehabil* 2 : 15 - 20
3. Birmingham T (2000) Test-retest reliability of lower extremity functional instability measures. *Clin J Sport Med* 10 : 264-268
4. Brouwer B, Culham EG, Liston RA, Grant T (1998) Normal variability of postural measures: implications for the reliability of relative balance performance outcomes. *Scand J Rehabil Med* 30 : 131-137
5. Cambier D, Cools A, Danneels L, Witvrouw E (2001) Reference data for 4- and 5-year-old-children on the Balance Master: values and clinical feasibility. *Eur J Pediatr* 160 : 317
6. Emery CA, Cassidy JD, Klassen TP, Rosychuk RJ, Rowe BB (2005) Development of a clinical static and dynamic standing balance measurement tool appropriate for use in adolescents. *Phys Ther* 85 : 502-514
7. Figura F, Cama G, Capranica L, Guidetti L, Pulejo C (1991) Assessment of static balance in children. *J Sports Med Phys Fitness* 31 : 235-242
8. Fleiss JL (1986) Analysis of data from multiclinic trials. *Control Clin Trials* 7 : 267-75
9. Gabriel LS, Mu K (2002) Computerized platform posturography for children: test-retest reliability of the sensory test of the VSR System. *Phys Occup Ther Pediatr* 22 : 101-117
10. Hatzitaki V, Zisi V, Kollias I, Kioumourtzoglou E (2002) Perceptual-motor contributions to static and dynamic balance control in children. *J Mot Behav* 34 : 161-170
11. Lafond D, Corriveau H, Hebert R, Prince F (2004) Intrasession reliability of center of pressure measures of postural steadiness in healthy elderly people. *Arch Phys Med Rehabil* 85 : 896-901
12. Lebedowska MK, Syczewska M (2000) Invariant sway properties in children. *Gait Posture* 12 : 200-204
13. Lee HY, Cherng RJ, Lin CH (2004) Development of a virtual reality environment for somatosensory and perceptual stimulation in the balance assessment of children. *Comput Biol Med* 34 : 719-733
14. McEvoy MP, Grimmer K (2005) Reliability of upright posture measurements in primary school children. *BMC Musculoskelet Disord* 6 : 35 - 45
15. Nolan L, Grigorenko A, Thorstensson A (2005) Balance control: sex and age differences in 9- to 16-year-olds. *Dev Med Child Neurol* 47 : 449-454
16. Pollock AS, Durward BR, Rowe PJ, Paul JP (2000) What is balance? *Clin Rehabil* 14 : 402-406
17. Riach C and Starkes J (1994) Velocity of centre of pressure excursions as an indicator of postural control systems in children. *Gait Posture* 2 : 167 - 172'.
18. Rival C, Ceyte H, Olivier I (2005) Developmental changes of static standing balance in children. *Neurosci Lett* 376 : 133-136
19. Schmid M, Conforto S, Lopez L, Renzi P, D'Alessio T (2005) The development of postural strategies in children: a factorial design study. *J Neuroengineering Rehabil* 30 : 29-39

CHAPTER 3 – PART 1

**EFFECTS OF A TWO-SCHOOL-YEAR MULTI-FACTORIAL BACK EDUCATION
PROGRAM IN ELEMENTARY SCHOOLCHILDREN**

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EFFECTS OF A TWO-SCHOOL-YEAR MULTI-FACTORIAL BACK EDUCATION PROGRAM IN ELEMENTARY SCHOOLCHILDREN

Abstract. Study design. A quasi-experimental pre-post design. **Objective.** To investigate effects of a two-school-year multi-factorial back education program on back posture knowledge and postural behavior in elementary schoolchildren. Additionally, self-reported back or neck pain and fear-avoidance beliefs were evaluated. **Summary of background data.** Epidemiological studies report mounting non-specific back pain prevalence among youngsters, characterized by multi-factorial risk factors. Study findings of school-based interventions are promising. Furthermore, biomechanical discomfort is found in the school environment. **Methods.** The study sample included 193 intervention children and 172 controls (baseline 9-11 year olds). The multi-factorial intervention consisted of a back education program and the stimulation of postural dynamism in the class through support and environmental changes. Evaluation consisted of a questionnaire, an observation of postural behavior in the classroom and an observation of material handling during a movement session. **Results.** The intervention resulted in increased back posture knowledge ($P<.001$), improved postural behavior during material handling ($P<.001$) and decreased duration of trunk flexion ($P<.05$) and neck torsion ($P<.05$) during lesson time. The intervention did not change fear-avoidance beliefs. There was a trend for decreased pain reports in boys of the intervention group ($P<.09$). **Conclusions.** The intervention resulted in improved postural aspects related to spinal loading. The long term effect of improved postural behavior at young age on back pain prevalence later in life is of interest for future research.

Key words: back education program, back pain, schoolchildren, primary prevention.

1. INTRODUCTION

Epidemiological studies over the last 20 years report mounting non-specific back pain prevalence among youngsters [1, 2, 3]. The reality that back pain occurrence can be classified as recurrent in a subgroup of children and the knowledge that back pain occurrence at young age may persist into adulthood [1, 4, 5], favored research into the early stages of the problem.

The multi-factorial nature of the risk for developing back pain in childhood is widely accepted [6, 7] and complicates the determination of predisposing factors and preventive measures. In order to provide evidence on early prevention in low back pain, the determination of modifiable risk factors and the results of school-based interventions are essential [8, 9].

Recent studies have demonstrated that psychosocial factors play an important

role in children's self-reported back pain [2, 3]. Epidemiological evidence [1, 2, 3, 6] and biomechanical argumentation related to the concepts of spinal loading [10] suggest that biomechanical factors might also be related to back pain occurrence at young age. The limited literature supports the presumption that the school environment exposes children to possible loading factors related to prolonged poor sitting [11, 12], absence of appropriate furniture [13, 14] and backpack use [15]. In consequence, the school is an ideal setting for back pain prevention since it has the potential of optimizing environmental conditions and giving prolonged feedback reaching a large percentage of the population [16].

Focusing on the results of school-based interventions, in a recent review [9] a limited number of multi-factorial intervention studies could be located [17-21]. In the study of Cardon et al. [18] the

implementation of a six-week back education program had a significant impact on the use of back education principles up to one year. However, a transfer of postural principles into the daily unconscious sitting behavior of the child was not found. In a supplementary study, extra support formulating specific guidelines for class teachers in order to enhance the implementation of learned principles turned out to be efficacious [22]. The intervention study performed by Mendez [19], established increased back-care-related knowledge and improved general postural habits. Three other intervention studies had methodological restrictions, like limited participants [21], a non-randomized study design [17] and a relatively short implementation time [20]. It was concluded that intervention studies in the elementary school are promising but too limited to formulate evidence-based guidelines [8, 9]. However, in contrast to the promising aspects of early back education, Burton [23] warned for a possible increase of children's fear-avoidance beliefs due to increased awareness. Moreover, the lack of evidence for the direct impact of primary prevention on back pain prevalence, certainly in children, is a critical point in the prevention discourse [24].

Therefore, the purpose of the current intervention study was to investigate the effects of an optimized two-school-year multi-factorial back education program on knowledge and postural behavior in elementary schoolchildren in Flanders. An additional aim was to evaluate self-reported back and neck pain at young age and fear-avoidance beliefs. As such, the present intervention study eliminated restrictions regarding a unimodal approach, small and non-randomized study samples and relatively short intervention periods. Correspondingly, effects were studied in a pretest posttest design over two school-years using an experimental and a control group with randomization at school level. The comprehensive intervention to optimize the daily load on young spinal structures was a multi-factorial program during two school-years with additional focus on sitting in the school context and with interactive involvement of external experts, physical education teachers and class teachers.

2. MATERIAL AND METHODS

2.1 Subjects

Eight Flemish elementary schools were selected by simple randomization. Children were simply randomized at school-level into the intervention and the control group (10 intervention class groups out of 4 schools, 10 control class groups out of 4 schools). All schools were comparable with regard to geographic location and parental education levels. Identical standard chairs and school desks were used in all classes, both in the control and the intervention schools. At baseline, the study sample consisted of 398 schoolchildren. Thirty-three children dropped out as they changed school. The total drop-out of 8.5% was equally distributed in the intervention group (9.7%) compared to the controls (7.1%). At posttest the intervention group consisted of 193 participants (93 boys, 100 girls; age 11.3 ± 0.8 years) and the control group included 172 children (82 boys, 90 girls; age 11.4 ± 0.8 years).

Before the start of the intervention, all parents signed an informed consent form for the observations of postural behavior. The intervention was considered to be a part of the health education program in the intervention schools. The study protocol was approved by the Ethical Committee of the University Hospital of the Ghent University.

2.2 Intervention

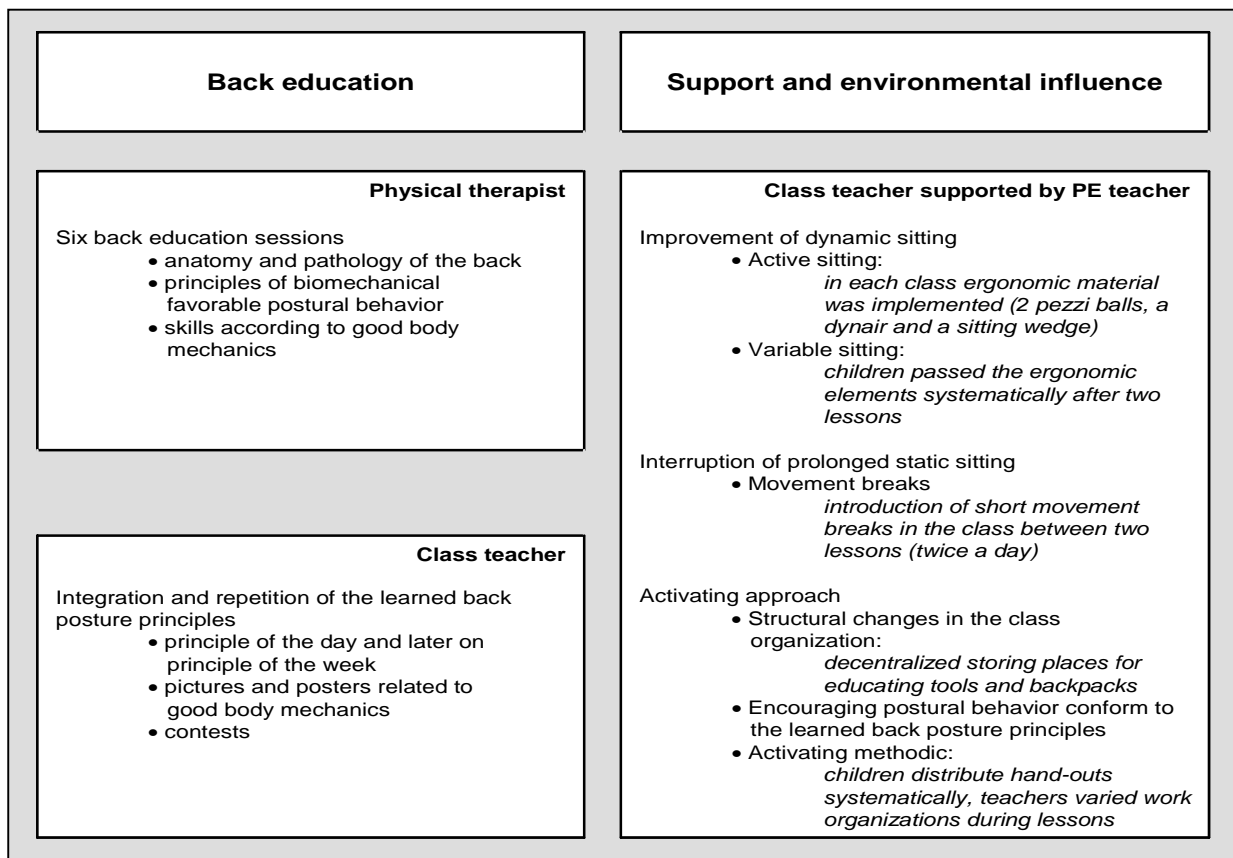
The multi-factorial intervention was based on prior studies [9, 19, 22, 25-27] and consisted of a back education program and the stimulation of postural dynamism through support and environmental changes, as presented in figure 1. 'Postural dynamism' stands for frequent posture changes in addition to variable and dynamical activities.

Back education. The basic program consisted of six back education lessons at one-week interval, taught by a physical therapist to one class group at a time. In the context of loading the body structures optimally, pupils were taught anatomy and pathology of the back and the basic principles of biomechanical favorable

postures during standing, sitting, lying, lifting, pushing and bending. To allow an easy understanding of the 'back posture principles' two comic characters were introduced: 'Fit Fred', who does everything right, and 'Lazy Leo', who 'makes his disks very unhappy' by being very lazy and doing everything wrong. Besides back posture theory, skills related to good body mechanics were taught and practiced. This part of the intervention study was identical to the intervention evaluated in previous research [18].

large pictures representing the back posture principles presented by 'Fred Fit' and 'Lazy Leo'. Teachers were instructed to implement the 'principle of the day' and later on the 'principle of the week'. Therefore, during the day and afterwards during the week, one back posture principle was discussed in the class group and the concerning picture was posted in the class environment, encouraging the pupils to pay extra attention to application of the principle.

Figure 1: Components of the multi-factorial back education intervention.



PE teacher: physical education teacher

Additionally, the current intervention included intensifying components in order to optimize the integration of the back posture principles into the daily classroom routine. Therefore, teachers were asked to be present during all sessions and received a comprehensive manual including the six lessons and back ground information. Besides, didactic material was provided and guidelines were presented in order to optimize integration of the back posture principles. Each class teacher received ten

Support and environmental influence. Another optimization compared to the intervention evaluated in previous research [18], included the focus on postural dynamism during daily class activities. Based on the German project 'Bewegte Schule' [27, 28], encouraging movement into the lesson through work organization, and through environmental and behavioral influence, two basic principles were elaborated to increase postural dynamism in the class: stimulation

of dynamical sitting and prevention of prolonged static sitting. Stimulating dynamical sitting, active and variable sitting were reinforced by providing two pezzi balls, a dynair and a wedge in each classroom. The children passed the ergonomic elements systematically in the recess after two lessons. Furthermore, in order to interrupt prolonged static sitting, short movement breaks between the lessons were introduced. Twice a day the movement breaks were organized in the class, supplementary to the recess. A large picture illustrating the movement break was posted in the classroom. On a repetitively four-week interval there was a different movement break for every day of the week. Finally, class teachers were encouraged to teach following an activating approach (e. g. distribution of handouts systematically through children, variable work organizations, use of sitting alternatives) and to change structural aspects in the class organizations (e. g. decentralized storing places for educational tools, textbooks and schoolbags).

2.3 Procedure

Evaluation. Pre-testing occurred during September and October 2002. The intervention started in November 2002. Post-testing was performed from April until June 2004. For the total sample, pre- and post-test evaluation consisted of a questionnaire and of an observation of material handling. Additionally, in each class group three children were selected by simple randomization in order to observe postural behavior in the classroom (intervention group n=26, control group n=35). In each class, the same subjects were observed at baseline and at post-test. However, due to technical limitations and absence on day of testing, the intervention group included less classroom observations. After the two years of intervention all teachers were asked to fill out a questionnaire about implementation, possible interference with other programs and perceptions related to the promotion of good body mechanics.

Intervention. The intervention started with six sessions back education taught by a physical therapist.

Subsequently, class teachers were involved in the promotion of good body mechanics integrating the intervention guidelines during two school-years. All parents of the intervention children were informed about the program through an information session and a brochure.

Teacher's application of guidelines was not encouraged externally. However, six activities related to good body mechanics were organized by the test leader for the teachers and the children (a quiz, a picture contest, a tinker contest, a repetition lesson, a 'weight your book bag' action and an 'incline your work surface' action).

2.4 Instruments

Questionnaire. Children completed a questionnaire at school under supervision of the class teacher. The questionnaire was based on previous research in 9 to 11 year olds [19, 25], representing good test-retest stability.

One part evaluated specific back posture knowledge and included 10 questions directly corresponding to the content of the back education program. Another part evaluated general back posture knowledge and consisted of a multiple-choice quiz including 11 items related to general principles of good body mechanics. Additionally, the questionnaire evaluated prevalence of back and neck pain within the last week. Severity of back or neck pain was indicated on a 5-point-scale (a little bit pain, a bit pain, modest pain, much pain, very much pain) and frequency on a 4-point-scale (once, several times, frequently, continuous). Moreover, fear-avoiding beliefs were evaluated analyzing five questions on a 5-point-scale (definitely yes to definitely no on questions related to physical activity; for example 'When your back hurts it is dangerous to swim'). A high score represented low-fear-avoidance.

Furthermore, intervention pupils and class teachers were respectively asked in which degree they found the implementation of back posture education and movement breaks and the use of ergonomic elements, pleasant (5-point-scale) and useful (4-point-scale). Additionally, children were asked which

sitting mode they preferred. Controlling for possible interference, all teachers were asked whether or not the class had participated in activities related to good body mechanics. Evaluating implementation, intervention teachers were asked to rate on a 5-point-scale how frequently they applied the intervention guidelines. Moreover, intervention teachers were asked if they understood the intervention guidelines explained in the oral presentation and the manual (definitely yes to definitely no on a 5-point-scale).

Observation of material handling.

During recess a movement session was organized in order to observe the use of learned back posture principles in a play situation, based on previous research [26]. The observation of 'material handling' was organized in the gymnasium and presented to the children as an evaluation of throw and catch skills. Children were not told that the use of back posture principles was being tested.

A side-view positioned camera registered the children during lifting, carrying and putting down a bench, picking up a light object (shuttle) and moving a heavy object (medicine ball). Afterwards, children's postural behavior performing the latter tasks was encoded qualitatively (0-4) with high scores representing performances conform the learned back posture principles. Two graduate students were trained to practice the encoding system, i. e. categorizing body postures following the descriptions of postural behavior conform to the qualitative performance scores.

Portable Ergonomic Observation (PEO) method with video take. Using the Portable Ergonomic Observation (PEO) method [29], children's body postures and activities in the classroom were recorded with unmanned cameras. Children were observed during 30 minutes of a regular lesson. Afterwards, the PEO-registration

was executed by two graduate students who had been trained during 15 hours. The categorizing of 'postures' and 'activities' from a previous study reporting baseline results was used [30]. For all postures and activities, the percentages of the observed time interval (duration to the nearest 1 second) were recorded by the PEO software package. To evaluate inter-rater reliability, video-tapes of thirty randomly selected participants were evaluated by the two observers on an individual basis.

2.5 Data analysis

Data analysis was performed using SPSS 11.0. Intra-class correlations coefficients (ICC's) were used to determine inter-rater agreement on items of the PEO and on the observation of material handling.

To evaluate intervention effects in a pre-post design, Repeated Measures ANOVA were used. Time was included as within-subjects factor (pre versus post) and condition as between-subjects factor (intervention versus control group). Gender was analyzed as second between-subjects factor (boys versus girls). The level of significance was set at 5%. P-values between 0.05 and 0.10 were defined as a trend towards significance.

3. RESULTS

The ICC's determining inter-rater agreement of two observers on postural behavior in the classroom using the PEO varied between 0.83 and 0.94 ($P < .001$) for 7 of the 11 variables. Lower ICC's were found for the duration of 'reading and writing' (0.76, $P < .001$), 'static sitting' (0.78, $P < .001$), 'walking around' (0.61, $P < .05$) and 'trunk torsion over 45°' (0.65, $P < .001$). The ICC's for inter-rater agreement among two observers on postural behavior during

Table 1: Mean scores on knowledge for the intervention and the control groups at baseline and in the posttests.

Knowledge (<i>theoretical maximum</i>)	Score ($\bar{x} \pm SD$)				Interaction-effect
	Pre		Post		F
	Intervention	Control	Intervention	Control	T x C
General back posture knowledge (11)	1.0 \pm 3.9	0.7 \pm 3.4	5.1 \pm 2.9	2.7 \pm 3.0	18.984**
Specific back posture knowledge (10)	4.9 \pm 7.4	5.0 \pm 7.2	7.5 \pm 4.6	6.3 \pm 4.2	12.594**

\bar{x} = mean, SD = Standard Deviation
T x C = time x condition
(intervention group n=156, control group n=161)
** P < .001

material handling varied from 0.81 to 1.00 ($P < .001$).

The change in back posture related knowledge is presented in table 1. A positive interaction effect (time x condition) was found for specific and general back posture related knowledge ($P < .001$), revealing a significantly higher increase between pretest and posttest scores in the intervention group compared to the controls. The three-way interactions (gender x time x condition) on specific ($F = 1.264$, ns) and general ($F = .065$, ns) back posture related knowledge were not significant, which means that the intervention effects were similar in boys and girls.

The change in postural behavior during material handling is shown in table 3. Repeated Measures ANOVA revealed a significant interaction effect for all but three postural items. Additionally, a positive interaction effect was found for the total score on material handling ($P < .001$) with a significantly higher improvement in the intervention group compared to the controls. None of the three-way interactions on postural behavior during material handling were significant.

Repeated Measures ANOVA revealed no significant interaction effect for back and neck pain prevalence within the last week, as presented in table 4. The

Table 2: Mean durations of postural behavior during lesson time for the intervention and the control groups at baseline and in the posttests.

Postural behavior during lesson time		Duration in % (x ± SD)				Interaction-effect
		Pre		Post		F
	Postural aspects	Intervention	Control	Intervention	Control	T x C
	Reading and writing	66.3 ± 21.2	67.8 ± 32.3	66.4 ± 27.2	60.7 ± 21.3	.559
	Static sitting	86.8 ± 9.9	84.3 ± 9.1	76.5 ± 9.8	77.9 ± 10.3	1.383
Activities	Dynamic sitting	8.8 ± 6.1	8.7 ± 5.1	17.5 ± 7.1	15.6 ± 7.6	.641
	Standing	2.4 ± 3.5	3.1 ± 4.0	1.2 ± 2.5	1.3 ± 2.5	.410
	Walking around	0.9 ± 1.5	1.5 ± 1.5	1.3 ± 1.6	1.1 ± 1.6	2.590
	Trunk flexion	36.0 ± 26.7	16.5 ± 19.4	18.1 ± 27.3	25.5 ± 31.4	8.931*
	Trunk torsion	4.2 ± 4.7	2.3 ± 3.6	1.1 ± 1.6	1.3 ± 2.2	3.452 [§]
Postures	Neck flexion	50.4 ± 15.6	45.8 ± 19.1	51.4 ± 16.1	48.1 ± 15.7	.040
	Neck torsion	15.9 ± 9.6	9.8 ± 7.8	13.9 ± 9.4	14.5 ± 7.4	4.207*
	Use of backrest	31.1 ± 25.4	35.4 ± 25.2	67.8 ± 26.8	75.2 ± 29.3	.114
	Arm support	86.3 ± 12.1	83.2 ± 12.3	82.9 ± 13.2	85.8 ± 9.3	2.736

x= mean, SD= Standard Deviation
T x C = time x condition
* P < .05; [§] P < .07

(Intervention group n=26, control group n=35)

The change in postural behavior in the classroom is presented in table 2. There were no significant interaction effects on the duration of activities. Positive interaction effects were found for the duration of trunk flexion ($P < .05$) and neck torsion ($P < .05$), revealing a decrease in the duration between pretest and posttest in the intervention group compared to an increase in the control group. Additionally, there was a trend towards significance for decreased trunk torsion in the intervention group compared to the controls ($P < .07$). None of the three-way interactions on postural behavior in the classroom were significant.

three-way interaction showed a tendency towards significance for self-reported pain to be different between boys and girls in the intervention group compared to the controls ($F = 3.596$, $P < .07$). There was a tendency toward significance for decreased back and neck pain reports in boys of the intervention group compared to boys of the control group ($P < .09$). The pain reports between pre- and posttest did not differ significantly in girls of the intervention group compared to the control group. At baseline, 53% of the intervention children and 62% of the controls reported low intensity of pain (very little or a little bit pain). At posttest,

respectively 75% and 77% reported low intensity of pain.

Furthermore, at pretest 78% of the

intervention children and 89% of the controls reported that the pain occurred only once or several times.

Table 3: Mean scores on postural behavior during material handling for the intervention and the control groups at baseline and in the posttests.

Postural behavior during material handling Items (<i>maximal encode score</i>)	Score per item ($x \pm SD$)				Effect
	Pre		Post		F
	Intervention	Control	Intervention	Control	T x C
Back position while lifting bench (4)	0.99 ± 1.23	0.55 ± 0.97	2.99 ± 1.10	2.52 ± 1.28	.027
Frequency of encode score in percentage	0	60.2%	72.6%	2.7%	11.2%
	2	33.5%	25.6%	44.0%	52.2%
	4	6.3%	1.8%	53.3%	36.6%
Knee bending while lifting bench (4)	1.65 ± 0.97	1.58 ± 1.08	3.10 ± 1.25	1.85 ± 1.26	40.797**
Frequency of encode score in percentage	0	21.5%	26.8%	7.1%	23.6%
	2	74.3%	67.3%	30.2%	60.9%
	4	4.2%	6.0%	62.6%	15.5%
No twisting while lifting bench (4)	3.34 ± 1.23	3.52 ± 1.08	3.64 ± 1.00	3.35 ± 1.35	6.065*
Frequency of encode score in percentage	0	8.4%	8.3%	4.9%	12.4%
	2	17.3%	11.9%	7.1%	8.1%
	4	74.3%	79.8%	87.9%	79.5%
Body posture while moving bench (4)	3.10 ± 1.29	2.98 ± 1.46	3.81 ± 0.63	3.11 ± 1.17	9.115*
Frequency of encode score in percentage	0	9.1%	14.6%	0.5%	4.3%
	2	28.9%	21.1%	8.8%	32.9%
	4	61.9%	64.3%	90.7%	62.4%
Body position (back, knees) putting down bench (4)	1.51 ± 1.29	1.28 ± 1.19	2.78 ± 1.36	1.06 ± 1.39	55.299**
Frequency of encode score in percentage	0	34.2%	44.5%	11.5%	61.1%
	2	55.1%	49.7%	39.0%	27.4%
	4	10.7%	5.8%	49.5%	11.5%
No twisting while putting down bench (4)	2.91 ± 1.78	3.35 ± 1.49	3.85 ± 0.77	3.14 ± 1.65	21.855**
Frequency of encode score in percentage	0	24.5%	17.3%	3.3%	21.7%
	2	-	-	-	-
	4	75.5%	82.7%	96.7%	78.3%
Picking up light object (4)	2.25 ± 1.00	2.00 ± 0.96	2.51 ± 0.83	2.20 ± 0.96	.167
Frequency of encode score in percentage	0	1.0%	1.1%	-	-
	1	31.8%	38.3%	9.9%	24.6%
	2	27.9%	26.9%	45.1%	39.5%
	3	31.8%	29.1%	33.0%	24.0%
	4	7.5%	4.6%	12.1%	12.0%
Knee bending while lifting heavy object (4)	0.64 ± 1.14	0.45 ± 1.04	1.23 ± 1.77	0.25 ± 0.93	14.264**
Frequency of encode score in percentage	0	73.5%	79.3%	66.7%	87.1%
	2	20.5%	15.5%	7.2%	9.7%
	4	6.0%	5.2%	26.1%	3.2%
No twisting while moving heavy object (4)	0.96 ± 1.25	0.74 ± 1.27	1.54 ± 0.99	1.00 ± 1.06	2.770
Frequency of encode score in percentage	0	59.0%	69.1%	26.1%	50.3%
	2	33.0%	24.0%	70.6%	48.5%
	4	8.0%	6.9%	3.3%	1.2%
Total score on good body mechanics (36)	17.36 ± 4.82	16.46 ± 4.20	25.44 ± 4.66	18.48 ± 5.43	72.130**

x= mean, SD= Standard Deviation
T x C = time x condition
** P <.001; * P <.05

(intervention group n=153, control group n=124)

Table 4: Differences in self-reported back and neck pain between boys and girls of the intervention and the control groups at pretest and at posttest (Repeated Measures ANOVA).

Prevalence	Prevalence in %						Interaction-effect F
	Pre			Post			
	Intervention	Control	Total	Intervention	Control	Total	T x C
Total (n=331)	31%	31%	31%	30%	34%	32%	.331
Boys (n=158)	32%	22%	27%	27%	34%	31%	2.933 ^{SS}
Girls (n=173)	29%	39%	34%	33%	34%	34%	.853
T x C = time x condition						(intervention n=166, control n=165)	
SS P <.09							

At posttest, 80% of the intervention children and 83% of the controls mentioned that their pain occurred only 'once' or 'several times' within the last week.

No significant time by condition interaction was found for fear-avoidance beliefs ($F=1.527$, ns). At pretest, the mean score (range 5-25) was 13.2 (± 5.2) in the intervention group and 11.8 (± 4.6) in the control group. At posttest, the mean score was 13.3 (± 4.2) in the intervention group and 12.7 (± 4.2) in the control group. The three-way-interaction on fear-avoidance beliefs was not significant ($F=2.284$, ns).

The perceptions about the back education program among children and teachers are presented in table 5. Furthermore, 68% of the children preferred sitting on a pezzi ball, while 14% preferred a chair, 13% a dynair and 5% a wedge. Both in the control and the intervention classes no supplemental actions related to good body mechanics were organized during the two school-years.

Implementation and understanding of the intervention guidelines are presented

in table 6. The mean implementation score on the 17 items was 61.44/85 and comparable for the 10 intervention teachers (range 56-67). With the exception of one teacher, all intervention teachers were prepared to persist independently in the promotion of good body mechanics after intervention completion, matching the guidelines of the current back posture program.

4. DISCUSSION

The present back education program in elementary schoolchildren resulted in improved general and specific back posture knowledge. In the current study design a control group and interference check were incorporated to minimize the influence on factors unrelated to the intervention. The present study findings are in line with previous research [18, 19, 25] evaluating effects of back education. Furthermore, children found the promotion of good body mechanics pleasant. In addition, teachers reported that the different aspects of the

Table 5: Children's and teachers' perceptions about the multi-factorial back education program.

Perceptions	Percentages				
	Not at all pleasant	Not pleasant	Sometimes	Pleasant	Very pleasant
Children					
Back care education	2%	4%	16%	36%	42%
Movement breaks	4%	3%	19%	35%	39%
Ergonomic material					
pezzi ball	3%	2%	9%	22%	64%
wedge	5%	8%	22%	24%	41%
dynair	4%	4%	12%	18%	62%
Teachers					
Back care education	-	-	30%	70%	
Movement breaks	-	10%	70%	20%	
Ergonomic material					
pezzi ball	-	10%	60%	30%	
wedge	-	-	60%	40%	
dynair	-	-	60%	40%	

(children n=200, teachers n=10)

multi-factorial program were useful. Therefore, it can be concluded that back posture promotion through the school curriculum seems to be an effective strategy to teach back posture related principles in a young population.

Furthermore, postural behavior during material handling improved more in the intervention group compared to the controls. The positive change of the total score during material handling in a play situation showed that the learned skills became generalized. The latter study finding corresponded to the study of Mendez and Gomez-Conesa [19] pointing out that some positive changes as a result of a postural hygiene program were generalized in natural situations.

The two-school-year promotion of good body mechanics resulted also in decreased duration of trunk flexion and neck torsion during sitting. Moreover, there

was a trend for a decrease in duration of trunk torsion in the intervention group. These are important findings since in previous research in 8 to 11 year olds [30] and according to the study of Murphy in 11 to 14 year olds [11], it was demonstrated that flexed postures and trunk torsion were associated with self-reported lumbar pain. Moreover, in a previous intervention study sitting postures during lesson times did not improve [25]. The present intervention was optimized by implementing several ergonomic elements encouraging active and variable sitting in the classroom. Due to randomized selection, all children were sitting on traditional material during the class observation. Nevertheless, even when children used traditional furniture, several aspects in sitting postures improved due to the intervention. Although standard school furniture was used in all classes, the lack of information about the dimensions of the

Table 6: Teachers' answers on implementation of the intervention guidelines.

Implementation check	Percentages				
	Never	Sporadically	Sometimes	Frequently	Always
Guidelines in order to increase postural dynamism					
Distribution of handouts through children	-	-	-	10%	90%
Decentralized storing place for schoolbags	20%	-	-	40%	40%
Decentralized storing places for educational tools	-	-	30%	70%	
Make children stand up during music lesson	10%	-	10%	70%	10%
Make children stand up teaching at the blackboard	-	-	10%	80%	10%
Make children stand up during listening activities	50%	30%	20%	-	-
Make children stand up answering questions	40%	10%	50%	-	-
Variable position during teaching	-	-	-	50%	50%
Variable work organization – class group in circle	10%	-	30%	60%	-
Variable work organization – work at different locations	10%	-	70%	20%	-
Support children to incline the work surface at the desk	-	-	40%	40%	20%
Support children to change position	-	-	50%	50%	-
Support towards prolonged and loading positions	-	-	10%	90%	-
Advise children filling schoolbags	-	-	20%	50%	30%
Use of ergonomic material	-	-	20%	20%	60%
Children pass ergonomic material	-	-	-	10%	90%
Movement breaks between 2 lessons	-	-	10%	80%	10%
Understanding the intervention guidelines	No!	No	No-yes	Yes	Yes!
Oral presentation	-	-	-	80%	20%
The manual	-	-	-	70%	30%

(teachers n=10)

furniture in relation to the children's individual anthropometrics is a limitation of the current study.

In the current intervention program, teachers were made responsible to increase postural dynamism in the class through an activating approach. Therefore, they were asked to integrate didactical guidelines interrupting prolonged static sitting and introducing dynamical activities during lesson time. Based on the implementation evaluation, teachers integrated most of the didactical principles in order to interrupt prolonged static sitting. However, according to the PEO-observations the intervention did not result in the introduction of more variable or dynamical activities during lesson time. Some teachers reported reluctance towards changing their traditional methodic towards an activating approach introducing variable and dynamical activities being concerned with authority and discipline. In the same line, several teachers stated that their knowledge and experience according to an activating approach were insufficient. Furthermore, Flemish elementary classroom spaces are limited compared to the classroom spaces of previous research demonstrating favorable postural habits in children of the 'Moving School' [27]. Maybe an effect on postural activities could be realized if classroom spaces were larger and teachers were more familiar with postural dynamism and good body mechanics in the classroom. The inclusion of applied biomechanics in the professional training of future teachers, with focus on the elementary class environment and the role of the class teacher, may improve postural activity in the classroom.

An additional purpose of the current study was to evaluate intervention effects on self-reported back and neck pain and on fear-avoidance beliefs. In line with the literature [6, 31], pain reports reflected mainly mild pain occurring only once or several times within the last week. There was a tendency for boys in the intervention group to report less back or neck pain (pre 32%, post 27%) compared to an increase of self-reported pain in the control group (pre 22%, post 34%). Conversely, in girls the pain reports did not differ significantly between the intervention (pre 29%, post

33%) and the control group (pre 39%, post 34%). Gender specific effects on back pain prevalence could not be explained by the intervention effects on back posture related knowledge or on postural behavior as the change over two school-years did not differ between boys and girls. Since feeling pain is a subjective phenomenon and children are in the middle of a learning process experiencing their body and reporting their aches [32], results on back pain prevalence and differences in pain reports between boys and girls need to be interpreted with caution. Furthermore, one could question whether self-reported back or neck pain is the right outcome of a back education program in elementary schools. In the scope of intervention studies, back pain prevalence could better be approached as a long term effect while the evaluation of a back education program should focus on the direct effects like better back posture knowledge and modifications in risk factors related to spinal loading in the school environment. However it is relevant to examine whether fear-avoidance beliefs increase as a result of the attention for pain. The present intervention did not indicate increased fear-avoidance beliefs in the intervention group compared to the controls. Since about eighty percent of the western children will experience back or neck pain once in their lifetime, it is important that early back education in children does not result in increased fear-avoidance beliefs.

In conclusion, the current study findings demonstrated that the optimized promotion of good body mechanics with focus on postural dynamism in the class improved several postural aspects related to daily biomechanical load. According to the studies of Salminen et al. [33] and Siivola et al. [5], even at a young age the spinal structures may undergo degenerative changes which not only implicate increased risk of recurrent pain at young age, but also a long term risk of recurrent pain up to early adulthood. If children develop a biomechanical healthy lifestyle considering optimal daily loading, the burden for back pain could possibly be reduced. As a result, the long term effect of improved postural behavior at a young age on back pain prevalence later in life needs to be adopted in future research.

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REFERENCES

1. Harreby M, Nygaard B, Jessen T, et al. Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. *Eur Spine J* 1999;8:444-50.
2. Watson KD, Papageorgiou AC, Jones GT, et al. Low back pain in schoolchildren: occurrence and characteristics. *Pain* 2002;97:87-92.
3. Jones GT, Watson KD, Silman AJ, et al. Predictors of low back pain in British schoolchildren: A population-based prospective cohort study. *Pediatrics* 2003;111:822-8.
4. Brattberg G. Do pain problems in young school children persist into early adulthood? A 13-year follow-up. *Eur J Pain* 2003;8:187-99.
5. Siivola SM, Levoska S, Latvala K, et al. Predictive factors for neck and shoulder pain: A longitudinal study in young adults. *Spine* 2004;29:1662-9.
6. Balagué F, Troussier B, Salminen JJ. Non-specific low back pain in children and adolescents: risk-factors. *Eur Spine J* 1999;8:429-8.
7. Jones MA, Stratton G, Reilly T, et al. Biological risk indicators for recurrent non-specific low back pain in adolescents. *Br J Sports Med* 2005;39:137-40.
8. European Commission COST Action B13. European guidelines for the management of low back pain. November, 2004. Available at: www.backpaineurope.org.
9. Cardon G, Balagué F. Low back pain prevention's effects in schoolchildren. What is the evidence? *Eur Spine J* 2004;13:663-79.
10. McGill S. *Low Back Disorders*. United States: Human Kinetics, 2002.
11. Murphy S, Buckle P, Stubbs D. Classroom posture and self-reported back and neck pain in schoolchildren. *Appl Ergon* 2004;35:113-20.
12. Sjölie AN. Persistence and change in non-specific low back pain – A 3-year prospective study. *Spine* 2004;29:2452-7.
13. Panagiotopoulou G, Christoulas K, Papanicolaou A, et al. Classroom furniture dimensions and anthropometric measures in primary school. *Appl Ergon* 2004;35:121-8.
14. Limon S, Valinsky LJ, Ben-Shalom Y. Children at risk - Risk factors for low back pain in the elementary school environment. *Spine* 2004;29:697-702.
15. Negrini S, Carabalona R. Backpacks on! Schoolchildren's perceptions of load, associations with back pain and factors determining the load. *Spine* 2002;27:187-95.
16. Johnson J, Deshpande C. Health education and physical education: disciplines preparing students as productive, healthy citizens for the challenges of the 21st century. *J School Health* 2000;70:66-8.
17. Balagué F, Nordin M, Dutoit G, et al. Primary prevention, education, and low back pain among school children. *Bull Hosp Jt Dis* 1996;55:130-4.
18. Cardon G, De Clercq D, De Bourdeaudhuij I. Effects of back care education in elementary schoolchildren. *Acta Paediatr* 2000;89:1010-7.
19. Mendez FJ, Gómez-Conesa A. Postural hygiene program to prevent low back pain. *Spine* 2001;26:1280-6.
20. Storr-paulssen A, Aagaard-Hensen J. The working positions of schoolchildren. *Appl Ergon* 1994;25:63-4.
21. Feingold AJ, Jacobs K. The effect of education on backpack wearing and posture in middle school population. *Work* 2002;18:287-94.
22. Cardon G, De Bourdeaudhuij I, De Clercq D. Back care education in elementary school: a pilot study

- investigating the complementary role of the class teacher. *Patient Educ Couns* 2001;45:219-26.
23. Burton K. Low back pain in children and adolescents: to treat or not. *Bull Hosp Jt Dis* 1996;55:127-9.
 24. Linton S, van Tulder MW. Preventive interventions for back and neck pain problems. What is the evidence? *Spine* 2001;26:778-87.
 25. Cardon G, De Bourdeaudhuij I, De Clercq D. Back education efficacy in elementary schoolchildren: a one year follow-up study. *Spine* 2002; 27:299-305.
 26. Cardon G, De Bourdeaudhuij I, De Clercq D. Generalization of back education principles by elementary schoolchildren: evaluation with a practical test and a candid camera observation. *Acta Paediatr* 2001;90:143-50.
 27. Cardon G, De Clercq D, De Bourdeaudhuij I, et al. Sitting habits in elementary schoolchildren: a traditional versus a 'Moving school'. *Patient Educ Couns* 2004;54:133-42.
 28. Breithecker D. Lust auf Schule: Lust auf Lernen. Mehr Gesundheit und Wohlbefinden am Arbeitsplatz Schule, Ein Projectbericht (Enjoying school: fun in learning. More health and well being in the school as place of work, A project report). *Haltung und Bewegung* 2000;4.
 29. Murphy S, Buckle P, Stubbs D. The use of the portable ergonomic observation method (PEO) to monitor the sitting posture of schoolchildren in the classroom. *Appl Ergon* 2002;33:365-70.
 30. Geldhof E, Cardon G, De Bourdeaudhuij I, De clercq D. Classroom postures of 8 to 12 year old children, *Ergonomics*, in press.
 31. Staes F, Stappaerts K, Lesaffre E, et al. Low back pain in Flemish adolescents and the role of perceived social support and effect on the perception of back pain. *Acta Paediatr* 2003;92:444-51.
 32. Balagué F, Dudler J, Nordin M. Low-back pain in children. *Lancet* 2003;361:1403-4.
 33. Salminen JJ, Erkintalo MO, Pentti J, et al. Recurrent low back pain and early disc degeneration in the young. *Spine* 1999;24:1316-21.

CHAPTER 3 – PART 2

EFFECTS OF BACK POSTURE EDUCATION ON ELEMENTARY SCHOOLCHILDREN'S BACK FUNCTION

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EFFECTS OF BACK POSTURE EDUCATION ON ELEMENTARY SCHOOLCHILDREN'S BACK FUNCTION

Abstract. Background. The possible effects of back education on children's back function were never evaluated. Therefore, main aim of the present study was to evaluate the effects of back education in elementary schoolchildren on back function parameters. Since the reliability of back function measurement in children is poorly defined, another objective was to test the selected instruments for reliability in 8 to 11 year olds. **Methods.** The multi-factorial intervention lasting two school-years consisted of a back education program and the stimulation of postural dynamism in the class. Trunk muscle endurance, leg muscle capacity and spinal curvature were evaluated in a pre-post design including 41 children who received the back education program (mean age at post-test: 11.2 ± 0.9 years) and 28 controls (mean age at post-test: 11.4 ± 0.6 years). Besides, test-retest reliability with a one-week interval was investigated in a separate sample. Therefore, 47 children (mean age: 10.1 ± 0.5 years) were tested for reliability of trunk muscle endurance and 40 children (mean age: 10.2 ± 0.7 years) for the assessment of spinal curvatures. **Results.** Reliability of endurance testing was very good to good for the trunk flexors (ICC=0.82) and trunk extensors (ICC=0.63). The assessment of the thoracic (ICC=0.69) and the lumbar curvature (ICC=0.52) in seating position showed good to acceptable reliability. Low ICC's were found for the assessment of the thoracic (ICC=0.39) and the lumbar curvature (ICC=0.37) in stance. The effects of two year back education showed an increase in trunk flexor endurance in the intervention group compared to a decrease in the controls and a trend towards significance for a higher increase in trunk extensor endurance in the intervention group. For leg muscle capacity and spinal curvature no intervention effects were found. **Conclusion.** The small samples recommend cautious interpretation of intervention effects. However, the present study's findings favor the implementation of back education with focus on postural dynamism in the class as an integral part of the elementary school curriculum in the scope of optimizing spinal loading through the school environment.

Key words: back education program, prevention, schoolchildren, back function.

1. INTRODUCTION

The high prevalence of low back pain (LBP), the increasing levels of non-specific LBP among youngsters in our society and the indications that juvenile and adult LBP are related [4, 17] suggest the need for research into the early stages of the problem.

The multi-factorial nature of the risk for back pain in childhood and adolescence is widely accepted [23, 24]. Recent studies have demonstrated that psychosocial factors play an important role in children's self-reported back pain [21, 22, 48]. However, the underlying mechanisms for back pain at young age remain unclear and most reported factors associated with back

pain reports in childhood are still controversial [6].

Based on a previous study [16], the implementation of a multi-factorial back posture program with focus on postural dynamism through the school curriculum showed significant improvement in children's postural behavior during material handling and decreased duration of trunk flexion, neck torsion and trunk torsion during lesson time. In contrast, the intervention did not affect children's back pain reports or fear-avoidance beliefs. An interesting research question included whether in children, the change towards biomechanical favorable postural behavior was associated with an improvement of the underlying mechanisms for postural

behavior, namely back functioning. In the evaluation of back function with respect to postural behavior, both muscle activity and spinal curvature are important aspects. To the authors' knowledge the possible effects of a school-based multi-factorial back posture program on children's back function have never been evaluated.

As a first aspect of back function we focus on children's trunk muscle capacity. The literature pointed out that low endurance of trunk flexors was a risk indicator for recurrent and nonspecific LBP in a group of adolescents [23] and insufficient trunk extensor endurance was associated with adolescents' present and future LBP [41]. Consistently, Salminen [39] found in his cross-sectional study a decreased isometric endurance of both trunk extensors and flexors among LBP sufferers at the age of 15 years. In contrast to the consistent study findings on trunk muscle endurance, research on the relationship between trunk muscle strength and back pain reports in adolescents revealed conflicting findings. Newcomer et al. [33] found that back pain was associated with decreased trunk muscle strength in 10 to 19 year olds. On the other hand, Balagué et al. [3] could not establish a relation between isokinetic trunk muscle strength and history of LBP in 10 to 16 year olds. In agreement, Feldman et al. [15] demonstrated that poor isometric trunk flexor strength was not a risk factor for the development of LBP in adolescents. Furthermore, an imbalance in trunk muscle strength was identified as a risk factor for LBP in 15 to 19 year olds. It was demonstrated that a reduced development of trunk extensors compared to trunk flexors was a predictor for future LBP [27]. Based on the literature, one could thus suggest that both trunk muscle strength and trunk muscle endurance may have an influence on LBP at young age. However, in terms of spinal protection, there are indications that trunk muscle endurance can have more influence on LBP than trunk muscle strength since fatigued muscles may leave the spine structures more vulnerable resulting in uncontrolled spinal motions [1].

A second aspect of back function embraces the strength capacity of the leg muscles. The relationship between lifting

and low back problems is recognized in adult populations performing work-related activities. Therefore, some ergonomic prevention programs for LBP in adults pay attention to biomechanical favorable lifting techniques, such as the squat technique [45]. Performing a squat correctly requires sufficient strength in the leg muscles. In addition, Lee et al. [26] found reduced leg muscle capacity and trunk muscle strength in adults with LBP. Correspondingly, Suter and Lindsay [43] found that patients with LBP had higher than normal inhibition in their quadriceps muscles, which resulted in reduced functional capacity of the leg muscles. However, to the authors' knowledge no earlier work investigated children's leg muscle capacity in association to back pain. Although, one may assume that children need adequate leg muscles to perform lifting tasks and multiple activities during daily life.

The spinal curvature was included as a third aspect of back function since the general principle for an optimal load distribution in the human body is a neutral spinal curvature. In the study of Salminen et al. [40] 33% of the young individuals aged 14 year old demonstrated abnormalities of the spinal structures. The latter study findings indicated that even at a young age the spinal structures may undergo degenerative changes. On the other hand, Widhe et al. [49] reported that back pain was not related to children's posture and the study of Poussa et al. [37] suggested that spinal posture did not predict back pain assessing children's sagittal posture at age 11 to 14 and later at age 22 years.

Taking the latter into account, only a small number of studies investigated the relationship between back functioning and back pain reporting at a young age. The limited studies reported conflicting results and the multi-factorial risk for back pain reporting at young age indicates that other factors as well play a significant role in children's self-reported back pain, e. g. psychosocial factors [22, 48]. So, the literature provides no conclusive evidence regarding the relationship between functional risk factors and back pain at young age. However, trunk muscle endurance, leg muscle capacity and the spinal curvature are three important

determinants for adequate back function. Accordingly, good back functioning is a decisive factor for good spinal loading and could thus play a critical role within optimal daily loading. As such, in the scope of optimal daily loading, an adequate back function in young individuals could possibly play a part in the multidimensional approach to prevent back pain. However, it was never investigated whether back education could result in optimized back function at elementary school-age. Therefore, the main purpose of the current study was to evaluate in elementary schoolchildren the effects of a two-school-year promotion of good body mechanics on back function with regard to trunk muscle endurance, leg muscle capacity and spinal curvature.

Measuring back function in 9 to 12 year olds is only useful when reliability is determined. Most studies on the reliability of test methods have been carried out in adults while a minority has been carried out in adolescents and children. In the same line, the reliability for trunk extensor and trunk flexor endurance testing was found to be good in adolescents [32, 35] and adult populations [2, 5, 14, 21, 24, 34]. However, reliability studies on trunk muscle endurance performance testing in children at elementary school-age could not be located. Additionally, the non-invasive objective assessment of static curvatures using the Zebris® system was never used to evaluate children's spinal curvatures. As a result, another important objective of the current study was to test trunk muscle endurance performance and the Zebris® technique for reliability in children at elementary school-age. Test-retest measurement for isokinetic leg strength was not investigated in the current study since isokinetic testing of the knee flexors and knee extensors is well documented in children [10] as in adults [11].

2. MATERIALS AND METHODS

2.1 Subjects

Intervention effects. The multi-factorial back education program was implemented in eight Flemish elementary schools which were selected by simple

randomization. All schools were comparable with regard to geographic location and parental education levels. Before the start of the intervention study, children were randomized at school-level into the intervention and the control group (10 intervention class groups out of 4 schools, 10 control class groups out of 4 schools). All teachers were only associated to one particular school excluding risk of contamination. The parents of all participants signed an informed consent form.

In order to evaluate the effects of the back posture program on children's back function, the present study sample including children out of four randomly selected elementary schools (2 intervention and 2 control schools) was drawn for more in depth measurement. At pre-test, the parents of all 197 4th and the 5th grade children out of four schools were notified by a letter and asked for the participation of their child. A total of 77 parents signed the informed consent form (44 intervention parents and 33 control parents). All 77 children performed the back function measurements at pre-test. Eight children dropped out at post-test (3 intervention children and 5 controls). Finally, the intervention group consisted of 41 participants (19 boys, 22 girls; mean age at post-test 11.2 ± 0.9 years) and the control group included 28 children (11 boys, 17 girls; mean age at post-test 11.4 ± 0.6 years). The participants of the in depth measurements showed no differences for chronological age when compared to the non-responders ($t=.601$, ns). In the same way, at baseline anthropometrics showed no significant differences between responders and non-responders (weight: $t=.220$, ns; height: $t=1.336$, ns), as well as the change of children's weight and height over the two intervention years showed no differences between both groups (change in weight: $t=.056$, ns; change in height: $t=1.217$, ns). Additionally, no differences were found for their self-reporting on total amount of physical activity per week ($t=.726$, ns).

The study protocol was approved by the Ethical Committee of the University Hospital of the Ghent University.

Test-retest reliability. Test-retest reliability for back function measurements was investigated in a separate sample of elementary schoolchildren. Out of a simply randomized selected school, the parents of all 4th and 5th grade children (n=153) were contacted. This invitation was accepted by 87 parents who signed the informed consent form for their child. Out of this group, children were randomly allocated to the study sample evaluating test-retest reliability for either trunk muscle endurance (n=47; mean age: 10.1 ± 0.5 years) or spinal curvature assessment (n=40; mean age: 10.2 ± 0.7 years).

2.2 Intervention

The multi-factorial intervention consisted of a back education program and the stimulation of postural dynamism in the class through systematical support and environmental changes with active involvement of the class teacher, as described in a previous study [16]. 'Postural dynamism' stands for frequent posture changes in addition to variable and dynamical activities. The back posture intervention was integrated into the elementary school curriculum within the lessons health education. As such, the children of the intervention group did not receive additional lessons. Control teachers educated other health-related topics, such as dental hygiene.

Back education. The basic program consisted of six back education lessons at one-week interval, taught by a physical therapist to one class group at a time. Pupils were taught anatomy and pathology of the back in the context of optimal loading of the body structures. Furthermore, the basic principles of biomechanical favorable postures during standing, sitting, lying, lifting, pushing and bending were taught and practiced. In addition to the six back education sessions, didactic material was provided for the class teachers and guidelines were presented in order to optimize integration of the learned back posture principles.

Support and environmental influence. The multi-factorial intervention incorporated an extra focus on postural dynamism in the class. Therefore two basic

principles were elaborated: stimulation of dynamical sitting and prevention of prolonged static sitting. In order to stimulate dynamical sitting, active and variable sitting were reinforced by providing two pezzi balls, a dynair and a wedge in each classroom. The children passed the ergonomic elements systematically in the recess after two lessons. Further, in order to interrupt prolonged static sitting, short movement breaks between the lessons were introduced. Twice a day movement breaks were organized in the class, supplementary to the recess. Additionally class teachers were encouraged to teach following an activating approach (e. g. distribution of handouts systematically through children, use of sitting alternatives, variable work organizations like standing work places) and to change structural aspects in the class organization (e. g. decentralized storing places for educational tools, textbooks and schoolbags).

2.3 Procedure

Test-retest reliability. The reproducibility study in 8 to 11 year olds for trunk muscle endurance and spinal curvature assessment included test and retest measurement with a one week interval. Test and retest measurements were performed by the same researchers and took place on the same day of the week. The subjects' measurement order, test mode, testing sequence and surrounding factors were identical during the two measurement sessions. The test-settings were identical to the evaluation of the back function measurements as described below.

Intervention effects. Pre-testing occurred during September and October 2002. The multi-factorial intervention started in November 2002 for the following two school-years. Post-testing was performed from April until June 2004. The children were tested in the Centre for Sports Medicine at the Ghent University Hospital. Therefore, parents were asked by phone to make an appointment on a Wednesday afternoon or a Saturday morning, when Flemish children do not attend school. On one of the 10 proposed testing days, the children performed the back function

measurements taking about one hour. The evaluation consisted of back function measurements with regard to trunk muscle endurance, leg muscle capacity and spinal curvature.

On the day of testing, children's age and basic anthropometrical data were registered before starting the functional measurements. Weight was assessed to the nearest 0.1 kg (Seca, max 200 kg). Using a wall-mounted stadiometer (Siber Hegner), height was measured to the nearest 1 mm. Children were moved to the functional measurements in a variable order, as a position became available for testing. For each child, the test sequence and the required 20 minutes rest between two physical exertions was supervised by a test leader. Children were barefoot and a standardized test-setting was used for the three measurements, as described below. During the measurements of trunk muscle endurance and leg muscle capacity, children were given verbal encouragement in a consistent way to achieve their best performance. The test leaders were blinded to group assignment.

In the scope of another study [8], children's physical activity pattern was assessed completing a questionnaire with parental assistance which showed good reproducibility and validity [46]. Children's amount of physical activity was assessed by asking for their main sports in leisure time with a maximum of three sports, participated in organized as well as non-organized involvement.

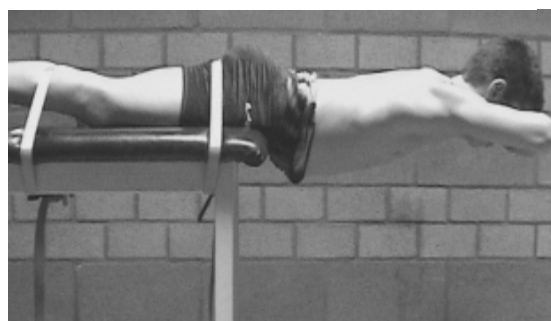
2.4 Evaluation instruments

Capacity of the leg muscles. A calibrated isokinetic testing machine (Biodex System 3 Pro, Biodex Corp., Shirley, NY) was used for bilateral leg muscle capacity. Since velocity affects torque [12], the 'Isokinetic Bilateral – Knee (extension/ flexion) – Conc/Conc 60/60 180/180' test was selected to measure children's knee extension and knee flexion capacity of both legs. This test assessed each leg at two velocities, evaluating maximal strength at low speed (60°/sec, 5 repetitions, high resistance) and endurance at high speed (180°/sec, 15 repetitions, low resistance). Therefore, the child was seated

upright on the adjustable chair of the Biodex with the axis of the dynamometer corresponding to the knee joint axis of the active leg. The active leg was fixed with a strap at the thigh. The cuff was secured approximately 2 cm superior to the lateral malleolus of the ankle. Before the start of the test, the range of motion (ROM) was set up for the active leg. The ROM was determined by the horizontal position of the extended leg towards the smallest flexed position. Children were instructed to perform the 'slow speed' and the 'fast speed' extension/flexion tests maximally. Additionally, the test leader informed the children about the three training trials before both tests, the 10 seconds rest between the two tests at different angular velocities and the identical protocol for both legs. The outcome parameters were 'maximal torque/body weight' (%), 'total work' (Joule) and 'average power' (Watt). Each leg muscle parameter comprised the sum score of bilateral flexion and extension at the two velocities, consistent with the measurement of leg muscle strength by Ho et al. [20].

Trunk muscle endurance. Trunk extensor endurance testing. Based on the method of Sørensen [5], children's isometric endurance of the trunk extensors was evaluated, as presented in figure 1.

Figure 1: The trunk extensor endurance test.



Therefore, the subject was lying prone with extended legs and the cranial border of the iliac crest (SIAS) at the edge of a research table. In the present study the legs were fixed with two belts: one across the middle of the gluteal regions and one across the gastrocnemius zone. After positioning the subject on the research table with decreased inclination under an angle of 35°, the subject had to bring the head and the upper part of the body unsupported

through a horizontal position with the arms in a 'wing position'. Sitting at eye-level of the table-leaf, the researcher supervised that the correct horizontal posture was maintained in the sagittal plane. The subject kept the horizontal position until exhausted. The score for the trunk extensor endurance testing was the endurance time, measured with a stopwatch, for a maximum of 240 seconds as originally prescribed [5].

Trunk flexor endurance testing.

Based on the literature [30, 31, 32, 38], the static curl was used to determine trunk flexor endurance, as presented in figure 2. Therefore, the subjects were in a supine position on a research table with the legs fixed by a belt proximal to the knee-joint. Before the start of the endurance test, children's inferior angle of the scapulae were marked standing in an anatomical position and the two marks were connected with tape. With the arms crossed on the shoulders, the subjects had to curl up until the researcher could see the taped line between the inferior angles of the scapulae. The children maintained this flexed position as long as possible, with a maximum of 240 seconds. During testing the researcher checked whether the posture was steady. If the tester could no longer see the taped line on the back of the child, the correct posture was lost and the test was stopped. The endurance time was recorded with a stopwatch.

Figure 2: The trunk flexor endurance test.



Static back curvatures. An ultrasound analysis system (Zebris CMS70P, Isny, Germany) and the accompanying WinData software were used for the objective assessment of static back curvatures by three-dimensional opto-electronic recording. Previous research

including adult study samples reported sufficient reproducibility, accuracy and validity for use of the Zebris technique [28, 29, 42, 47]. The system consisted of a basic unit which was connected with a computer, a pointer and a sensory unit. The ultrasound pointer was used to define surface reference points on the back of the child (the processi spinosi of thoracic and lumbar vertebrae were palpated and marked with a pen) and comprised two markers that sent ultrasound pulses. The sensory unit received signals from the transmitters located in the measuring unit. The data were collected at a sampling rate of 10 Hz. The measuring principle was based on the timing of the interval between emission and reception of ultrasound pulses. By means of triangulation, the markers' absolute three-dimensional coordinates were calculated. Afterwards, the data were processed in thoracic kyphosis and lumbar lordosis angles with use of a soft-ware algorithm (BioAnalyse v2). Based on Coorevits et al. [9] their method for analysis of the Zebris data, the thoracic kyphosis angle was calculated as the complementary of the enclosed angle between two lines; the 1st line incorporated the markers representing T1 and T7 while the 2nd line contained the markers for T7 and T12. The lumbar lordosis angle was calculated as the complementary of the enclosed angle between two lines; the 1st line incorporated the markers representing L1 and L3 while the 2nd line contained the markers for L3 and L5.

The static curvatures were measured three times for two positions; while standing in anatomical position and while seating on an adjustable piano stool with a prescribed seating height for knee angles of 90°. The test leader informed the children about the three measurements for both positions. Furthermore, the children were requested to keep each position as still as possible fixating a point at eye level. When the lowest stance of the piano stool was too high for knee angles of 90°, wooden blocks were positioned to attain the prescribed 90° knee angle. For the seating condition, children were asked to take a 'correct' sitting position.

2.5 Data analysis

Analyses were performed using SPSS 12.0. The level of significance was 5%. P-values between 0.05 and 0.09 were defined as a trend towards significance.

Intra-class correlations coefficients (ICC's), model 'Two-Way Mixed' type 'Consistency', were used to determine test-retest reliability with a one-week interval for trunk muscle endurance performance and spinal curvature assessment.

To determine possible group differences between the intervention condition and the controls, the samples were evaluated in relation to anthropometrics, age and physical activity pattern performing Independent-Samples T-tests. In order to evaluate intervention effects on back function parameters in a

pre-post design, Repeated Measures ANOVA were used. Time was included as within-subjects factor (pre versus post) and condition as between-subjects factor (intervention versus control group). Since the change in children's weight and height over the two intervention years may affect back function, the analyses for back function parameters were adjusted when Repeated Measures ANCOVA indicated the latter anthropometrical parameters as significant covariates. Gender was analyzed as second between-subjects factor (boys versus girls).

3. RESULTS

Test-retest reliability. Mean endurance times and Single Measure ICC's for the measurement of trunk extensor and

Table 1: Means and test-retest reproducibility for trunk muscle endurance.

Measurement (n= 47)		Endurance time (sec)			ICC <i>Test-retest</i>
		Mean	±	SD	
Trunk Flexor endurance	<i>test</i>	71	±	55	0.82**
	<i>retest</i>	73	±	51	
Trunk Extensor endurance	<i>test</i>	153	±	51	0.63**
	<i>retest</i>	162	±	56	

Abbreviation: SD, standard deviation of the mean. ICC, Intraclass Correlation Coefficient.
** P<.001; * P<.05

Table 2: Means and test-retest reproducibility for spinal curvature assessment.

Measurement (n= 40)		Including angle (deg)			ICC <i>Test-retest</i>
		Mean	±	SD	
Standing posture thoracic curvature	<i>test</i>	24	±	5.9	0.39*
	<i>retest</i>	24	±	8.2	
lumbar curvature	<i>test</i>	-14	±	7.2	0.36*
	<i>retest</i>	-14	±	6.1	
Seating posture thoracic curvature	<i>test</i>	20	±	6.4	0.69**
	<i>retest</i>	20	±	6.6	
lumbar curvature	<i>test</i>	11	±	4.6	0.52**
	<i>retest</i>	13	±	4.9	

Abbreviation: SD, standard deviation of the mean. ICC, Intraclass Correlation Coefficient.
** P<.001; * P<.05

trunk flexor endurance are presented in table 1. Very good to good reliability was found for trunk flexor (ICC=0.82, $P<.001$) and trunk extensor (ICC=0.63, $P<.001$) endurance testing respectively. Reliability and mean angles according to the assessment of the spinal curvature are presented in table 2. Assessing the spinal curvature in seating position showed good to acceptable reliability for the thoracic (ICC=0.69, $P<.001$) and the lumbar curvature (ICC=0.52, $P<.001$) respectively. Low ICC's were found for the assessment of the thoracic (ICC=0.39, $P<.05$) and the lumbar curvature (ICC=0.37, $P<.05$) in stance.

Intervention effects. Both conditions were comparable for anthropometrical values, age and physical activity pattern as presented in table 3. There were only significant differences for weight at baseline and change in weight over the two school-years.

extensor endurance' time between pre-test and post-test in the intervention group compared to the controls ($P<.09$). No interaction effect was found for the 'ratio of trunk flexor/extensor endurance time'.

Analyzing leg muscle capacity, no interaction effect was found for the parameter 'maximal torque/body weight'. In addition, Repeated Measures ANCOVA revealed no significant interaction effect for 'total work' and 'average power' of the leg muscles.

When evaluating children's spinal curvature, no interaction effects were found for the 'thoracic' or the 'lumbar curvature' in the seating position. The children's spinal curvature in stance was not analyzed because of the low reliability using the Zebris® technique in the current study.

Finally, none of the three-way interactions (gender x time x condition) were significant when analyzing the different back function parameters. This means that the intervention effects on back function were similar in boys and girls.

Table 3: Group differences for age, anthropometrics and physical activity between the intervention and the control group of the present study sample evaluating back function parameters (Independent Samples T-test).

Age, anthropometrics and physical activity	Mean \pm SD		Group difference	
	Intervention	Control	df	t
Age at baseline (y)	9.8 \pm .9	9.9 \pm .6	66	.829
Height at baseline (cm)	142.2 \pm 8.9	140.5 \pm 7.0	65.1	.857
Weight at baseline (kg)	36.0 \pm 7.4	32.7 \pm 4.3	64.3	2.369*
Change in height pre-post (cm)	10.1 \pm 2.3	9.0 \pm 2.7	66	1.775
Change in weight pre-post (kg)	8.2 \pm 3.5	6.5 \pm 2.3	65.9	2.401*
Total amount of physical activity (min/week)	1277 \pm 759	1254 \pm 796	61	.906

Abbreviation: SD= Standard Deviation
 * $P<.05$, § $P<.09$

Intervention group: n= 41
 Control group: n= 28

The change over time for the back function parameters with regard to trunk muscle endurance, leg muscle capacity and spinal curvature is presented in table 4. For 'trunk flexor endurance' a significant interaction effect was found, revealing an increase in endurance time between pre-test and post-test in the intervention group compared to a decrease in the controls ($P<.05$). Additionally, Repeated Measures ANCOVA indicated a trend towards significance for a higher increase in 'trunk

4. DISCUSSION

The present study examined test-retest reliability for trunk muscle endurance testing and assessment of the spinal curvature in 4th and 5th grade elementary schoolchildren with respect to the evaluation of primary intervention effects on back function in this young study population.

Test-retest reliability. The present reliability values demonstrated that in 8 to

Table 4: Mean scores for back function parameters in the intervention and the control groups at baseline and at post-test.

Back function parameter	Mean \pm SD				Statistics
	Pre		Post		T x C
	Intervention	Control	Intervention	Control	F _(df=1)
Trunk muscle endurance					
Trunk flexor endurance time (sec)	41.7 \pm 27.1	48.7 \pm 27.8	49.2 \pm 28.7	44.2 \pm 24.6	4.066*
Trunk extensor endurance time (sec)	125.3 \pm 55.2	159.5 \pm 62.3	166.2 \pm 58.3	182.1 \pm 61.6	3.087 [§]
Ratio (flexor/extensor)	.42 \pm .36	.32 \pm .19	.30 \pm .18	.25 \pm .19	.437
Leg muscle capacity					
Maximal torque/body weight (%)	121.1 \pm 21.2	130.3 \pm 16.3	132.2 \pm 2.9	141.7 \pm 20.2	.001
Total work (Joule)	290.3 \pm 65.1	289.1 \pm 53.6	441.9 \pm 99.1	403.2 \pm 90.3	2.399
Average power (Watt)	37.3 \pm 10.9	37.5 \pm 8.1	53.5 \pm 15.5	49.4 \pm 12.3	1.086
Spinal curvature in seating posture					
Thoracic curvature (deg)	17.8 \pm 6.7	18.2 \pm 7.1	17.9 \pm 6.9	21.9 \pm 6.3	2.714
Lumbar curvature (deg)	15.3 \pm 4.6	11.6 \pm 3.4	12.9 \pm 3.9	11.4 \pm 4.6	1.038

Abbreviation: SD= Standard Deviation
Intervention group: n= 41
Control group: n= 28

T x C = time x condition (interaction effect)
* P<.05, [§] P<.09

11 year old children the reproducibility with a one-week interval was good for trunk flexor endurance (ICC=0.82) and acceptable for trunk extensor endurance (ICC=0.63). Although the reliability values of the present study were slightly lower compared to the coefficients in other reliability studies in adolescent and adult populations [2, 21, 25, 35, 38], they were still acceptable because of the young age of the participants. Motivation, fatigue, point in time of the test, feeling of pain and relationship with the test leader, are all parameters affecting reproducibility [35], especially in this young population. In the current study, the testers observed that the children were enthusiastic to perform the test to the best of their ability. Furthermore, in order to minimize variations between the performances on the test and retest measurement, measurement order, test mode, testing sequence, test leader and surrounding factors were identical during the two measurement sessions. Taking the latter into account, it can be concluded from the present study findings that the current procedure for trunk flexor and extensor endurance testing is reliable in 8 to 11 year old children.

Using the Zebris® technique for the assessment of children's spinal curvature,

the level of agreement between test and retest at one-week interval showed good to poor reliability. Assessing the spinal curvature in seating position showed good to acceptable reliability for the thoracic (ICC=0.69) and the lumbar curvature (ICC=0.52) respectively. However, the reliability for the assessment of the thoracic (ICC=0.39) and the lumbar curvature (ICC=0.37) in stance was poor and lower when compared to the sitting condition. Though, a consistent measurement was aspired using standardized protocols for both the sitting condition and the standing posture. The different outcome for reliability of the standing and the sitting condition could possibly be explained by the reality that a sitting posture is more stable than a standing posture [19]. Based on these findings, we concluded that the reliability of the stance position was too low for possible interpretation of intervention effects.

Intervention effects. The study's main aim was to evaluate intervention effects of a multi-factorial back education program on children's back function. The sample of the present study included two comparable conditions. There were no differences related to height, chronological age or weekly physical activity pattern between the two conditions while the

intervention children were some heavier when compared to the controls. Statistical analyses were adjusted to exclude possible interference of anthropometrical differences. The present findings showed that the two-school-year promotion of good body mechanics throughout the school curriculum resulted in increased endurance of the trunk flexors compared to a decrease of trunk flexor endurance in the control group. This finding significantly supports the effectiveness of back posture education in schoolchildren with regard to trunk flexor endurance. However, due to the higher endurance time at baseline of the trunk flexors in the control group compared to the intervention group and the relatively small changes in endurance time between the two conditions over the two school-years, the biological meaning of this effect is unknown. Furthermore, there was a trend for a higher increase of trunk extensor endurance in children who had received promotion of good body mechanics. O' Sullivan et al. [36] hypothesized that active sitting may result in a positive accommodation of the stabilizing muscles. Correspondingly, the present study's findings supported the focus on postural dynamism in the class by encouraging variable and dynamic sitting and interrupting prolonged static sitting as part of the multi-factorial back education program. Moreover, multiple prospective studies comprising adolescents [23, 41] as well as adults [44] reported trunk muscle endurance as a risk indicator for future back pain. So, one may suggest that the promotion of good body mechanics throughout the elementary school curriculum could play a key role in prevention because of the potential to improve children's trunk muscle endurance.

Furthermore, children's leg muscle capacity was evaluated as a measure of back function. During lifting tasks, the legs act as a multi-joint system (hip, knee and ankle) implying activity of both the knee flexors and the knee extensors [13]. Therefore, in the present study children's leg muscle capacity was included, considering bilateral strength and endurance parameters of both knee flexors and extensors. The present multi-factorial back education program had improved children's spontaneous postural behavior

during material handling conform a squat technique with a neutral spine position, as reported in a previous study [16]. However, the two-school-year back posture program in elementary schoolchildren did not result in improved leg muscle capacity in comparison to the control group.

Finally, the spinal curvature in a seating position was evaluated. In a previous study [7] it was demonstrated that children in a traditional school spend on average 97% of the lesson time in a static sitting posture, from which one third with the trunk forward bent. Sitting and certainly sitting with a bent trunk results in a reduction of lumbar lordosis or even in a lumbar kyphosis, resulting in increased muscle effort and disc pressure [18]. Focusing on the intervention effects of children's postural behavior in the class, the children who had received promotion of good body mechanics were sitting less frequently with a flexed trunk and a rotated neck during lesson time [16]. However, in contrast to the effects on sitting behavior, the spinal curvature in seating position was not changed after the promotion for good body mechanics when comparing the intervention children to the controls. The present data suggest that back posture promotion throughout the school curriculum did not change children's sitting position in a test situation and that children take a sitting position with a slightly kyphotic lumbar curvature.

A limitation of the current intervention study was the relatively small size of the study sample recommending careful interpretations of the study results. On the other hand, the present study sample was not a self-selected group since the comparison of the present sample to the total study population showed no difference for anthropometrics or age and weekly physical activity.

5. CONCLUSIONS

The findings of the present study showed that the current procedure for trunk muscle endurance testing is reliable in 8 to 11 year olds. Additionally, the Zebris® technique can be used in elementary schoolchildren for the objective assessment of the spinal curvature in the seating

condition. Besides, the implementation of a back education program in elementary schoolchildren resulted in improved trunk muscle endurance, but there was no change in leg muscle capacity or spinal curvature. Based on the literature, there are indications that efficient back function is important to prevent chronic back pain later in life. Therefore, back education with focus on postural dynamism in the class as an integral part of the elementary school curriculum is advocated in the scope of optimizing spinal loading through the school environment. Further, long-term investigation on the impact of school-based interventions with regard to the promotion of good body mechanics later in life is recommended.

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REFERENCES

- Adams MA, Mannion AF, Dolan P (1999) Personal risk factors for first-time low back pain. *Spine* 24:2497-2505
- Alaranta H, Hurri H, Heliovaara M, Soukka A, Harju R (1994) Non-dynamometric trunk performance tests - reliability and normative data. *Scand J Rehabil Med* 26:211-215
- Balagué F, Damidot P, Nordin M, Parnianpour M, Waldburger M (1993) Cross-sectional study of the isokinetic muscle trunk strength among schoolchildren. *Spine* 18:1199-1205
- Balagué F, Troussier B, Salminen JJ (1999) Non-specific low back pain in children and adolescents: risk-factors. *Eur Spine J* 8:429-438
- Biering-Sørensen F (1984) Physical measurement as risk indicators for low back trouble over a one-year period. *Spine* 9:143-148
- Cardon G, Balagué F (2004) Low back pain prevention's effects in schoolchildren. What is the evidence? *Eur Spine J* 13:663-679
- Cardon G, De Clercq D, De Bourdeaudhuij I, Breithecker D (2004) Sitting habits in elementary schoolchildren: a traditional versus a 'Moving school'. *Patient Educ Couns* 54:133-142
- Cardon GM, de Clercq DL, Geldhof EJ, Verstraete S, de Bourdeaudhuij IM (2006) Back education in elementary schoolchildren: the effects of adding a physical activity promotion program to a back care program. *Eur Spine J* : Epub ahead of print
- Coorevits P, Danneels L, Ramon H, Van Audekercke R, Cambier D, Vanderstraeten G (2005) Statistical modelling of fatigue-related electromyographic median frequency characteristics of back and hip muscles during a standardized isometric back extension test. *J Electromyogr Kines* 15:444-451
- Deighan M, Croix M, Armstrong N (2003) Reliability of isokinetic concentric and eccentric knee and elbow extension and flexion in 9/10 year old boys. *Isokinet Exerc Sc* 11:109-115
- Drouin JM, Valovich-mcLeod TC, Shultz SJ, Gansneder BM, Perrin DH (2004) Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque and position measurements. *Eur J Appl Physiol* 91:22-29
- Elftman H (1966) Biomechanics of muscle with particular application to studies of gait. *J Bone Joint Surg Am* 48:363-377
- Escamilla RF, Fleisig GS, Lowry TM, Barrentine SW, Andrews JR (2001) A three-dimensional biomechanical analysis of the squat during varying stance widths. *Med Sci Sport Exer* 33:984-998
- Essendorp M, Schibye B, Hey-Knudsen C (2002) Intra-abdominal pressure increases during exhausting back extension in humans. *Eur J Appl Physiol* 87:167-173
- Feldman DE, Shrier I, Rossignol M, Abenham L (2001) Risk factors for the development of low back pain in adolescence. *Am J Epidemiol* 154:30-36

16. Geldhof E, Cardon G, De Bourdeaudhuij I, De Clercq D (2006) Effects of a two-school-year multi-factorial back education program in elementary schoolchildren. *Spine* 31(17)
17. Harreby M, Neergaard K, and Hesseloe G (1995) Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low back pain in adults? *Spine* 20:2298-2302
18. Harrison DD, Harrison SO, Croft AC, Harrison DE, Troyanovich SJ (1999) Sitting biomechanics part I: review of the literature. *J Manipulative Physiol Ther* 22:594-609
19. Heather C, Shrawan K, Sharon W (1995) Postural aberrations in low back pain. *Arch Phys Med Rehab* 76:218-224
20. Ho CW, Chen LC, Hsu HH, Chiang SL, Li MH, Jiang SH, Tsai KC (2005) Isokinetic muscle strength of the trunk and bilateral knees in young subjects with lumbar disc herniation. *Spine* 30:528-533
21. Hyytiainen K, Salminen JJ, Suvitie T, Wickstrom G, Pentti J (1991) Reproducibility of 9 tests to measure spinal mobility and trunk muscle strength. *Scand J Rehabil Med* 23:3-10
22. Jones GT, Watson KD, Silman AJ, Symmons DP, Macfarlane GJ (2003) Predictors of low back pain in British schoolchildren: A population-based prospective cohort study. *Pediatrics* 111:822-828
23. Jones MA, Stratton G, Reilly T, Unnithan VB (2005) Biological risk indicators for recurrent non-specific low back pain in adolescents. *Br J Sports Med* 39:137-140
24. Kristjansdottir G, Rhee H (2002) Risk factors of back pain frequency in schoolchildren: a search for explanations to a public health problem. *Acta Paediatr* 91:849-854
25. Latimer J, Maher CG, Refshauge K, Colaco I (1999) The reliability and validity of the Biering-Sorensen test in asymptomatic subjects and subjects reporting current or previous nonspecific low back pain. *Spine* 24:2085-2089
26. Lee JH, Ooi Y, Nakamura K (1995) Measurement of muscle strength of the trunk and the lower extremities in subjects with history of low back pain. *Spine* 20:1994-1996
27. Lee JH, Hoshino Y, Nakamura K, Kariya Y, Saita K, Ito K (1999) Trunk muscle weakness as a risk factor for low back pain - A 5-year prospective study. *Spine* 24:54-57
28. Malmstrom EM, Karlberg M, Melander A, Magnusson M (2003) Zebris versus Myrin: a comparative study between a three-dimensional ultrasound movement analysis and an inclinometer/compass method: intradevice reliability, concurrent validity, intertester comparison, intratester reliability, and intraindividual variability. *Spine* 28:433-440
29. Mannion AF, Klein GN, Dvorak J, Lanz C (2000) Range of global motion of the cervical spine: intraindividual reliability and the influence of measurement device. *Eur Spine J* 9:379-385
30. McGill SM, Childs A, Liebenson C (1999) Endurance times for low back stabilization exercises: Clinical targets for testing and training from a normal database. *Arch Phys Med Rehab* 80:941-944
31. McIntosh G, Wilson, Affleck M, Hall H (1998) Trunk and lower extremity muscle endurance: normative data for adults. *J Rehabil Outcomes Meas* 2:20-39
32. Newcomer K, Sinaki M (1996) Low back pain and its relationship to back strength and physical activity in children. *Acta Paediatr* 85:1433-1439
33. Newcomer K, Sinaki M, Wollan PC (1997) Physical activity and four-year development of back strength in children. *Am J Phys Med Rehabil* 76:52-58
34. Nordin M, Kahanovitz N, Verderame R, Parnianpour M, Yabut S, Viola K, Viola K, Greenidge N, Mulvihill M (1987) Normal trunk muscle strength and endurance in women and the effect of exercises and electrical-stimulation. Part 1: Normal endurance and trunk muscle strength in 101 women. *Spine* 12:105-111
35. Oksanen A, Salminen JJ (1996) Tests of spinal mobility and muscle strength in the young: Reliability and normative

- values. *Physiotherapy Theory and Practice* 12:151-160
36. O'Sullivan PB, Grahamslaw KM, Kendell MM, Lapenskis SC, Möller NE, Richards KV (2001) The effect of different standing and sitting postures on trunk muscle activity in a pain free population. In: *Proceedings of the interdisciplinary World Congress on Low Back and Pelvic Pain, Montreal*, pp 180-183
 37. Poussa MS, Heliovaara MM, Seitsamo JT, Kononen MH, Hurmerinta KA, Nissinen MJ (2005) Predictors of neck pain: a cohort study of children followed up from the age of 11 to 22 years. *Eur Spine J* 14:1033-1036
 38. Salminen JJ, Maki P, Oksanen A, Pentti J (1992) Spinal mobility and trunk muscle strength in 15-year-old schoolchildren with and without low-back-pain. *Spine* 17:405-411
 39. Salminen JJ, Erkintalo M, Laine M, Pentti J (1995) Low-back-pain in the young - a prospective 3-year follow-up-study of subjects with and without low-back-pain. *Spine* 20:2101-2107
 40. Salminen JJ, Erkintalo M, Pentti J, Oksanen A, Kormano M (1999) Recurrent low back pain and early disc degeneration in the young. *Spine* 24:1316-1321
 41. Sjölie AN, Ljunggren AE (2001) The significance of high lumbar mobility and low lumbar strength for current and future low back pain in adolescents. *Spine* 26:2629-2636
 42. Strimpakos N, Sakellari V, Gioftsos G, Papathanasiou M, Brountzos E, Kelekis D, Kapreli E, Oldham J (2005) Cervical spine ROM measurements: optimizing the testing protocol by using a 3D ultrasound-based motion analysis system. *Cephalalgia* 25:1133-1145
 43. Suter E, Lindsay D (2001) Back muscle fatigability is associated with knee extensor inhibition in subjects with low back pain. *Spine* 26:361-366
 44. Udermann BE, Mayer JM, Graves JE, Murray SR (2003) Quantitative Assessment of Lumbar Paraspinal Muscle Endurance. *J Athl Train* 38:259-262
 45. van Dieen JH, Hoozemans MJM, Toussaint HM (1999) Stoop or squat: a review of biomechanical studies on lifting technique. *Clin Biomech* 14:685-696
 46. Verstraete SJ, De Bourdeaudhuij IM, Cardon GM (2003) Validation of a physical activity questionnaire for children. In: *proceedings of the American College of Sports Medicine. Med Sci Sport Exer* 35(5):64
 47. Wang SF, Teng CC, Lin KH (2005) Measurement of cervical range of motion pattern during cyclic neck movement by an ultrasound-based motion system. *Man Ther* 10:68-72
 48. Watson KD, Papageorgiou AC, Jones GT Taylor S, Symmons DP, Silman AJ, Macfarlane GJ (2002) Low back pain in schoolchildren: occurrence and characteristics. *Pain* 97:87-92
 49. Widhe T (2001) Spine: posture, mobility and pain - A longitudinal study from childhood to adolescence. *Eur Spine J* 10:118-123

CHAPTER 3 – PART 3

BACK POSTURE EDUCATION IN ELEMENTARY SCHOOLCHILDREN: STABILITY OF 2-YEAR INTERVENTION EFFECTS

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BACK POSTURE EDUCATION IN ELEMENTARY SCHOOLCHILDREN: STABILITY OF 2-YEAR INTERVENTION EFFECTS

Abstract. Background. *The study's first objective was to evaluate class teachers' efforts to promote good body mechanics after a structured back education program was finished. Secondary, the stability of intervention effects on children's back posture knowledge, fear-avoidance beliefs and back pain reports following a two-school-year multi-factorial back education program was evaluated at 1-year follow-up. An additional focus was put on what young children learned about good body mechanics in the obligatory school curriculum compared to intensive back posture promotion. Methods.* *The quasi-experimental study included at baseline 398 elementary schoolchildren aged 8-11 years. The back education program consisted of back education and the stimulation of postural dynamism in the class through support and environmental changes. Evaluation consisted of a questionnaire, which was filled out by 121 intervention children and 124 controls at pre-test, post-test and follow-up. Teachers were interviewed at the end of the follow-up school-year. Results.* *Teachers continued with initiatives to increase postural dynamism in the class when they had been instructed about that matter. However, teachers' efforts to continue the promotion of good body mechanics showed no additional effect on children's knowledge. Improved back posture knowledge demonstrated stability at 1-year follow-up. Whereas the obligatory curriculum provided children with fundamental postural knowledge, the back posture program added important aspects. Fear-avoidance beliefs and self-reported pain were not increased at 1-year follow-up. Conclusion.* *The stable intervention effects point out that intensive implementation of a structured multi-factorial back education program in the elementary school curriculum is effective.*

Keywords: back education, elementary schoolchildren, back pain, primary prevention.

1. INTRODUCTION

Epidemiological studies over the last 20 years report mounting non-specific back pain prevalence among youngsters [1, 2, 3]. Furthermore, the multi-factorial risk for developing back pain in childhood is widely accepted [4, 5]. Subsequently, research into the early stages of the problem is favored in order to provide evidence on early prevention in low back pain.

Although causative mechanisms for back pain occurrence at young age remain largely undetermined, a number of risk factors repeatedly appear in a reasonable body of the literature related to back pain in childhood and adolescence. Accordingly, recent studies have indicated that psychosocial factors play a significant role in children's self-reported back pain [2]. Furthermore, the school environment may expose children to possible loading

factors related to prolonged poor sitting [6, 7] absence of appropriate furniture [8, 9] and backpack use [10].

The school is considered as an ideal setting for back pain prevention since it has the potential of optimizing environmental conditions in relation to spinal loading and giving prolonged feedback regarding good body mechanics, reaching a large percentage of the population. Consequently, the results of school-based interventions at young age play a key role in the prevention discourse. According to a recent review a limited number of multi-factorial intervention studies could be located in the literature [4]. It was concluded that the impact of back education in the elementary school was promising through the significant improvement of children's knowledge and postural behavior [11, 12]. However, some intervention studies had methodological restrictions, like limited participants [13], a

non-randomized study design [14] and a relatively short implementation time [15]. Consequently, intervention studies were considered as too limited to formulate evidence-based guidelines [4, 16, 17].

In a previous study the effects of a two-school-year multi-factorial back education program on knowledge and postural behavior were investigated in 9 to 12 year olds [18]. Restrictions regarding a unimodal approach, small and non-randomized study samples and relatively short intervention periods were eliminated in this study design. The study findings demonstrated that the promotion of good body mechanics with focus on postural dynamism during class activities resulted in increased back posture knowledge, improved postural behavior during material handling and decreased duration of trunk flexion and neck torsion during lesson time after two years of intervention. Furthermore, the intervention did not result in increased fear avoidance beliefs.

The stability of intervention effects plays an important part in the discussion about the effectiveness of early back education. When discussing the stability of a school-based intervention, the class teachers' role with regard to environmental support needs to be reflected upon. In a previous study, specific guidelines for the class teachers in order to enhance the implementation of learned principles turned out to be efficacious [19]. However, to the authors' knowledge it has never been evaluated what class teachers do with the guidelines subsequent to a structured intervention promoting good body mechanics. Therefore, the study's first aim was to investigate the class teachers' efforts promoting good body mechanics after the two-school-year back education program was finished in relation to the stability of intervention effects on children's back posture knowledge, fear-avoidance beliefs and back pain reports. A second important facet within the prevention discourse embraced the stability of 2-year intervention effects in the quasi-experimental design including the comparison of children who participated in the multi-factorial back education program to a control group at 1-year follow-up. At follow-up age (11 to 14 years) children were in a critical phase of life,

characterized by biological maturation, psychological development, fast transitions, a switch in educational system and exposure to plenty of new interests and influences throughout the peer group. Finally, a third aim with regard to back education was to focus on the different aspects of children's back posture knowledge in addition to the composite knowledge scores. The change in the specific aspects of back posture knowledge enabled us to have a more detailed insight on back posture knowledge and to draw adjustments for future interventions promoting good body mechanics.

In conclusion, the current study investigated in a sub-sample whether class teachers who had participated in a back education program persisted in the promotion of good body mechanics. It was hypothesized that support through the class teacher during the follow-up school-year resulted in better intervention effects at follow-up. A second hypothesis within the quasi-experimental design was that children who had followed a two-school-year back education program in the elementary school scored better at 1-year follow-up on general and specific postural knowledge, fear-avoidance beliefs and self-reported pain compared to their contemporaries in the control group.

2. MATERIAL AND METHODS

2.1 Subjects

Eight Flemish elementary schools were selected by simple randomization. Flanders is the Dutch speaking part of Belgium, in the center of Europe. Children were randomized at school-level into the intervention and the control group (10 intervention class groups out of 4 schools, 10 control class groups out of 4 schools). All schools were comparable with regard to geographic location and parental education levels.

The multi-factorial back education program started in November 2002 for the following two school-years, after pre-testing in September and October 2002. Post-testing was performed from April until June 2004. Follow-up evaluation was organized from April until June 2005.

At baseline, the study sample consisted of 398 schoolchildren who started in the 4th and 5th grade (9.7 ± 0.8 years of age). At post-test the participants were at the end of their 5th or 6th grade. According to the Flemish school establishment, children have to finish six grades in the elementary school (ages 6 till 12) following six grades in secondary school (ages 13 till 18). In Flanders, elementary and secondary schools are independent from each other, with their own entities and buildings. Consequently, at follow-up a part of the study sample included elementary schoolchildren who finished their 6th grade at the end of the school-year. The other part consisted of pupils out of multiple secondary schools that finished the 7th grade at the end of the school-year. At follow-up, the 6th grade children were reached through the school whereas the 7th grade pupils were contacted by a letter. At follow-up, eight 6th grade children (5 intervention children and 3 controls) dropped out as they changed school. The addresses of four 7th grade pupils (2 intervention pupils and 2 controls) were missing according to a change of address. The response rate at the three measurements in relation to the composition of the study sample is presented in figure 1.

were used. The items were described in previous work [18] and summarized below.

Specific back posture knowledge was evaluated through 10 questions directly corresponding to the content of the back education program. A multiple-choice quiz including 11 items evaluated general back posture knowledge. Fear-avoidance beliefs were evaluated through five questions on a 5-point-scale with a low score representing low fear-avoidance. Furthermore, the questionnaire evaluated prevalence of back and neck pain within the last week.

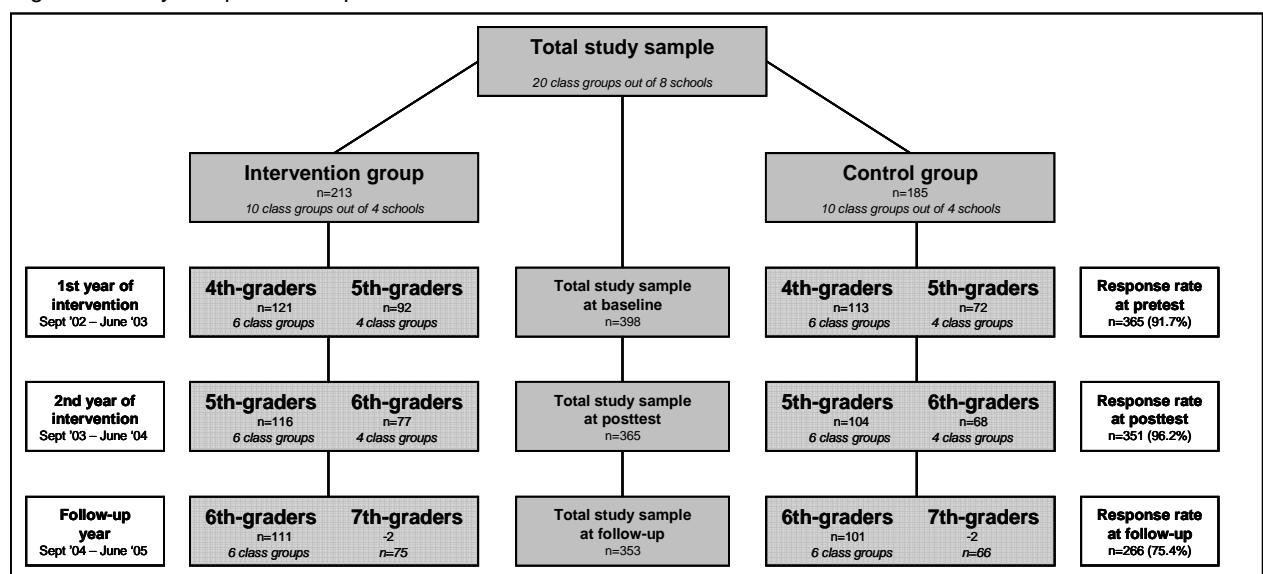
At follow-up, the questionnaire included an additional part for the intervention children asking if they could remember the back education sessions (nothing, little, much or everything) and how frequently they used the back posture principles in their current daily live (never, now and then, sometimes, almost or ever).

Interview with teachers. At the end of the follow-up school-year, all 6th grade class teachers (n=12) were asked whether ergonomic material was available for the pupils during the follow-up school-year and whether or not the class had participated in events related to good body mechanics. Furthermore, teachers of the intervention schools (n=6) were asked if they had integrated the intervention guidelines increasing postural dynamism in the class during the follow-up school-year. When teachers answered positively, they were asked to rate how frequently they applied the intervention guidelines

2.2 Instruments

Questionnaire for children. At all measurements, the same questionnaires

Figure 1: Study sample and response rate.



(17 questions answering never to always on a 5-point-scale). The asked guidelines for teachers in order to promote good body mechanics in the class are presented in figure 2.

grade teachers (n=12) were interviewed at the end of the follow-up school-year.

The study protocol was approved by the Ethical Committee of the University Hospital of the Ghent University.

Figure 2: Interview for teachers including 17 intervention guidelines to increase postural dynamism in the class.

Promotion of good body mechanics in the class through support and environmental influence	
1.	Do you let children distribute handouts?
2.	Do you create decentralized storing place for schoolbags?
3.	Do you create decentralized storing places for educational tools?
4.	Do you make children stand up during music lesson?
5.	Do you make children stand up teaching at the blackboard?
6.	Do you make children stand up during listening activities?
7.	Do you make children stand up answering questions?
8.	Do you vary your position during teaching?
9.	Do you vary work organizations (e.g. class group in circle)?
10.	Do you vary work organizations (e.g. work at different locations)?
11.	Do you support children to incline the work surface at their desks?
12.	Do you support children to change position?
13.	Do you support children to avoid prolonged loading positions?
14.	Do you advise children when filling schoolbags?
15.	Do you allow children to use ergonomic material in the class?
16.	Do you supervise that children pass the ergonomic material?
17.	Do you introduce movement breaks between 2 lessons?

2.3 Procedure

Intervention. The intervention to promote good body mechanics in elementary schoolchildren was a multi-factorial program with involvement of the class teacher during two school-years and was described in a previous study [18]. During the follow-up school-year class teachers were not encouraged to promote good body mechanics.

Follow-up. The follow-up questionnaires were identical to the evaluations at pre- and post-test. At pre- and post-test, children filled out the questionnaire under supervision of the class teacher. Contrary, at follow-up the questionnaires were completed at home. Therefore, 6th grade elementary schoolchildren received the questionnaire at school and were asked to fill it out at home independently. For all 7th grade pupils, the questionnaire was sent to their private address. A letter was enclosed with the request to return the independently completed questionnaire in a stamped and addressed envelope. In addition, all 6th

2.4 Data analysis

Data analysis was performed using SPSS 12.0. The level of significance was set at 5%. P-values between 0.05 and 0.09 were defined as a trend towards significance.

Based on the interview with teachers at follow-up, the sub-sample of 6th grade children out of the intervention group could be subdivided in two groups. The 6th grade class groups with class teachers who reported that they had promoted good biomechanics until follow-up (support until follow-up, 3 class groups, n=51) were compared to the 6th grade children where the promotion of good biomechanics was finished at post-test (no support during follow-up, 3 class groups, n=50). Repeated Measures Ancova were performed in the sub-sample with time as within-subjects factor (post-test versus follow-up) and group as between-subjects factor (support until follow-up versus no support during follow-up group). The baseline scores were included as covariates. Furthermore, the stability of 2-year intervention effects was explored in

the total study sample using Repeated Measures Ancova, with the baseline scores as covariates. Time was included as within-subjects factor (post versus follow-up) and condition as between-subjects factor (intervention versus control group). Gender was included as a second between-subjects factor (three-way-interaction effect).

3. RESULTS

3.1 Promotion of good body mechanics during follow-up

Teachers' efforts to promote good body mechanics are illustrated in table 1.

Table 1: The promotion of good body mechanics in the class during the follow-up school-year.

Question	Intervention group at follow-up (6 teachers in the 6 th -grade)		Control group at follow-up (6 teachers in the 6 th -grade)
	Intervention class teachers (n=3)	New class teachers (n=3)	Control class teachers (n=6)
<i>Continuity of the 2-schoolyear promotion of good body mechanics focusing on the increase of postural dynamism in the class</i>	The 3 class teachers, who had been class teacher in an intervention class during one of the 2 intervention-years, persisted in the application of the intervention guidelines to increase postural dynamism in the class.	Three class teachers had not been a class teacher of an intervention class during the 2-year intervention. The teachers were not informed about the 2-year promotion of good body mechanics. During follow-up they did not apply the intervention guidelines to increase postural dynamism in the class.	–
<i>Postural dynamism in the class by implementing intervention guidelines</i>	The frequency of implementing intervention guidelines to increase postural dynamism in the class was evaluated using 17 items on a 5-point-scale (never to always). The class teachers had an intensity score of 49, 56 and 65 to 85.	–	–
<i>Ergonomic material (two pezzi balls, a dynair and a wedge)</i>	In all class groups the 4 originally introduced ergonomic elements were used. The elements were passed in the recess after two lessons. In one class group 4 supplemental sitting balls were purchased.	In all schools the original ergonomic material was available for the children. The elements remained in the grades with the class teachers who had been class teacher of an intervention class during one of the 2 years of intervention.	In none of the classes ergonomic material was available.
<i>Movement breaks</i>	All teachers organized sporadically a movement break between two lessons (category 2 on a 5-point-scale)	–	–
<i>Activities with regard to back education and good body mechanics</i>	Besides the integration of intervention guidelines and the activities encouraging postural dynamism in the class based on the 2-schoolyear promotion of good body mechanics, no additional activities were organized.	No activities were organized during the follow-up interval.	No activities were organized.

Table 2: Back posture knowledge, fear-avoidance beliefs and back and/or neck pain prevalence in the intervention group when comparing the support until follow-up group to the no support during follow-up group between post-test and follow-up (Repeated Measures Ancova).

Variable (<i>theoretical range</i>)	Mean Total Score (SD) and Prevalence				Effect	
	Post		Follow-up		T x C	C
	Support	No support	Support	No support	F _(df=1)	F _(df=1)
General back posture knowledge (-11, 11)	4.2 (2.7)	4.8 (2.5)	4.5 (2.7)	4.9 (2.9)	.041	3.121
Specific back posture knowledge (-10, 10)	7.2 (2.5)	7.5 (2.1)	8.0 (1.8)	8.0 (2.1)	.333	.658
Fear-avoidance beliefs (5,25)	16.1 (3.8)	16.7 (4.9)	15.2 (3.7)	16.1 (3.5)	.212	1.116
Self-reported back and/or neck pain (%)	28%	30%	22%	28%	.081	1.317

SD, standard deviation.
 Support, intervention children finishing the 6th-grade with support through the class teacher until follow-up (n=50).
 No support, intervention children finishing the 6th-grade without support during follow-up (n=47).
 T x C, time x condition (interaction effect).
 C, condition (main effect of group).
 ** P <.001, * P <.05

3.2 Stability of intervention effects

Support through the class teacher during follow-up. When comparing the 6th grade class-groups with support until follow-up to the 6th grade class-groups where the promotion of good body mechanics was finished at post-test (table 2), Repeated Measures Ancova revealed no difference between post-test and follow-up scores for postural knowledge, fear-avoidance beliefs and pain reports.

Postural knowledge, fear-avoidance beliefs and self-reported pain in the total sample. The changes in total back posture knowledge, fear-

avoidance beliefs and pain reports within the quasi-experimental study sample are presented in table 3. For general and specific back posture knowledge the interaction effects were not significant, revealing stable knowledge scores between post-test and follow-up for both the intervention and the control groups. The main effect of condition showed that both at post-test and at follow-up the knowledge scores were better in the intervention group compared to the controls. The three-way interactions including gender on general (F=2.204, ns) and specific (F=1.751, ns) back posture knowledge were not significant, which means that the intervention effects were

Table 3: Back posture knowledge, fear-avoidance beliefs and back and/or neck pain prevalence in the intervention and the control groups at post-test and follow-up (Repeated Measures Ancova).

Variable (<i>theoretical range</i>)	Mean Total Score (SD) and Prevalence				Effect	
	Post		Follow-up		T x C	C
	I	C	I	C	F _(df=1)	F _(df=1)
General back posture knowledge (-11, 11)	5.0 (2.9)	3.1 (3.0)	5.0 (2.7)	3.5 (3.3)	.735	29.280**
Specific back posture knowledge (-10, 10)	7.5 (2.2)	6.7 (2.4)	8.0 (1.9)	7.1 (2.0)	.006	15.041**
Fear-avoidance beliefs (5,25)	16.4 (4.2)	17.2 (4.2)	15.6 (3.4)	16.7 (3.7)	.222	4.112*
Self-reported back and/or neck pain (%)	31%	33%	26%	26%	.112	.048

SD, standard deviation
 I, intervention group (n=121).
 C, control group (n=124).
 T x C, time x condition (interaction effect).
 C, condition (main effect of group).
 ** P <.001, * P <.05

similar in boys and girls. For fear-avoidance beliefs, no significant interaction effect was found between post-

test and follow-up. A group difference was found for fear-avoidance beliefs showing lower scores in the intervention group. The

Table 4a: Percentages of the children with a correct answer on general back posture questions in the intervention and the control groups at post-test and follow-up (Repeated Measures Ancova).

General back posture knowledge <i>Correct answer: score = 1</i> <i>No answer or fault answer : score = 0</i>	Children with a correct answer (%)				Effect	
	Post		Follow-up		T x C	C
	I	C	I	C	F _(df=1)	F _(df=1)
1. When lifting a heavy box off the floor a) keep your feet as far apart as possible b) do most of the work with your back c) <i>bend your knees</i> d) keep the box on one side of the body	97%	83%	95%	94%	7.202*	na
2. The best way to carry your groceries is a) in one big bag b) <i>in two bags</i>	95%	92%	98%	98%	.516	1.039
3. The best way to carry your book bag is a) over one shoulder b) <i>over two shoulders</i> c) in one hand	98%	96%	99%	98%	.100	1.929
4. The best way to carry a heavy box is a) <i>as close as possible to your body</i> b) a little further from your body c) as far as possible from your body	77%	73%	78%	70%	.398	1.554
5. If you move woodblocks from a pile in a wheelbarrow a) you should not move your feet turning your body b) <i>you should move your feet each time</i> c) you should move your feet a little and then turn your body	54%	53%	67%	43%	4.215*	na
6. The most strenuous position for your back is a) laying down on your side b) <i>sitting</i> c) standing up d) laying on your back	25%	17%	22%	24%	2.877	.795
7. A spine has a) no curves b) 2 curves c) <i>3 curves</i> d) has 4 curves	41%	17%	32%	20%	2.398	12.494**
8. During recess, it's the best for your back to a) sit down b) <i>move a lot</i> c) stand still	99%	83%	95%	85%	1.707	26.296**
9. Which book bag is loaded the best way? a) picture of inaccurately loaded book bag b) picture of inaccurately loaded book bag c) <i>picture of correctly loaded book bag</i> d) picture of inaccurately loaded book bag	71%	60%	65%	65%	3.912*	na
10. If you have to move equipment in the gym, you should a) <i>push</i> b) pull	68%	74%	74%	71%	.677	.201
11. How much should be the maximum weight of your book bag? a) your own weight b) your body weight, divided by 2 c) your body weight, divided by 5 d) <i>your body weight, divided by 10</i>	83%	53%	86%	56%	.068	38.609**

I, intervention group (n=121)

C, control group (n=124)

na, not applicable.

T x C, time x condition (interaction effect).

C, condition (main effect).

** P <.001, * P <.05

three-way-interaction including gender was not significant for fear-avoidance beliefs ($F=.019$, ns), revealing similar effects in boys and girls. For back and neck pain prevalence within the last week, an interaction effect or a main effect of condition was not found. The three-way interaction with gender showed no significance for self-reported pain ($F=.842$, ns), which means that the pain-reports were similar in boys and girls.

When focusing on the recurrence of self-reported pain over the three years, 46.5% of the children never reported back and or neck pain within the last week, 28.6% of the children reported pain once, 18.4% reported pain twice and 6.5% reported pain at the three evaluations.

Postural knowledge at item-level in the total sample. The changes in percentage of children's correct answers on general back posture questions are presented in table 4a. For three questions the percentages of correct answers

showed significant group differences. Both at post-test and at follow-up, the percentages of correct answers on the questions about 'the spinal curvature', 'moving during recess' and 'maximal book bag weight' were higher in the intervention group compared to the controls.

An interaction effect was found asking for 'the best way to move woodblocks from a wheelbarrow', revealing in the intervention group an increased percentage with a correct answer between post-test and follow-up compared to the controls.

A second interaction effect was found for the question on 'bending the knees when lifting a box', revealing in the control group an increased percentage of correct answers between post-test and follow-up comparable to a steady percentage in the intervention group.

A third interaction effect was found asking for 'the best way to load a book bag', revealing in the intervention group a

Table 4b: Percentages of the children with a correct answer on specific back posture questions in the intervention and the control groups at post-test and follow-up (Repeated Measures Ancova).

Specific back posture knowledge <i>Correct answer: score = 1</i> <i>No answer or fault answer : score = 0</i>	Children with a correct answer (%)				Effect	
	Post		Follow-up		T x C	C
	I	C	I	C	$F_{(df=1)}$	$F_{(df=1)}$
1. To move a lot is healthy Yes	98%	94%	96%	94%	.021	1.606
2. To keep your back straight is healthy Yes	99%	87%	92%	94%	9.441*	na
3. To lift with straight legs is healthy No	75%	74%	78%	76%	.012	.589
4. To lift heavy objects is healthy No	87%	81%	92%	89%	.198	2.773
5. To carry a heavy load far away from your body is healthy No	87%	82%	87%	88%	1.655	.287
6. To change frequently position when sitting, is healthy Yes	69%	48%	71%	54%	.124	13.672**
7. To change frequently position when standing, is healthy Yes	56%	51%	66%	58%	.404	2.604
8. To bend your legs when lying, is healthy Yes	62%	36%	67%	48%	.449	20.214**
9. To join sports is healthy Yes	97%	95%	98%	95%	.520	1.430
10. To do exercises every day is healthy Yes	85%	79%	84%	83%	.420	.504

I, intervention group (n=121)
C, control group (n=124)
na, not applicable.
T x C, time x condition (interaction effect).
C, condition (main effect).
** P <.001, * P <.05, § P <.09

decrease in percentage of correct answers compared to an increased percentage of correct answers in the control group. No significant interaction or main group effect was found on the other five general back posture items.

Children's correct answers on specific back posture questions are presented in table 4b. For two questions the percentages of correct answers showed significant group differences. Both at post-test and at follow-up, the percentages of correct answers on the questions about 'the best rest position for the back' and 'changing position when sitting' were higher in the intervention group compared to the controls. An interaction effect was found asking if 'a straight back position is healthy', revealing in the control group an increased percentage of correct answers between post-test and follow-up comparable to a decreased percentage in the intervention group. For the other seven specific back posture questions, both the interaction and main group effects were not significant.

When evaluating the non-significant back posture items, the majority of both the intervention children and the controls answered correctly on half of the postural items such as 'carrying groceries in two bags' (about 90%), 'carrying back packs over two shoulders' (about 90%), 'carrying a heavy box as close as possible to the body' (about 70%) and 'moving equipment in the gym while pushing' (about 70%). Accordingly, children knew that 'to move a lot' (about 90%), 'to join sports' (about 90%), 'to do exercises' (about 80%) and to 'change frequently position while standing' (about 60%) are healthy and that 'lifting heavy objects' (about 90%), 'carrying heavy loads far from the body' (about 80%) and 'lifting with straight legs' (about 70%) are not recommended. On the other hand, children did not know which position is the most strenuous for the back (about 20% answered correctly).

Children about the promotion of good body mechanics. After a 1-year follow-up, 96% of the children could remember the back education sessions. The major part (63%) reported that they remembered 'much' to 'everything' of the back education sessions, 36%

remembered a 'little' and only one child reported to remember 'nothing'. Additionally, a comparable large part reported to use the principles 'almost always to always' (42%) and 'sometimes' (43%), while only 15% of the children used the learned back posture principles 'now and then'. None of the children reported to use the principles 'never' in daily live.

4. DISCUSSION

A first research question with respect to the effectiveness of back education was related to the initiatives of teachers to continue the promotion of good body mechanics during class activities. The present data demonstrated that class teachers persisted voluntarily in the promotion of good body mechanics, confirming the intentions reported by teachers in a previous study [18]. In the latter study, 5th and 6th grade class teachers found the implementation of back education with focus on postural dynamism in the school curriculum feasible. Teachers' continuing application of guidelines to increase postural dynamism is an essential finding, since class teachers play a fundamental part in the promotion of good biomechanics throughout the school curriculum. Regrettably, when teachers were not engaged within the 2-year promotion of good body mechanics taking place in their schools, they were not informed about the guidelines encouraging postural dynamism in the class. The school policy should take the blame and should manage the information flow on the promotion of good body mechanics throughout the elementary school curriculum. Though, teachers' efforts to continue with initiatives to promote good body mechanics in the class until follow-up showed no additional effect on the children's postural knowledge scores. The latter finding could possibly be explained by the high intensity of the intervention. The present intervention consisted of a structured multi-factorial back education program in the elementary school curriculum that was implemented for two school-years with active participation of the class teacher. This intervention was a more intensive program compared to other school-based

intervention studies for back pain prevention in schoolchildren. The intervention study of Balagué (1996) included two sessions of 90 minutes plus an annual 2-hour session over a 3-year period [14], the study of Cardon (2002) evaluated the effect of teaching six sessions of 60 minutes at 1-week interval [12], in the study of Feingold (2002) children were educated during 30 minutes assisted by a video presentation [13], the postural hygiene program of Mendez (2001) consisted of 11 sessions for a total of 19 hours [11] and in the study of Storr-Paulsen (2002) the awareness of teachers was increased by a body conscious program in order to investigate the effects on children after one year [15]. Furthermore, the majority of the children reported at 1-year follow-up that they frequently used the learned postural principles and that they remembered 'much to anything' of the back education sessions. The current study finding is in contrast to the study findings of Balagué et al. [14] and may be an indication for the high intensity level of the current back posture program. However, the results on the stability of 2-year intervention effects comparing class groups with and without support of class teachers during the follow-up school-year need to be interpreted with caution. Our study-design prescribed an implementation time of two school-years following the introduction of back posture promotion in 4th and 5th grade elementary schoolchildren. As a result of the Flemish school establishment, at 1-year follow-up the analyses could only be conducted in the 6th grade children who had received back posture promotion in the 4th and the 5th grade. This is a relatively small sub-sample (6 intervention class groups, 3 with and 3 without support during the follow-up school-year) out of the total study sample (20 class groups). Though, the possible influence of teachers' continuing application of the back posture program during the follow-up school-year was a fundamental research question in order to control for possible interference regarding environmental differences between class groups after two comparable intervention years.

Drawing on the results of previous research [18], the two-school-year multi-

factorial back education program in elementary schoolchildren resulted in improved general and specific back posture knowledge. The current follow-up study demonstrated in the total study sample stability at 1-year follow-up for the improved back posture knowledge in children who had received the two-school-year promotion of good body mechanics. When discussing intervention effects of a back posture program, according to Burton (1996) it is relevant to examine whether fear-avoidance beliefs increase as a result of the attention for pain [20]. Since about eighty percent of the children will experience back or neck pain once in their lifetime, it is important that children who received early back education have no increased fear-avoidance beliefs. The present follow-up study indicated that fear-avoidance beliefs remained stable when comparing the intervention and the control groups between post-test and follow-up. Favorably, children who had received the 2-year promotion for good body mechanics had lower fear-avoidance beliefs compared to the controls. However, the impact of this effect is unknown. Further, the prevalence for back and neck pain including self-reports by 26% to 33% of the children corresponded to the week prevalence for back and neck pain of 30% reported in a previous study by 9 to 12 year olds [12]. Additionally, the current study results demonstrated that 26% of the children recurrently reported back and or neck pain within the last week (19% reported twofold back and or neck pain within the last week over the three years while 7% reported three times pain within the last week). Similar results were found in the epidemiological literature [21], which reported a range between 7% and 27% for children with recurrent self-reported pain.

When focusing on children's back posture knowledge, the obligatory elementary school curriculum in Flanders provides children with fundamental postural knowledge. The major part of the children answered correctly on half of the postural items at age 10-13 and a year later, at age 11-14. Furthermore, when the obligatory curriculum was compared to the multi-factorial back posture program, the control children caught up three postural items in the course of the follow-up school-

year, namely 'one should bend the knees when lifting a box from the floor', 'the best way to load a book bag' and 'keeping your back straight is healthy'. One may assume that these three principles belong to the rather 'traditional' back posture principles. On the other hand, the 2-year promotion for good body mechanics resulted in improved and stable postural knowledge related to 'movement during recess', 'frequent position changes during sitting', 'the recommended maximal book bag weight', 'the best resting position for the back' and 'the best way to transfer a load'. The latter postural principles are all important aspects with respect to the optimal daily load for the spinal structures [22]. Unfortunately, the back posture program did not result in satisfactory knowledge concerning the 'anatomy of the spine' and the 'most strenuous position for the back'. Drawing up the surplus of 2-year back education, the teaching method through guided discovery resulted in improved back posture knowledge for important postural items but the results were poor for two theoretical aspects.

A limitation of the current study was the different method for data collection in the pre-post-follow-up design. Filling in a questionnaire at home might reflect on children's psychosocial status and hence their reporting. However, identical evaluations were conducted in the intervention and the control groups allowing the possibility to detect intervention effects and stability of intervention effects.

5. CONCLUSIONS

The stable intervention effects at 1-year follow-up pointed out that the intensive implementation of a structured multi-factorial back education program in the elementary school curriculum for two school-years is effective to teach children postural knowledge. Additionally, the 2-year back posture promotion did not result in an increase of fear-avoidance beliefs and self-reported back and/or neck pain at 1-year follow-up which are potential consequences of attention for the back. Even though the theoretical back education sessions could be enhanced for a few knowledge aspects, back posture

promotion in the elementary school resulted in better understanding of important postural principles at age 11-14 years. Furthermore, when teachers were instructed about the back posture matter related to the promotion of good body mechanics, they continued with initiatives to encourage postural dynamism in the class. Long-term studies are needed to identify the impact of early back education into adulthood.

REFERENCES

1. Jones GT, Watson KD, Silman AJ, Symmons DP, Macfarlane GJ. Predictors of low back pain in British schoolchildren: A population-based prospective cohort study. *Pediatrics* 2003;111(4 Pt 1):822-8.
2. Watson KD, Papageorgiou AC, Jones GT, Taylor S, Symmons DP, Silman AJ, Macfarlane GJ. Low back pain in schoolchildren: occurrence and characteristics. *Pain* 2002;97(1-2):87-92.
3. Harreby M, Nygaard B, Jessen T, Larsen E, Storr-Paulsen A, Lindahl A, et al. Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. *Eur Spine J* 1999;8(6):444-50.
4. Cardon G, Balagué F. Low back pain prevention's effects in schoolchildren. What is the evidence? *Eur Spine J* 2004;13(8):663-9.
5. Jones MA, Stratton G, Reilly T, Unnithan VB. Biological risk indicators for recurrent non-specific low back pain in adolescents. *Br J Sports Med* 2005;39(3):137-40.
6. Murphy S, Buckle P, Stubbs D. Classroom posture and self-reported back and neck pain in schoolchildren. *Appl Ergon* 2004;35(2):113-20.
7. Sjölie AN. Persistence and change in nonspecific low back pain among adolescents: a 3-year prospective study. *Spine* 2004;29(21):2452-7.
8. Panagiotopoulou G, Christoulas K, Papanicolaou A, Mandroukas K. Classroom furniture dimensions and anthropometric measures in primary school. *Appl Ergon* 2004;35(2):121-8.
9. Limon S, Valinsky LJ, Ben-Shalom Y. Children at risk - Risk factors for low

- back pain in the elementary school environment. *Spine* 2004;29(6):697-702.
10. Negrini S, Carabalona R. Backpacks on! Schoolchildren's perceptions of load, associations with back pain and factors determining the load. *Spine* 2002;27(2):187-95.
 11. Mendez FJ, Gómez-Conesa A. Postural hygiene program to prevent low back pain. *Spine* 2001;26(11):1280-6.
 12. Cardon G, De Bourdeaudhuij I, De Clercq D. Back education efficacy in elementary schoolchildren: a one year follow-up study. *Spine* 2002;27(3):299-305.
 13. Feingold AJ, Jacobs K. The effect of education on backpack wearing and posture in middle school population. *Work* 2002;18(3):287-94.
 14. Balagué F, Nordin M, Dutoit G, Waldburger M. Primary prevention, education, and low back pain among school children. *Bull Hosp Jt Dis* 1996;55(3):130-4.
 15. Storr-paulssen A, Aagaard-Hensen J. The working positions of schoolchildren. *Appl Ergon* 1994;25(1):63-4.
 16. European Commission COST Action B13. European guidelines for the management of low back pain. November, 2004. Available at: www.backpaineurope.org. November, 2004.
 17. Burton AK. How to prevent low back pain. *Best Pract Res Clin Rheumatol* 2005;19(4):541-55.
 18. Geldhof E, Cardon G, De Bourdeaudhuij I, De Clercq D. Effects of a two-school-year multi-factorial back education program in elementary schoolchildren. *Spine*; In press.
 19. Cardon G, De Bourdeaudhuij I, De Clercq D. Back care education in elementary school: a pilot study investigating the complementary role of the class teacher. *Patient Educ Couns* 2001;45(3):219-26.
 20. Burton K. Low back pain in children and adolescents: to treat or not. *Bull Hosp Jt Dis* 1996;55(3):127-9.
 21. Brattberg G. Do pain problems in young school children persist into early adulthood? A 13-year follow-up. *Eur J Pain* 2004;8(3):187-99
 22. McGill S. *Low Back Disorders*. Champaign, IL: Human Kinetics; 2002.

CHAPTER 3 – PART 4

BACK POSTURE EDUCATION IN ELEMENTARY SCHOOLCHILDREN: A 2-YEAR FOLLOW-UP STUDY

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BACK POSTURE EDUCATION IN ELEMENTARY SCHOOLCHILDREN: A 2-YEAR FOLLOW-UP STUDY

Abstract. Background. Within the scope of primary prevention regarding back functioning in children, research on the stability of intervention effects is indispensable. Along this line, the transition from childhood to adolescence is an important phase to evaluate the potential stability of intervention effects because of the typically mechanical and psychological demands related to adolescence. The main aim of the current study was to investigate the effects of a back education program at 2-year follow-up, in youngsters aged 13 to 14 years, on back posture knowledge, fear-avoidance beliefs and self-reported pain. An additional purpose was to evaluate which aspects of postural behavior were integrated in youngsters' lifestyles. **Methods.** At 2-year follow-up, the study sample included 94 secondary schoolchildren in the intervention group (mean age 13.3 ± 0.8 years) and 101 controls (mean age 13.2 ± 0.7 years). The back posture program that had been implemented for two school-years consisted of back education and the stimulation of postural dynamism in the class through support and environmental changes. A questionnaire was completed comparable to the pretest, posttest and follow-up evaluations. **Results.** The current study demonstrated at 2-year follow-up stability of the improved general ($F=1.590$, ns) and specific ($F=.049$, ns) back posture knowledge in children who had received early back posture education. Back posture education did not result in increased fear-avoidance beliefs ($F=1.163$, ns) or mounting back and/or neck pain reports ($F=.001$, ns). Based on self-reports for postural behavior, youngsters who had received the back posture program in the elementary school curriculum integrated crucial sitting and lifting principles conform to biomechanical favorable postural behavior. **Conclusion.** The steady intervention effects 2-year post-intervention demonstrated that intensive back posture education through the elementary school curriculum is effective till adolescence. Future research on the impact of early school-based back posture promotion in relation to the integration of back posture principles according to a biomechanical favorable lifestyle and back pain prevalence later in life is essential.

Key words: back education program, prevention, schoolchildren, follow-up.

1. INTRODUCTION

In children and adolescents epidemiological evidence indicated life-time prevalence for back pain varying from 13% to 51% and point prevalence ranging from 1% to 31% [15, 16]. For the majority of the children, back pain experiences are mainly non-specific and mild in nature [17] not leading to functional restrictions in their daily life [16, 28]. However, epidemiological research established a range of 7% to 27% children with recurrent low back pain [15]. Children with recurrent or continuous back pain reported a reduced quality of life and were found to use more medical attention and to consume more analgesics [15]. Besides, the findings of tracking studies consistently pointed out that back pain reports in

childhood and early adolescence are significantly related to back pain reports in adulthood [2, 11, 15]. Therefore, several authors recommended research into the early stages of the problem in order to determine the possible key role of early prevention efforts [6, 30].

Notwithstanding, the multi-factorial risk for developing back pain in childhood [17] complicates the determination of predisposing factors and preventive measures. In order to provide evidence on early prevention in low back pain, the determination of modifiable risk factors and the results of school-based intervention studies are essential [5].

However, the findings of multiple studies on modifiable risk factors for back pain at young age considering personal characteristics, lifestyle correlates and

functional aspects presented conflicting results [5]. Further, the limited literature has indicated that the school environment exposes children to the possible loading factors with respect to prolonged poor sitting [18, 23] and absence of appropriate furniture [19, 22, 24, 25]. Therefore, the school system represents an ideal setting for back pain prevention since it has the potential of optimizing environmental conditions in relation to spinal loading and giving prolonged feedback with regard to good body mechanics. Another advantage of prevention through the school setting includes that nearly all children can be reached.

The promising findings of school-based interventions with respect to good body mechanics in schoolchildren supported the implementation of back posture programs in the school curriculum. However, Cardon and Balagué [5] reported methodological restrictions of intervention studies regarding limited participants, non-randomized study designs and short implementation times. The European guidelines regarding the prevention of back pain, which were formulated at request of the European Commission, stipulated the need for school-based intervention studies and confirmed the methodological shortcomings of intervention studies [10]. Furthermore Steele et al. [29] recently evaluated the quality of school-based interventions and correspondingly concluded that the majority of intervention studies was limited owing to methodological restrictions with regard to intervention characteristics or study aspects.

Therefore, a comprehensive intervention study was designed excluding limitations with regard to a short implementation time, a unimodal approach, small study sizes and a non-randomized controlled sample. In a previous study [13] the intervention effects of the latter two-school-year multi-factorial back education program on school-related correlates were investigated in 9 to 12 year old schoolchildren. The study findings indicated that the intervention resulted in increased back posture knowledge, improved postural behavior during material handling and while sitting during lesson

time. Additionally, the intervention did not result in increased fear avoidance beliefs or augmented back pain prevalence, which may be a negative consequence of attention for back-related topics [3, 4].

Within the scope of primary prevention regarding back functioning in children, research on the stability of intervention effects is indispensable [5, 29]. Along this line, the stability of intervention effects was shown in our 1-year follow-up study [12]. According to the study-design, the study sample at 1-year follow up included a mixed population of elementary (12 years of age) and secondary (13 years of age) schoolchildren. Since the intervention comprised back posture education in addition to the stimulation of postural dynamism through environmental influence and support by the class teacher, the possible influence of continued environmental support through the elementary school setting needed to be considered during the first year post-intervention. Conversely, two years after intervention completion, all children attended secondary schools (13 to 14 years of age) implying considerable differences when compared to the elementary school outline. In the first place, the secondary school is known for significant homework after school time in comparison to the elementary school. In the second place, at 13 to 14 years of age the transition from childhood to adolescence takes place which is characterized by a biological impact (maturation) and psychosocial implications (psychological development, switch in educational system, exposure to plenty of new interests and influences throughout the peer group). During this transition period, stooping postures are frequently adopted for whatever reason (feelings of shame for the changing body or imitations in conscious of being 'cool') which may result in pressure on the anterior aspects of the vertebral growth plates [32]. As a final aspect, the mounting back pain reporting around the growth spurt [1] justifies research on the stability of early intervention effects in youngsters at secondary school-age.

Accordingly, the main aim of the current study was to investigate the effects

of a back posture education program at 2-year follow-up on back posture knowledge, fear-avoidance beliefs and self-reported pain. Since the 2-year intervention to promote good body mechanics by increasing postural dynamism attempted to introduce biomechanical favorable back posture principles in children's daily lifestyle, an additional purpose was to evaluate which aspects of postural behavior were intensively integrated in their lifestyle.

2. MATERIAL AND METHODS

2.1 Subjects

Eight Flemish elementary schools were selected by simple randomization. Flanders is the Dutch speaking part of Belgium. Children were randomized at school-level into the intervention and the control group (10 intervention class groups out of 4 schools, 10 control class groups out of 4 schools). All schools were comparable with regard to geographic location and parental education levels.

The multi-factorial back education program started in November 2002 after pre-testing in September and October 2002. Post-testing was performed from April until June 2004. The first follow-up evaluation was organized in April until June 2005.

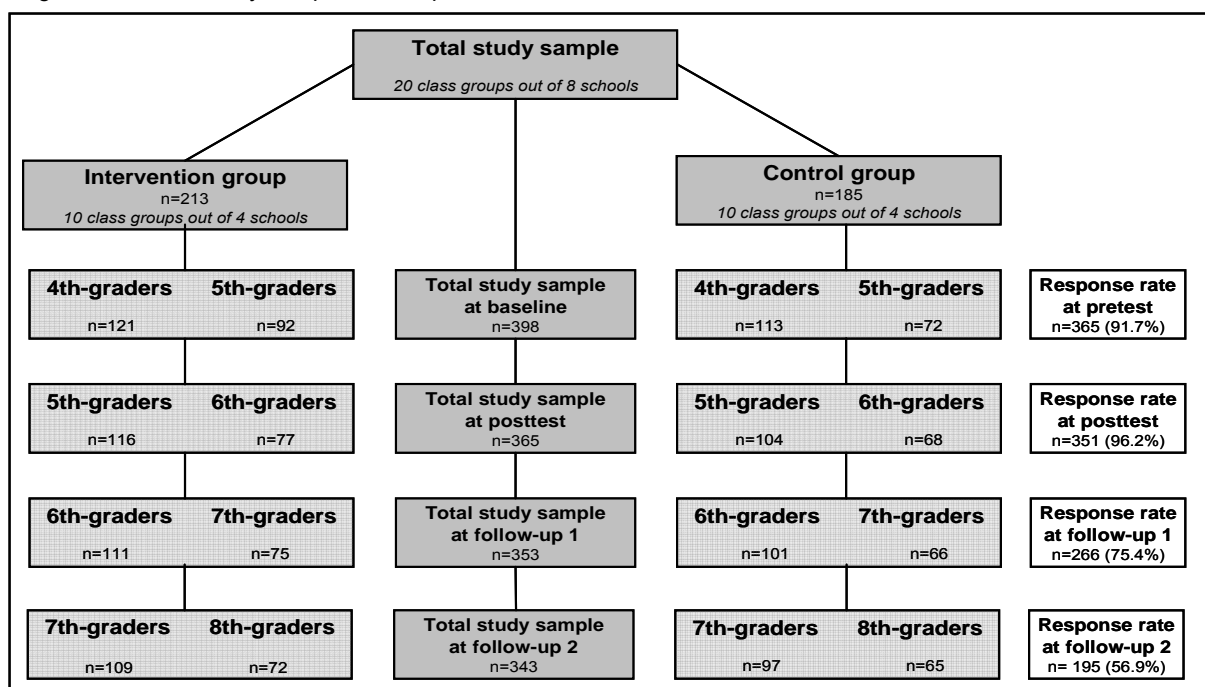
The current follow-up evaluation was organized in March 2006, two years after the program was finished.

At baseline, the study sample consisted of 398 schoolchildren who started 4th and 5th grade of elementary school (ages 9 to 11). At 2-year follow-up, the intervention group consisted of 94 secondary schoolchildren in the 7th or 8th grade (43 boys, 51 girls; mean age at 2-year follow-up 13.3 ± 0.8 years) and the control group included 101 children in secondary schools (45 boys, 56 girls; mean age at 2-year follow-up 13.2 ± 0.7 years). The response rate in relation to the composition of the study sample over the four years is presented in figure 1.

2.2 Evaluation instruments

Children completed a questionnaire with regard to back posture knowledge and back function which demonstrated good test-retest reproducibility [8]. Specific back posture knowledge was evaluated through 10 questions directly corresponding to the content of the back education program. A multiple-choice quiz including 11 items evaluated general back posture knowledge. Fear-avoidance beliefs were evaluated through five questions on a 5-point-scale with a low score representing low fear-avoidance.

Figure 1: Flow of study sample and response rate.



Finally, the questionnaire included questions related to back and neck pain prevalence within the last week.

At 1- and 2-year follow-up, the questionnaire integrated an additional part for children of the intervention group asking in which degree they could remember the back education sessions (4-point-scale from nothing to everything) and how frequently they used the back posture principles in their current daily live (5-point-scale from never to ever).

At 2-year follow-up, 20 supplemental questions on children's postural behavior were included. Therefore, the use of back posture principles during daily live was evaluated through 10 questions (see table 3). In addition, postural behavior in the class during lesson time (2 questions) and during studying at home (3 questions) was questioned. Furthermore, postural aspects with regard to spinal loading during regularly sitting on a chair (3 questions) and the use of ergonomically designed material in the class (1 question) and at home (1 question) were asked. All supplemental questions were rated on a 5-point-scale (from never, to ever) and addressed to both the intervention and the control group.

2.3 Procedure

The questionnaire used at 2-year follow-up was for the major part identical to the preceding evaluations. At pre- and post-test, the questionnaires were filled out at school under supervision of the class teacher. At 2-year follow-up, all children were reached by mail to complete the questionnaires independently at home. Children were asked to fill out their names on the surveys. To minimize socially desirable answers, they were clearly informed about the anonymous data processing. They were invited to return the questionnaire in a presented stamped and addressed envelope. One month after mailing the questionnaires, the non-responders were contacted once by a personal phone call in order to stimulate them to complete and return the questionnaires. The study protocol was approved by the Ethical Committee of the

University Hospital of the Ghent University.

2.4 Intervention

The intervention to promote good body mechanics in elementary schoolchildren was a multi-factorial back posture program with involvement of the class teacher during two school-years, as described in a previous study [13]. The basic program consisted of six back education lessons at one-week interval, taught by a physical therapist to one class group at a time. Pupils were taught anatomy and pathology of the back in the context of optimal loading of the body structures. Furthermore, the basic principles of biomechanical favorable postures were taught and practiced. In addition to the back education sessions, didactic material was provided for the class teachers and guidelines were presented in order to optimize integration of the learned back posture principles. Furthermore, the multi-factorial intervention incorporated an extra focus on postural dynamism in the class by stimulation of dynamical sitting and prevention of prolonged static sitting. Active and variable sitting were reinforced by providing two pezzi balls, a dynair and a wedge in each classroom. Further, short movement breaks were introduced between the lessons. Additionally class teachers were encouraged to teach following an activating approach (e. g. distribution of handouts systematically through children, use of sitting alternatives, variable work organizations like standing work places) and to change structural aspects in the class organization (e. g. decentralized storing places for textbooks and schoolbags).

2.5 Data analysis

Data analysis was performed using SPSS 12.0. The level of significance was set at 5%. A drop-out analysis was executed using Independent Samples T-tests in order to determine baseline group differences between non-responders versus responders. The stability of the intervention effects after a 2-year follow-up interval was explored using Repeated Measures Ancova, with baseline scores as

covariates. Time was included as within-subjects factor (post versus 2-year follow-up evaluation) and condition as between-subjects factor (intervention versus control group). Gender was included as a second between-subjects factor in order to evaluate three-way-interaction effects. Intention to treat analyses were performed but provided identical results (non-significant interaction effects for all variables: $F < 2.260$, ns; in addition to mixed main effects of condition: general back posture knowledge, $F = 48.840$, $P < .001$; specific back posture knowledge, $F = 23.386$, $P < .001$; fear-avoidance beliefs, $F = .051$, ns; back pain reporting $F = .379$, ns). Therefore, the results were only reported for the responding children out of study sample at 2-year follow-up. Finally, the 2-year follow-up data on children's self-reported postural behavior during school time and daily activities were analyzed performing Pearson Chi-Square techniques after recoding the variables (the scores 1 to 3 on the 5-point-scale ranging between never and ever were recoded into 0 and represented 'unusual postural behavior' while the scores 4 to 5 were recoded into 1 representing 'usual postural behavior').

3. RESULTS

3.1 Drop-out analyses

A comparison between responders and non-responders within the pre-post-2-year-follow-up design is presented in table 1. Children who answered questionnaires at 2-year follow-up had a higher general back posture knowledge score at baseline

and were 0.2 years younger in comparison to the non-responders.

3.2 Stability of Intervention Effects

Postural knowledge, fear-avoidance beliefs and self-reported pain. Table 2 and figures 2 to 5 present the changes in general and specific back posture knowledge, fear-avoidance beliefs and self-reported pain comparing the intervention group versus the controls between post-test and 2-year follow-up evaluation. For none of the variables interaction effects were found revealing stable effects when comparing the intervention group to the controls between post-test and 2-year follow-up. For general and specific back posture knowledge the main effect of condition was significant, revealing better knowledge scores in the intervention group compared to the controls both at post-test and at follow-up. No main effect of condition was found for fear-avoidance beliefs and self-reported pain. The three-way interaction including gender showed no significance for specific back posture knowledge ($F = .916$, ns), fear-avoidance beliefs ($F = .484$, ns) or self-reported pain ($F = .406$, ns), which means that the specific knowledge scores, fear-avoidance beliefs and back pain-reports changed similarly in boys and in girls. The three-way interaction on general back posture knowledge was significant ($F = 2.242$, $P < .05$). Further analyses showed that the scores on general back posture knowledge were stable in boys of the intervention group compared to improved back posture knowledge in boys of the control group ($F = 4.017$, $P < .05$). In

Table 1: Group differences between responders and non-responders within the pre-post-2-year-follow-up design (Independent Samples T-test).

At baseline variable (<i>theoretical range</i>)	Mean Total Score (<i>range</i>)		Group difference	
	Responders (n=195)	Non-responders (n=203)	t-value	df
General back posture knowledge (-11-11)	1.4 (-2-11)	0.3 (-2-10)	2.899*	362
Specific back posture knowledge (-10-10)	5.1 (-7-10)	4.8 (-11-9)	1.461	362
Fear-avoidance beliefs (5-25)	16.9 (5-25)	17.0 (5-25)	.271	362
Self-reported back and/or neck pain (%)	32%	30%	.430	363
Gender (% girls)	55%	48%	1.361	396
Age (year)	9.8 (8.1-12.5)	10 (8.7-12.5)	2.492*	359

** $P < .001$, * $P < .05$

Table 2: Back posture knowledge, fear-avoidance beliefs and back and/or neck pain prevalence in the intervention and the control groups at post-test and at 2-year follow-up (Repeated Measures Ancova).

Variable (<i>theoretical range</i>)	Mean Total Score (SD) and Prevalence				Effect	
	Post		2-year Follow-up		T x C	C
	I	C	I	C	F _(df=1)	F _(df=1)
General back posture knowledge (-11-11)	5.4 (2.8)	3.1 (3.0)	5.9 (2.8)	4.2 (2.7)	1.590	31.482**
Specific back posture knowledge (-10-10)	7.7 (2.1)	6.7 (2.3)	8.6 (1.4)	7.6 (2.0)	.049	20.750**
Fear-avoidance beliefs (5-25)	16.3 (4.7)	17.2 (3.9)	15.2 (3.8)	15.4 (3.3)	1.163	1.293
Self-reported back and/or neck pain (%)	29%	32%	20%	23%	.001	.522

SD, standard deviation
I, intervention group (n=86).
C, control group (n=99).
T x C, time x condition (interaction effect).
C, condition (main effect of group).
** P <.001, * P <.05

intervention girls the scores on general back posture knowledge did not differ significantly between post-test and follow-up in comparison to the controls which means that the change over time was similar in girls of both conditions.

Children's perceptions about the promotion of good body mechanics.

Two years after program completion, 96% of the children remembered the back posture education sessions. The major part (70%) reported that they remembered 'much' to 'everything' of the back education sessions, 29% remembered only a 'little' and one child reported to remember 'nothing'. Additionally, a large part reported to use the back posture principles 'almost always to always' (55%) and 'sometimes' (35%), while only 9% of the children used the learned back posture principles 'now and then' and two children (1%) reported to use the principles 'never' in daily live.

3.3 Postural behavior at 2-year follow-up (post-intervention evaluation)

Table 3 presents group differences at 2-year follow-up in personalized aspects of postural behavior conform a biomechanical favorable lifestyle between children who had received back posture education and controls. Significant differences were found for three of the ten back posture principles, which were all aspects conform good lifting technique.

Evaluation of the reports on other back posture principles showed no differences between both groups. Further, the major part of the children reported that carrying a book bag on the back, carrying an object as close as possible to the body and joining sport activities three times a week were common habits (>60% of all children). On the other hand, a limited percentage of children (<30 % of all children) reported to pay attention for the neutral spinal curvature, to relax with lifted legs, to check the weight of their school bags and to place homework on an inclined surface. Furthermore, a significant larger proportion of children in the intervention group reported that they pay attention to their posture while sitting during class activities compared to the controls (31% versus 14%). Accordingly, there was a trend towards significance for a larger part of the intervention children reporting to pay attention to their posture while sitting during study time (19% versus 10%). The low percentages showed that these aspects were only generalized in the lifestyle of a limited number of children. Finally, significantly more intervention children reported that they had included postural aspects preventing spinal loading during sitting activities when compared to the control group (back rest use: 68% versus 50%, arm support: 59% versus 41%, feet on the floor: 68% versus 45%). Further, children reported that ergonomic materials were not applicable in their

secondary schools. Finally, between intervention children and controls no differences were found with regard the use of ergonomic materials at home.

4. DISCUSSION

The main aim of the current study was to investigate 2-year follow-up effects of early back posture education through the elementary school curriculum. Additionally, self-reported postural behavior in youngsters' daily activities was investigated in relation to a biomechanical favorable postural lifestyle. The transition from childhood to adolescence is an important phase to evaluate the potential

stability of intervention effects after early back posture education because of the typically mechanical and psychological demands related to adolescence.

Based on our previous study [13], immediate intervention effects of multi-factorial school-based back posture program included improved general and specific back posture knowledge. The current study demonstrated for the two years following after completion of the back posture program an increase of back posture knowledge in both conditions, but at a higher level for the children who had received the back posture program. The latter picture may support the presumption that children's knowledge expands with

Table 3: Comparison of the number of children with personalized good back posture principles between the intervention group and the controls at 2-year follow-up (Chi-Squared Test).

Questions about postural behavior	Children with good postural behavior (%)		Group difference
	I	C	$\chi^2_{(df=1)}$
Back posture principles			
Do you pay attention to the natural curvature of your spine?	20%	16%	.637
Do you join sport activities 3 times a week (e.g. swimming, jogging)?	67%	63%	.344
When you relax, do you lie down on your back with your legs lifted?	26%	26%	.013
When you bend, do you bend your knees and not your back?	71%	54%	6.162**
When you lift, do you stand as close as possible to the object?	78%	59%	7.530**
Do you ask for help to lift a heavy object?	68%	55%	3.708*
Do you carry an object as close as possible to your body?	77%	66%	2.649
Do you carry your book bag on your back?	96%	93%	.712
Do you check the weight of your book bag?	17%	11%	1.394
Do you place your book/homework on an inclined working table/ring binder?	17%	17%	.038
Postural behavior in the class			
When you sit in the class room, do you pay attention to your posture?	31%	14%	7.741*
When you sit in the class room, do you change your posture?	60%	61%	.053
Postural behavior during study time			
When you make your homework, do you pay attention to your posture?	19%	10%	3.284 ^s
When you make your homework, do you change your posture?	53%	42%	2.026
When you make your homework, do you interrupt your sitting activity?	48%	38%	1.999
Loading factors related to sitting			
When you sit on a chair with a back rest, do you use the back rest?	68%	50%	6.833*
When you sit, do you make that your arms are supported?	59%	41%	6.277*
When you sit, do you sustain your both feet to the ground?	68%	45%	10.868**
Use of ergonomic material			
Do you use ergonomic material in the class room (like sitting ball or wedge)?	-	-	na
Do you use ergonomic material at home (like a sitting ball or wedge)?	6%	11%	1.394

I, intervention group (n=86)
 C, control group (n=99).
 na, not applicable.
 χ^2 , Pearson Chi-Square
 ** P <.001, * P <.05, ^sP <.09

age. Further, it seemed that improved back posture knowledge after back posture education may persistently assure greater back posture related knowledge. A right conception of biomechanical favorable postural behavior is a necessary condition for the development of a conscious and lifetime healthy lifestyle with respect to good body mechanics [21]. However, good back posture knowledge is not the only aspect promising adequate postural behavior in relation to a biomechanical favorable lifestyle [9].

Figure 2: Change of general back posture knowledge over four years.

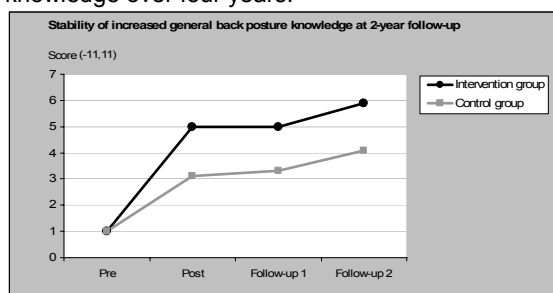
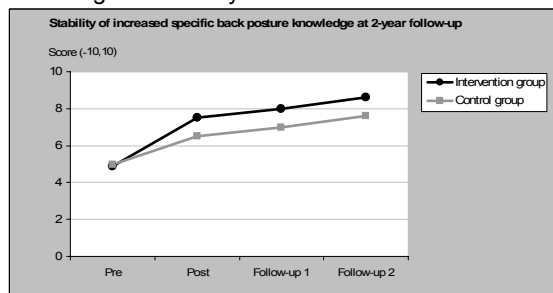


Figure 3: Change of specific back posture knowledge over four years.



Two years after completion of the back posture program, more intervention children reported that they had integrated biomechanical favorable back posture principles into their daily lifestyles with regard to lifting (bending knees, standing close to object, asking for help) and sitting (back rest use, arm support, feet to the ground) when compared to the reporting of the controls. These study findings may be important since a review on risk factors related to back pain at young age indicated that sitting is the most common factor associated with back pain reports in youngsters [1]. Furthermore, at adolescent age youngsters typically adopt stooping postures which may result in pressure on the anterior aspects of the vertebral growth plates [32]. In addition, the present findings at 2-year follow-up on lifting

aspects which suggest the implementation of principles in relation to a biomechanical favorable lifestyle are positive owing to the impact of lifting activities that may increase in youngsters' daily life at secondary school age (such as in vocational education). On the other hand, the reports of the youngsters on postural aspects in the class and during study time did not differ between the intervention and the control groups with the exception that youngsters who had received back posture education reported regularly paying attention to their posture during class activities (31% versus 14%). Based on the reports of the youngsters, the more specific aspects promoting optimal daily load on the spinal structures such as lifting the legs when relaxing and working on an inclined surface did not seem to be integrated into their daily lifestyles. Concluding the reporting on postural behavior, one can assume that youngsters who received back posture education may have relieved some daily loading factors by integrating biomechanical favorable postural principles. An interesting research question is whether these principles will be used later in the occupational setting and whether this has an impact on adult back pain with regard to work-related consequences.

Besides the wide range of arguments to justify back posture education at young age, Burton [4] warned for the potential of increased fear-avoidance beliefs as a consequence of early back education. Based on the literature, high fear-avoidance beliefs and misconceptions about pain are persistent in adults playing a significant part in the development of long-term disability [14]. Given the life time prevalence for back pain in adulthood, 80% of the children will experience back pain at some point in life [31]. Therefore, it is important that children who received early back education have no increased fear-avoidance beliefs. The present 2-year follow-up study indicated that the back posture program did not result in increased fear-avoidance beliefs between post-test and 2-year follow-up evaluation and over the 4-year time span.

The present back posture program in the elementary school did not result in decreased back pain reporting. The lack of

evidence for the direct impact of primary prevention on back pain prevalence [20] is a critical point in the prevention discourse, certainly in children [5]. The general nature of common back pain experiences implies a limited scope for preventing back pain incidence. Therefore, early interventions might better focus on the possible change of correlates influencing spinal loading in the school environment in relation to the possible change of back pain prevalence in the longer term. However, the evaluation of short-term effects on back pain reporting is ambitious because of the double knife-edge. Even though the intervention did not lead to reduced back pain reporting in children, the early back posture education did not result in increased back pain reporting two year after intervention completion which may be a negative result of the attention for back topics. Overall, the current prevalence rates for back and neck pain varying from 20% to 32% over the 4-year time span are in line with the prevalence reports in the literature [7, 27]. The lack of effect on pain reporting at young age may be due to the mild nature of pain and the fact that children's pain reports are mainly associated with psycho-social factors.

Figure 4: Change of fear-avoidance beliefs over four years.

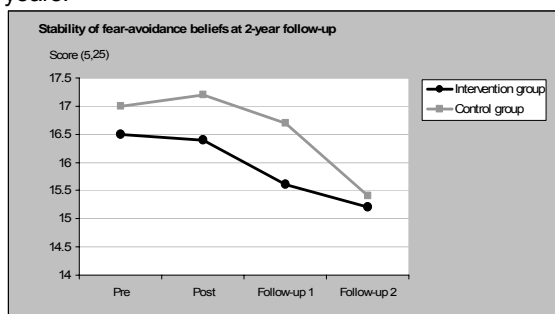
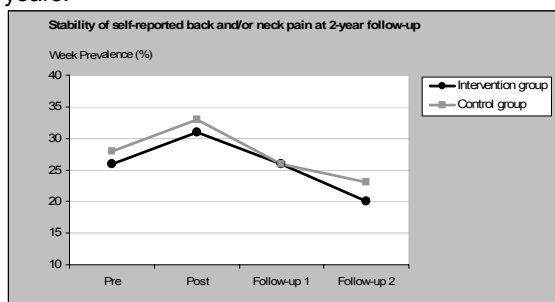


Figure 5: Change of back pain reporting over four years.



Judging the limitations of the present study, the use of self-reported

postural behavior needs a critical approach. Although the children were informed about the anonymous data processing, children who have received the back posture program may have reported social desirable answers (conform to good body mechanics), which may have resulted in an over-reporting of good postural behavior. However, in the current study the percentages showed realistic figures in addition to variability between the different questions (not 'every' aspect was 'simply' integrated), which may suggest adequate reporting of postural behavior. Nevertheless, the objective measurement of youngsters' postural behavior in order to evaluate the longer term practice of different postural aspects with regard to daily sitting and lifting after back posture education at early age, may embrace a suggestion for future research.

The 50% dropout after the four evaluations and the reality that those who were lost at follow-up were slightly older at baseline having less general back posture knowledge in comparison to the responders at 2-year follow-up included a second limitation. Therefore, the findings of the current study need careful interpretation with regard to generalization. However, the dropout rate of the present study was comparable to the 38% dropout in the 1-year prospective study by Feldman et al. [11]. Furthermore, the present total study sample still consisted of 195 subjects. This sample size is relatively large compared to the study samples of other intervention [29] or prospective [26] studies and may suggest some general relevance.

Considering a last limitation, the possible influence of confounding factors unrelated to the back posture intervention was carefully controlled during the 2-year interval of back posture education in elementary schoolchildren [13]. In the present evaluation at secondary school-age, possible interfering factors related to the intervention program were not controlled. Pragmatically, there is a chance that secondary schools provide back posture topics since in Flanders school policies may autonomously decide to include health related topics within the mandatory curriculum. However, the fact

that the participants of both conditions attended multiple secondary schools makes the possible influence of interfering factors similar in both conditions. The black box condition during the follow-up period may even strengthen the current findings on the stable intervention effects of early back posture education.

5. CONCLUSIONS

The steady intervention effects 2-year post-intervention demonstrated that the intensive implementation of the present multi-factorial back education program in the elementary school curriculum improved children's back posture knowledge. Additionally, the back posture program did not result in increased fear-avoidance beliefs or mounting back and/or neck pain reports over the 4-year time span. Finally, based on self-reports for postural behavior the present study results indicated that youngsters who had received back posture education in the elementary school curriculum integrated crucial sitting and lifting principles conform to biomechanical favorable postural behavior. Future research on the impact of early school-based back posture programs in relation to the integration of back posture principles according to a biomechanical favorable lifestyle and back pain reporting later in life is essential.

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REFERENCES

1. Balagué F, Troussier B, Salminen JJ (1999) Non-specific low back pain in children and adolescents: risk-factors. *Eur Spine J* 8:429-438
2. Brattberg G (2004) Do pain problems in young school children persist into early adulthood? A 13-year follow-up. *Eur J Pain* 8:187-199
3. Burton K, Clarke D, McClune D, Tillotson M (1996) The natural history of low back pain in adolescents. *Spine* 2:2323-2328
4. Burton K (1996) Low back pain in children and adolescents: to treat or not. *Bull Hosp Jt Dis* 55:127-129
5. Cardon G, Balagué F (2004) Low back pain prevention's effects in schoolchildren. What is the evidence? *Eur Spine J* 13:663-679
6. Cardon G, De Clercq D, De Bourdeaudhuij I (2000) Effects of back care education in elementary schoolchildren. *Acta Paediatr* 89:1010-1017
7. Cardon G, De Bourdeaudhuij I, De Clercq D (2002) Back education efficacy in elementary schoolchildren: a one year follow-up study. *Spine* 27:299-305
8. Cardon G, De Bourdeaudhuij I, De Clercq D (2002) Knowledge and perceptions about back education among elementary school students, teachers, and parents in Belgium. *J Sch Health* 72:100-106
9. Cherkin DC, Deyo RA, Street JH, Hunt M, Barlow W (1996) Pitfalls of patient education. Limited success of a program for back pain in primary care. *Spine* 21:345-355
10. COST B13: European guidelines for the management of low back pain. *Eur Spine J* 15 (Suppl. 2):S125-S297
11. Feldman DE, Shrier I, Rossignol M, Abenhaim L (2001) Risk factors for the development of low back pain in adolescence. *Am J Epidemiol* 154:30-36
12. Geldhof E, Cardon G, De Bourdeaudhuij I, De Clercq D (submitted) Back posture education in elementary schoolchildren: stability of 2-year intervention effects. *Eura Medicophys*

13. Geldhof E, Cardon G, De Bourdeaudhuij I, De Clercq D (2006) Effects of a two-school-year multi-factorial back education program in elementary schoolchildren. *Spine* 31:1965-1973
14. Goubert L, Crombez G, De Bourdeaudhuij I (2004) Low back pain, disability and back pain myths in a community sample: prevalence and interrelationships. *Eur J Pain* 8:385-394
15. Harreby M, Nygaard B, Jessen T, Larsen E, Storr-Paulsen A, Lindahl A, Fisker I, Laegaard E (1999) Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. *Eur Spine J* 8:444-450
16. Jones MA, Stratton G, Reilly T, Unnithan VB (2004) A school-based survey of recurrent non-specific low-back pain prevalence and consequences in children. *Health Educ Res* 19:284-289
17. Jones MA, Stratton G, Reilly T, Unnithan VB (2005) Biological risk indicators for recurrent non-specific low back pain in adolescents. *Br J Sports Med* 39:137-140
18. Knight G, Noyes J (1999) Children's behaviour and the design of school furniture. *Ergonomics* 42:747-760
19. Limon S, Valinsky LJ, Ben-Shalom Y (2004) Children at risk - Risk factors for low back pain in the elementary school environment. *Spine* 29:697-702
20. Linton S, van Tulder MW (2001) Preventive interventions for back and neck pain problems. What is the evidence? *Spine* 26:778-787
21. Mendez FJ, Gómez-Conesa A (2001) Postural hygiene program to prevent low back pain. *Spine* 26:1280-1286
22. Milanese S, Grimmer K (2004) School furniture and the user population: an anthropometric perspective. *Ergonomics* 47:416-426
23. Murphy S, Buckle P, Stubbs D (2004) Classroom posture and self-reported back and neck pain in schoolchildren. *Appl Ergon* 35:113-120
24. Panagiotopoulou G, Christoulas K, Papanckolaou A, Mandroukas K (2004) Classroom furniture dimensions and anthropometric measures in primary school. *Appl Ergon* 35:121-128
25. Parcels C, Stommel M, Hubbard R, (1999) Mismatch of classroom furniture and student body dimensions. *J Adolesc Health* 24:265-273
26. Sjölie AN (2004) Persistence and change in non-specific low back pain – A 3-year prospective study. *Spine* 29:2452-2457
27. Szpalski M, Gunzburg R, Balague F, Nordin M, Melot C (2002) A 2-year prospective longitudinal study on low back pain in primary school children. *Eur Spine J* 11:459-464
28. Staes F, Stappaerts K, Lesaffre E, Vertommen H (2003) Low back pain in Flemish adolescents and the role of perceived social support and effect on the perception of back pain. *Acta Paediatr* 92:444-451
29. Steele EJ, Dawson AP, Hiller JE (2006) School-based interventions for spinal pain: a systematic review. *Spine* 31:226-233
30. Troussier B, Tesniers C, Fauconnier J, Grison J, Juvin R, Phelip X (1999) Comparative study of two different kinds of school furniture among children. *Ergonomics* 42:516-526
31. Walker BF (2000) The prevalence of low back pain: a systematic review of the literature from 1966 to 1998. *J Spinal Disord* 13:205-217
32. Wilke HJ, Neef P, Hinz B, Seidel H, Claes L (2001) Intradiscal pressure together with anthropometric data - a data set for the validation of models. *Clin Biomech* 16 (Suppl 1):111-126

SECTION 3

GENERAL CONCLUSIONS

PART 1: MAIN FINDINGS

The aim of this doctoral thesis was to investigate postural behavior and back functioning in schoolchildren. Therefore, immediate intervention effects of a two-school-year comprehensive back posture program on elementary schoolchildren's postural behavior, back functioning, back posture knowledge, fear-avoidance beliefs and back pain reporting were evaluated. With respect to the longer-term effects of early back posture education, the stability of the intervention effects was investigated one and two years after completion of the multi-factorial back posture program. The doctoral thesis included two additional purposes: the exploration of postural behavior in the elementary school-environment in relation to back pain reporting at young age and the determination of reliability for back function measurements in elementary schoolchildren.

In this part the main findings of the doctoral thesis are portrayed. Therefore, we start with the description of our study findings on the reliability of measuring back function parameters in 8 to 11 year olds. Subsequently, classroom postures in elementary schoolchildren are discussed and related to self-reported back pain. To end, we present an overview of the intervention effects after the two-school-year promotion of good body mechanics through the elementary school curriculum including stability of the intervention effects.

Reliability of measuring back function in 8 to 11 year old children

Postural stability is a component of back functioning and considered to be an important indicator of musculoskeletal health. It refers to the inherent ability of a person to maintain, achieve or restore a specific state of balance and not to fall (Pollock et al. 2000). The most frequently used technique to evaluate postural stability is the measurement of the position and displacement of the centre of pressure (COP) using a ground reaction force plate. Force plate measurements are widely used and the reliability is well documented in adults (Birmingham 2000, Brouwer et al. 1998, Lafond et al. 2004). However, reports on reliability for postural stability assessments in elementary schoolchildren are limited. This reliability is an absolute prerequisite before a reference data set could be developed and possible associations to back pain reporting or impairments within the clinical field might be investigated in early stages of the potential problems. The Neurocom Balance Master® System is frequently used to evaluate postural stability. Therefore, in the study '**Static and dynamic standing balance: test-retest reliability and reference values in 9 to 10 year old children**' the reliability of standing balance assessment using the Neurocom Balance Master® System in 9 to 10 year olds was examined and reference values were reported

(Section 2 – Chapter 2). Using the Balance Master® in 9 to 10 year olds, the one-week reproducibility for standing balance assessments pointed out fair to good and even excellent reliability for most composite parameters (four parameters showed ICC's between 0.44 and 0.62, one parameter had an ICC of 0.77 while only one parameter's ICC was not significant). This reliability obtained within a population of elementary schoolchildren was in accordance to a study in adults aged 20 to 32 years (Brouwer et al. 1998). Considering the reference values, girls performed better on nearly all the composite balance parameters compared to boys (exception of Reaction Time and Movement Velocity), while no differences were found between the groups of 9 and 10 years of age. Furthermore, the present study results showed no age by gender interactions for postural parameters, which are in agreement with the developmental study findings of Figura et al. (1991) who assessed static balance in children aged 6 to 10 years old. In summary, the postural parameters presented in the current study may be used in other elementary schoolchildren aged 9 to 10 years old. Thus, the current data on postural control in 9 to 10 year olds may be relevant for research in other domains within the clinical field or in relation to back pain prevalence at early age. However, force plate measurements using the portable Balance Master® System in elementary schoolchildren should be further investigated, as well as the strategies for improving specific reliability aspects (like foot positioning and number of trials).

In line with the findings on reliability for postural stability assessment, a separate study within the intervention study '**Effects of back posture education on elementary schoolchildren's back function**' demonstrated reliable values for trunk flexor (ICC=0.82) and trunk extensor (ICC=0.63) endurance testing in 8 to 11 year old children (Section 2 – Chapter 3 – Part 2). Although the reliability values of the present study were slightly lower compared to the coefficients found for adolescent and adult populations, they were still acceptable because of the young age of the participants. Motivation, fatigue, point in time of the test, feeling of pain and relationship with the test leader, are all parameters affecting reproducibility, especially in this young population. In the current study, the researchers observed that the children were enthusiastic to perform the endurance test to the best of their ability. Furthermore, in order to minimize variations between the performances on the test and retest measurement, measurement order, test mode, testing sequence, test leader and surrounding factors were identical during the two measurement sessions. Taking the latter into account, it can be concluded that the current procedure for trunk flexor and extensor endurance testing is reliable in 8 to 11 year old children. In addition to the measurement of postural stability and trunk muscle endurance, the assessment of children's spinal curvature was evaluated as a third back function parameter (Section 2 – Chapter 3 – Part 2). The Zebris® technique showed for the static assessment of children's spinal curvatures four

ICC's representing a range from good to poor reliability. Assessing the spinal curvature in seating position showed fair to good reliability for the thoracic (ICC=0.69) and lumbar curvature (ICC=0.52). However, the reliability values for the assessment of the thoracic (ICC=0.39) and lumbar curvature (ICC=0.37) in stance were poor and lower when compared to the seating condition. The different outcomes for reliability of the standing and the sitting condition could possibly be explained by the reality that a sitting posture is more stable than a standing posture. Owing to the unsatisfactory reliability of the Zebris® use in stance position, the spinal data of the standing condition were not further interpreted.

Postural behavior in the class in relation to back pain reporting

In literature, the sitting posture has been discussed repeatedly with respect to back pain reporting and is found to be associated with back pain, in adults as well as in children and adolescents (Balagué et al. 1999, Murphy et al. 2004, Sjolie and Ljunggren 2001). The literature concentrating on sitting in the school environment indicated that prolonged static sitting and poor postures are common and related to back pain reports (Murphy et al. 2004). However, the sample sizes of available studies were relatively small and mainly included pupils from secondary schools. Therefore, in the cross-sectional study '**Classroom postures in 8 to 12 year old schoolchildren**', sitting behavior was evaluated in a large number of elementary schoolchildren out of multiple classes and schools in order to provide an objective and differentiating picture of children's sitting habits during class activities (Section 2 – Chapter 1). The Portable Ergonomic Observation Method (PEO) was used to evaluate classroom postures in 105 elementary schoolchildren from 41 different class groups. Making use of questionnaires, children's postural outcome was related to their back and/or neck pain reporting. The study results indicated that prolonged static kyphotic sitting without using the backrest was common in Flemish elementary schoolchildren. Pupils sat statically during 85% of the observed time, of which during 28% the trunk was bent. During 9% of lesson time children were sitting dynamically and they used their back rest for only 36% of time. Although, children were sitting on traditional school furniture without arm rests, a positive finding was that they supported their arms on their desks or thighs during 85% of the time. Taking a closer look at the relationship between sitting aspects and back pain reporting, the study results demonstrated that children who spend more time sitting with a flexed trunk reported significantly more thoraco-lumbar pain compared to pain free children and to children with cervical pain. In summary, the latter study findings pointed out that prolonged static sitting with a poor posture is a general condition in Flemish elementary schoolchildren and from a biomechanical point of view, a supplementary spinal load may be assumed. The current study indicated that the concept of dynamic sitting and the practice of ergonomic

biomechanics are absent in the Flemish actual class environment. Seemingly, elementary schoolchildren's postural behavior is to a certain extent affected by decisive class environmental components such as school furniture, teaching method, organizational class structures, pedagogic concept and school management. Besides, thoraco-lumbar pain reporting was related to a stooped sitting position. However, the cross-sectional design of the pilot study requires cautious interpretation.

The effectiveness of early promotion of good body mechanics

In line with the latter cross-sectional study and the evidence-based call for primary intervention studies with respect to good back functioning in children (Cardon and Balagué 2004, Steele et al. 2006), a comprehensive multi-factorial intervention was developed by optimizing a previous intervention study (Cardon et al. 2000, Cardon et al. 2001, Cardon et al. 2002). The optimized intervention was the first in the field promoting good body mechanics in elementary schoolchildren including a focus on postural dynamism for a period of two school-years (Section 1 – Summarize and reasoning of the study aims, p 24).

The quasi-experimental study '**Effects of a two-school-year multi-factorial back education program in elementary schoolchildren**' evaluated the impact of the comprehensive multi-factorial back posture program on back posture knowledge, postural behavior, fear-avoidance beliefs and self-reported back pain in elementary schoolchildren (Section 2 – Chapter 3 – Part 1). The study design eliminated some limitations, as reported by Cardon and Balagué (2004), with regard to a unimodal approach, small and non-randomized study samples and relatively short intervention periods. The present study findings indicated that the two-school-year back posture program resulted in improved general and specific back posture knowledge in elementary schoolchildren. Additionally, postural behavior during material handling was improved in the children who followed the back posture program. This positive change in material handling in a play situation suggested that the learned skills became generalized. Furthermore, the promotion of good body mechanics resulted in decreased duration of trunk flexion and neck torsion during class activities and there was a trend for decreased duration of trunk torsion in the intervention group. These were important findings since in previous research (Section 2 – Chapter 1) and according to the study of Murphy et al. (2004) it was demonstrated that flexed postures and trunk torsion were associated with schoolchildren's lumbar pain reporting. Moreover, in a preceding intervention study (Cardon et al. 2001) sitting postures during lesson times were not improved after back education. As a last intervention aspect, the two-school-year back education program did not change children's fear-avoidance beliefs or back pain reporting. It

was positive to discover that children's back pain reports and fear-avoidance beliefs were not increased as a result of the attention for the back. On the other hand, children who had received the back posture program did not report fewer back pain experiences after the two-school-year promotion. However, considering the effectiveness of school-based promotion of good body mechanics within the school environment back pain prevalence could better be approached as a long term effect, as addressed in the literature. Above and beyond, the receptiveness of children and teachers to the back posture program was an important finding. Children found the promotion of good body mechanics pleasant and teachers reported that the different aspects of the multi-factorial program were useful. Based on the implementation evaluation, teachers integrated most of the didactical principles in order to interrupt prolonged static sitting. However, the classroom observations demonstrated that the intervention did not result in the introduction of more variable or dynamical activities during lesson time. This could be coupled to teachers' reported reluctance towards changing their traditional methodic towards an activating approach by introducing variable and dynamical activities being considered as conflicting with authority and discipline. In the same line, several teachers stated that their knowledge and experience according to an activating approach in the class situation were insufficient. In summary, the promotion of good body mechanics at young age resulted in improved postural aspects related to spinal loading in the school environment and the program was well received by children and teachers.

In the framework of the positive effects on postural behavior in the school environment, an interesting research question included whether in children the change towards biomechanical favorable postural behavior was associated with an improvement of the underlying mechanisms for their postural behavior, namely their back functioning. In the literature, the possible effects of back posture education on schoolchildren's back functioning were never evaluated. Therefore the quasi-experimental study '**Effects of back posture education on elementary schoolchildren's back function**' evaluated the effects of the two-school-year promotion of good body mechanics on elementary schoolchildren's back functioning with regard to trunk muscle endurance, leg muscle capacity and spinal curvature (Section 2 – Chapter 3 – Part 2). The study showed that the promotion of good body mechanics throughout the school curriculum resulted in increased endurance of the trunk flexors compared to a decrease of trunk flexor endurance in the control group. Furthermore, there was a trend for a higher increase of trunk extensor endurance in children who had received promotion of good body mechanics. Along this line, multiple prospective studies comprising secondary schoolchildren (Jones et al. 2005, Sjolie and Ljunggren 2001) as well as adults (Udermann et al. 2003) reported trunk muscle endurance as a risk indicator for future back pain. In addition, it was hypothesized that active sitting may result in a positive

accommodation of the abdominal muscles since regularly adopting passive posture for long periods possibly will de-activate and de-condition the stabilizing muscles (O' Sullivan et al. 2002). So, based on the literature and our results one may suggest that the promotion of good body mechanics throughout the elementary school curriculum including the use of active-dynamical ergonomic material could play a key role in optimizing daily loading because of the potential to improve children's trunk muscle endurance. On the other hand, back posture education in elementary schoolchildren did not result in improved leg muscle capacity or changes in spinal curvatures while seating in a test situation when compared to the control group. Anyhow, based on the literature in adult samples there are indications that efficient back functioning is important to prevent chronic back pain. Therefore, back posture education with focus on postural dynamism in the class as an integral part of the elementary school curriculum might be recommended in the scope of early prevention for back pain.

The stability of intervention effects plays an important part in the discussion about effectiveness of early back education, as recently addressed in the review by Steele et al. (2006). In our 1-year follow-up study '**Back posture education in elementary schoolchildren: stability of 2-year intervention effects**', the stability of intervention effects was considered (Section 2 – Chapter 3 – Part 3). When discussing stability of a school-based intervention, the class teachers' role with regard to environmental support needs to be reflected upon. To our knowledge, it has never been evaluated what class teachers do with the guidelines subsequent to a structured intervention promoting good body mechanics throughout the elementary school curriculum. Therefore, we explored the class teachers' efforts promoting good body mechanics after the two-school-year back education program was finished. A final study purpose was to focus on the different aspects of children's back posture knowledge at item-level which enables us to have a more detailed insight into children's back posture related knowledge and to make adjustments for future interventions promoting good body mechanics. The study results demonstrated that class teachers persisted voluntarily in the promotion of good body mechanics, confirming the intentions reported by teachers who participated in the intervention study (Chapter 3 – part 1). Class teachers' continuing application of guidelines to increase postural dynamism is an essential finding, since they play a fundamental role in the promotion of good biomechanics throughout the school curriculum. Regrettably, when teachers were not engaged within the 2-year promotion of good body mechanics taking place in their schools, they were not informed about the guidelines encouraging postural dynamism in the class. At 1-year follow-up, half of the total study sample consisted of 6th grade children out of elementary schools while the other part included 7th grade pupils in secondary schools. Based on the interviews with the class teachers of the 6th grade, the sub-sample of 6th grade children out of the intervention

group could be subdivided in two groups. The 6th grade intervention class groups with class teachers who reported that they had promoted good biomechanics until follow-up (support until follow-up, 3 class groups, n=51) were compared to the 6th grade children where the promotion of good biomechanics was finished at post-test (no support during follow-up, 3 class groups, n=50) using Repeated Measures Ancova with the baseline scores included as covariates. However, statistical analyses indicated that the efforts to continue with initiatives to promote good body mechanics in the class until follow-up showed no additional effect on the children's postural knowledge scores. The latter finding could possibly be explained by the high intensity of the intervention program. Based on the literature, the present promotion of good body mechanics was a more intensive program compared to other school-based interventions for back pain prevention in schoolchildren considering the two-school-year implementation time and the multi-componential approach. On the other hand, the follow-up study demonstrated stability at 1-year follow-up for the improved back posture knowledge in children who had received the promotion of good body mechanics. Further, fear-avoidance beliefs remained stable when comparing the intervention and the control groups between post-test and follow-up. Accordingly, the prevalence for back and neck pain remained stable considering the self-reported rates of 26% to 33%. Though, children's self-reported back pain seemed to be inconsistent over the 3-year time span owing to children's reporting of cumulative back pain. In this line, the check up of cumulative back pain figures pointed out that 20% of the youngsters reported at post-test that they had experienced back pain 'ever' while they did not report cumulative back pain at 1-year follow-up. As a final point, the study demonstrated that the obligatory elementary school curriculum and probably external resources in Flanders provided children with fundamental back posture knowledge. The major part of the children answered correctly on half of the postural items both at age 10-13 and at age 11-14 years. Drawing up the balance of the back education program, the teaching method through guided discovery resulted in improved back posture knowledge for important postural items regarding postural dynamism (movement during recess, frequent position changes during sitting, the best way to transfer a load, the recommended maximal book bag weight and the best resting position for the back) but the results were too limited for two theoretical aspects (anatomy of the spine and sitting position as the most strenuous position for the back). As a final interesting finding, the 1-year follow-up study established that the majority of the children reported at 1-year follow-up the frequent use of the learned postural principles and the remembrance of 'much' to 'anything' of the back education sessions, contrasting the intervention study findings of Balagué et al. (1996).

Within the scope of primary prevention regarding back functioning in children focusing stability, the stability of intervention effects was also investigated in our 2-year follow-up

study. The study sample of the 1-year follow up investigation included a mixed population of elementary (12 years of age) and secondary (13 years of age) schoolchildren. Since the intervention comprised back posture education in addition to the stimulation of postural dynamism through environmental influence and support by the class teacher, the possible influence of continued environmental support through the elementary school setting needed to be considered during the first year post-intervention. Conversely, two years after intervention completion, all children attended secondary schools (13-14 years of age). Being a pupil of secondary school-age implies considerable differences when compared to a child of elementary school-age, such as significant homework after school time and the typical transition from childhood to adolescence with feelings of shame or being 'cool' related to stooping postures that may result in pressure on the anterior aspects of the vertebral growth plates. These aspects could possibly be associated with the mounting back pain reporting around the growth spurt. Therefore, the study '**Back posture education in elementary schoolchildren: a 2-year follow-up study**' investigated 2-year follow-up effects of early back posture education through the elementary school curriculum in secondary school aged pupils (Section 2 – Chapter 3 – Part 4). Additionally, self-reported postural behavior in youngsters' daily activities was investigated in relation to a biomechanical favorable postural lifestyle. Immediate intervention effects of the multi-factorial back posture program included improved general and specific back posture knowledge. The current study demonstrated an increase of back posture knowledge in both conditions over the four years, but at a higher level for the children who had received the back posture program. The latter picture may support the presumption that children's knowledge expands with age. Further, it seemed that improved back posture knowledge after back posture education may persistently assure greater back posture related knowledge. A right conception of biomechanical favorable postural behavior is a necessary condition for the development of a conscious and lifetime healthy lifestyle with respect to good body mechanics (Mendez and Gómez-Conesa 2001). However, good back posture knowledge is not the only aspect promising adequate postural behavior in relation to a biomechanical favorable lifestyle (Cherkin et al. 1996). The results on self-reporting for postural behavior indicated that youngsters who had received back posture education in the elementary school curriculum integrated crucial sitting aspects (back rest use, arm support, feet to the ground) and lifting principles (bending knees, standing close to object, asking for help) conform to biomechanical favorable postural behavior. These study findings may be important since sitting is found to be the most common factor associated with back pain reports in youngsters and the impact of lifting activities may increase at secondary school-age (such as in vocational education). On the other hand, the more specific aspects promoting optimal daily load on the spinal structures (such as lifting the legs when relaxing referring to the psoas rest position and working on an inclined

surface) did not seem to be integrated into their daily lifestyles. Further, the present 2-year follow-up study indicated both in the intervention and control pupils steady fear-avoidance beliefs between post-intervention and 2-year follow-up evaluation. Focusing on youngsters' reporting over a 4-year time span, fear avoidance beliefs were not reinforced following the back posture program. Regarding back pain prevalence's double knife-edge, the present study demonstrated that the implementation of a back posture program in the elementary school curriculum did not result in significantly increased or decreased back pain reporting. Overall, the prevalence rates for back and neck pain varying from 20% to 32% over the 4-year time span are in line with the prevalence reports in the literature (Cardon et al. 2002, Szpalski et al. 2002). In summary, the steady intervention effects 2-year post-intervention demonstrated that the intensive implementation of a multi-factorial back education program in the elementary school curriculum improved youngsters' back posture knowledge. Additionally, the back posture program did not result in increased fear-avoidance beliefs or mounting back and/or neck pain reports over the 4-year time span. As a final aspect, one can assume that youngsters who received back posture education may have relieved some daily loading factors by integrating biomechanical favorable postural principles. An interesting research question is whether these principles will be used in the occupational setting later in life and whether this has an impact on adult back pain regarding work-related consequences.

PART 2: LIMITATIONS REGARDING METHODOLOGICAL ISSUES

The limitations of the separate studies are reported in the original papers (Section 2). In the following part, two more general limitations are formulated regarding methodological issues.

Quasi experimental design

The present intervention study included a quasi-experimental design which increases the probability for differences at baseline. However, baseline differences were taken into account in our statistical analyses using Repeated Measures ANOVAs. Besides, the randomized controlled field trial with the school as unit of randomization enrolled a relatively small number of schools. Based on statistical evidence, multi-level analyses are recommended to take the clustering of children within schools into account allowing to adjust for variability and error at both the individual and the school level. However, a sample size of 8 schools with on average 50 children per school was too limited to conduct multi-level analyses. Since the current statistical analyses could not embrace clustering, this may have lead to a possible inflation of intervention effects. Compromising the recommendation on clustering, future studies should involve more schools making up their design, which may have a serious impact on the extent of future studies and hence the practicability.

Maturation-effect

During adolescence maturation typically occurs in relation to the growth spurt, which is characterized by an increased growth rate compared to the steady growth rate during childhood. A growth spurt means a disproportion of height versus strength in the growing child. In boys, the mean onset of a height growth spurt is determined at the chronological age of 12.5 years (Beunen et al. 1988) while in Flemish girls the onset was found to occur at the age of 11 years (Beunen et al. 1990).

In the current study maturity was not evaluated due to practical limitations. However, at baseline 9 to 10 year old children were investigated over a 4-year time span. So, at the end of the research period the participants were 13 to 14 year olds. As a result, this intervention study could suffer from a selection-maturation interaction effect. However, in the present study the participants were simply randomized at school-level expecting small inter-group variability between both conditions. Along this line, the current study sample showed no differences for chronological age between the intervention and the control groups ($t=1.131$, ns). Correspondingly, at baseline anthropometrics showed no significant differences between both groups (weight: $t=1.224$, ns; height: $t=-.878$, ns) and the change in children's weight and

height over the two intervention years showed no differences between both conditions (change in weight: $t=.510$, ns; change in height: $t=1.167$, ns). Since the change in children's weight and height may be considered as a reflection of the growth spurt and hence maturity, the possible influence of maturation differences between the two conditions may be excluded. The comparable state of maturity is an important outcome in relation to back pain reporting around adolescence. It is common knowledge that back pain reporting increases in adolescence, at the time of pubertal age. Based on the hypothesis that back pain reports may be related to physical disproportions during growth spurt (Feldman et al. 2001), different levels of maturation between the two groups could have affected children's back pain reporting. However, in the present study the conditions' comparable state of maturity is a control for possible bias on back pain reporting.

PART 3: GENERAL CONCERNS

In this part some general thoughts are expressed in relation to the fast evolving research on the back pain issue.

Mixed quality of studies on back pain at young age

In the literature remarkable differences were found in relation to the quality of studies on back pain issues. In the recent report of COST B13, study results on risk factors and prevention for back pain in adulthood were evaluated. The latter evidence-based reporting included a quality appraisal related to the Cochrane range criteria which is a four-level rating system. However, to day the multiple studies related to back pain in childhood and adolescence are not labeled by different levels of quality. This reality may complicate a definite judgment with regard to potential risk factors for back pain at young age and the documentation on possible evidence-based intervention effects in the school environment.

Recent literature during the last four years

The general introduction of the present thesis includes scientific studies till the year 2006-2007. However, our field-research in the school setting started in September 2002-2003. As a result, the development of our intervention study optimizing both intervention aspects and study characteristics, was based on studies published before 2002-2003 as well as on the scientific expertise related to the previous intervention study of Cardon et al. (2000-2002). Due to Dr. Cardon, being a member of our research group, the findings of the review by Cardon and Balagué (2004) could have been incorporated drawing the design of the present back posture intervention study. Because of time indication, the conclusions of the review by Steele et al. (2006) were not included in our intervention set-up. However, the present study design as well as the introduced modifications were in line with the recently reported findings judging the quality of school-based intervention studies. Based on their recommendations, only two aspects were not included in our intervention design, namely the consideration of parental spinal pain and the reflection on the validity of practical tests.

Back pain reporting in children

An inherent limitation of the present study and every investigation on back pain is the subjective nature of back pain related to the need to rely on self-reports and subject recall. However, personal recall is the only valid approach to evaluate pain since feeling pain is a subjective phenomenon. In contrast with other studies of back pain in children indicating an increase of back pain reporting across the teenage years, our study findings showed over the 4-year time span a slight but overall decrease of back pain reporting at older age. According to Owens (1984), children express pain in a different way from adults and adolescents. Seemingly around the teenage years children are in a general learning process (Balagué et al. 2003) while taking a specific vocabulary to describe pain (McGrath 1990). Even so, pain is characterized by a complex concept and a wide range of response systems embracing interaction of emotional, psychosocial, neurophysiological, cultural and anthropometrical factors (Owens 1984). Accordingly, it's a reality that all people will suffer one day from a painful condition. However, people vary in their manner to manage this pain considering fear-avoidance beliefs and coping strategies. Along this line, there is substantial evidence that high fear-avoidance beliefs and passive coping strategies are important factors in the chronification of back pain (Goubert et al. 2004).

Evaluation of long term effects on back pain prevalence

Back pain is characterized by a multi-factorial nature. Multiple factors play a part over a long period. The implementation of a school-based intervention puts the focus on the modification of some specific factors. The present multi-factorial back education program promoted optimal daily loading. Therefore, children's postural behavior and environmental factors were modified by educating biomechanical favorable principles and by increasing postural dynamism in the class. The result of the present intervention was positive, suggesting a reduction in daily mechanical load towards the optimum of optimal daily load. However, these modifications regarding improved postural behavior may not result in a reduction of back pain reporting within this short period of time. One other hand, over the long term biomechanical favorable postural behavior may have a positive effect by the modest contribution towards optimal daily mechanical load. One has to consider the multi-factorial nature of back pain and the remaining risk factors that are not modified by the school-based intervention.

Interference of socio-economic background and psychosocial correlates

One variable that seems to be dominantly associated with back pain reporting and that may serve as an overall confounding variable is socio-economic status (Hestbaeck et al. 2004). It is conceivable that socio-economic background throughout childhood may be connected with family life-style, timetable and daily habits, home equipment, educational approach, relationship with parents and siblings, and hence communication, ways to express feelings and somatisation. An attempt to control for the possible interfering effect of socio-economic background on back pain reporting at young age may include research in children considering the different strata of our society based on parental socio-economical status (low, medium and high SES). However, one must realize that the causes and the effects of back pain experiences and other health issues do not exist in isolation but in a complex interplay of multiple intervening factors. Summarizing the general concerns, further research should continue to determine risk indicators for back pain within a full model including personal, environmental, functional, lifestyle related and psychosocial factors. Therefore, the scientific field should attempt to improve the quality of studies in future research regarding back pain and intervention studies for back pain. Additionally, the value of possible risk factors to be incorporated in intervention programs should be focalized in future work.

PART 4: RECOMMENDATIONS FOR FURTHER RESEARCH

The present doctoral thesis focused on the one hand on the immediate 2-year intervention effects in addition to the stability of the latter effects. The results indicated that the intervention had favorable effects on children's postural behavior and back posture knowledge and did not increase their fear-avoidance beliefs or back pain reporting. On the other hand, the follow-up evaluations pointed out that the intervention effects remained stable 2-years after completion of the back posture program. The stable intervention effects of early promotion of good body mechanics may be a precondition for a lifelong biomechanical favorable lifestyle. However in the scope of early prevention, further follow-up of this sample is needed to explore the long-term effects regarding the integration of biomechanical postural behavior in their lifestyles as adults and in relation to the impact on back pain reporting in adulthood. Furthermore, evaluating our intervention study, some specific issues may be of interest for further investigation, as expressed below. The specific issues related to the experimental study are formulated after two recommendations with regard to posturography at young age and the assessment of static curves in children using the Zebris® technique.

Further research on posturography in children

Based on Danneels' concept for functional spinal stability (Danneels 2001), the present doctoral research investigated postural control as one of the subsystems determining spinal stability. Postural control is a recent topic with respect to the low back pain discourse. However, the underlying mechanisms in relation to the risk for low back pain are not clear. On the other hand, research on the reliability of measuring postural control in children within the age-category 9-11 years is limited. Therefore, the present doctoral research performed a reliability study with the additional aim to report reference values for postural control within the age-group of 9-11 year olds (Original research - Section 2). Based on the lack of evidence-based information regarding the postural control topic in relation to back pain and the questionable reliability for some parameters using the Neurocom Balance Master® in children, the present doctoral thesis recommends caution with regard to posturography in children. Depending on the evolutions in the posturographic field, future research on the definition of normal postural control, on the improvement of the measurement methods and on the possible relationship between abnormal postural control and back pain in children, could be of interest.

An alternative device to assess spinal curvatures

With regard to the present selection of measurements used to evaluate back function parameters in children, the static assessment of the neutral spinal curvatures by using the Zebris® technique delivered some shortcomings regarding consistency (no reliable test-retest values in the standing condition and fair to good values in the seating condition). In the supposition that future research may highlight that the evaluation of spinal curvatures in neutral position is an important structural-functional variable regarding back functioning at young age, the use of the Zebris® technique should be tested to optimize reliability results. Along this line, an alternative methodic to measure spinal curvatures could exist in the recently developed Spinal Mouse device. The use of the Spinal Mouse provides reliable measurements in the standing condition (Mannion et al. 2004) and is little time consuming (the required time to measure the whole length of the spinal column takes 2 to 4 seconds).

Promotion of good body mechanics by schools - role of physical education teachers

The evidence-based effectiveness of the present back posture program through the school-curriculum asks for future research to consider the implementation of promotion for good body mechanics through the schools themselves. The current comprehensive intervention to optimize the daily load on children's spinal structures was a multi-factorial program with interactive involvement of external experts, physical education (PE) teachers and class teachers. Further research is advocated to evaluate the effects of multi-factorial back posture education when the class teachers are in charge for implementation of the entire program, including the back education sessions. However, to day class teachers do not feel confident enough regarding the matter related to good body mechanics. So, PE teachers may play a complementary role having an executive task in the promotion of good body mechanics regarding stimulation and coordination. Along the same line, the contribution of the PE curriculum promoting good body mechanics in elementary schoolchildren may be an interesting research question (see below – The role of adding a physical activity program to back posture education & Exercise in physical education lessons).

Sitting behavior on ergonomic tools

The two-school-year promotion of good body mechanics resulted in more favorable postural behavior during sitting activities. The present intervention program was optimized by implementing several ergonomic elements encouraging active and variable sitting in the classroom. Due to randomized selection all children were sitting on traditional material during

the class observation. Nevertheless, even when children used traditional furniture, several aspects in sitting postures improved after the promotion of good body mechanics. Although the use of ergonomic material was embedded within a multi-componential intervention program, the effects of this specific intervention component on children's postural behavior during class activities may be of interest for future research. Future studies on the use of ergonomic tools in relation to postural behavior in the class should evaluate intensified implementation of ergonomic tools relative to the present intervention design and in combination with ergonomically designed school work stations. Research on the impact of ergonomically designed school furniture in relation to class room postures is justified due to little evidence to support that just sitting on active-dynamical tools may be sufficient to improve back functioning (McGill et al. 2006).

Parental involvement

Parental involvement was one of the components in the multi-factorial back posture program. Unfortunately, the latter component was not soundly investigated because of the low attendance at the informative back posture session. At young age, the efficacy of parental stimulation on children's behavior is common knowledge. Therefore, the complementary role of parental support during back posture education at elementary school-age needs to be considered in further intervention programs.

Objective assessment for class teachers' implementation of guidelines and youngsters' postural behavior

The current study used self-reports for the evaluation of children's postural behavior and class teachers' implementation fidelity. Due to practical implications with regard to the large study sample size required for evidence-based studies, it seems impossible to organize objective observations of children's postural behavior once children leave the elementary schools (and attend multiple secondary schools). Reliable reporting of both children and teachers may be assumed because of the realistic outcome analyzing their answers. Additionally, the staff members visited all elementary schools during the two years of implementation time. On the basis of these meetings in the class environment, the class teachers' answers could be confirmed by the staff members. However, the development of a practical evaluation tool for the objective assessment of children's lifestyle in relation to biomechanical favorable postural behavior and class teachers' implementation fidelity may be a surplus for future school-based investigation. Possible opportunities may embrace the use of observation lists for the postural behaviors of children (a check list for the class

teachers evaluating sitting behavior and one for the physical education teachers evaluating lifting behavior) and an objective observation of class teachers' use of intervention guidelines by a staff member.

Role of adding a physical activity program to back posture education

The conclusion of the evidence-based literature research of COST action B13 pointed out that the most promising approaches to prevent adults' back pain involved physical activity or exercise and bio-psycho-social education (COST B13). Furthermore, tracking studies have revealed that low levels of physical activity remain stable from adolescence into adulthood (Lefevre et al. 2000). Therefore, the promotion of a physically active lifestyle whilst focusing on optimal daily loading at young age may be recommended in the scope of early prevention efforts for the promotion of good back functioning. Recently, the effectiveness of adding promotion of physical activity to the promotion of good body mechanics through the elementary school curriculum was investigated by Cardon et al. (2006), as mentioned in the introduction (Section 1 – Part 2 – Research context). The interaction of physical activity promotion and promotion for good body mechanics was investigated in elementary schoolchildren. The latter study included the 'back posture' and the 'control' groups out of the current intervention study in addition to a 'back posture plus physical activity' group. In the 'back posture plus physical activity group' the present back posture intervention was implemented as well as a comprehensive physical activity program (Cardon et al. 2006). The promotion of physical activity included a health-related physical education program (guidelines for physical education teachers to increase children's activity levels during lesson time), class-room based health education sessions (teaching behavior change skills, such as goal setting, time planning, problem solving and self-talk) and an extracurricular physical activity promotion program (organization of structured physical activities during lunch break, providing game equipment during recess). The study results showed both in the 'back posture' and the 'back posture plus physical activity' groups improved back posture knowledge and improved postural behaviors conform to the learned biomechanical favorable principles when compared to the control group. Post-intervention, the total score on postural behavior during material handling was significantly higher in the 'back posture' group than in the 'back posture plus physical activity' group. Further, control children's fear-avoidance beliefs were significantly increased between pre-test and post-test in comparison to the better scores in both the 'back posture' group and the 'back posture plus physical activity' group. No group differences were found for daily levels of physical activities. The latter study findings indicated that adding a physical activity program to a back posture program may be favorable in the scope of early promotion for good body mechanics. However, the study

findings also suggested the disadvantage of implementing both programs simultaneously in an already full curriculum. Therefore, further study is needed to make both programs matching with regard to intensity and content in favor of an optimal implementation in the elementary school curriculum. In this perspective, it seems interesting to evaluate the impact on elementary schoolchildren's back functioning when the different components of both multi-factorial programs are fully integrated in the mandatory school curriculum. A complete integration could be realized by some little accentuations in the provided lesson times for physical education or health-related lessons as well as by more fundamental and officially authorized adjustments in the school curricula.

Exercise in physical education lessons

Van Tulder and Koes (2004) concluded that exercise is the most effective strategy to prevent low back pain in adults. The suspected underlying mechanisms of exercise within the prevention of low back pain are strengthening of the stabilizing muscles, the increase of spinal mobility, the blood flow towards the spinal structures related to recovery and the improvement of the mental condition changing perceptions of pain. To day, the possible effectiveness of implementing an exercise program in elementary schoolchildren is not investigated, with the exception of the school-based interventions of Cardon (2002) and Mendez (2001) that included only exercise to some extent, namely in one of six and three of 11 sessions respectively. The convincing evidence provided by studies in adult populations might be at least an indication to make up and evaluate future intervention programs to promote back functioning taking into account the inclusion of an exercise program. The most pertinent way to apply exercise in the school setting may be the physical education lesson. The physical education teacher has the appropriate qualities to apply the right exercises, in an adequate dosage and within an optimal pedagogic atmosphere.

Focus on children with recurrent back pain at young age

The present study findings indicated that the back pain reporting of youngsters over the 4-year time span was in agreement with the study results of Burton et al. (1996). Based on our own data (not presented before), youngsters mentioned repetitive spells for back pain (46% never reported pain, 23% reported pain once, 17% twice, 9% three times and 5% reported pain within the last week at all evaluations) rather than a single chronic spell (at all measurements children reported low frequency rates at the 4-point-scale for back pain experience within the last week). Jones et al. (2004, 2005) pronounced that there is a clear rationale to focus on the subgroup of children with recurrent back pain when investigating

indicators for back pain at young age since this condition leads to greater disabling consequences during childhood (Harreby et al. 1995, Salminen et al. 1995 & 1999). Moreover, the economic and public health burden of recurrent low back pain during childhood is considerable regarding the potential tracking into (chronic) back pain in adulthood (Feldman et al. 2001, Harreby et al. 1999). Along this line, secondary prevention efforts could possibly be favorable attempting to reduce the number of children with recurrent back pain episodes by investigating possible modifications of correlates influencing back functioning in the school environment and the effects of back posture programs. Regarding research on the effectiveness of back posture interventions, children's back posture knowledge, postural behavior and fear-avoidance beliefs might be focused in particular associated with their potential change in reporting recurrent back pain. The possible further attention for children with recurrent back pain at young age might be spread over the paramedical sector, but in the scope of inclusive education it could also be incorporated in the health-education or physical education lessons of the mandatory school curriculum.

PART 5: PRACTICAL IMPLICATIONS

Drawing the results of the original studies within the present doctoral thesis, some evidence based recommendations are formulated attempting to enhance the promotion of good body mechanics through the school curriculum.

Back posture education should be taught within the school curriculum

Children should learn at school how they can develop and maintain a biomechanical favorable lifestyle in the scope of lifelong good back functioning. The school policies have thus the charge to educate children conform a biomechanical favorable lifestyle and to emphasize that they are responsible for their own back functioning in relation to their daily lifestyle. Furthermore, the positive aspects of being physically active should be emphasized in the scope of a lifelong healthy and biomechanical favorable lifestyle. Therefore back posture education should become a more extensive part of the elementary school curriculum instead of a component, additionally to an already full curriculum.

Professional training of future class teachers should incorporate back education

Class teachers are assigned to implement back posture programs. Unfortunately, teachers acknowledge a lack of expertise in back posture matters which may obstruct optimal implementation of back posture education in the daily timetable. Therefore, the incorporation of back posture matters into the professional course of future elementary school teachers may be recommended. When the training for future teachers provides back posture education, teachers may integrate biomechanical favorable principles into their daily and occupational lifestyles, feeling more confident to provide successful promotion for good body mechanics through the school curriculum.

Job description of the physical education teacher should be extended

In the present program promoting good body mechanics, the back education sessions were taught by an external expert. In fact, the physical education teacher has the required expertise to teach back posture matters since the training for physical education teachers incorporates biomechanical background and specific back posture related topics. However, the current lack of time and space in the physical education timetables does not encourage physical education teachers to implement back posture education in their lessons. Furthermore, to day the promotion of good body mechanics is stringently not a part of the

mandatory job description of physical education teachers. A possible solution may be outlined by the government providing physical education teachers with an additional function to promote good body mechanics conform a biomechanical favorable lifestyle in children. Their job description may be extended with the charge to support the class teacher with the implementation of the multi-componential program to promote good body mechanics in the class setting and the assignment to educate the specific back posture sessions about a biomechanical favorable lifestyle.

Provide ergonomic material and structurally change timetabling

Providing ergonomic material in the classes seems useful to increase children's postural dynamism. To day, a cost-benefit analysis with regard to the introduction of ergonomic material in the class room is not obtainable because of the lacking long term research on early prevention efforts in addition to the multi-factorial nature of the risk for back pain. However, a focus on the optimal loading of the young spinal structures by increasing postural dynamism seems to be justified by the loading factors in association with sitting in the school environment as well as by the common back pain reporting at young age related to sitting activities (Balagué et al. 1999). Therefore, the government should provide financial support to buy adequate active-dynamic ergonomic material (some elements for each class group) and follow-up the standardization of ergonomically favorable school furniture when this documentation becomes available. Additionally, the government and school policies should deal with the number of hours children spend sitting, by modifying structural aspects such as the length of the lessons and timetabling.

Last grades of elementary school be focused

Based on the stable intervention effects, one can conclude that a two-school-year back posture program that is intensively integrated in the school curriculum between the 4th and the 6th grade was effective to teach children back posture knowledge and biomechanical favorable skills, possibly leading to a lifelong biomechanical favorable lifestyle. The transition from childhood to adolescence with its typically mechanical load is an important phase for the promotion of good body mechanics since back pain prevalence is found to increase during adolescence. However, health education seems easier to be organized in the elementary school setting than in the secondary school scenery due to a more flexible system. Therefore the last grades of elementary school should be focused for the promotion of good body mechanics.

Fear-avoidance beliefs must be avoided

High fear-avoidance beliefs and misconceptions about pain are persistent in adults playing a significant part in the development of long-term disability (Goubert et al. 2004). Therefore, the promotion of good body mechanics through the school curriculum should concentrate on education of the right concepts regarding fear-avoidance. Correct beliefs preventing fear-avoidance should be instructed in a way similar to the current back posture program, but the approach might be quite more intensively.

Work-related back education is needed for a lifelong biomechanical favorable lifestyle

Back posture education through the school environment may provide children with an important foundation of good postural behavior. However, reaching the work environment, the children's biomechanical concepts of good postural behavior will need to be completed with more specific back posture documentation corresponding to their specific job description (favorable postures and unloading aspects during occupational activities). Employers and politicians should act on lifelong promotion of good body mechanics by sustained reflection upon optimal loading in the occupational environment. Within this framework, Flemish policy makers recently started to focus on the school as a bridge towards the work setting and vice versa. Maybe the biomechanical matter related to occupational activities could be elaborated in this context.

REFERENCES

- Balagué F, Nordin M, Dutoit G, Waldburger M (1996) Primary prevention, education, and low back pain among school children. *Bull Hosp Jt Dis* 55 : 130-134
- Balagué F, Troussier B, Salminen JJ (1999) Non-specific low back pain in children and adolescents: risk-factors. *Eur Spine J* 8 : 429-438
- Balagué F, Dudler J, Nordin M (2003) Low-back pain in children. *Lancet* 36 : 1403-1404
- Beunen G, Malina RM (1988) Growth and physical performance relative to the timing of the adolescent spurt. *Exerc Sport Sci Rev* 16 : 503-540
- Beunen G, Lefevre J, Ostyn M, Renson R, Simons J, Van Gerven D (1990) Skeletal maturity in Belgian youths assessed by the Tanner-Whitehouse method (TW2). *Ann Hum Biol* 17 : 355-376
- Birmingham T (2000) Test-retest reliability of lower extremity functional instability measures. *Clin J Sport Med* 10 : 264-268
- Brouwer B, Culham EG, Liston RA, Grant T (1998) Normal variability of postural measures: implications for the reliability of relative balance performance outcomes. *Scand J Rehabil Med* 30 : 131-137
- Burton AK (1996) Low back pain in children and adolescents: to treat or not. *Bull Hosp Jt Dis* 55 : 127-129
- Burton AK, Clarke RD, McClune TD, Tillotson KM (1996) The natural history of low back pain in adolescents. *Spine* 21 : 2323-2328
- Cardon G, De Bourdeaudhuij I, De Clercq D (2000) Effects of back care education in elementary schoolchildren. *Acta Paediatr* 89 : 1010-1017
- Cardon G, De Bourdeaudhuij I, De Clercq D (2001) Back care education in elementary school: a pilot study investigating the complementary role of the class teacher. *Patient Educ Couns* 45 : 219-226
- Cardon G, De Bourdeaudhuij I, De Clercq D (2001) Generalization of back education principles by elementary schoolchildren: evaluation with a practical test and a candid camera observation. *Acta Paediatr* 90 : 143-150
- Cardon G, De Bourdeaudhuij I, De Clercq D (2002) Back education efficacy in elementary schoolchildren: a one year follow-up study. *Spine* 27 : 299-305
- Cardon G, De Bourdeaudhuij I, De Clercq D (2002) Knowledge and perceptions about back education among elementary school students, teachers, and parents in Belgium. *J Sch Health* 72 : 100-106
- Cardon G, De clercq D, De Bourdeaudhuij I, Breithecker D (2004) Sitting habits in elementary schoolchildren: a traditional versus a 'Moving school'. *Patient Educ Couns* 54 : 133-142

- Cardon G, Balagué F (2004) Low back pain prevention's effects in schoolchildren. What is the evidence? *Eur Spine J* 13 : 663-679
- Cardon GM, De Clercq DL, Geldhof EJ, Verstraete S, De Bourdeaudhuij IM (2006) Back education in elementary schoolchildren: the effects of adding a physical activity promotion program to a back care program. *Eur Spine J* : Epub ahead of print
- Cherkin DC, Deyo RA, Street JH, Hunt M, Barlow W (1996) Pitfalls of patient education. Limited success of a program for back pain in primary care. *Spine* 21 : 345-355
- Cost B13 (2006) European guidelines for the management of low back pain. Official publication of the spine society of Europe. *Eur Spine J* 15(2) : 125-300
- Danneels L (2001) Evaluation and rehabilitation of functional spinal stability. *Doctoral thesis*.
- Feldman DE, Shrier I, Rossignol M, Abenhaim L (2001) Risk factors for the development of low back pain in adolescence. *Am J Epidemiol* 154 : 30-36
- Figura F, Cama G, Capranica L, Guidetti L, Pulejo C (1991) Assessment of static balance in children. *J Sports Med Phys Fitness* 31 : 235-242
- Goubert L, Crombez G, De Bourdeaudhuij I (2004) Low back pain, disability and back pain myths in a community sample: prevalence and interrelationships. *Eur J Pain* 8 : 385-394
- Harreby M, Neergaard K, Hesseloe G (1995) Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low back pain in adults? *Spine* 20 : 2298-2302
- Hestbaek L, Iachine IA, Leboeuf-Yde C, Kyvik KO, Manniche C (2004) Heredity of low back pain in a young population: a classical twin study. *Twin Res* 7 : 16-26
- Jones GT, Watson KD, Silman AJ, Symmons DP, Macfarlane GJ (2003) Predictors of low back pain in British schoolchildren: A population-based prospective cohort study. *Pediatrics* 111 : 822-828
- Jones GT, Silman AJ, Macfarlane GJ (2004) Parental pain is not associated with pain in the child: a population based study. *Ann Rheum Dis* 63 : 1152-1154
- Jones GT, Macfarlane GJ (2005) Epidemiology of low back pain in children and adolescents. *Arch Dis Child* 90 : 312-316
- Jones MA, Stratton G, Reilly T, Unnithan VB (2004) A school-based survey of recurrent non-specific low-back pain prevalence and consequences in children. *Health Educ Res* 19 : 284-289
- Jones MA, Stratton G, Reilly T, Unnithan VB (2005) Biological risk indicators for recurrent non-specific low back pain in adolescents. *Br J Sports Med* 39 : 137-140
- Lefevre J, Philippaerts RM, Delvaux K, Thomis M, Vanreusel B, Eynde BV, Claessens AL, Lysens R, Renson R, Beunen G (2000) Daily physical activity and physical fitness from adolescence to adulthood: A longitudinal study. *Am J Hum Biol* 12 : 487-497

- Mannion AF, Knecht K, Balaban G, Dvorak J, Grob D (2004) A new skin-surface device for measuring the curvature and global and segmental ranges of motion of the spine: reliability of measurements and comparison with data reviewed from the literature. *Eur Spine J* 13 : 122-136
- McGill SM, Kavcic NS, Harvey E (2006) Sitting on a chair or an exercise ball: various perspectives to guide decision making. *Clin Biomech* 21 : 353-360
- McGrath PA (1990) Pain in children: Nature, assessment, and treatment. New York : Guilford Press
- Mendez FJ, Gómez-Conesa A (2001) Postural hygiene program to prevent low back pain. *Spine* 26 : 1280-1286
- Murphy S, Buckle P, Stubbs D (2004) Classroom posture and self-reported back and neck pain in schoolchildren. *Appl Ergon* 35 : 113-120
- O'Sullivan PB, Grahamslaw KM, Kendall MM, Lapenskis SC, Möller NE, Richards KV (2002) The effect of different standing and sitting postures on trunk muscle activity in a pain-free population. *Spine* 27 : 1238-1244
- Owens ME (1984) Pain in infancy: conceptual and methodological issues. *Pain* 20 : 213-230
- Pollock AS, Durward BR, Rowe PJ, Paul JP (2000) What is balance? *Clin Rehabil* 14 : 402-406
- Salminen JJ, Erkintalo M, Laine M, Pentti J (1995) Low-back-pain in the young - a prospective 3-year follow-up-study of subjects with and without low-back-pain. *Spine* 20 : 2101-2107
- Salminen JJ, Erkintalo MO, Pentti J, Oksanen A, Kormano MJ (1999) Recurrent low back pain and early disc degeneration in the young. *Spine* 24 : 1316-1321
- Sjolie AN, Ljunggren AE (2001) The significance of high lumbar mobility and low lumbar strength for current and future low back pain in adolescents. *Spine* 26 : 2629-2636
- Steele EJ, Dawson AP, Hiller JE (2006) School-based interventions for spinal pain: a systematic review. *Spine* 31 : 226-233
- Szpalski M, Gunzburg R, Balague F, Nordin M, Melot C (2002) A 2-year prospective longitudinal study on low back pain in primary school children. *Eur Spine J* 11 : 459-464
- Udermann BE, Mayer JM, Graves JE, Murray SR (2003) Quantitative Assessment of Lumbar Paraspinal Muscle Endurance. *J Athl Train* 38 : 259-262
- Van Tulder MW, Koes BW (2004) Evidence-based handelen bij lage rugpijn. Epidemiologie, preventie, diagnostiek, behandeling en richtlijnen. Houten : Bohn Stafleu Van Loghum

