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Trunk abnormalities in adolescence

A school health care based epidemiological cohort study

Alice A J M Hazebroek-Kampschreur

Departments of Youth Health Care and Epidemiology, Municipal Health Service Rotterdam, Rotterdam, The Netherlands
ISBN 90-9006278-5

The aim of this study was to assess whether an extra screening should be added to the two school medical examinations during adolescence.

In Rotterdam, The Netherlands, examination for trunk abnormalities is a routine procedure in the full medical examination performed by school physicians in children at the age of 4 years and six months, 7 years, 11 years, and 13 or 14 years (when in second grade of secondary school). In the early 1980s introduction of annual screening for scoliosis in children aged from 10 to 15 years was discussed.

Between 1984 and 1987, prevalence and cumulative incidence data regarding trunk abnormalities, including scoliosis and kyphosis, and their determinants were obtained in a 3-year prospective follow-up study in a cohort of 4,915 children aged 11 years (born in 1973). In the first and third year, the study was embedded in the school health care program, i.e. medical examination in 11-year-old children and in second grade of secondary school. In the second year of the study, scoliosis screening was performed by school nurses in a randomly selected number of the cohort. The examination of back and posture included recording of eight variables of the standing examination (symmetry of shoulders, symmetry of waistline, imbalance, of the trunk, scoliosis, lordosis, kyphosis, swayback and flexibility) and four variables of the forward bending test (FBT) (rib hump or lumbar prominence, persistence of scoliosis noted in the standing examination, correction of abnormal kyphosis, lateral aspect). Besides several background variables (gender, ethnic origin, month of birth, school) anthropometric data such as height, weight, puberty characteristics, onset of growth spurt and menarche were recorded. A follow-up study was conducted in 210 children, born in 1973, who had been referred for trunk abnormalities between 1984 and 1987. Data about observing the referral, the policy of the family doctor, and the findings and policy at the first orthopedic examination were collected within three months after referral; an additional follow-up study was done in 1989/1990.

Results: 82% of the children had a normal FBT both at age 11 years and two years later.

At age 11 years, abnormalities on FBT were seen in 9% of the children (boys 7%, girls 11%), and 2% of the children were referred to the family doctor for further examination.

At age 13 years, two-year cumulative incidence was 11% (boys 10%, girls 13%), and 2% was referred to the family doctor.

At age 13 years, in more than half of the children who had an abnormal FBT at the age of 11 years, no abnormalities on FBT were seen.

At the screening performed by school nurses, 21% of the children was screened as positive. At reexamination, school physicians confirmed the abnormalities in half of these cases; this involved 11% of the screened population.

The consistency of an abnormal FBT in three consecutive years was low, only 2%.

Two-year cumulative incidence of trunk abnormalities was associated with gender, with height at baseline in both sexes, and with menarche and onset of growth spurt at baseline in girls. Taller eleven-year-old girls with onset of adolescent growth spurt have an increased risk of future trunk abnormalities, but having reached menarche has a protective effect.

Between 1984 and 1987, 210 children (3% of the cohort of 11-year-old children) were referred to their family doctor. The family doctor referred 139 children for further orthopedic evaluation. Structural deformities were diagnosed in 81 (1.2%) children, of whom 10 had a scoliosis exceeding 20° and 9 had Scheuermann's disease. Ten children were braced, none needed surgical treatment. Compliance with orthopedic observation was low. Observation of mild curves by school physicians may increase compliance.

Addition of an extra scoliosis screening to the two regular school medical examinations for adolescents is not necessary. The method employed in examination of back and posture and the frequency of school medical examination contributed sufficiently to early recognition of trunk abnormalities.

Lumbar nerve root compression syndromes

Symptoms, signs and surgical results

Bo Jönsson

Department of Orthopedics, Lund University Hospital, S-221 85 Lund, Sweden

All patients (n=429), who underwent surgical treatment for lumbar disc herniation or lumbar spinal stenosis (central and lateral) were studied in a prospective and consecutive series between 1986 and 1991. Preoperatively, a number of variables associated with the patient's pain were collected, as were the findings from SLR-test and neurological examination. All patients had follow-up investigations 4, 12 and 24 months postoperatively.

Pain on coughing, regular use of analgesics and positive SLR-test was most common in disc herniation. In central spinal stenosis, a severe reduction of walking capacity, a long preoperative symptom duration and reflex disturbances were most common.

The clinical appearance of disc herniation differed with the age of the patient and the type of herniation. The clinical findings in primary and recurrent disc herniation were almost identical and differed from those in the postdiscectomy syndrome.

In patients with disc herniation, the result from the preoperative SLR-test correlated with the parameters describing pain. A positive SLR-test postoperatively was of prognostic value. EHL-paresis was noted in 11% of the patients with disc herniation, 8% of the patients with lateral stenosis and 5% of those with central stenosis. Improvement did not occur in central stenosis but was equally common (7/10) in lateral stenosis and disc herniation. In elderly patients (>70 years), central spinal stenosis was the commonest lesion; there was no anaesthesiological complication recorded and the results were similar to those in younger patients. In lateral spinal stenosis, 88% were improved by the operation and 73% of the employed patients returned to work. In patients with a previous operation, the result from repeat decompression was dependent on diagnosis with poor results in patients with fibrosis while the results in disc herniation and stenosis were rewarding.

Lower extremity amputation in diabetic patients

Jan Larsson

Department of Orthopedics, Lund University Hospital, S-221 85 Lund, Sweden

General characteristics and local signs and symptoms were evaluated prospectively in 187 consecutively presenting diabetic patients with foot ulcers, treated by a multidisciplinary team. High age, history of cerebrovascular disease and low haemoglobin levels were associated with major (above the ankle) amputation as well as pain, progressive gangrene, and intermittent claudication. However, none of these factors excluded healing of a minor (below the ankle) amputation and thus selection of amputation level can not be based upon these factors exclusively. The predictive value of distal blood pressure measurements was studied in 159 of the patients. No patient with a systolic ankle blood pressure below 50 mmHg healed with a minor amputation. A toe pressure below 15 mmHg or an ankle pressure below 75 mmHg was seldom associated with healing after a minor amputation. At or above that pressure level, the ankle pressure had no predictive value. Distal blood pressure measurements provide important support for the selection of amputation level but is no golden standard.

Mortality, new amputations on the same or the contralateral leg, and rehabilitation were studied prospectively in 189 amputated patients. The mortality

rate was higher in patients who had healed after major compared to minor amputation. There was no difference in the total rate of new amputations but the rate of new major amputations was higher in patients with an original major amputation. Eighty-five percent of new amputations were precipitated by a foot ulcer. Patients with minor amputations had a considerably better rehabilitation potential.

All diabetes related primary amputations (n=387) from toe to hip during 1982-1993 were reviewed in a retrospective, population-based study. The incidence of major amputations decreased by 78% from 16.1 to 3.6/100,000 inhabitants. The absolute number of amputations with a final level below the ankle did not increase, but their proportion doubled. Seventy-one percent of the amputations were precipitated by a foot ulcer. Only two thirds of all amputation procedures, irrespective of diagnosis, appeared in the official register and not more than one third of such procedures in diabetic patients were registered together with a diagnosis of diabetes. A substantial decrease in the incidence of major amputation in diabetic patients can be achieved and maintained. A multidisciplinary approach towards diabetic foot lesions is an important tool in this regard.

A successful intervention program for patients with subacute low back pain

A randomized study using an operant-conditioning behavioral approach with special reference to pain, pain behavior, subjective disability, physical performance, physical work demands and sick-leave

Ingalill Lindström

Institute for Surgical Disciplines, Department of Orthopedics, Göteborg University, Sahlgrenska University Hospital, S-413 45 Göteborg, Sweden
ISBN 91-628-1384-6

The aims of the study were to determine the intra-individual improvement and the correlation between pain, pain behavior, subjective disability and physical performance, to study the relationship between patient-reported and physical therapist's observation of work posture, to investigate the effect of the early intervention program and to analyse the correlations between sick-leave and the other factors studied.

The design of the study was a randomized prospective controlled study with a two-year follow-up. 103 patients were included, 51 of them in the intervention group. They were blue-collar workers sick-listed for six weeks due to LBP with no sick-leave during the preceding 12 weeks. The average age was 41 (SD 11) years. 75 percent of the patients were immigrants from 13 different countries.

The intervention program started after the pre-randomization medical and psychosocial examination. The individually graded exercise program with an

operant-conditioning behavioral approach was based on individual physical performance and individual work demands. The end-point of the intervention was return to the ordinary workplace.

The results demonstrated that 1) traditional care plus an early intervention program was superior to traditional care only, 2) the operant conditioning behavioral approach was effective for patients with subacute LBP, 3) the patients intra-individually improved in pain, pain behavior, subjective disability and physical performance (i.e. the patients learned that it was safe to move while regaining function), 4) pain, pain behavior, subjective disability and a few measures of physical performance predicted the rate of return to work and the amount of sick-leave during the second follow-up year, 5) none of the studied work factors was correlated to sick-leave and 6) the intervention program produced four times the benefits as compared with the costs.

Flexion-distraction injury of the lumbar spine

An experimental study

Pavel Neumann

Department of Orthopaedics, Institute for Surgical Sciences, Göteborg University, Sahlgrenska University Hospital, S-413 45 Göteborg, Sweden
ISBN 91-628-1460-5

Post-traumatic instability of the spine is still a subject of controversy. There is a need to know the true mechanism of spinal injury as well as a need for instability criteria of lumbar spine injuries. In an injury model the biomechanical effects on the spine of a flexion-distraction injury similar to seat-belt injuries as seen in frontal car collisions was studied.

74 functional spinal unit segments (FSU) obtained at autopsy were tested. The ultimate strength of the FSU subjected to a combined load of static bending and shear was determined in sixteen FSUs. The ultimate bending moment was 156 Nm and the ultimate tensile and shear forces were 2.8 kN and 620 N respectively. The flexion-angulation at failure was 20°. In static testing the threshold for flexion-distraction injury of ten lumbar FSUs was 121 Nm in bending and 486 N in shear at a flexion-angulation of 16°. The biomechanical parameters both at the ultimate strength and at the threshold of injury showed significant correlations to the vertebral bone mineral content (BMC) in these static experiments.

A method for dynamic flexion-shear loading of the FSU with varying loads and loading rates to create a flexion-distraction injury was developed. Forty-eight lumbar FSUs were subjected to six different, combi-

nations of load-loading rates. The biomechanical response of the lumbar FSU was dependent on the amount of load and also on the loading rate. An increase in the loading rate from 0.80 to 2.40 g/ms. engaged the visco-elastic response of the tissues composing the lumbar FSU. At a high loading rate the FSU could absorb more energy with less displacement. The threshold for lumbar spine instability in a dynamic flexion-distraction injury was also determined. Twenty lumbar FSUs were subjected to load impacts with a loading rate at the threshold of visco-elasticity. The translatory and angular displacements were determined at the first sign of injury (yield) and at failure. Radiographic guidelines for instability in lumbar fracture-dislocations without posterior vertebral body compression were proposed: Instability exists if there is 1) kyphosis of the lumbar motion segments $\geq 12^\circ$ (impending instability), or $\geq 19^\circ$ (total instability) on lateral radiographs, 2) increase in interspinous distance ≥ 20 mm (impending instability), ≥ 33 mm (total instability) on A-P radiographs.

The vertebral BMC explained most of the biological variation in the results. In a spine with low BMC, relatively less displacement and angulation will cause instability.

Reconstructive options in revision surgery of failed total hip arthroplasties

B Willem Schreurs

Department of Orthopedics, Academic Hospital Nijmegen, Nijmegen, The Netherlands

Despite the impressive results of total hip arthroplasty, about 10 percent fails within 10 years postoperatively. This dissertation concentrates on some aspects of cemented revision hip surgery.

The fatigue strength of bone cement is an important factor for fixation endurance of both primary and revision prostheses. To improve it, reduction of porosity is critical. In the literature, several methods were suggested to reduce porosity. In our study, 4 acrylic cement preparation techniques were investigated: hand-mixing, pressurization in a pneumatic pistol, centrifugation, and vacuum mixing. The best results were obtained with vacuum mixing, using a newly designed experimental system, yielding porosity reductions of 60–80 percent relative to hand mixing.

High energy shock waves (HESW) generated by a lithotripter were suggested as a technique to facilitate the removal of bone cement. A study was performed with HESW, focused on discs of polymethyl methacrylate bone cement. The high energy shock waves caused microscopic lesions only (< 0.1 mm) on the frontal surface of the discs. Microfractures were only seen if the waves were focused on pores in the cement.

An important problem in revision arthroplasty is the bone stock loss. Impacted morsellized bone allografts have been used in combination with cemented cups in severe cases of acetabular bone stock loss. The results in the clinical setting were favorable, which led to the development of a special set of instruments for the application of impacted grafts on the femoral side in case of extensive intramedullary bone loss. This technique created a central prosthesis bed within the construction of grafts.

First, in an *in vitro* study in femora of the goat, the initial stability of the stem immediately after insertion was determined with a cemented stem and a non-cemented hydroxylapatite coated stem in a loading experiment. Displacements of the stems relative to bone were determined with radiostereometric analy-

sis (RSA). The most important movements were axial rotations (cemented stems up to 2.1° , noncemented stems up to 6.8°) and subsidence (cemented stems up to 0.5 mm, noncemented stems up to 2.9 mm).

Next, *in vivo* tests were done in goats with cemented and noncemented stems to obtain information about their mechanical stability postoperatively, and to study consolidation and incorporation of the allograft histologically. The goats were followed for 6 or 12 weeks. Subsidence of the cemented stems on maximal loading was very consistent, in both the 6 and 12 weeks specimens, at 0.10–0.15 mm. Histologically, revascularization and remodeling of the graft was evident. Hence, the stability of loaded cemented stems in combination with impacted morsellized allografts permitted incorporation of the graft. In the noncemented group, the postoperative failure rate was relatively high. However, the non-failed stems were very stable for subsidence (maximal 0.036 mm). These stems achieved improved secondary stability relative to the initial stability. Histological examination showed partial revascularization and remodeling of the graft in all specimens. Bone incorporation was mainly seen in the proximal areas. Graft lysis was evident in the midshaft region and at distal levels around the prosthesis.

Based on the animal revision set, a human revision set (X-CHANGE Revision Instruments) was developed in collaboration with the Princess Elizabeth Orthopaedic Hospital, Exeter, U.K., and Howmedica International. The first clinical experience was reported in 10 patients with a mean follow-up of 24 months. All patients were clinically improved. There were no signs of radiographic loosening and there was radiographic evidence of incorporation of the grafts. The application of impacted morsellized allografts in cases with severe femoral intramedullary bone loss seems a promising reconstructive option. However, long-term studies are required to judge the true value of this technique.

Lipid-extracted bone grafts

Klas Thorén

Department of Orthopedics, Lund University Hospital, S-221 85 Lund, Sweden

Bone implants are used to refill bone defects in many clinical situations. In some cases, the amount of bone required cannot be obtained from the patient and a substitute also has to be used. Bone allografts are usually frozen or freeze-dried. Freezing or freeze-drying reduces the immunological characteristics of the allografts which are then normally accepted and incorporated. These grafts contain no living cells. In the first stage, mesenchymal tissue from the recipient penetrates the graft and starts to resorb graft bone and form new bone. In the second stage, the new bone is remodeled. Such remodeling adapts the structural shape to the mechanical loads. The incorporation of a large graft may be slow and incomplete. Further, repeated loading causes microfractures which may lead to fracture or collapse. Allografting increases the risk of deep bacterial infections and transmission of viral infections, such as HIV, hepatitis B and C. A major part of the frozen cancellous graft consists of necrotic marrow tissue, which must be replaced during the incorporation process. The aim of the present study was to evaluate the effects of further processing of frozen cancellous allografts by chloroform-methanol-lipid extraction, thus destroying the tissue struc-

ture of the marrow debris and partly washing it out. An increased incorporation due to defatting was found by using titanium bone ingrowth chamber models in rabbits and rats. The results were evaluated by histology, histomorphometry and scintimetry. By comparing series of experiments, a reduction was detected in the immune response due to defatting. However, the immunologic effects could only partly explain the enhanced incorporation. Further processing of defatted grafts was performed with three other treatments: hydrogen peroxide, ethylene oxide and radiation, the latter two being standard methods for bank-bone sterilization. Ethylene oxide-treated grafts showed impaired incorporation, although gas chromatography showed no detectable remnants of ethylene oxide, ethylene chlorohydrin or ethylene glycol at implantation. The mechanical strength and stiffness of defatted calf bone were tested by compression. No important change due to defatting was found. Implants of cancellous defatted bone blocks in the human iliac crest were followed by CT, MRI and biopsy and seemed to be fully incorporated after one year. Lipid extraction appears to be a useful treatment for improving cancellous bank bone.

Fracture and biochemical markers of bone metabolism

Kristina Åkesson

Department of Orthopedics, Malmö General Hospital, S-214 01 Malmö, Sweden
ISBN 91-628-1494-X

The relation between fracture and bone turnover was evaluated in women, by assessment of biochemical markers of bone metabolism. Bone formation was measured by serum osteocalcin (Oc), alkaline phosphatase (ALP), bonespecific ALP and procollagen I C-terminal extension peptide (PICP). In addition, measurements were made of vitamin K, including vitamin K1 and the menaquinones, MK-7 and MK-8. Vitamin K is an essential cofactor for the γ -carboxylation of Oc and a deficient γ -carboxylation may impair the hydroxyapatite-binding capacity of Oc. Bone resorption was measured by the urinary excretion of pyridinoline (Pyr) and deoxypyridinoline (D-pyr) and in serum by the collagen type I crosslinked telopeptide (ICTP). Bone mineral content (BMC) was measured by single photon absorptiometry (SPA) of the distal forearm.

In 174 elderly women with hip fracture, measurements of Oc and Pyr and D-pyr, gave indirect evidence of an imbalance of bone turnover prior to fracture, with depressed bone formation and higher bone resorption. A progressive decrease of indices of bone formation in serum, was noted during the first post-operative days, followed by increasing levels of Oc and ALP. In a subgroup (n=51), measurements showed that vitamin K1 and the menaquinones, MK-7 and MK-8 were decreased at the time of fracture. Fifty-eight women were re-evaluated 3–7.5 months after fracture. Bone turnover, as measured by Oc and ALP, was increased by 44% and 26%, respectively, from the initial value. This response to fracture suggests an intact capacity of fracture repair, but may also pertain to other changes related to fracture, such as the development of post traumatic osteopenia.

After distal radius fracture (n=36), fracture-related alterations of bone turnover result in long-term dynamic changes of bone mineral content as measured by SPA of the distal forearm. Evaluating the effect of any type of fracture on bone metabolism, by individual matching of women with previous fracture (n=26) with controls (n=26) of equal age and BMC, indicated a decreased bone turnover assessed by Oc or 20%, persisting up to 6 years after fracture. In a population-based study including 328 women, age 40–80 years, biochemical markers and BMC were evaluated in relation to fracture. In women having sustained a fracture within the 6 years prior to measurement, Oc was decreased by 20% and in 70–80 year old subjects also PICP was decreased by 10%. Bone resorption as measured by ICTP was unchanged. A second registration of fracture was made after 5 years. In this prospective part of the study, a decrease of one standard deviation of PICP and ICTP was associated with an increased risk for fracture, independent of age and BMC, odds ratio 1.8 and 1.9, respectively.

These data suggest that there is an influence from fracture and fracture-related changes on the levels of biochemical markers of bone metabolism, in the short-term, days to weeks and in the long-term, several years, with a decreased bone formation persisting several years after fracture. In women with hip fracture, indirect evidence points to an uncoupling between formation and resorption prior to fracture. Similar to the association between a decrease of bone mass and future fracture, a decrease of bone turnover assessed by PICP and ICTP may have an influence on fracture risk.

Fixation of total hip components in rheumatoid arthritis and arthrosis

A radiographic, roentgen stereophotogrammetric, densitometric and histomorphometric study

Ingemar Önsten

Department of Orthopedics, Malmö General Hospital, S-214 01 Malmö, Sweden

The radiographic survival of the Charnley prosthesis was studied in two retrospective, matched-pair cohorts of rheumatoid arthritis (RA) and arthrosis (OA) patients. In RA, the 7-year radiographic socket survival improved from 87% to 96% after the introduction of flanged sockets, bone transplants in cases of acetabular protrusion and the rejection of the pilot hole technique. In OA the 10-year radiographic socket survival was 95%. In both groups the 7-year radiographic stem survival improved from 80% to 96% following the introduction of the new cementing technique.

Migration of the Charnley prosthesis in the first two years was evaluated by roentgen stereophotogrammetric analysis (RSA) in RA and OA patients, and related to the histomorphometric characteristics of trabecular bone in the acetabulum and the femur. In RA, sockets migrated six times more in the proximal

direction as compared with OA; there was no difference in migration in other directions. Stem fixation was equally secure in RA and OA. RA cases had more osteoid in both the femur and the acetabulum, but the amount of osteoid was not correlated with the degree of migration.

The bone mineral content (BMC) of RA and OA hips was assessed by dual photon roentgen absorptiometry prior to hip replacement. Patients with RA had 20% less BMC than those with OA but there were no signs of a relative peri-acetabular deficit.

In two randomized trials of 81 OA patients, migration of the uncemented, Harris-Galante type I socket was evaluated by RSA and compared with Charnley sockets. After a minimum follow-up of 2 years, no difference in migration between the two socket designs was found.