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

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Objective: To examine whether adolescent flexibility, endurance strength, and physical activity can predict the later occurrence of recurrent low back pain, tension neck, or knee injury.

Methods: In 1976, 520 men and 605 women participated in a sit and reach test (flexibility) and a 30 second sit up test (endurance strength). In 1976 and 2001 (aged 37 and 42 years) they completed a questionnaire. Lifetime occurrence and risk of self reported low back pain and self reported, physician diagnosed tension neck and knee injury were calculated for subjects divided into tertiles by baseline results of strength and flexibility tests.

Results: Men from the highest baseline flexibility tertile were at lower risk of tension neck than those from the lowest tertile (odds ratio (OR) 0.51, 95% confidence interval (CI) 0.28 to 0.93). Women from the highest baseline endurance strength tertile were at lower risk of tension neck than those from the lowest tertile (OR 0.60, 95% CI 0.40 to 0.91). Men from the highest baseline endurance strength tertile were at lower risk of knee injury than those from the lowest tertile (OR 1.96, 95% CI 1.05 to 3.64). Men who at school age participated in physical activity were at lower risk of recurrent low back pain (OR 0.61; 95% CI 0.42 to 0.88) than those who did not.

Conclusions: Overall good flexibility in boys and good endurance strength in girls may contribute to a decreased risk of tension neck. High endurance strength in boys may indicate an increased risk of knee injury.

Original Article

The role of physical fitness characteristics and participation in physical activity as predictors of musculoskeletal pain symptoms and injuries has been studied with different study designs. These studies include reports on how baseline muscular strength, flexibility, or physical activity are associated with the future occurrence of low back pain or tension neck in adults.1–3 Higher endurance strength in boys predicted lower occurrence of neck/shoulder pain in adulthood, and higher strength in adolescent girls predicted lower occurrence of low back pain.1 Participation in specific types of sports and exercise can increase the risk of specific injuries. The most common clinically significant acute injury in sport is knee injury, often causing permanent disability and leading to the development of osteoarthritis.4–5 Some sports, such as soccer, predispose the player to knee injury, but it is not known whether some fitness characteristics have either a protective or a predisposing role in knee injury. However, it has been reported that occupational activities such as kneeling or squatting, or independent joint laxity, increase the risk of degenerative meniscal lesion.6

Twin and family studies have shown that physical fitness characteristics (including flexibility and muscle strength) are at least moderately determined by genes,7–16 and differ by sex. Physical activity habits also represent a mild to moderate genetic component, and inherited physical fitness characteristics may play a role in the adoption of a physically active lifestyle.11–14 Physical fitness tracks more consistently from adolescence to adulthood than does physical activity.15–17 Flexibility tracking from adolescence to adulthood18 is higher than endurance strength tracking measured by sit ups,19 or endurance or maximal aerobic power tracking.15

Inherited factors also influence some but not all musculoskeletal symptoms.20 A significant genetic influence on the risk of low back pain has been established in both sexes21–24 and on the risk of neck pain in women.24 The influence of genetic factors on knee injury may appear through joint laxity, which is a risk factor for meniscal lesions,2 but contradictory results exist.25

Overall, our understanding of the association between physical fitness characteristics, participation in physical activity, and the occurrence of musculoskeletal pain syndromes and injuries is limited. We investigated whether physical fitness characteristics (flexibility, endurance strength) and physical activity in adolescence predict the occurrence of common chronic musculoskeletal symptoms (low back pain and tension neck) or knee injuries up to the age of about 40 (37–42 years) separately in men and women.

METHODS

Subjects
At baseline in April–May of 1976, a trained measuring group, who followed exactly the rules of the International Standards for School Fitness Tests, measured fitness in a random sample of 9–21 year old Finnish pupils in school.26 A total of 20 towns and communities were randomly selected from the four geographical areas (west, east, middle, and north) of Finland. The random sample of 56 schools was taken from these towns and communities so that the sizes of the schools from towns and communities corresponded to each other. Classes were randomly selected and either pupils were chosen from the beginning or the end of the alphabet or, at the beginning of the measurement, they were lined up and chosen at equal intervals (every second or third etc). The target group in this study included 801 boys and 886 girls aged 12–17 years, all apparently healthy, who in 1976 participated in a sit and reach test and a 30 second sit up test (table 1) and responded to a questionnaire. The final study group consisted of the 520 men and 605 women who
participated in both of the baseline tests and responded to a follow up questionnaire in 2001. In winter 2001, a questionnaire on health, physical activity, and disease risk factors was sent to all 1687 subjects (801 men and 886 women). Of these, 1133 (67%) responded (522 (65%) men and 611 (69%) women) (table 1). No differences in school fitness test results existed between those who participated in 1976 and returned the questionnaire and those who failed to answer the questionnaire in 2001.

Baseline measurements
The baseline tests had been recommended by an international standardising committee for the testing of children and young adults. Flexibility was measured by a sit and reach test in which subjects sat on the floor, with legs held straight by a tester. They were then asked to bend forward slowly and reach as far forward as possible. A bench bearing a scale by a tester. They were then asked to bend forward and reach as far forward as possible. A bench bearing a scale was placed in front of the subject, whose hands reached along the top of the bench to measure maximum reach.

Endurance strength was measured by a sit up test, in which subjects lay on their backs with knees flexed at a right angle and with hands on the back of the neck. A tester kept the subject’s heels in contact with the floor. For 30 seconds subjects continually sat up to touch their knees with their elbows.

The reliability of the chosen tests has been shown to be good. The construct validity of the whole test battery was tested at baseline with factor analysis and correlations. Varimax rotation of four factors (flexibility versus power, endurance strength, endurance, explosive strength) showed that the variance in the sit and reach test was mostly explained by flexibility. The variance in the sit up test was explained by endurance strength and endurance. The concurrent validity of fitness tests was evaluated by comparing field tests conducted in schools with individual tests in the laboratory. The correlation of the sit up test in boys was 0.84. The correlation between two consecutive sit and reach tests was 0.98 in both boys and girls. The intratester reliability in a subgroup of 15 year old boys, who were tested again after two months, was 0.93 for the sit and reach test and 0.83 for the sit up test. Intertester reliability was not tested.

The baseline test results at school showed that the mean (SD) sit and reach test was 56.8 (7.5) cm for boys and 60.9 (6.1) cm for girls, whereas the mean (SD) sit up test result was 20.40 (4.1) repetitions for boys and 16.6 (3.8) repetitions for girls.

For our statistical analyses, we divided each age group into three age specific tertiles according to their flexibility test and endurance strength test results at school (low, intermediate, and high tertile) in 1976.

At baseline, the subjects responded to a questionnaire on their physical activity habits. This questionnaire included the question “How often do you participate in physical activity outside school hours for at least 30 minutes per session?” with seven response alternatives (never, every day, 2–6 times a week, once a week, 2–3 times a month, once a month, less than once a month). Those who reported participating at least twice a week were classified as “physically active”.

Follow up questionnaire
The follow up questionnaire included 52 questions, nine of which concerned musculoskeletal problems. The main outcome variables determined before statistical analyses were based on the following questions: “Has a doctor said that you have or have ever had (a) tension neck symptoms, (b) meniscal knee injury, and/or (c) ligamentous knee injury?” Those who reported having had either meniscal or ligamentous knee injury were combined into one group of subjects with self confirmed knee injuries. The definition of low back pain was based on self reports to the question “Have you ever had low back pain lasting longer than one day?” with five response alternatives (never, 1–2 times, 3–9 times, 10–20 times, more than 20 times). Those who reported having had low back pain at least 10 times were classified as having recurrent low back pain.

Other questions dealt with (a) the number of days during the preceding 12 months on which difficulties in daily living had been experienced because of neck pain, (d) the age at which the back pain had been at its worst, (c) if the back pain was sciatica, lumbago, or other back problem, (d) if hospital admission had been necessary because of low back pain, (e) the number of days during the preceding 12 months on which difficulties in daily living had been experienced because of low back pain, (f) frequency of knee symptoms during preceding 12 months, (g) if hospital admission had been necessary because of a sports injury to the knee. On the basis of a structured question on the frequency of participation in leisure physical activity, we classified the subjects into three activity categories (at least 5 times a week, 1–4 times a week, or less than once a week). The questionnaire also included a question on current height (cm) and weight (kg), from which body mass index (BMI, kg/m²) was calculated. The correlation between self reported and measured BMI in a subgroup of 64 subjects was 0.99.

Statistical analysis
All analyses were carried out for men and women separately. After descriptive statistics had been produced, logistic regression univariate analysis was used to estimate the crude odds ratio (OR) with 95% confidence interval (CI) for the risk for occurrence of tension neck, knee injury, and recurrent low back pain by baseline flexibility and endurance strength tertiles, and by participation in leisure physical activity at school age and in adulthood and by follow up age and BMI. A multivariate analysis was then performed including all the variables in the model. Differences between the prevalence of symptoms in low, intermediate, and high tertiles of fitness in adolescence were calculated using the Cochran-Armitage trend test. Analyses were performed with SPSS 12.0 and Stata Statistical Software version 8.0.

RESULTS
The occurrence of tension neck was 2.5 times higher for women (37.4% (226 of 605); 95% CI 33.5 to 41.4) than for men (15.2% (79 of 520); 95% CI 12.2 to 18.6). During the preceding year, 2.7% of men and 2.9% of women reported having difficulties in daily living for more than 30 days because of neck pain.

The occurrence of recurrent low back pain was 1.5 times higher for men (23.1% (120 of 520); 95% CI 20.0 to 26.1) than for women (15.2% (92 of 604); 95% CI 12.5 to 18.3). The mean age at which low back pain was worst was 31.4 (6.7) years in men and 32.8 (6.0) years in women. The worst back

| Table 1 Number of subjects in 1976 and proportion who responded to questionnaire in 2001 |
|---------------------------------|-----------------|
| **Test**                       | **1976** | **2001** |
| Sit and reach test             | Boys     | 801     | 522 (65%) |
|                                | Girls    | 886     | 611 (69%) |
| 30 second sit up test          | Boys     | 801     | 521 (65%) |
|                                | Girls    | 880     | 607 (69%) |
pain experienced was sciatica in 22.6% of men and 21.8% of women and lumbago in 22.5% of men and 17.0% of women. Back pain had been treated at hospital in 6.7% of men and 3.9% of women. During the preceding year, 4.4% of men and 3.7% of women reported having difficulties in daily living for more than 30 days because of back pain.

The occurrence of meniscal or ligamentous knee injury was two times higher for men (14.4% (75 of 520); 95% CI 11.5 to 17.7) than for women (7.1% (43 of 605); 95% CI 5.2 to 9.5). During the preceding year, 7.4% of men and 6.0% of women reported at least weekly knee symptoms. Hospital admission for a sports knee injury had occurred in 13.3% of men and 4.0% of women.

Table 2 shows the occurrence of tension neck, low back pain, and knee injuries in both sexes by tertiles of flexibility and endurance strength, school age physical activity, and adult physical activity.

Table 3 shows the results of univariate and multivariate analysis of the risk of tension neck for subjects in the highest and intermediate tertiles compared with those in the lowest tertile. The risk of tension neck increased with each unit increase in BMI by 9% in men and 5% in women. Men from the highest baseline flexibility tertile were at about 50% lower risk of the occurrence of tension neck than were those from the lowest tertile. Significance of the trend over the tertiles was 0.026, showing an inverse dose-response type of association. Good flexibility decreased the risk of tension neck in women, too, but significantly only in the intermediate group in multivariate analysis. The trend over tertiles was not significant (p = 0.18). Women with high endurance strength were at 34% lower risk of tension neck than women with low endurance strength. Significance of the trend over the tertiles was 0.016. Adult BMI had a slight effect of increased risk of recurrent low back pain (table 4). Men who were physically active in adolescence were at a lower risk of recurrent low back pain. Women showed a similar but insignificant tendency. In univariate analysis, risk of low back pain was lower in women who were moderately active at follow up.
The risk of knee injury in men increased 1.3 times for each successive 1 year increase in age (table 5). In women, an increase of one unit of BMI increased the risk of knee injury by 16%. Men with high school age endurance strength had twice the risk of knee injury as those with low endurance strength. Significance of the trend over tertiles was 0.027. The tendency was similar in women but insignificant (p = 0.48). Physical activity in adolescence increased the risk of knee injury in both sexes, but the finding was statistically insignificant.

DISCUSSION

In our 25 year follow up study, high adolescent flexibility predicted low occurrence of tension neck in men. In women, high endurance strength predicted low occurrence of tension neck, whereas in men it was a predictor of knee injury. Participation in leisure physical activity in adolescence predicted low occurrence of recurrent low back pain in men. Of the adulthood factors, physical activity 1–4 times a week may lower the risk of low back pain in women. In addition, the higher the BMI, the greater the risk of tension neck and low back pain in both sexes, and knee injury in women.

Our study cohort was a representative sample of Finnish children. The strengths of our study include the fitness test results from 1976, a very thorough follow up despite the various whereabouts of the subjects, and a reasonable response rate (68%) after 25 years of follow up. Unfortunately, we could follow up only 65% of men and 69% of women, which may have influenced the results. In addition, differences in morbidity, physical activity, or social class among subjects and dropouts cannot be excluded. At follow up, our subjects were about 40 years old, when severe musculoskeletal degeneration is uncommon. The occurrence of degenerative changes in older subjects, however, could modify associations found in our study.

Our original aim was to study components of adolescent physical fitness (endurance, endurance strength, and flexibility) as predictors of adult musculoskeletal problems (tension neck, low back pain, knee injury, and Achilles

![Table 3](image)

![Table 4](image)
The sit and reach test measures mainly hamstring flexibility, but is dependent on hip and back mobility, too. If we assume that the sit and reach test describes overall flexibility, one explanation for the association between low flexibility and tension neck is that general stiffness predicts tension neck. Flexibility, as well as muscle training, may be important in reducing the reinjury risk. Physical activity in boys is usually more vigorous than in girls. Hypotheses differ about the mechanism by which adolescent physical activity in boys prevents adult low back pain. Although extreme sport related loading may cause injury to an adolescent’s back, physical activity during growth may improve the development of some of the low back structures enabling them to withstand more robustly physical loading in adulthood. Also, physical activity...
increases trunk muscle strength, endurance, and motor abilities, which may help the back to function better.\textsuperscript{6, 11} On the other hand, high physical performance is also related to sports with increased risk of low back pain, and this may dilute the beneficial effects of physical activity. Interestingly, hyperalgesia resulting from differences in experiencing pain stimuli at the level of the central nervous system occurs more often in patients with chronic low back pain than in controls.\textsuperscript{42} Physical activity during adolescence may modify the sensory perception of peripheral pain at the level of the central nervous system, which is one possible explanation for fewer pain symptoms in subjects who have been physically active during adolescence.

Our study agrees with the conclusions of most previous long term follow up studies: high muscular strength\textsuperscript{2} appears not to be a strong predictor of low back pain. Again, enhancing strength and flexibility may be important components in the rehabilitation of patients with chronic low back pain.

Our hypothesis suggested that predictors of different musculoskeletal problems would differ by outcome and sex. In cross sectional studies or short term follow ups, the cause and effect evaluation between factors such as neck pain and neck muscle strength is problematic. Also, the results of our study cannot simply be interpreted as causal associations; rather they may result from third variable differences. The inherent nature of these characteristics because of our long follow up period may at least partly explain the predictive value of measured physical fitness characteristics. Previous studies have shown that tracking of fitness characteristics is better in shorter follow ups,\textsuperscript{18} may vary between sexes, and may depend on the timing of the baseline measurement in relation to puberty.\textsuperscript{19}

Our study has several limitations. Low back pain was based only on self reports. However, in the \textit{International classification of diseases}, diagnosis of low back pain is also based on self report. The study lacks the intertester reliability of the baseline measurements, has limitations in evaluating the validity, and only two fitness tests could be used. The validity of the questionnaire at baseline was not tested separately. The validity of the follow up questionnaire was not tested either, but it included questions tested and used before in other epidemiological studies in Finland.\textsuperscript{41} The effect of maturation cannot be excluded because the timing of puberty is not known. It is probable that some of the boys had not completed puberty. Overall, our study adds an important, often unrecognised, perspective to studies evaluating the associations between physical fitness characteristics, activity, and musculoskeletal problems.

In conclusion, our results provide evidence that overall good flexibility in men and good endurance strength in women may help to decrease the risk of tension neck symptoms. High endurance strength in boys may indicate an increased risk of knee injury probably because of overtraining with participation in activities with high injury risk. The possible beneficial effects of childhood and adolescent physical activity on low back pain in men and women require further study.

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Competing interests: none declared

Contributors: UM participated in the planning of the study, organised the recruitment of subjects and data collection at follow up, and participated in analysing and interpreting the results and writing the article. HN participated in the planning and supervision of the study, organised the recruitment of subjects and data collection at baseline, and participated in the interpretation of the results and writing of the article. JK and UK participated in the planning and supervision of the study, and in the interpretation of the results and writing of the article. MM participated in the data collection and interpretation of the results and writing of the article. HK participated in analysing and interpreting the results and writing the article. All authors reviewed and accepted the final version.

Ethics approval: the study protocol was approved by the ethics committee of Keski-Suomi district.

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ECHO

Sports activities 5 years after total knee or hip arthroplasty: the Ulm Osteoarthritis Study

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Objective: To analyse sports activities of patients with hip or knee osteoarthritis (OA) over lifetime, preoperatively, and 5 years after arthroplasty.

Methods: In a longitudinal four centre study, 809 consecutive patients with advanced OA of the hip (420) or the knee (389) joint under the age of 76 years who required total joint replacement were recruited. A completed questionnaire about sports activities at 5 year follow up was received from 636 (79%) of the 809 patients.

Results: Although most patients with hip (97%) and knee (94%) OA had performed sports activities during their life, only 36% (hip patients) and 42% (knee patients) had maintained sports activities at the time of surgery. Five years postoperatively, the proportion of patients performing sports activities increased to 52% among patients with hip OA, but further declined to 34% among those with knee OA. Accordingly, the proportion of patients with hip OA performing sports activities for more than 2 hours a week increased from 8 to 14%, whereas this proportion decreased from 12 to 5% among patients with knee OA. Pain in the replaced joint was reported by 9% of patients with hip and by >16% with knee OA.

Conclusion: Differences in pain 5 years after joint replacement may explain some of the difference of sports activities between patients with hip and knee OA. Reasons for reduction of sports activities may include the increasing age of the patients, their worries about an "artificial joint", and the advice of their surgeon to be cautious.

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