ORIGINAL ARTICLE

Greek adolescents, fitness, fatness, fat intake, activity, and coronary heart disease risk

C Bouziotas, Y Koutedakis, A Nevill, E Ageli, N Tsigilis, A Nikolaou, A Nakou

Arch Dis Child 2004;**89**:41–44

Background: A dramatic increase in adult mortality rates from coronary heart disease (CHD) in Greece, accompanied by increased prevalence of CHD risk factors in children, has been documented. However, there is controversy about the independent effects of certain lifestyle parameters on primary CHD risk factors.

Aims and Methods: To examine the association between CHD risk factors (HDL-C, LDL-C, HDL-C/TC, triglycerides, systolic and diastolic blood pressure) and lifestyle parameters (fitness, fatness, fat intake, and physical activity) in 210 12-year old Greek pupils.

Results: Correcting for the fixed factors of gender and maturation, analyses of covariance (ANCOVA) with backward elimination of the lifestyle covariates revealed significant associations between three CHD risk factors (HDL-C, HDL-C/TC, systolic blood pressure) and physical activity levels. In contrast, the covariates aerobic fitness, fatness and fat intake failed to reach significance with any of the CHD risk factors.

Conclusions: In Greek schoolchildren, primary CHD risk factors are mainly associated with physical activity levels, independently of fitness, fatness, and/or fat intake. Prevention strategies should concentrate on enhancing physical activity early in life, if the increased prevalence of Greek adult CHD mortality is to be diminished.

See end of article for authors' affiliations

Correspondence to: Dr Y Koutedakis, TEFAA, Thessaly University, 42100 Trikala, Greece; y.koutedakis@uth.gr

Accepted 12 June 2003

Atherosclerosis, the underlying cause of coronary heart disease (CHD) begins early in life and progresses into adulthood.[1] In adults, adverse lipid profiles and hypertension have been identified as major risk factors for developing atherosclerosis.[2] Furthermore, accumulating evidence suggests a causative relation between blood lipids[3] and blood pressure[4] in childhood and adult CHD.

Paediatric studies have indicated that unfavourable blood lipid and blood pressure profiles may be associated with an array of different lifestyle parameters including poor aerobic fitness,[5] obesity,[6] increased dietary fat intake,[7] and inadequate levels of physical activity.[8] Recent studies in children have further suggested that lipid and blood pressure profiles are mediated mainly by body fatness, rather than fitness and other confounding variables.[9] From the above, it becomes evident that the independent effects of lifestyle parameters on primary CHD risk factors in children are not entirely clear.

Compared to children from other countries,[10 11] Greek children exhibit relatively low aerobic fitness and physical activity levels[12] and adverse lipid profile.[13] Furthermore, Greek children have shown high prevalence of obesity[14] and high consumption of dietary fat.[15] No epidemiological data are available on possible associations among lifestyle parameters and primary CHD risk factors. Therefore, we have examined the association between four aspects of lifestyle (physical activity, fatness, fitness, and fat intake) and selected CHD risk factors (high (HDL-C) and low (LDL-C) density lipoproteins, HDL-C/total cholesterol (TC), triglycerides (TG), systolic and diastolic blood pressure) in a cohort of 12 year old Greek children.

METHODS

This study is part of a longitudinal investigation of CHD risk factors in Greek children. We present a cross sectional analysis of the effects of a variety of lifestyle determinants on CHD risk factors. The original baseline survey, which provides the basis for the current investigation, was completed in 1999.[12]

Subjects

The population studied consisted of 210 healthy subjects (117 males and 93 females, mean age 12.3, SD 0.6 years). They volunteered from all seven secondary schools in the town of Katerini (~50 000 inhabitants), Greece. All measures of anthropometry, aerobic fitness, and physical activity were conducted in the school environment (during PE classes), at the beginning of the school year and by the same experienced investigator (the principal author), using the same order of testing procedures. Blood samples and blood pressure data were obtained at the local state hospital by three medical practitioners and nurses. Written informed consent was acquired from all subjects and their parents after full explanation of data collection procedures. The Research Ethics Committee of the University of Wolverhampton approved the investigation and permission was granted from the Greek Ministry of Education.

Data collection

Anthropometry

Weight was measured to the nearest 0.5 kg (Seca beam balance 710) with subjects being lightly dressed and barefooted, and standing height was measured to the nearest 0.5 cm (Seca stadiometer 208). Percentage body fat (defined as "fatness") was calculated according to published guidelines,[16] that is, from triceps and medial calf skinfold measures (average of two measurements of each site) using a Harpenden (John Bull, UK) calliper.

Sexual maturity

Assisted by a female medical doctor who specialised in paediatric medicine, sexual maturity status was assessed by

Abbreviations: CHD, coronary heart disease; HDL, high density lipoprotein; LDL, low density lipoprotein; TC, total cholesterol; TG, triglycerides self evaluation, according to Tanner's[17] criteria for breast, pubic hair, and genital development. It has been suggested that this is the most appropriate method for general application in evaluation of maturity status.[18]

Aerobic fitness
Defined as the maximal oxygen uptake ($\dot{V}O_2$ max), or the greatest rate at which oxygen can be taken in during exercise, aerobic fitness was assessed using the children's validated 20 metre shuttle run test.[19] Subjects had to run back and forth between two lines set 20 metres apart. Running pace was determined by audio signals, emitted from a pre-recorded cassette tape, with the initial velocity being 8.5 km/h. Running speed was increased at regular intervals of 0.5 km/h every minute. The test was terminated when children failed to reach the lines concurrent with the audio signals on two consecutive occasions. $\dot{V}O_2$ max was then predicted from the number of "laps" completed.[20]

Fat intake
Information on dietary fat intake was obtained by means of a seven day dietary diary. Photographs illustrating portion sizes of the most commonly consumed food items and beverages were used while keeping the diaries. Both pupils and their parents were instructed on how to keep a record of the amount and type of food and beverages consumed on seven consecutive days. After collection, each diary was checked by the principal investigator and the child involved to ensure accuracy of the recorded information. Using the Food Composition Tables for Greek food,[21] fat intake was estimated and expressed as percentage of total energy intake.

Physical activity
For the assessment of physical activity levels,[22] the Past Year Physical Activity Recall Questionnaire of Aaron *et al* was utilised. This questionnaire has been shown to yield reproducible and valid estimates of past year physical activity in adolescents aged 12–17 years. Briefly, subjects were asked to indicate all organised physical activities as a member of any sports club, including school PE, and all leisure time physical activities (for example, walking, cycling, stair climbing, etc) in which they participated during the past year. They also had to give detailed information regarding the frequency and duration of each individual activity. The metabolic cost of each activity[23] was then used to calculate a total physical activity score expressed in kcal per kg per day.

CHD biological risk factors; determination of lipid and blood pressure profiles
Procedures have been described in detail elsewhere.[12] Briefly, after an overnight fast, approximately 5 ml of blood was taken from each child with a vacutainer, for lipid and lipoprotein analyses using a Technicon R-XT autoanalyser. Serum total cholesterol (TC) and TG were determined by automated enzymatic techniques (CHOD-PAP, Boehringer Mannheim GmbH, Germany and CPO-PAP-method, Boehringer Mannheim GmbH, Germany) respectively. Serum HDL-C concentration was measured in the supernatant after precipitation of very low density and low density lipoproteins with phosphotungstic acid (Boehringer Mannheim Kit). Low density lipoprotein cholesterol (LDL-C) concentration was calculated according to the formula of Friedewald and colleagues.[24]

Blood pressure was measured using a standard mercury sphygmomanometer after the child had been sitting quietly for five minutes. The mean of two measurements of Korotkoff phase I was recorded for systolic blood pressure. The mean of two values of Korotkoff phase IV was recorded for diastolic blood pressure.[25]

Statistical analysis
The χ^2 test was used to examine whether there was a difference in the percentages of boys and girls participating in the present investigation. Preliminary evaluation of the variables using a Kolmogorov-Smirnov test of normality revealed that three variables (body fat, LDL-C, and TG) required logarithmic transformation in order to reach normality. Means (SD) were calculated for all parameters.

Pearson's product moment correlation coefficients were computed to assess relations among fitness, fatness (percentage body fat), and physical activity. A linear model was used to examine possible associations between each of the CHD risk factors and fitness, fatness, fat intake, and physical activity. Specifically, analyses of covariance with backwards elimination of the lifestyle covariates were used to investigate the effects of gender and maturation (as fixed factors) on each of the CHD risk factors (dependent variable), using fitness, fatness, fat intake, and physical activity as covariates. The level of statistical significant was set at $p<0.05$.

RESULTS
Fifty six per cent of the present subjects were males and 44% were females. χ^2 analysis revealed that there was no significant difference in the percentages of male and female participants ($\chi^2_1 = 2.74$, $p = 0.098$).

Table 1 presents descriptive data for all studied parameters. Apart from percentage body fat, which was higher, all other parameters were lower than internationally proposed cut-off points of selected CHD risk indicators in children.[26]

Table 2 shows the Pearson's product moment correlation coefficients among fitness, fatness, and physical activity. All these parameters were found to be modestly correlated at $p<0.01$.

Analyses of covariance revealed that, compared to lifestyle parameters of fitness, fatness, fat intake, and physical activity, only physical activity was significantly associated with selected CHD risk factors. Specifically, physical activity was associated positively with HDL-C ($p<0.001$) and HDL-C/TC ($p<0.001$), and negatively with systolic blood pressure ($p<0.001$).

DISCUSSION
Over the past 30 years, increased mortality rates from CHD have been observed in Greek adults.[27] This upward trend is reflected by lifestyle changes[28 29] and a high prevalence of CHD risk factors in Greek children.[12 13] However, the independent contribution of lifestyle parameters (for example, fitness, fatness, diet, and habitual physical activity levels)

Table 1 Subject characteristics for all studied parameters (n = 210); values are mean (SD)

Variable	Mean (SD)	Range
Age (y)	12.3 (0.6)	11–14
Height (cm)	154 (7.1)	135–178
Weight (kg)	48 (9.9)	28–85
Body mass index (BMI)	20.0 (3.3)	14–36
Body fat (%)	23 (9.1)*	9–50
P $\dot{V}O_2$ max (ml/min/kg)	33 (6.2)	21–49
Physical activity (kcal/kg/day)	45.0 (5.2)	32–59
Dietary fat (% of total energy intake)	25 (4.2)	13–36
TC (mg/dl)	151 (28.0)	94–251
LDL-C (mg/dl)	87 (25.7)*	32–185
HDL-C (mg/dl)	51 (10.9)	22–83
HDL-C/TC	0.34 (0.7)	0.18–0.57
TG (mg/dl)	63 (26.6)*	25–192
Systolic blood pressure (mm Hg)	101 (8.4)	80–130
Diastolic blood pressure (mm Hg)	56 (7.6)	40–75

*Values are before log transforming, following the evaluation for normality.

Table 2 Correlation coefficients among fitness, fatness, and physical activity (n = 210)

	Fitness	Fatness	Physical activity
Fitness	–	−0.63*	0.58*
Fatness	−0.63*	–	−0.69*
Physical activity	0.58*	−0.69*	–

*p<0.01.

on primary CHD risk factors (for example, blood lipids and blood pressure) remains unclear. The purpose of this study was to further explore this issue focusing on Greek children.

We found associations between physical activity and CHD risk factors to be stronger than between fatness, fitness, and fat intake and the same CHD risk factors. Specifically, correcting for the fixed factors of gender and maturation, analyses of covariance with backward elimination of the lifestyle covariates revealed three significant associations between the CHD risk factors (HDL-C, HDL-C/TC, and systolic blood pressure) and physical activity levels. In contrast, the covariates aerobic fitness, fatness, and fat intake failed to reach significance with any of the CHD risk factors. We did not find any associations between LDL-C, TG, diastolic blood pressure, and the lifestyle parameters, which may be attributed to genetic and metabolic factors[30] and/or to low baseline values. In general, these findings suggest that physical activity is the most significant lifestyle predictor for CHD risk factors in Greek children. This is despite the fact that our subjects revealed lower physical activity levels (45 kcal/kg/day) than those previously reported for other paediatric populations (58 kcal/kg/day).[11] Nevertheless, as young people assume responsibility for their own health related behaviour and attitudes,[31] the present findings may be particularly useful to health promotion strategists.

The present study complements previous reports showing strong associations between inadequate levels of physical activity and the atherogenicity of high lipid levels[8] and raised blood pressure.[32] Our data are also in line with a comprehensive recent review where aerobic fitness appeared not to be related to plasma lipids or lipoproteins.[33] The fact that a different pattern has been established for activity and fitness in relation to blood lipid and blood pressure parameters, supports the call for a distinction between these two attributes in children.[33] This is probably because, while physical activity is considered to be linked to behaviour—and hence to lifestyle—children's aerobic fitness is an attribute with a strong genetic component.[34] Furthermore, unlike fitness, physical activity appears to be an important determinant of certain lipid metabolic adaptations expected to confer a reduced risk of cardiovascular disease.[35] The activities of the lipid metabolism enzymes lipoprotein lipase (LP), lecithin-cholesterol acyltransferase (LCAT), and hepatic lipase (HL) seem to increase in parallel with increases in physical activity levels.[36]

In general, while physically active adults are usually regarded as being fit, a similar relation with children has not yet been firmly established. Although there are several different methods to assess physical activity levels in children, none has proven sufficiently practical and valid to emerge as a standard method.[37] Furthermore, interpretation of correlational studies is difficult because of differences in subject characteristics (including social and cultural backgrounds), in methods employed to assess fitness related parameters, and in statistical techniques employed to analyse multivariate data.

It is noteworthy that the present data contradict recent reports citing obesity as the single most important contributor in the pathogenesis of CHD during childhood.[9 38] Part of the explanation for this discrepancy may be that fitness, fatness, and physical activity levels are interrelated,[39] which has likewise been established by the present data. Although not directly monitored, social and cultural differences between the children studied may also account for the observed discrepancies.

Confirming a previous report in Greek children,[28] we found that the CHD risk factors studied were not substantially affected by qualitative aspects of diet. The relatively low baseline data found in the present study and/or the methodology used may account for this. For instance, the mean dietary fat intake of 25% of the total energy intake was lower than the 30% recommended for children of this age group.[40]

In conclusion, and within the study's limitations, primary CHD risk factors in Greek schoolchildren are mainly associated with physical activity levels, independent of fitness, fatness, and/or fat intake. As reduced activity is a well established CHD risk factor in adults, concern about the long term health implications in children is justified. CHD primary preventive strategies should aim at effective habitual physical activity interventions if the future CHD risk of the Greek population is to be reduced.

ACKNOWLEDGEMENTS

The authors wish to thank Michael Healy for his invaluable advice on statistical matters.

....

Authors' affiliations

C Bouziotas, A Nevill, School of Sport, Performing Arts and Leisure, University of Wolverhampton, UK
Y Koutedakis, Department of Sports and Exercise Science, Thessaly University, Trikala, Greece
E Ageli, A Nikolaou, A Nakou, State Hospital, Katerini, Greece
N Tsigilis, Department of Sports and Exercise Science, Aristotle University, Thessaloniki, Greece

REFERENCES

1 **Strong WB**. Physical activity and children. *Circulation* 1990;**8**:1697–701.
2 **Kemper HCG**, Storm-van Essen L, Verschuur R. Tracking of risk indicators for coronary heart diseases from teenager to adult: The Amsterdam Growth and Health Study. In: Oseid S, Carlsen KH, eds. *Children and exercise XIII.* Champaign, IL: Human Kinetics Books, 1989:235–45.
3 **Brox J**, Bjornstad E, Olaussen K, *et al.* Blood lipids, fatty acids, diet and lifestyle parameters in adolescents from region in northern Norway with a high mortality from coronary heart disease. *Eur J Clin Nutr* 2002;**56**:694–700.
4 **Sorof J**, Daniels S. Obesity hypertension in children: a problem of epidemic proportions. *Hypertension* 2002;**40**:441–7.
5 **Hofman A**, Walter HJ. The association between physical fitness and cardiovascular disease risk factors in children in a five-year follow-up study. *Int J Epidemiol* 1989;**18**:830–5.
6 **Morrison JA**, Barton BA, Biro FM, *et al.* Overweight, fat patterning, and cardiovascular disease factors in black and white boys. *J Pediatr* 1999;**135**:451–7.
7 **Deckelbaum RJ**. Nutrition, the child and atherosclerosis. *Acta Paediatr Scand* 1990;**365**(suppl):7–12.
8 **Takada H**, Harrell J, Deng S, *et al.* Eating habits, activity, lipids and body mass index in Japanese children: the Shiratori Children Study. *Inter J Obes Relat Metab Disord* 1998;**22**:470–6.
9 **Boreham C**, Twisk J, Murray L, *et al.* Fitness, fatness and CHD risk factors in adolescents—the Northern Ireland Young Hearts Project. *Med Sci Sports Exerc* 2001;**33**:270–4.
10 **McMurray RG**, Harrell JS, Bradley CB, *et al.* Predicted maximal aerobic power in youth is related to age, gender, and ethnicity. *Med Sci Sports Exerc* 2002;**34**:145–51.
11 **Torun B**, Davies PSW, Livingstone MBE, *et al.* Energy requirements and dietary energy recommendations for children and adolescents 1 to 18 years old. *Eur J Clin Nutr* 1996;**50**(suppl 1):S37–81.
12 **Bouziotas C**, Koutedakis Y, Shiner R, *et al.* The prevalence of selected modifiable coronary heart disease risk factors in 12-year-old Greek boys and girls. *Pediatr Exerc Sci* 2001;**13**:173–84.
13 **Brotons C**, Ribera A, Perich RM, *et al.* World-wide distribution of blood lipids and lipoproteins in childhood and adolescence: a review study. *Atherosclerosis* 1998;**139**:1–9.
14 **Mamalakis G**, Kafatos A. Prevalence of obesity in Greece. *Int J Obes* 1996;**20**:488–92.

15 **Manios Y**, Moschandreas J, Hatzis C, *et al.* Evaluation of a health and nutrition education programme in primary school children of Crete over a three-year period. *Prev Med* 1999;**28**:149–59.
16 **Lohman TG**. *Advances in body composition assessment: current issues in exercise science.* Monograph Number 3. Champaign, IL: Human Kinetics Publishers, 1992.
17 **Tanner JM**. *Growth at adolescence*, 2nd edn. Oxford: Blackwell, 1962:29–39.
18 **Faulkner RA**. Maturation. In: Docherty D, ed. *Measurement in paediatric exercise science.* Champaign, IL: Human Kinetics, 1988:129–58.
19 **Boreham C**, Paliczka VJ, Nichols AK. A comparison of the PWC170 and 20-MST tests of aerobic fitness in adolescent schoolchildren. *J Sports Med Phys Fitness* 1990;**30**:19–23.
20 **Brewer J**, Ramsbottom R, Williams C. *Multistage fitness test. A progressive shuttle-run test for the prediction of maximum oxygen uptake.* Leeds, UK: National Coaching Foundation, 1988.
21 **Trichopoulou A**. *Food composition tables of Greek foods and dishes.* Passianos: Athens, 1992.
22 **Aaron DJ**, Kriska AM, Dearwater SR, *et al.* Reproducibility and validity of an epidemiologic questionnaire to assess past year physical activity in adolescents. *Am J Epidemiol* 1995;**142**:191–201.
23 **Ainsworth BE**, Haskel WL, Whitt MC, *et al.* Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000;**32**(suppl):S498–516.
24 **Friederwald WT**, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma without the use of preparative ultracentrifuge. *Clin Chem* 1972;**18**:499–502.
25 **Report of the Second Task Force on Blood Pressure Control in Children**. Task Force on Blood Pressure Control in Children. *Pediatrics* 1987;**79**:1–25.
26 **Bell RD**, Macek M, Rutenfranz J, *et al.* Health indicators and risk factors of cardiovascular diseases during childhood and adolescence. In: Rutenfranz J, Mocellin R, Klimt F, eds. *Children and Exercise XII.* Vol.17. International Series on Sport Science. Champaign, IL: Human Kinetics Books, 1986:19–27.
27 **Kafatos A**, Papoutsakis G. Mortality rates in Greece and their relationship to the Mediterranean diet and to health and nutrition education. *Iatriki* 1998;**73**:287–301.
28 **Petridou E**, Malamou E, Doxiadis S, *et al.* Blood lipids in Greek adolescents and their relation to diet, obesity, and socio-economic factors. *Ann Epidemiol* 1995;**5**:286–91.
29 **Manios Y**, Kafatos A, Codrington C. Gender differences in physical activity and physical fitness in young children in Crete. *J Sports Med Physiol Fitness* 1999;**39**:24–30.
30 **Third JLHC**, Montag J, Flynn M, *et al.* Primary and familial hypoalphalipoproteinemia. *Metabolism* 1984;**33**:136–46.
31 **Coates TJ**, Peterson AC, Perry C, eds. *Promoting adolescent health: a dialog on research and practice.* New York: Academic Press, 1982.
32 **Katzamarzyk PT**, Malina RM, Bouchard C. Physical activity, physical fitness, and coronary heart disease risk factors in youth: the Quebec Family Study. *Prev Med* 1999;**29**:555–62.
33 **Tolfrey K**, Jones AM, Campbell IG. The effect of aerobic exercise training on the lipid-lipoprotein profile of children and adolescents. *Sports Med* 2000;**29**:99–112.
34 **Bouchard C**, Daw EW, Rice T, *et al.* Familial resemblance for $\dot{V}O_2$ max in the sedentary state: the HERITAGE family study *Med Sci Sports Exerc* 1998;**30**:252–8.
35 **Hardman AE**. Accumulation of physical activity for health gains: what is the evidence? *Br J Sports Med* 1999;**33**:87–92.
36 **Superko HR**. Exercise training, serum lipids, and lipoprotein particles: is there a change threshold? *Med Sci Sports Exerc* 1991;**23**:677–85.
37 **Montoye HJ**, Kemper HCG, Saris WHM, *et al. Measuring physical activity and energy expenditure.* Champaign, IL: Human Kinetics, 1996.
38 **Twisk JWR**, Boreham C, Cran G, *et al.* Clustering of biological risk factors for cardiovascular disease and the longitudinal relationship with lifestyle of an adolescent population: The Northern Ireland Young Hearts Project. *J Cardiovasc Risk* 1999;**6**:355–62.
39 **Twisk JWR**, Kemper HCG, van Mechelen W. Tracking of activity and fitness and the relationship with cardiovascular disease risk factors. *Med Sci Sports Exerc* 2000;**32**:1455–61.
40 **National Cholesterol Education Program**. *Report of the Expert Panel on Blood Cholesterol Levels in Children and Adolescents.* Bethesda, MD: US Dept of Health and Human Services, Public Health Service, National Heart, Lung, and Blood Institute, National Institutes of Health, 1991:91–732.

IMAGES IN PAEDIATRICS

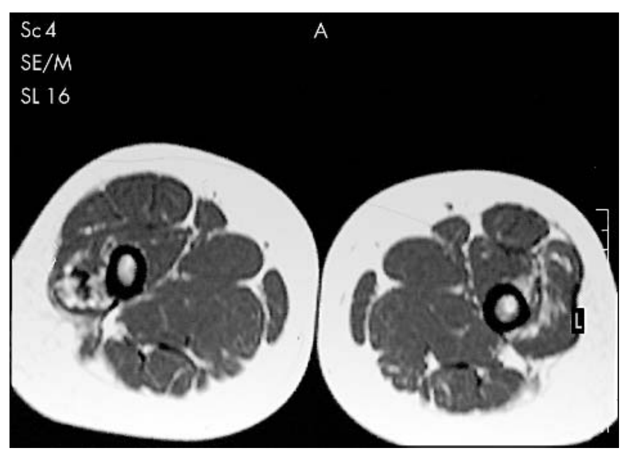
Progressive fibrosis of the quadriceps muscle

This 15 year old boy presented when 3 years old because of maternal concern about "not walking right". He was born at term weighing 2.4 kg, was admitted to the special care baby unit, and treated for septicaemia with intramuscular benzylpenicillin four times daily and gentamicin twice daily, for nine and ten days respectively. He subsequently received intramuscular immunisations.

Initial examination revealed limitation of flexion in both knees. A muscle biopsy showed no acute inflammation and a predominance of type 1 fibres. Muscle enzymes and EMG studies were normal. A diagnosis of progressive fibrosis of the quadriceps muscles secondary to intramuscular injections was made. Reduction in flexion at both knee joints progressed rapidly. Bilateral quadroplasty was performed with the rectus femoris mainly affected.

Magnetic resonance imaging of his quadriceps (see fig) showed patchy fibrosis and fatty infiltration, especially of the vastus lateralis and intermedius. He currently has about 90° of flexion in both knees.

Progressive fibrosis of skeletal muscle is a well recognised condition.[1] Several case reports have shown a link with intramuscular injections. Typically the vastus intermedius and lateralis components of the quadriceps are affected. The vastus intermedius is enclosed in an osteofascial compartment and has a relatively poor blood supply.[2] It is postulated that injection of large volumes of fluid into this confined space causes ischaemia, followed by necrosis, then fibrosis. Treatment involves early intensive physiotherapy and surgical intervention if severe.



This case highlights the importance of avoiding intramuscular injections if possible.

R L Boon, E Baildam
Booth Hall Children's Hospital, Charlestown Road, Blackley, Manchester M9 7AA, UK; robboon69@hotmail.com

References

1 **Hnevkovsky O**. Progressive fibrosis of the vastus intermedius in children. *J Bone Joint Surg* 1961;**43-B**:318.
2 **Natarajan M**. Kini memorial oration. *Indian Journal of Orthopaedics* 1968;**4**:70.