Effects of long-term recreational table tennis on health related fitness, plasma lipids and bone density in middle-aged women

Yoshio Kobayashi*1, Teruo Hosoi*1, Toshiko Takeuchi*1, and Noriaki Okuda*2

*1 The Laboratory for Health and Human Performance, School of Arts and Sciences, Chukyo University, 101-2 Yagoto-hommachi, Showa, Nagoya 466, *Japan*
*2 Okuda Internal Medicine and Clinic and Hinatacho, Mizuho, Nagoya 465, *Japan*

Abstract

The relationship of habitual physical activity to various components of health-related fitness as well as bone density were investigated in middle-aged women. Ten female athletes were recruited each from table tennis, volleyball and jogging associations as well as 10 sedentary controls. The table tennis group showed significantly higher $\dot{V}O_{2max}$, and lower resting heart rate and per cent body fat than the sedentary group. In addition, plasma HDL cholesterol concentration tended to be higher in the table tennis than in sedentary groups. These results may indicate that habitual table tennis activity is beneficial to maintaining a high level of aerobic fitness as well as reducing the risk of coronary heart disease. Ultrasound bone measurement was evaluated on os calcis using the Achilles densitometer (Lunar Corp.). Bone density was expressed as a calculated "stiffness" index. The volleyball and jogging groups demonstrated significantly greater values in bone stiffness than the sedentary group while the table tennis group did not. Isokinetic muscle strength of the knee extensors was also measured in this study. The values of peak torque in the table tennis group were significantly lower than values in the volleyball and jogging groups. Again no significant difference was found between the table tennis and sedentary groups. Significant positive correlations ($P<0.001$) were noted between bone stiffness and peak torque of knee extensors. Results of the measurements indicate that muscle activities in table tennis may not be sufficient to stress the bone to maintain a high level of bone mass.

Habitual exercise, isokinetic muscle strength, bone stiffness, plasma lipids

Physical activity has been shown in previous studies (20,29,32,35,38) to be inversely related to coronary heart disease incidence and mortality. The mechanism by which this protection occurs appears in part to be related to decreased blood pressure, lower body mass, higher HDL cholesterol, and lower total cholesterol and HDL ratio associated with physical activity (19).

These physiological benefits generally stem from the so-called aerobic exercises involving an intensity of 50 to 85% of maximal oxygen uptake (1). However, typical aerobic exercises such as running, swimming, cross-country skiing, and bicycling are simple continuous activities. Many people prefer sports or games to develop and maintain cardiovascular fitness.

Recreational activities have become increasingly popular in today's society because people have more time for leisure activities. Large numbers of people have taken up a variety of sports and have now been exercising for many years. Racket sports have become a popular form of exercise in Japan.

Table tennis is a popular participant sports. Many players have enjoyed the game pursuing it not only for recreational purposes but also for enhancing fitness. Considering the popularity of this sport, a study of the physiological characteristics of middle-aged table tennis players is appropriate. It is of considerable concern whether table tennis, if played for years, can provide similar physiological effects on prevention of cardiovascular diseases as running or swimming.

Besides the problem of cardiovascular diseases, osteoporosis is also major health concern in the senior citizen community of our country, particularly for older women. Numerous reports indicate that physical activity is positively related to bone density and may, therefore, be an important factor in the prevention of osteoporosis. There is someindication that greater bone density may be more related to high intensity endurance types of activities (22). It is also of concern whether table tennis activity for recreation and fitness can contribute to slowing bone loss.

Little information is available with regard to the effects of table tennis activity on lowering coronary heart disease risk and bone density in female recreational players. The purpose of this study was to evaluate health-related fitness, plasma lipids, leg muscle strength, and bone stiffness in middle-aged women whose exclusive mode of regular exercise was table tennis. The results are compared to values for active women participating in other forms of exercise, and sedentary controls.

Methods and procedures

Ten female players each were recruited from the Women's Table Tennis Association, the Recreation Volleyball Association of Nagoya City, and jogging clubs. All subjects had a history of at least 15 years of participating in their sports. In addition to these subjects, 10 sedentary females volunteered as controls.

The subjects arrived at the medical laboratory in the morning, after at least a 12 hr fast, and with subjects seated a 10 ml blood sample was drawn from an ante-cubital vein using a disposable syringe. Plasma samples were analyzed for lipid and lipoprotein levels. Total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and triglycerides (TG) were assessed, and the risk ratios of TC/HDL-C calculated. Low-density lipoprotein cholesterol (LDL-C) was estimated according to the equations of Friedewald et al. (14).

After the blood tests, the subjects took a light breakfast and moved to the exercise laboratory, where all assessments except for the treadmill exercise test were conducted on the same day as the blood test. The treadmill test was conducted on a later day.

Ultrasound of the os calcis was measured with an Achilles densitometer (Lunar Corp.). With this instrument, the foot is placed in a waterbath for approximately 3 min. Measurements of the speed of sound (SOS) and the broadband ultrasound attenuation (BUA) are then obtained through a trabecular region on the os calcis approximately 2.5 cm in diameter. The "Stiffness index" (calculated by a computer program provided by the manufacturer from the combined SOS and BUA data) was also recorded.

Body-fat percentage was estimated from skinfolds at 4 sites (triceps, anterior thigh, abdomen, and suprailiac), and body density (18). A compact spirometer (Minato Medicine & Science, Tokyo) was used to evaluate pulmonary functions by calculating the forced vital capacity (FVC) and forced expired volume in one second ($FEV_{1.0}$). The better of two trials was used for data analysis of FVC.

Isokinetic strength of the quadriceps muscle was assessed for the dominant leg with a CYBEX 330 Extremity System (Division of Lumex, Inc. Ronkonkoma, NY). The back rest of the seat was adjusted to 15° from the vertical. Restraining Velcro strapping was placed around the chest and hips, and a knee brace for maximum stabilization clamped over the distal third of the quadriceps. The subjects grasped handles on the sides of the seat, and leg extension was initiated from a relaxed position with approximately 90° of knee flexion. Isokinetic strength was evaluated during knee extension at angular velocities of 120°, 180°, and $240°s^{-1}$. Gravity-effect torque was corrected for all subjects as indicated by the manufacturer.

The subjects were allowed to extend the knee 4 times as practice prior to each test. Three maximal voluntary muscular torque contractions were required. A rest period of 60 seconds was allowed between test speeds. Maximal graded exercise was conducted using a modified Balke-Were protocol. The treadmill (Quinton Q 4000) test started with a workload of 3.3 mph and 0% grade for the first one min. For the second one min, the treadmill was elevated by 2%, and then 1% increments every minute thereafter. Metabolic measurements of expired gases were determined with Mijnhardt Oxycon System (Oxycon Sigma) calibrated with standardized gases. Criteria for $\dot{V}O_{2max}$ included achieving two of the following three: 1) within 10 beats of age-predicted maximum heart rate, 2) RER greater than 1.15, or 3) the subject's inability to continue despite urging by testing staff.

Heart rate was monitored throughout the test using chest electrodes in the CM5 position using the ML1200 electrocardiograph (Fukuda Electronics Co., Tokyo).

Statistical analyses of data were performed using analysis of variance (ANOVA) with repeated measures. When significant differences occurred among the means, a Scheffe post-hoc analysis was utilized to determine which groups were different.

Results

Physical characteristics of the subjects are presented in Table 1. All subjects were similar in age and height, but the sedentary subjects were significantly greater than the joggers and table tennis players in body mass. Resting heart rates (RHR) of the table tennis players and joggers were significantly lower than those of the volleyballers and sedentary women while no difference was found in both resting systolic (BP_S) and diastolic (BP_D) blood pressure among the groups.

Table 2 presents various health related physical fitness data and lung functions of the subjects. The highest value in maximal oxygen uptake ($\dot{V}O_{2max}$) was observed in the jogging group ($P<0.001$). In addition, the value for the table tennis group was also significantly higher ($P<0.05$) than that of the sedentary group. However, no difference was found between the table tennis and jogging groups.

Similar to $\dot{V}O_{2max}$, the jogging and table tennis groups demonstrated lower body fat (%fat) than the sedentary group. FVC in the table tennis group was significantly greater ($P<0.01$) than those in volleyball and sedentary groups. However, the highest value in

$\%FEV_{1.0}$ was seen in the volleyball players.

Figure 1 shows that the mean torques of the knee extensors decreased with increasing angular velocity in the three athletes and control groups.The mean values (SD) at 120°/s in the table tennis, jogging, volleyball and sedentary groups were 65.1 (14.7), 74.6 (9.6), 79.3 (17.1) and 56.1(10.1) newton-meters, respectively. Corresponding values for the testspeed of 180°/s and 240°/s were 47.2 (12.5), 64.4 (10.0), 62.6 (13.8) and 43.6 (5.3); and 34.0 (11.0), 47.7 (8.1), 47.2 (11.5) and 29.8 (5.0),respectively. The volleyball group showed significantly greater muscle strength than the sedentary ($P<0.001$) and table tennis groups ($P<0.05$) at all test speeds. No significant differences were found between the table tennis and sedentary groups at the three test speeds.

Results of the bone stiffness measurements are presented in Fig. 2.The highest value for stiffness was seen in the volleyball group (93.2 with 6.9 SD) followed by the jogging (88.4 with 12.4 SD), table tennis (84.4 with 8.6SD) and sedentary (75.9 with 5.8SD) groups. ANOVA revealed significant differences between the volleyball and sedentary groups ($P<0.001$) and between the jogging and sedentary groups ($P<0.05$). Student t tests were applied and differences found between the table tennis and sedentary groups ($P<0.05$), and between the volleyball and table tennis groups ($P<0.05$).

Relation of bone stiffness and muscle strength is presented in Fig. 3. Bone stiffness was positively correlated with the peak torque of the knee extensors ($r = 0.56$, $P<0.001$). The regression equation was : bone stiffness = 59.08 + 0.39 (peak torque) at a test speed of 120°/s. Significant correlation was also found at the two other test speeds.

Values for serum lipoprotein variables and glucose are shown in Table 3. For all subjects, although mean values of HDL-C in the active groups were higher than that in the control group, a significant difference was only found between the jogging and the sedentary groups ($P<0.05$). The ratio of HDL-C to T-C (T-C/HDL-C) in the jogging group was significantly lower than that in the sedentary group ($P<0.05$). Although the table tennis group showed the ratio as the second lowest, no significant difference was found between this group and sedentary group.

The TG of the jogging group was significantly lower than the value for any other group. Compared with the sedentary subjects, the values of plasma glucose were significantly lower in the jogging and table tennis groups ($P<0.05$). All plasma variables measured in this study were within clinical normal limits.

Discussion

Several epidemiological studies have found that HDL-C is a strong, negative, independent predictor of coronary heart disease in women: an increase of 0.26 mmol/L is associated with a 42-50% decrease in risk (21). One positive influence on HDL-C may be physical activity, as endurance-trained women are reported to have concentrations nearly 30% higher than comparable sedentary women (28). In the present study the jogging group demonstrated very similar values, being 28% higher than the levels of their inactive counterparts. Although no significant difference was found in HDL-C levels between the table tennis and sedentary groups (66.7 vs 56.7 mg/dl), the levels of the table tennis group can be classified as "Excellent" while the sedentary group are "Fair"according to the norm proposed by Cooper (10). The table tennis and volleyball groups had HDL-C levels about 15% and14% higher than the sedentaries respectively, values that are similar to the difference (12%) between active men and sedentaries reported by Gordon et al.(15).

The higher HDL-C level in the table tennis group compared with that in the sedentaries was associated with a significantly higher value ($P<0.05$) in $\dot{V}O_{2max}$. This may indicate that aerobic effects can be expected in table tennis activity if the sport is adopted as a long-term exercise habit. This observation may be supported by a study (16) in which more favorable blood lipid profiles were found in women who were physically active, although not endurance trained, compared to sedentary women.

The T-C/HDL-C ratio, an important predictor of CHD (25,35), was significantly lower ($P<0.05$) in the jogging group than in the sedentary group. No significant difference in this ratio was found between the table tennis and sedentary groups, although the table tennis group showed a lower value. With improved aerobic capacity, the variation in this calculated cardiovascular risk ratio of HDL to total cholesterol decreases, and ratios in the pathological range of <0.2 to >5.0, (2,3), are found less frequently in endurance trained individuals (6).

Low plasma TG concentrations, compared to those for the general population, have been reported for long-distance runners (26,44) and tennis players (43), whose plasma TG levels are typically below 100 mg/dl. In the present study, the jogging group showed a value (70.1 mg/dl) less than 100 mg/dl, significantly lower than the other three groups ($P<0.05$-0.001).

Other measures of cardiovascular fitness include resting heart rate (RHR) and resting blood pressure. It has long been established that trained individuals exhibit a slower RHR compared to untrained persons matched for age and sex (5). In this study the mean RHR of the table tennis players was identical to that of the joggers and was significantly lower than those of the volleyballers ($P<0.01$) and the sedentaries ($P<0.001$) as shown in Table 1. No significant difference in blood pressure was found among the groups. Sedentary persons with normal blood pressure experience either little (12) or no (4) decrease in resting blood pressures with training. Because of the higher $\dot{V}O_{2max}$ and the lower RHR, the cardiovascular fitness levels in the habitual table tennis players are considered to be higher than those of inactive people. The lower % body fat level in the table tennis group may also support the aerobic aspect of the sport.

The Achilles densitometer used in this study has been shown to provide good precision (<2%) in adults (13,24,37). The bone stiffness values for our subjects who have participated in sports for years tended to be higher ($P<0.05$-0.01) than those of the sedentary controls (Fig.3). This result is in agreement with a number of previous studies concerning effects of exercises on bone mineral density (9,11,36,42). Two studies (8,17) selected the calcaneus for bone mineral measurements. One of them (17), using a single energy X-ray densitometer, reported a 12% higher value in a high-load group than in a low load group of 26 to 51 year old men. Another study (8) found an 8% higher bone mineral density in vigorously exercising women (50-60 years old) than in less active women. Our results, which were 10 to 18% higher in the active groups than sedentary group, may be comparable to those reported above.

Nilsson (30) reported that within athlete groups, sports activities involving a heavy load on the lower limb were associated with higher bone density at the distal end of the femur. The swimmers did not differ significantly from the non-athletes when both exercising and non- exercising controls were included in the comparison. In the present investigation measured at the calcaneus, the highest value of bone stiffness was found in the volleyball group followed by the jogging group (Fig.2). The results of this study support the concept that the dominant factor in daily physical activity relating to bone mineral density is the participation in site-specific, high-load activities, i.e., high calcaneal load in this case. The higher values of bone stiffness in the volleyball and jogging groups than in the table tennis group might be related to their daily activities that impose significantly higher forces placed on the calcaneus than table tennis does. When the force imposed on the lower limb is expressed as ground reaction force (GRF_z), the GRF_z on the supportive leg in jogging ranges from 2 to 3 times body weight (27) and is between 5 and 7 times body weight at impact of landing from a jump (23) in volleyball. Compared to jogging and volleyball, table tennis has less GRF_z and less movements of the lower limbs.

Another factor which has an effect on increasing bone density is the type of muscle activity. Muscle strength has been found to correlate positively with bone density (7,33,34). Furthermore, several studies (22,39) have reported that greater bone mineral content may be more related to high-intensity, weight-resistance types of activities than to lower-intensity, endurance types. The finding that muscle stress suffices to stress bone, without a requirement for weight bearing, was reported by Orwoll et al. (31). Our results confirm the correlations between muscle strength and bone mineral density reported by those studies. The highest value of mean bone stiffness was associated with the highest value of mean isokinetic muscle strength measured as knee-extensor peak torque (Figs.1 and 2). Furthermore, a significant positive correlation was found between the bone stiffness of the os calcis and the knee extensor peak torque ($r=0.56$, $P<0.001$) as shown in Fig.3. Such positive correlation in this study was in agreement with studies reporting a significant positive correlation between bone mineral content of the midradius and the power grip of the nondominant extremity (41), and between bone mineral density of the spine and back muscle strength in postmenopausal women (40). Muscle strengths of the lower limb may characterise exercise related to overall physical activity such as walking, jogging, volleyball, soccer, etc. Therefore, decline of muscle strength caused by disuse may be pronounced in the lower limb and be less pronounced in the upper limb. Results of the grip strength measurements (Table 2), which showed no significant difference between the active group and the sedentary controls, reflect this speculation. Consequently, because of less use of the lower limb the bone stiffness on the os calcis for the control was significantly lower than those for the active subjects of volleyball and jogging. For the table tennis players, muscle activities of their lower limbs may not be sufficient to stress the bones. A recommendation to include resistance training besides the table tennis games may be appropriate when we consider bone fitness.

In summary, the results of this study indicate that table tennis players who have engaged in the sport for years as their habitual exercise, had better cardiorespiratory fitness as shown in higher $\dot{V}O_{2max}$ and plasma HDL-C concentrations, and lower RHR and %body fat. However, bone stiffness on the os calcis was lower than those of volleyball and jogging groups. This lower bone mass may be related to the lower muscle strength of their lower limbs and the lower mechanical impact loads placed on the bones of the lower limb, compared with middle-aged women in volleyball and jogging. Therefore, it may be recommended for table tennis players to engage in both strength and high impact endurance-type training to enhance bone mass.

This study was supported by funds from Faculty Award for Research from Chukyo

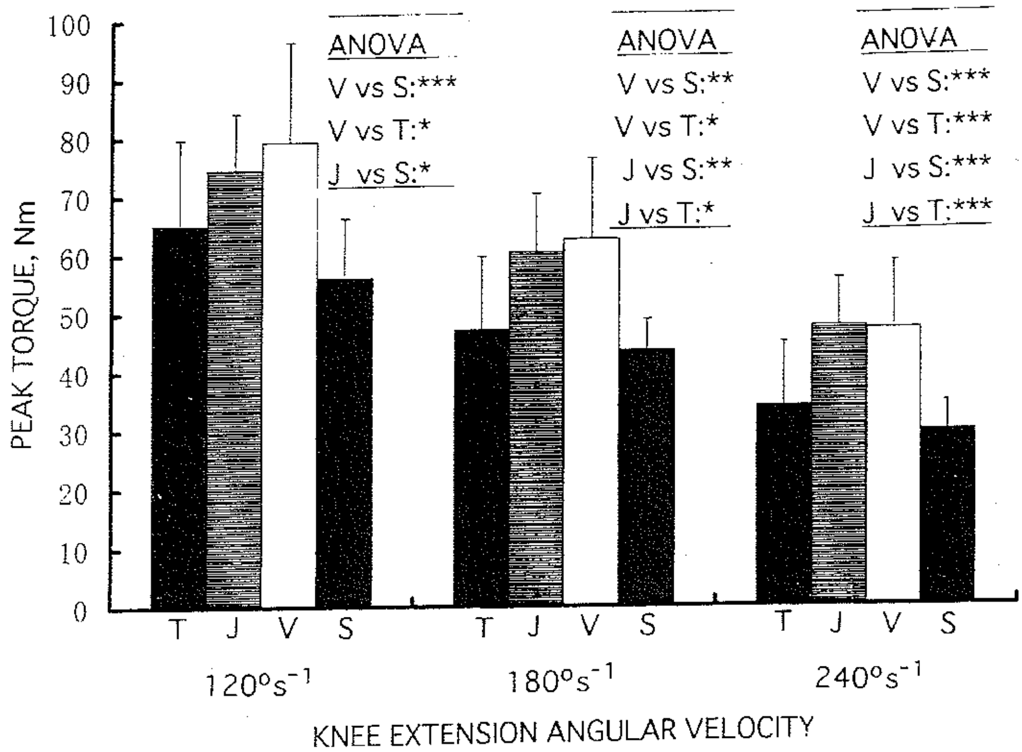
University.

References

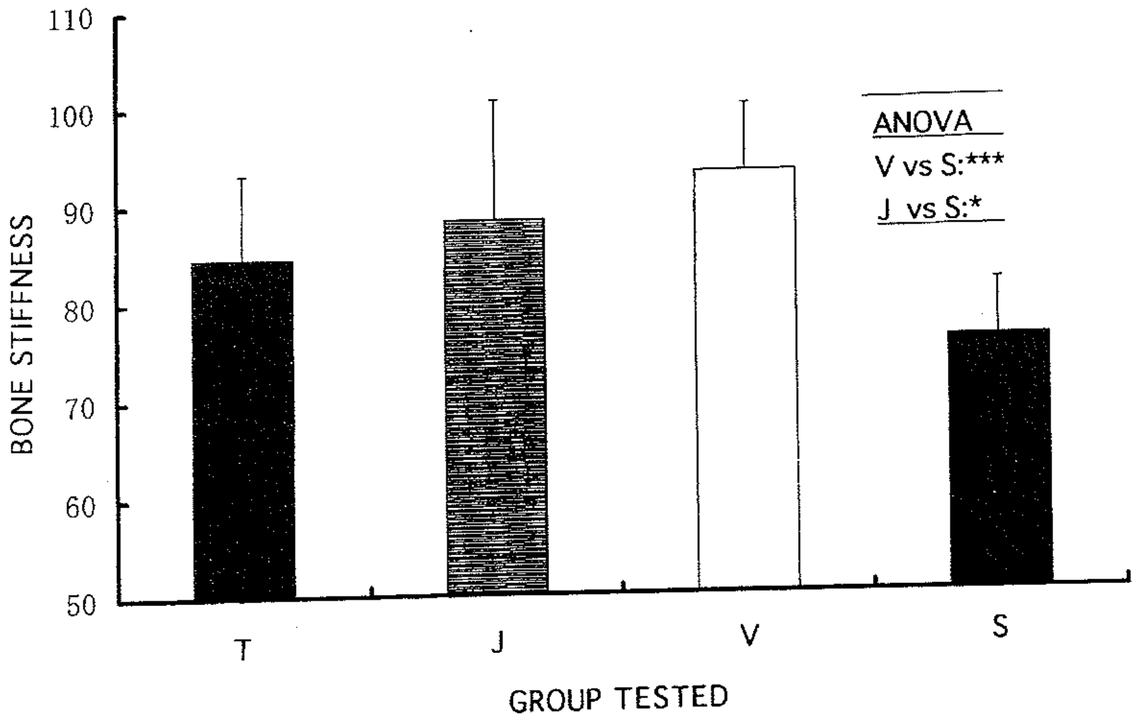
1. American College of Sports Medicine Position Statement (1978): The Recommended Quantity of Exercise for Developing and Maintaining Fitness in Healthy Adults. Med. Sci. Sports 10: viix.
2. Assmann, G., D.J. Betteridge, A.M. Gotto Jr. and G. Steiner (1991). Management of hyper triglyceridemic patients. A treatment classification and goals. Am. J. Cardiol. 68: 30A-34A.
3. Assmann, G. and H. Schulte (1992). Relation of high-density lipopro- tein cholesterol and triglycerides to incidence of atherosclerotic coronary artery disease (the PROCAM experience). Am. J. Cardiol. 70: 733-737.
4. Astrand, P.O. (1956). Human physical fitness with special reference to sex and age. Physiol. Rev. 36: 307-335.
5. Astrand, P.O. and K. Rodahl (1970). Textbook of Work Physiology. pp 403-404, New York, McGraw-Hill.
6. Berg, A. and J. Keul (1985). Influence of maximum aerobic capacity and relative body weight on the lipoprotein profile in athletes. Atherosclerosis 55: 225-231.
7. Bevier, W.C., R.A. Wiswell, G. Pyka, K.C. Kozak, K.M. Newhall and R. Marcus (1989). Relationship of body composition, muscle strength, and aerobic capacity to bone mineral density in older men and women. J. Bone Miner. Res. 4: 421-432.
8. Cheng, S., H. Suominen, T. Parkatti and E.Heikkinen (1991). Bone mineral density and physical activity in 50 to 60 year-old women. Bone and Mineral 12: 123-132.
9. Chow, R., J.E. Harrison and C. Notarius (1987). Effects of two randomised exercise programmes on bone mass of healthy postmeno- pausal women. Brit. Med. J. 295: 1441-1444.
10. Cooper, K.H. (1982). The aerobocs program for total well-being. New York, M. Evans and Company, Inc., pp 93-95.
11. Dalsky, G.P., B.S. Stocke, A.A. Ehsani, E. Slatopolsky, W.C. Lee and S.J. Brige (1988). Weight-bearing exercise training and human bone mineral content in post-menopausal women. Ann. Inter. Med. 108: 824-828.
12. Ekblom, B.(1969). Effect of physical training on oxygen transport system in man. Acta Physiol. Scand.(Suppl.) 328: 1-45.
13. Faulkner, K.G., M.R. McClung, L.J. Coleman and E. Kingston- Sandahl (1994). Quantitative ultrasound of the heel: correlation with densitometric measurements at different skeletal sites. Osteoporosis Int. 4: 42-47.
14. Friedewald, W.T., R.I. Levy and D.S. Fredrickson (1972). Estima- tion of the concentration of low-density lipoprotein cholesterol in plasma, without the use of the preparative ultracentrifuge. Clin. Chem. 18: 499-502.
15. Gordon, D.J., J.L. Witztum, D. Hunninghake, S. Gates and C.J. Glueck (1983). Habitual physical activity and high-density lipoprotein cholesterol in men with primary hyper cholesterolemia. Circulation 67: 512-520.
16. Haskell, W.L., H.L. Taylor, P.D. Wood, H. Schrott and G. Heiss. (1980). Strenuous physical activity treadmill exercise test performance and plasma high-density lipoprotein cholesterol. Circulation 62(Suppl. IV) IV35-IV61.

17. Hutchinson, T.M., R.T. Whalen, T.M. Cleek, J.M. Vogel and S.B. Arnaud (1995). Factors in daily physical activity related to calcaneal mineral density in men. Med. Sci. Sports Exerc. 27: 745-750.
18. Jackson, A.S., M.L. Pollock and A. Ward (1980). Generalized equations for predicting body density of women. Med. Sci. Sports Exerc. 12: 175-182.
19. Kannel, W.B., P. Wilson and S.N. Blair (1985). Epidemiological assessment of the role of physical activity and fitness in development of cardiovascular disease. Am. Heart J. 109: 876-885. 20. Kannel, W.B., A. Belanger, R.D. Agostino and I. Israel (1986). Physical activity and physical demand on the job and risk of cardiovascular disease and death: The Framingham Study. Am. Heart J. 112: 820-825.
21. Kannel, W.B.(1987). Metabolic risk factors for coronary heart disease in women: perspective from the Framingham Study. Am. Heart J. 114: 413-419.
22. Lane, N., W. Beview, M. Bouxsein, R. Wiswell, D. Carter and R. Marcus (1988). Effects of exercise intensity on bone mineral. Med. Sci. Sports Exerc. 20(Suppl. 2) : S51.
23. Lees, A.(1981). Methods of impact force absorption when landing from a jump. Engineering Med. 10: 207-211.
24. Lees, A. and J.C. Stevenson (1993). Preliminary evaluation of a new ultrasound bone densitometer. Calcif. Tissue Int. 5149-152.
25. Lipinska, I. and V. Gurewich (1982). The value of measuring percent high density lipoprotein in assessing risk of cardiovascular disease. Arch. Intern. Med. 142: 469-472.
26. Martin, R.P., W.L. Haskell and P.D. Wood (1977). Blood chemistry and lipid profiles of elite distance runners. Ann. N.Y. Acad. Sci. 301: 346-360.
27. McMahon, T.A. and G.C. Cheng (1990). The mechanics of running: how does stiffness couple with speed. J. Biomech. 23: 65-78.
28. Moore, C.E., H. Hartung, R.E. Mitchell, C.M. Kappus and J. Hinderlitter(1983). The relationship of execise and diet on high- density lipoprotein cholesterol level in women. Metabolism 32: 189-196.
29. Morris, J.N., D.G. Clayton, M.G. Everitt, A.M. Semmence and E.H. Burgess (1986). Exercise in leisure time: coronary attack and death rates. Br. Heart J. 63: 325-334.
30. Nilsson, B.E. and N.E. Westlin (1971). Bone density in athletes. Cli. Orthopaedics Related Res. 77: 179-182.
31. Orwoll, E.S., J. Ferar, S.K. Oviatt, K. Huntington and M.R. McClung (1987). Swimming exercise and bone mass. In: Christiansen, C., J.S. Johnson and R.J. Riis eds. Osteoporosis. Viborg Sweden: Norhaven A/S pp. 494-498.
32. Paffenbarger, R.S., R.T. Hyde, A.L.Wing and C.C. Hsieh (1986). Physical activity, all-cause mortality and longevity of college alumni. N. Engl. J. Med. 314: 605-613.
33. Pocock, N.A., J.A. Eisman, T.H. Gwinn, P.N. Sambrook, M.G. Yeates and J. Freund (1988). Regional muscle strength, physical fitness and weight but not age predict femur bone mass. J. Bone Miner. Res. 3: 584-588.
34. Pocock, N.A., J.A. Eisman and T.H. Gwinn (1989). Muscular strength, physical fitnes, and weight but not age predict femoral neck bone mass. J. Bone Miner. Res. 4: 441-448.
35. Rhoads, G.G., C.L. Gulbrandsen and A. Kagen (1976). Serum lipoproteins and coronary heart disease in a population study of Hawaii-Japanese men. N. Engl. J. Med.

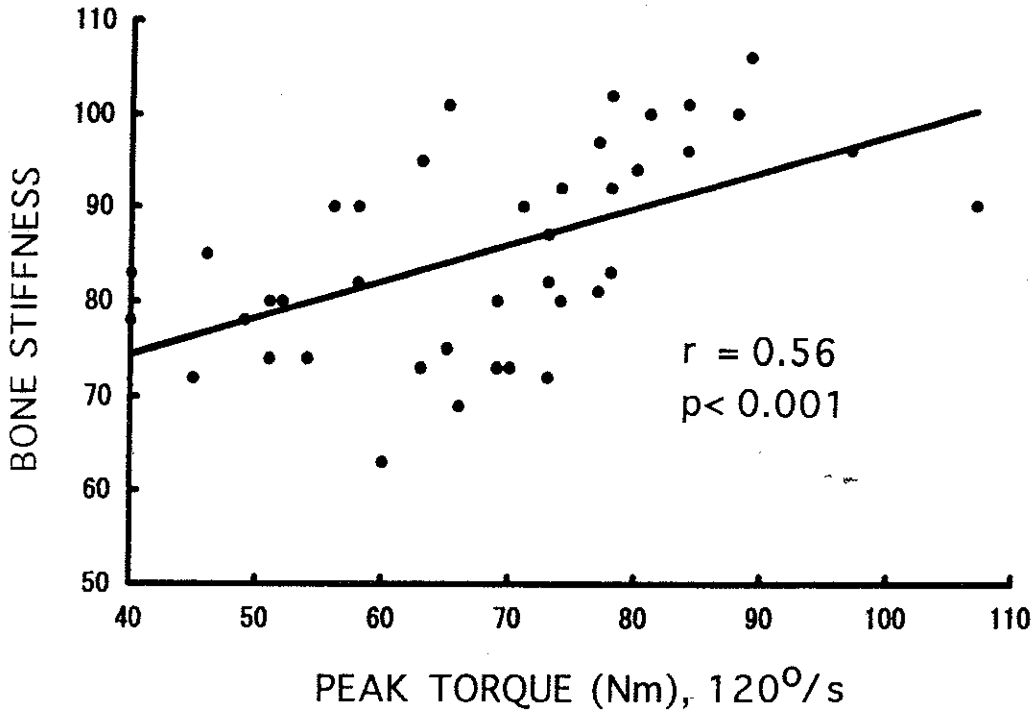
294: 293-297.
36. Sandler, R., J. Cauley, R. LaPorte, A. Kriska, D. Hom and D. Sashin (1987). Physical activity and postmenopausal bone loss: Results of a 3-year clinical trial. Calcif. Tissue Int. 41: 65-69.
37. Schott, A.M., D. Hans, E. Sornay, P.D. Delmas and P.J. Meunier (1993). Ultrasound measurements on os calsis: Precision and age- related changes in a normal female population. Osteoporosis Int. 3: 249-254.
38. Shaper, A.G. and G. Wannamethee (1991). Physical activity and ischemic heart disease in middle-aged British men. Br. Heart J. 66: 584-594.
39. Simkin, A., J. Ayalon and J. Leichter (1987). Increased trabecular density due to bone-loading exercises in postmenopausal osteoporotic Kobayashi et al. 23 women. Calcif. Tissue Int. 40: 59-63.
40. Sinaki, M. and K.P. Offord (1988). Physical activity in postmenopausal women: effect on back muscle strength and bone mineral density of the spine. Arch. Phys. Med. Rehabil. 69: 277-280.
41. Sinaki, M., H.W. Wahner and K.P. Offord (1989). Relationship between grip strength and related regional bone mineral content. Arch. Phys. Med. Rehabil. 70: 823-826.
42. Stillman, R.J., T.G. Lohman, M.H. Slaughter and B.H. Massey (1986) Physical activity and bone mineral content in women aged 30 to 85 years. Med. Sci. Sports Exerc. 18: 576-580.
43. Vodak, P.A., P.D. Wood, W.L. Haskell and P.T. Williams (1980). HDL-cholesterol and other plasma lipid and lipoprotein concentrations in middle-aged male and female tennis players. Metabolism 29: 745-752.
44. Wood, P.D., W. L. Haskell, H. Klein, S. Lewis, M.P. Stern and J.W. Farquhar (1976). The distribution of plasma lipoproteins in middle-aged male runners. Metabolism 25: 1249-1257.



1. Knee extension peak torque in groups with different exercise habits.
Values are mean ± SD. * P<0.05, *** P<0.001.
T denotes table tennis, J jogging, V volleyball and S sedentary groups.



2. Bone stiffness on the os calcis in groups with different exercise habits. Values are mean ± SD. * P<0.05, ** P<0.01, * P<0.001.
T denotes table tennis, J jogging, V volleyball and S sedentary groups.



3. Relationship between bone stiffness on the os calcis and level of peak torque of the knee extensors.

Table 1. Physical characteristics of fitness athletes and sedentary controls [mean (SD)]

	Age (years)	Height (cm)	Mass (kg)	RHR (bpm)	BPs (mmHg)	BPd
Table Tennis(T) Players (n=10)	49.4 (4.2)	154.2 (4.5)	53.4 (5.8)	64 (5)	122 (16)	81 (13)
Joggers (J) (n=10)	50.0 (7.2)	154.4 (2.9)	50.1 (3.2)	66 (6)	117 (14)	79 (7)
Volleyball (V) Players (n=10)	49.2 (2.2)	152.7 (2.2)	55.3 (3.3)	74 (8)	119 (8)	79 (7)
Sedentary (S) Controls(n=10)	49.8 (2.7)	154.2 (2.7)	58.3 (7.4)	79 (6)	124 (17)	84 (4)
ANOVA			J vs S* T vs S*	J vs S*** J vs V* T vs S*** T vs V**		

Significantly different, * P<0.05; ** P<0.01; *** P<0.001

Table 2. Selected health related physical fitness and lung function for fitness athletes and sedentary controls [mean (SD)]

	$V_{O_2\ max}$ (ml/kg/min)	Body fat (%)	Sit & Reach (cm)	Grip (kg) R	Grip (kg) L	FEV (L)	$FEV_{1.0}$ (L)	$\%FEV_{1.0}$
Table Tennis (T) Players (n=10)	35.9 (3.1)	27.5 (4.4)	12.6 (6.9)	26.6 (4.1)	24.7 (3.4)	2.82 (0.41)	2.36 (0.31)	83.6 (4.0)
Joggers (J) (n=10)	44.3 (7.6)	23.7 (4.0)	15.4 (5.1)	31.2 (6.2)	28.1 (5.4)	2.74 (0.56)	2.24 (0.47)	83.3 (3.5)
Volleyball (V) Players (n=10)	31.3 (3.0)	28.2 (3.1)	16.2 (5.6)	27.5 (3.4)	25.1 (3.4)	2.71 (0.11)	2.36 (0.10)	87.1 (3.6)
Sedentary (S) Controls(n=10)	27.2 (8.8)	33.1 (3.3)	9.7 (4.7)	24.8 (3.2)	22.1 (2.7)	2.45 (0.45)	1.96 (0.24)	80.0 (3.2)
ANOVA	J vs S*** J vsV* T vs S*	T vs S* J :vs S** J :vs V*		J vs S*		T vs S** T vs V**		V vs S**

Significantly different, * P<0.05; **P<0.01; ***P <0.001

Table 3. Plasma lipid variables and glucose for fitness athletes and sedentary conterols [(mean (SD)]

	Total cholesterol (mg/dl)	HDL cholesterol (mg/dl)	LDL cholesterol (mg/dl)	T-C/HDL	Triglyceride (mg/dl)	Glucose (mg/dl)
Table Tennis(T) Players(n=10)	206.3 (28.5)	66.7 (14.8)	117.5 (21.4)	3.1 (0.8)	109.8 (84.8)	91.7 (5.2)
Joggers (J) (n=10)	228.0 (30.5)	78.4 (14.9)	136.0 (32.0)	2.9 (0.9)	70.1 (1.8)	84.7 (6.3)
Volleyball (V) Players (n=10)	214.4 (28.2)	65.8 (14.6)	127.8 (30.4)	3.3 (0.8)	104.0 (38.4)	92.7 (10.3)
Sedentary (S) Controls(n=10)	212.1 (13.1)	56.7 (16.6)	131.5 (27.9)	4.0 (1.0)	117.3 (61.5)	101.1 (10.0)
ANOVA		J vs S*		J vs S*	J vs T*** J vs S** J vs V*	J vs S* Tvs S*

Significantly different, * P<0.05; ** P<0.01; *** P<0.001