Anterior-posterior knee laxity increased by exercise

Quantitative evaluation of physiologic changes

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To quantify physiologic changes in anterior-posterior laxity of the normal knee caused acutely by exercise, we evaluated the exercise level and the duration of exercise needed to cause changes in laxity, the magnitude of changes in laxity, and the time needed for laxity to return to the level before exercise, by continuously applying a fixed exercise load.

After a 20-minute run at 7 km/hr, anterior laxity with a displacement force of 133 N increased by about one third, and the compliance increased by one half with anterior drawer between 0 and 67 N. These changes were maintained at a similar level during exercise. The levels before exercise were restored gradually over 1 hour after exercise. As the muscle strength showed no changes during exercise, we consider these changes in laxity are not associated with a decrease in muscle strength. Furthermore, since the changes in knee laxity after triathlon (in which the knee is subjected to prolonged excessive exercise) are similar to those after running at 7 km/hr, we believe that the magnitude of changes in laxity after exercise is fixed, regardless of the level of the exercise load. Moreover, the threshold of exercise that causes the maximum change is low.

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Submitted 98-04-24. Accepted 99-02-09

Acute changes in knee laxity after exercise have been reported by several investigators (Weisman et al. 1980, Stoller et al. 1983, Skinner et al. 1986, Steiner et al. 1986, Johannsen et al. 1989, Sakai et al. 1992). The knee joint is considered to have viscoelastic properties during exercise. However, details about physiologic changes in laxity of the normal knee caused by exercise have not been quantified.

We quantified the time-course of physiologic changes in anterior-posterior laxity of the normal knee caused by exercise, i.e., the time when the changes occurred, the exercise load required to cause changes, and the time needed for recovery.

Subjects and methods

Test groups

Two groups were examined. Goup 1 performed mild exercise, and group 2 performed hard exercise.

Group 1 comprised 10 male athletes from the college volleyball team. These subjects were chosen because they were physically healthy and had no history of knee disorders, and on physical examination no knee abnormalities were found. Their mean age was 22 (19–23) years, mean height was 173 (165–186) cm, and body weight was 63 (57–76) kg.

Group 2 comprised 10 male athletes randomly selected among 390 male participants in the 13th All-Japan Triathlon Series at Kaike. They were physically healthy and had no history of knee disorders, and on physical examination no knee abnormalities were found. Their mean age was 31 (28–34) years, mean height was 178 (165–179) cm, and body weight was 64 (55–72) kg. Exercise consisted of 135 km biking and 42 km marathon; swimming was canceled because of bad weather. The mean time used for the race among our test persons was 8 hours and 46 minutes.

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Table 1. Comparison of knee arthrometer measurements (mm) in the right and left knees. Mean (SD)

	Anterior laxity			Posterior laxity
	67 N	89 N	133 N	89 N
Group 1, n 10				
Right knee	4.3 (1.4)	5.2 (1.4)	6.1 (2.1)	2.8 (1.9)
Left knee	4.5 (1.2)	5.1 (1.2)	6.2 (1.3)	3.0 (1.0)
Group 2, n 10				
Right knee	5.0 (1.2)	5.8 (1.2)	6.8 (1.4)	3.2 (1.0)
Left knee	5.0 (1.9)	5.7 (2.1)	6.3 (2.2)	4.1 (1.1) *

Right versus left knee: * $p < 0.005$, paired t-test

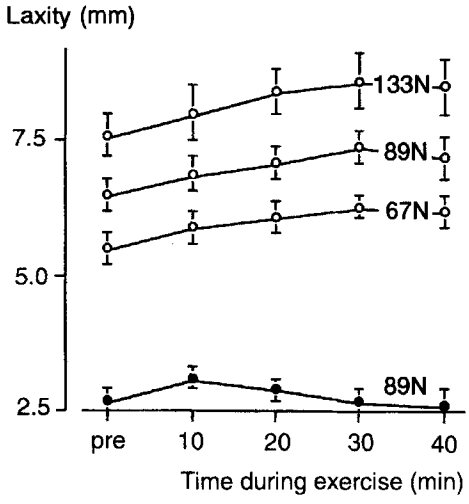


Figure 1. Anterior (○) and posterior (●) knee laxity before and during treadmill running at 7 km/hr. Pre – preexercise.

Test protocol

Group 1. After the initial laxity measurements, the subjects ran on a treadmill at 7 km/hour. The joint laxity was measured every 10 minutes after they begun to run, and the time when changes in laxity appeared was noted.

On another day, after the initial measurements of laxity and muscle strength, the subjects ran at the same speed for 30 minutes, and the time for recovery of laxity from changes due to exercise was evaluated by serial measurements of laxity and muscle strength.

Group 2. Laxity was measured on the day before and immediately after the triathlon race, and changes in laxity after prolonged intense exercise were evaluated.

Apparatuses for tests

All laxity measurements were made using the KT-2000 knee ligament arthrometer (Med Metric, San Diego, CA). The test was conducted at 20 degrees of knee flexion, with the foot in a neutral position. Anterior laxity was measured at 133 N and posterior laxity measurements were made at 89 N. The data output was printed on an X-Y plotter as applied force versus tibial displacement.

The force-displacement curve was analyzed with a digitizer, anterior laxity at 67, 89, and 133 N, posterior laxity at 89 N, and compliance, i.e., the change in displacement required to produce incremental changes in force, were determined. All measurements were performed by one investigator (KN). They were made in triplicate, and the mean values were used in the analyses.

Before exercise, no laterality was observed in anterior laxity or posterior laxity in group 1, but posterior laxity was significantly greater in the left than in the right knee in group 2 (Table 1). Therefore, only the values obtained in the right knee were used in the subsequent evaluations.

Concerning muscle strength, isometric knee extension and flexion powers were measured, using a Hydromusculator GT500 (OG Giken, Tokyo) at 20° of knee flexion, with the foot in a neutral position.

Statistics

The time taken for changes in knee laxity and changes in muscle strength were analyzed with the repeated measure ANOVA and Dunn test. The laxity values of the right and left knees were compared with the paired two-tailed t-test. The knee laxity values before and after exercise were compared with the paired two-tailed t-test. The differences in mean values between the groups were assessed with the t-test. A p-value less than 0.05 was regarded as statistically significant.

The reproducibility was evaluated in 6 healthy men (mean age 26 years). Knee laxity was measured 6 times on the same day in each subject by one investigator (KN), and coefficients of variation (CV) were calculated.

CV of the measurements were 3.5% with anterior drawer at 133 N and 8.7% with posterior drawer at 89 N.

Table 2. Comparison of knee arthrometer measurements before and after exercise (right knee). Mean (SD)

	Anterior laxity			Posterior laxity
	67 N	89 N	133 N	89 N
Group 1, n 10 (30-min run)				
Pre-exercise	4.3 (1.4)	5.1 (1.6)	6.3 (2.1)	2.7 (0.9)
Postexercise	6.2 (1.3) [b]	7.2 (1.5) [b]	8.4 (1.8) [b]	2.8 (0.7)
Group 2, n 10 (Triathron)				
Pre-exercise	5.0 (1.2)	5.8 (1.2)	6.8 (1.4)	3.2 (1.0)
Postexercise	5.9 (1.2) [a]	7.1 (1.6) [a]	8.3 (2.0) [a]	3.1 (1.3)

No significant difference in any values between groups 1 and 2. Pre- versus post-exercise: [a] $p < 0.005$, [b] $p < 0.001$, paired t-test.

Table 3. Compliance (× 10 mm/lb) before and after exercise (right knee). Mean (SD)

	Anterior drawer			Posterior drawer
	0–67 N	67–89 N	89–133 N	0–89 N
Group 1, n 10 (30-min run)				
Pre-exercise	2.0 (0.9)	1.5 (0.8)	1.2 (0.5)	1.4 (0.5)
Postexercise	4.1 (0.9) [b]	2.0 (1.0)	1.9 (1.8)	1.5 (0.6)
Group 2, n 10 (Triathron)				
Pre-exercise	3.4 (0.8)	1.5 (0.4)	1.0 (0.3)	1.6 (0.5)
Postexercise	4.0 (0.8) [a]	2.4 (1.9)	1.2 (0.8)	1.5 (0.6)

Pre- versus post-exercise: [a] $p < 0.005$, [b] $p < 0.001$, paired t-test.

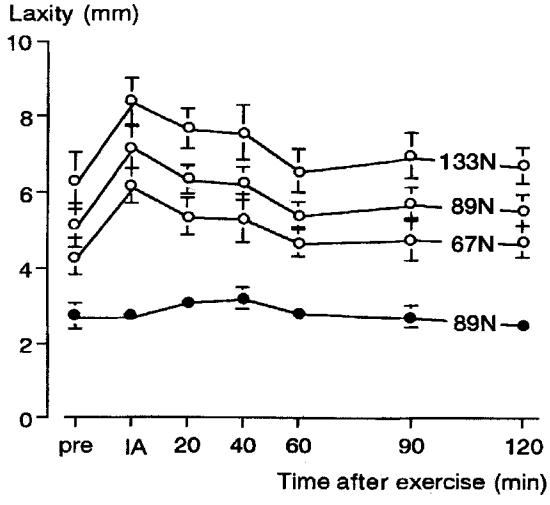


Figure 2. Anterior (○) and posterior (●) knee laxity before and after a 30-minute run. Pre – preexercise, IA – immediately after 30 min. running.

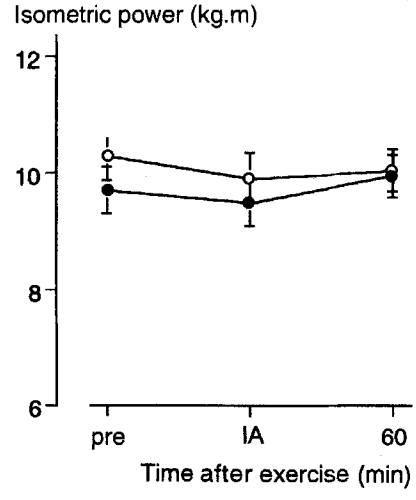


Figure 3. Isometric muscle power in extension (●) and in flexion (○) before and after a 30-minute run. Pre – preexercise, IA – immediately after 30 min. running.

Results

Group 1. Anterior laxity increased from 20 minutes after the beginning of the treadmill run at 7 km/hr, compared to the value before exercise ($p = 0.4$) and remained constant thereafter. Posterior laxity was similar before and after the exercise (Figure 1).

After a 30-minute run, anterior laxity had increased, compared to the value before exercise ($p = 0.001$), but no changes were noted in posterior laxity (95% confidence interval (CI) for the difference: –0.6 mm to 0.6 mm; Table 2). Compliance after exercise increased above the level before exercise with anterior drawer at 0–67 N ($p = 0.001$; Table 3). Anterior laxity increased ($p = 0.001$) immediately after a 30-minute run, decreased gradually thereafter, and returned to the level before exercise 1 hour after exercise. No change was observed in posterior laxity (Figure 2). The isometric knee flexion and extension powers did not differ before and after a 30-minute run (Figure 3).

Group 2. After the race, anterior laxity increased ($p = 0.005$), but no change was noted in posterior laxity (95% CI for the difference: –1.0 mm to 0.44 mm; Table 2). Compliance after the

race increased ($p = 0.005$) with anterior drawer at 0–67 N (Table 3).

Anterior and posterior laxity after exercise were similar in the two groups before and after exercise (Table 2).

Discussion

Reports on changes in knee laxity after exercise have varied according to exercise type, laxity evaluated, and the measuring instruments used. Weisman et al. (1980) reported that valgus compliance increased by mean 23% after sports activities such as basketball, skiing and hockey, and that the values were restored 1 hour after exercise. Stoller et al. (1983) reported that torsional knee laxity, with 10-Nm internal and external torque to the tibia, increased by 14% after 30 minutes of running and that it returned to the level before exercise 52 minutes after running. Steiner et al. (1986) reported that, in sedentary controls who were mainly sitting, no change in laxity was noted over 2 hours. Squat power lifters showed no change in laxity. However, 20% increases in mean anterior and posterior laxity were noted in basketball players after 90 minutes of practice and in joggers after a 10-km race. Sakai et al. (1992) reported that anterior knee laxity in female basketball players increased by about 50% after game-style practice and the increased laxity recovered completely after 5 hours.

We found that after a 20-minute run at 7 km/hr, anterior laxity at 133 N increased by one third, and compliance increased by one half, with anterior drawer at 0–67 N. These changes were maintained at a similar level during exercise, but the levels before exercise were restored gradually over 1 hour after exercise. Since muscle strength showed no changes during exercise, we consider the changes in laxity are not associated with a decrease in muscle strength. Furthermore, since the changes in knee laxity after triathlon (in which the knee underwent prolonged excessive exercise) were similar to those after running at 7 km/hr, the magnitude of changes in laxity after exercise seems to be fixed, regardless of the level of exercise load. Moreover, the threshold of exercise that causes the maximum change is low.

This work was partly supported by a grant from the Japanese Ministry of Education (No. 07771150).

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