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Original Article

Changes of general fitness and muscle properties following police cadet training

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Abstract. [Purpose] This study was performed to examine the relationship between physical performance and muscle properties during police cadet training. The study's hypothesis was that improved physical performance brought about by training, would in turn cause a reduction in muscle flexibility. [Subjects and Methods] Fifty-nine police cadets were included in this study. Standard fitness tests and quantitative assessments of muscular biomechanical properties were conducted before, during and after the 20-week cadet training. [Results] General fitness had improved at the end of the police cadet training. There was no significant decrease in muscle flexibility as measured by the Sit-and-Reach test. However, muscle compliance of the non-dominant leg measured by the relaxation coefficient had decreased at the end of the police cadet training. [Conclusion] The increased sit-and-reach distance could be due in part to strengthening of the abdominal muscles. On the other hand, the biomechanical test, which was specific to muscle extensibility, showed a reduction in the relaxation coefficient of the non-dominant leg. Our data suggests that changes in muscle compliance as a result of lower extremity training should be considered. This data may be useful in the design of a training protocol that prevents the potential injuries caused by reduced muscle flexibility.
Key words: Police cadet, Flexibility, Muscle property

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INTRODUCTION

Strength and endurance training can lead to many physiological changes within the human body and it aims to improve overall physical performance. Training improves performance, in part, due to muscular adaptations in morphology, such as conversion between fiber types, and altered biomechanical properties, tendon stiffness, and increased elasticity of muscles[1)]. Such intrinsic muscular adaptations of mechanical properties are thought to enhance, or impact, muscle performance during muscle contraction[2, 3)]. Therefore, training is performed in an attempt to enhance the ability of a muscle to generate force, or to control the length change of its fibers in relation to the stretch of its tendon, which depends on the architecture and the physiological properties of its fibers[4)].

These morphological and biomechanical changes may impose an increased risk of injury on the muscle itself, due to the development of the stiffer muscle tissue necessary to generate increased force. In a study performed to determine the relationship between running economy and muscle stiffness it was postulated that there was a positive relation between muscle stiffness and power production[5)]. As a muscle increases in strength, it loses flexibility in order to maintain the elasticity to create a forceful contraction. Accordingly, the flexibility gained by active stretching might reduce the muscle power output[6)]. However the reduced flexibility may affect the sport performance[7)]. Injuries, such as a hamstring strain, are commonly associated with exercise that involves fast movements and sudden acceleration. The hamstrings are recognized as being the most frequently injured structure, and are estimated to account for between 12% and 16% of injuries in professional soccer leagues[8, 9)]. Hamstring injuries are injuries that often require a long recovery period and are especially prone to recurrent injury[10)].

The physical fitness component of police cadet training often emphasizes muscle power and endurance training. This might place the cadets at a higher risk of hamstring injuries. It is our understanding that there is no literature on the changes in muscle properties elicited by police cadet training. Therefore, our study aimed to investigate the effects of this physical exercise on lower extremity muscle properties. By observing the effects of physical exercise on Lowell Police Academy cadets, in Lowell, MA in the United States, this study aimed to describe the relationship between overall performance in physical activity, muscle property, and police cadet training. The study's hypothesis was that over the 20-week training period, the cadets would show changes in muscle properties and a decline in the flexibility of the hamstring and calf compound.

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SUBJECTS AND METHODS

Fifty-nine (10 females and 49 males) police cadets from the Lowell Police Academy, class of 2013, were initially recruited for the study. Eight males dropped out from the study due to schedule conflicts preventing them from attending all assessment sessions. All subjects prior to the study reported no known neuromuscular disorders, no recent (within a year) lower extremity injury or surgery, and no prosthetic joint. Subjects were excluded if their range of a straight leg raise (SLR) was less than 30°, greater than 100°, or the stabilized leg during SLR could not maintain at 0° of hip flexion. Fifty-one subjects were included in the data analysis. This study was approved by the institutional review board of University of Massachusetts Lowell, MA, USA. Informed consents were acquired before the study. Table 1 shows the demographics of the 51 subjects at the time they were recruited before undergoing the standard cadet training.

Standard fitness tests and quantitative assessments of muscle properties were conducted pre, during (1st and 2nd evaluations) and at the end (3rd evaluation) of cadet training at five to six weeks interval during the cadet training. Standard fitness tests included upper extremity muscle strength and endurance (bench-press, push-up and pull-up), trunk muscle strength and endurance (sit-up), the flexibility of back and leg muscles (sit and reach test), and general power (timed 1.5 miles run). The body size and the body composition were recorded at each of the four sessions.

To quantify the biomechanical properties of the hamstrings and calf compound, Ajjolos (Seign, LLC, North Reading, MA, USA) shown in Fig. 1 was used to evaluate subjects within the same week of the standard fitness test. Subject assumed the pre-stretch position, and he/she was positioned supine on the mat. A coin flip determined which lower extremity would be measured first for each subject. Once the subject was in proper alignment with the device and self-reportedly comfortable, the subject was instructed to raise the randomly selected leg and place it (ankle or calf) upon the inflatable ball. In most cases, the subject's initial positioning resulted in the raised leg having a SLR of approximately 70° or more depending on each individual's flexibility (Fig. 1). Once the test position was reached, the subject was requested to relax and to allow the device to passively apply a gentle stretch to the lower extremity. The device's passive applicator was gradually inflated to 0.3 PSI, over approximately 5 seconds, applying a gentle stretch to the subject's hamstring musculature. At the end of the inflation, the pressure placed on the ball over a 60 second timespan was recorded. After 60 seconds, the device gradually released the applied passive stretch by deflating the ball. Once the subject was back in the initial (pre-stretch) position, he/she was asked to assume a similar position with the opposite lower extremity, and the procedure was repeated.

The recorded pressure data were plotted against time over the 60-second period for each lower extremity (Fig. 2). Linear curve fitting was used to determine the slope of the decay curve. The slope of the fitted curve was defined as the relaxation coefficient (Relx) in this study. A smaller Relx (more negative number) implies a more compliant, i.e. less stiff, passive element of the soft tissues. The highest point of

Table 1 Descriptive characteristics of subjects at the time of recruitment

	Male (n=41)	Female (n=10)	Overall (n=51)
Age (yrs)	27 (3.8)	24.9 (3.2)	26.6 (3.7)
Height (cm)	177.4 (9.3)	166.8 (7.2)	175 (9.9)
Weight (kg)	85.2 (15.6)	64.5 (37.7)	81.2 (17.2)
Body fat (%)	15.6 (6.1)	22.8 (13.3)	17.0 (6.7)

Values are Mean (SD)

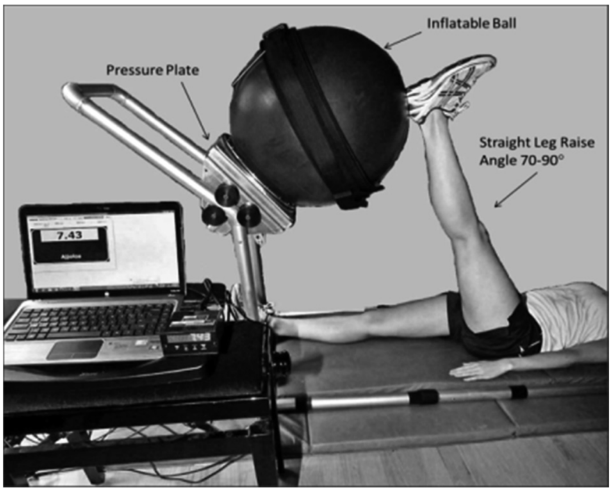

Fig. 1. Experimental setup for evaluating the biomechanical properties of the hamstring and the calf compound
A device containing a pressure plate and an inflatable ball connected to an electric pump was connected to a computer to record the tension changes during passive stretching. The device was activated manually using a 'dead man' switch so that the experimenter could stop ball inflation by taking a finger off the switch.

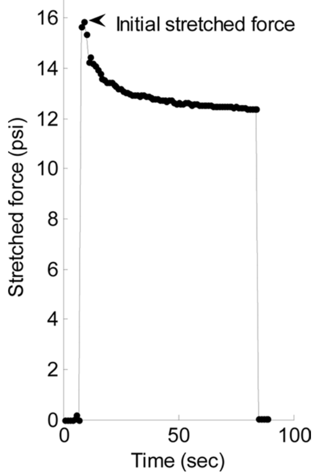

Fig. 2. An example of the pressure data measured by the device during the test in two consecutive sessions (before and after the police cadet training)
The decay curve indicates the stretched muscle became more relaxed over the one minute of stretching resulting in less pressure being applied to the inflated ball. The initial stretch force indicates the resistance caused by the stretched leg.

Table 2. Body size and composition

	Height (cm)	Weight (kg)	Body fat (%)
	Mean (SD)	Mean (SD)	Mean (SD)
Pre	175.4 (9.4)	82.1 (16.2)	17.0 (6.3)
1st Eval	175.8 (8.9)	82.0 (16.1)	16.0 (5.8)*
2nd Eval	175.8 (8.9)	80.1 (15.2)*^	16.3 (5.6)
3rd Eval	175.9 (9.5)	79.8 (14.4)*^	16.5 (5.6)

Values are Mean (SD)

*: $p<0.0125$ compared to *Pre* session, ^: $p<0.0125$ compared to *second* session

Table 3. Time course changes in general fitness of the police cadets

	Sit- up	1.5 mile run	Sit-and-reach
Pre	36.1 (8.0)	710.6 (67.3)	17.3 (2.4)
1st Eval	41.0 (7.4)*	653.8 (63.9)*	18.4 (2.2)*
2nd Eval	43.5 (7.1)*^	641.5 (81.7)*	19.1 (2.3)*^
3rd Eval	45.0 (6.0)*^#	641.2 (84.2)*	19.9 (2.1)*^#

Values are Mean (SD)

* $p<0.0125$ compared to *Pre* session, ^: $p<0.0125$ compared to *Post* session, #: $p<0.05$ compared to the previous session

Table 4. Biomechanical properties of the hamstring and calf compound

	ISF (dominant)	ISF (non-dominant)	Relx (dominant)	Relx (non-dominant)
Pre	10.73 (2.94)	10.03 (2.46)	−0.0079 (0.0118)	−0.0075 (0.0135)
1st Eval	9.63 (2.76)	9.66 (2.67)	−0.0061 (0.01054)	−0.0055 (0.01322)
2nd Eval	9.43 (2.55)*	9.53 (2.62)	−0.0079 (0.01162)	−0.0101 (0.0119)
3rd Eval	9.23 (2.61)*	8.96 (2.31)*	−0.0035 (0.02329)	−0.0039 (0.1314)#

Values are Mean (SD)

*: $p<0.0125$ compared to *Pre* session, #: $p<0.0125$ compared to the previous session

the stretching curve was defined as the initial stretch force (ISF). For each subject, the highest ISF indicated the tighter muscle group.

Repeated measures ANOVA was used in this study to compare measures (the relaxation coefficient (Relx), initial stretched force (ISF), sit-and-reach (SR) distance, sit-up and 1.5 miles run time) and body size/composition changes among the four longitudinal sessions. Bonferroni correction was then used as *post-hoc* test to examine the main effects. All analyses were performed using IBM SPSS Statistics 20 (IBM, Chicago, IL, USA) with a significance level of 0.0125.

RESULTS

Table 2 demonstrates the body size and the body composition of all subjects over the time course of the study. No significant height changes were seen while statistically significant weight losses were observed at the second and third evaluations compared to the pre and first evaluation sessions ($p<0.001$). Body fat decreased significantly after the first five weeks of the cadet training ($p<0.001$) but increased at the second ($p=0.009$) evaluation session.

Table 3 shows the changes of general fitness after the cadet training. The general fitness improved as expected. The time spent in running 1.5 miles significantly reduced at about the five weeks into the cadet training ($p<0.001$) and the effect was maintained to the end of training. Group data demonstrated that SR and sit-ups improved significantly at all three evaluation sessions ($p<0.001$).

Table 4 shows the biomechanical properties of back leg soft tissues on each side. The ISF of the dominant leg decreased after the training ($p=0.03$) and was maintained at the follow-ups while there was no significant change of Relx. The ISF of the non-dominant side did not change after the training, but there was a significant difference between Pre and 2nd follow-up ($p=0.007$). A significant difference was found in Relx of the non-dominant side between the first and 2nd follow-up ($p=0.025$).

DISCUSSION

As expected, an improvement in general fitness was observed during and at the end of the cadet training. There was no significantly negative change in the flexibility-related measures (Sit-and-reach, ISF, Relx) of the subjects between the pre and first evaluation sessions. The ISF decreases observed at the 2nd and 3rd evaluation sessions indicate that back leg musculature became less stiff and required less force to be moved to the extreme position. However the changes in ISF were not symmetrical which indicates the importance of being able to recognize the differences between two legs. Although the changes in the SR test and ISF were contrary to our hypothesis, the Relx of the both legs showed an increasing trend (less compliant) but it was not statistically significant except at the end of the cadet training.

The usage of SR is controversial, but it was recommended for estimating the extensibility of the hamstring when other forms of flexibility tests are impractical[11]. The criterion-related validity of the SR test might be impacted by the hamstring extensibility specifically among subjects with reduced hamstring extensibility[12]. Moreover, the SR test alone does not discriminate the potential differences between two legs (and there were asymmetrical changes in ISF) or the contributors to muscle properties. A sophisticated setup on the other hand can avoid these hindrances. For example, a stress relaxation curve was used to estimate muscle extensibility post-exercise in rabbits[13]: a second order polynomial was fitted to the relaxation curve over the period of 300 seconds after the stress was applied. In our study, we used a simple yet quantitative method to assess the muscle property. We a chose 60-seconds recording window and a linear regression model, which is appropriate because most tension decay occurs in the first 60 seconds after the application of a stretching force[13]. SR and ISF demonstrated changes opposite to Relx, but it is possible that the changes in Relx were confounded by back muscle extensibility, abdominal muscle strength, body and head positions, etc. Our data shows there were increases in both sit-up numbers and SR distance. Therefore, the possibility of an increase in SR distance as a result of an enhanced abdominal muscle performance cannot be ruled out. Measuring the straight leg raise with more sensitive sensors would allow us to better study the compliance of hamstrings.

Though the odds of developing a hamstring injury may seem intimidating, animal evidence shows that techniques such as passive stretching tend to reduce skeletal muscle injuries[14]. This might be one of the reasons that although the standard police cadet training emphasizes muscle power and endurance training, with warm-up and cool-down performed in the training, it seemed to not increase the risk of hamstring injuries. In our data, larger variances in Relx of both legs were observed. That might be due to the different activities they performed or reduced physical exercise changes in muscle properties. However, it is one of the limitations of this study, that since the activities during the cadet training could not be monitored or restricted, it is not possible to draw a causal conclusion. We are unable to make causal conclusion. The non-dominant legs became less compliant at the end of the cadet training; however no injury was reported at the follow-up, it might be due to the activities that police cadets conduct daily are not the sudden and fast motions made by athletes such as soccer players. Nonetheless our data show that muscle compliance changes due to the training involving and that the lower extremities should be taken into account when designing a training protocol. A future study of a longer training period (more than 20 weeks) is needed to see if the muscles involved become less compliant.

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