A Randomized Study of a Strength Training Program to Prevent Injuries in Runners of the New York City Marathon

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Background: Lower extremity overuse injuries are common among runners, especially first-time marathoners. Hip abductor and quadriceps strengthening is often recommended to reduce running-related injuries.

Hypothesis: A 12-week strength training program would decrease the rate of overuse injuries resulting in marathon noncompletion and improve race finishing time.

Study Design: Randomized trial.

Level of Evidence: Level 2.

Methods: Twelve weeks before the New York City Marathon, first-time marathon runners age 18 years and older were randomized into a strength training group or an observation group. The strength training group was instructed to perform a 10-minute program 3 times weekly using written and video instruction. This program targeted the quadriceps, hip abductor, and core muscle groups. Injuries were self-reported through biweekly surveys, with major injuries being those that resulted in marathon noncompletion and minor injuries being those that impaired training or race performance.

Results: A total of 720 runners were enrolled (mean age, 35.9 ± 9.4 years; 69.4% female), of whom 583 runners started the marathon and 579 completed it. The incidence of major injury was 8.9% and minor injury was 48.5%. Fifty two of 64 major injuries were overuse, of which 20 were bone stress injuries. The incidence of overuse injury resulting in marathon noncompletion was 7.1% in the strength training group and 7.3% in the observation group (risk ratio, 0.97; 95% CI, 0.57-1.63; $P = 0.90$). The mean finishing time was 5 hours 1 ± 60 minutes in the strength training group and 4 hours 58 ± 55 minutes in the observation group ($P = 0.35$).

Conclusion: There is a high prevalence of injury among first-time marathon runners, but this self-directed strength training program did not decrease overuse injury incidence resulting in marathon noncompletion.

Clinical Relevance: Prevention strategies such as strength training need to be developed and evaluated through clinical trials to reduce the high prevalence of overuse injuries in runners, especially for high-risk populations such as first-time marathon runners.

Keywords: running; prevention; marathon; overuse injuries; bone stress injuries

The health benefits of running have become well-established over the past several decades, a time during which the prevalence of obesity and associated comorbidities have been on the rise.[10,13,28] Concurrently, participation in running at the recreational and competitive levels has increased significantly.[12] The New York City Marathon is an example of such growth, as it is the largest marathon in the world with 50,773 finishers in 2017, up from 55 finishers in 1970.[9,11] Unfortunately, the momentum behind adopting running as a first step toward a healthier lifestyle is often disrupted by the high incidence of overuse injury.[15,37,38]

Retrospective surveys of marathon finishers and nonfinishers estimate the incidence of training-related injury to be from 19% to 58%.[6,7,14,20,36] Risk factors for overuse injuries in runners include

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history of prior injury, inexperience, greater running frequency, higher weekly mileage, and higher body mass index.[4,29,32-34,39] Additional biomechanical risk factors include inadequate strength and muscle control of the core and hip stabilizers.[1,16,21,26,31] Hip abductor and external rotator strengthening has been shown to improve running mechanics but has not been adequately studied to determine whether it can prevent injury.[26,40]

Previous randomized interventional studies attempting to reduce running injuries have focused on preconditioning, warm-up/cool-down, modifying shoe type, and a directed graduated training program.[2,5,18,19,23,25,30,35] These studies were carried out during training for shorter races (4-13.1 miles) or outside of the context of a race. Only 1 study showed a decrease in injury incidence with the use of motion control shoes in runners with pronated feet.[18]

The purpose of this study was to evaluate the effect of a self-directed strength training program on the incidence of overuse injury resulting in marathon noncompletion in a cohort of runners training for their first marathon. The prospective design of the study allowed for measurement of the proportion of runners who are registered for the race and are able to complete it, in addition to better classification of injury types experienced by first-time marathon runners. We hypothesize that runners who comply with a self-directed strength training program will have a lower incidence of overuse injury that results in marathon noncompletion.

METHODS

The study was approved by the institutional review board at the hospital of the study investigators. This is a prospective randomized study of first-time marathon runners who registered for the New York City Marathon. Eligibility criteria included English-speaking, able-bodied registrants at least 18 years old without a current injury who were willing to participate in a strength training program and who had never completed a marathon. Runners were recruited through email sent from New York Road Runners, the organizer of the New York City Marathon. Interested runners who met inclusion criteria were randomized into a strength training group or observation group (50% in each) using block randomization controlling for sex.

The strength training group received a 10-minute instructional video (Appendix 1, Figure A1, available in the online version of this article) and accompanying handout (Appendix 2, available online) focusing on core, hip abductor, and quadriceps strengthening with both beginner and advanced tracks.[8,17,27] They were instructed to perform the program 3 times per week during the 12 weeks prior to the race. Both groups were not restricted from participating in other forms of strength training or cross-training.

A baseline survey was administered on enrollment, which included demographics, running experience, and self-reported height and weight. Every 2 weeks during the 12-week study period, runners were emailed surveys on training progress, any injury limiting the training, and compliance with the program for those in the strength training group. One week after the marathon, a final survey was conducted about race performance, utilization of medical services, likelihood of registering for another race, and perceived benefit of the program for those in the strength training group. Runners who reported major injuries on the survey were interviewed by an investigator to obtain additional injury history, including if the injury was an overuse injury (no incident/trauma that caused the injury).

Statistical Analysis

Descriptive statistics were used for baseline demographics and running history data. The sample size needed to detect a 20% decrease in marathon noncompletion due to overuse injury was determined to be 560 (280 in each group) based on estimating that 70% of registered runners would complete the marathon, with 20% not completing the race due to overuse injuries and 10% not completing the race due to reasons unaffected by the strength training program, such as illness, travel disruptions, or personal reasons. A chi-square test was used to assess the primary hypothesis that a strength training program could reduce the rate of marathon noncompletion due to overuse injury. A 2-sample *t* test was used to compare marathon finishing times between groups. Injuries were defined as "major" if they resulted in marathon noncompletion (did not start or did not finish) and "minor" if they limited training and/or race performance.

RESULTS

A total of 804 runners responded to the study recruitment emails. There were 62 runners that did not meet inclusion criteria and 22 opted out before the start of the 12-week study period. This resulted in 720 runners who were randomized at the start of the intervention. The mean age was 35.9 ± 9.4 years (range, 19-70 years), and 69.4% were female (Table 1). A total of 45 runners opted out or were lost to follow-up over the course of the 12-week study period (11 in the observation group and 34 in the strength training group). The survey response rate was 97.2% and 98.0% for the strength training and observation groups, respectively.

Training

The number of weekly training runs averaged 3.3 ± 1.1 in the observation group and 3.4 ± 1.0 in the strength training group ($P = 0.14$). The longest run during training averaged 19.2 ± 2.9 miles in the observation group and 19.6 ± 2.8 miles in the strength training group ($P = 0.18$). Runners in the strength training group performed the program an average of 2.0 ± 1.2 times per week. Eleven (3.1%) runners reported experiencing a muscle strain or tendinitis as a result of doing the strength training program. During the 12 weeks prior to the race, 92 (12.8%) runners stopped training for the race (Table 2).

Marathon

A total of 583 runners participating in the study started the race, 310 in the observation group and 273 in the strength training

Table 1. Baseline runner characteristics

	All Runners (n = 720)	Observation Group (n = 368)	Strength Training Group (n = 352)
Age, y, mean ± SD	35.9 ± 9.4	36.3 ± 9.8	35.4 ± 9.1
Female, n (%)	500 (69.4)	255 (69.3)	245 (69.6)
Body mass index, kg/m^2, mean ± SD	24.1 ± 3.7	24.0 ± 3.3	24.2 ± 4.1
Completed prior race, n (%)	704 (97.8)	361 (98.1)	343 (97.4)
Completed prior half marathon, n (%)	640 (88.9)	331 (89.9)	309 (87.8)
Goal finishing time, mean ± SD	4 h 34.0 min ± 40.8 min	4 h 34.1 min ± 40.3 min	4 h 33.9 min ± 41.5 min
Method of qualification, n (%)			
Participated in the 9 + 1 or 9 + $1K program	259 (36.0)	130 (35.3)	129 (36.6)
Selected in drawing	261 (36.3)	128 (34.8)	133 (37.8)
Participating with charity organization	124 (17.2)	75 (20.4)	49 (13.9)
Cancelled previous year's entry	22 (3.1)	10 (2.7)	12 (3.4)
Based on half marathon time	11 (1.5)	4 (1.1)	7 (2.0)
Other	43 (6.0)	21 (5.7)	22 (6.3)

Table 2. Reasons for stopping training prior to the race

	All Runners (n = 720)	Observation Group (n = 368)	Strength Training Group (n = 352)	*P*
Total, n	92	47	45	0.99
Injury, n (%)	61 (66.3)	31 (66.0)	30 (66.7)	0.94
Overuse injury, n (%)	49 (53.3)	26 (55.3)	23 (51.1)	0.69
Nonoveruse injury, n (%)	12 (13.0)	5 (10.6)	7 (15.6)	0.48
Illness, n (%)	3 (3.3)	2 (4.3)	1 (2.2)	0.58
Personal reasons, n (%)	8 (8.7)	5 (10.6)	3 (6.7)	0.50
Unable to maintain training plan, n (%)	12 (13.0)	5 (10.6)	7 (15.6)	0.48
Other, n (%)	8 (8.7)	4 (8.5)	4 (8.9)	0.95

group (Appendix 1, Table A1, available online). Only 4 of the 583 runners (0.7%) who started the marathon did not finish. Three stopped due to injury (2 in the strength training group, 1 in the observation group) and 1 due to fatigue (observation group). Two of the 3 runners who did not finish due to injury were evaluated by race medical staff. The average finishing time was 5 hours 1.1 ± 60.4 minutes in the strength training group and 4 hours 57.5 ± 54.5 minutes in the observation group (P = 0.35). After the race, 74.8% of runners in the strength training group rated the program as beneficial, 67.6% reported anticipating continuing the exercises after the study, and 76.3% would recommend this program to a friend.

Table 3. Effect of independent strength training and compliance with strength training program

	Observation Group		Strength Training Group	
	Independent Strength Training[a] (n = 110)	No Independent Strength Training[a] (n = 247)	Compliant[b] (n = 176)	Noncompliant[b] (n = 137)
Race completion, n (%)	98 (89.1)	210 (85.0)	158 (89.8)	113 (82.5)
Average finishing time	5 h 3.9 min	4 h 54.5 min	5 h 2.7 min	4 h 58.2 min
Major injury, n (%)	10 (9.1)	22 (8.9)	16 (9.1)	11 (8.0)
Overuse, n (%)	9 (8.2)	18 (7.3)	13 (7.4)	9 (6.7)
Minor injury, n (%)	60 (54.5)	122 (49.4)	73 (41.5)	77 (56.2)

[a]Independent strength training was defined as reporting participation in strength training on ≥67% of biweekly surveys.
[b]Compliance was defined as reporting performance in exercise program an average of ≥2 times per week.

Major Injuries

The incidence of overuse injury resulting in marathon noncompletion was 7.3% (27/368) in the observation group and 7.1% (25/352) in the strength training group (risk ratio [RR], 0.97; 95% CI, 0.57-1.63; $P = 0.90$). A disproportionate amount of overuse injuries occurred in the latter half of training, as 25 (48.1%) occurred during a 4-week period between 6 and 2 weeks prior to the race (Appendix 1, Figure A2, available online). The most common overuse injuries were bone stress injuries, which totaled 20 (38.5%), followed by 11 tendon/fascia, 9 joint, 9 muscle, and 3 other/unspecified. An additional 12 runners experienced acute (nonoveruse) injuries that resulted in marathon noncompletion.

Minor Injuries

Minor injuries were reported at least once during the study period by 186 (50.5%) runners in the observation group and 163 (46.3%) runners in strength training group (RR, 0.92; 95% CI, 0.79-1.07; $P = 0.26$). Ninety of these runners experienced minor injuries during the race, which corresponded to 16.1% in the observation group and 14.7% in the strength training group (RR, 0.91; 95% CI, 1.33-0.62; $P = 0.62$). Only 15 runners (16.7%) with minor injuries during the race were evaluated by race medical staff. The 5 most frequently reported minor injuries were unspecified knee pain, calf strain, medial tibial stress syndrome, iliotibial band syndrome, and Achilles tendinitis.

Subgroup Analysis

Additional analysis was done on runners who completed the study and, in the strength training group, reported frequency of performing the program. Within the strength training group, when comparing the runners who were compliant with the exercise program (defined as performing the exercises an average of 2 or more times per week) with those who were noncompliant, the compliant runners were more likely to complete the race (89.8% vs 82.5%) and had a lower incidence of minor injury (41.5% vs 56.2%; $P = 0.01$) (Table 3). However, compliant runners had a slower finishing time (5 hours 2.7 minutes vs 4 hours 58.2 minutes) and a higher incidence of major injury (9.1% vs 8.0%).

DISCUSSION

Considering the high incidence of injury among runners, interventional studies to reduce injuries have been attempted in various populations of runners.[3,5,22,24,35] This current study represents the largest randomized interventional study to date and the first performed in the setting of training for a marathon. The prediction that overuse injuries were the primary cause of marathon noncompletion was confirmed. Minor injuries were found to be experienced by nearly half of runners during training and 1 in 6 runners on race day. The strength training intervention did not result in a statistically significantly lower incidence of overuse injury resulting in marathon non-completion or average faster finishing time. There was a nonstatistically significant decrease in minor injury incidence, average pain during the race, and use of the marathon medical tent.

The lack of difference in the incidence of major injury could be attributable to many factors. Despite careful selection of exercises included in the strength training program based on available evidence, the program itself may not have been effective at producing the strength gains or neuromuscular control needed to maintain optimal running biomechanics during long runs. Improved strength would likely be achieved with a longer program or by recommending that it be performed more frequently, though this would decrease compliance. The benefit that runners received from a strength training program was likely variable based on their baseline fitness level and prior running experience. A functional strength assessment may identify runners who would benefit most from a strength training program. We were unable to provide in-person instruction or to directly observe runners doing the

exercises to verify correct technique and to confirm reported compliance. Additionally, the observation group was not a true control group, as the athletes in this group were not restricted from independent strength training.

The study was strengthened by the large sample size, the completion rate of 94%, and a survey completion rate among active participants of over 97%. However, there were several limitations. Since data collection was done through surveys sent to runners, the reported training data and injury characteristics may not be entirely accurate. The sex distribution for our study population was 69.4% female, which is dissimilar to the sex distribution for New York City Marathon starters (41.5% female).[9] The study was also not powered to be able to show a statistical significance in outcomes between compliant and noncompliant subgroups. Despite being a randomized study, selection bias may have resulted in runners who were already doing independent strength training being more likely to enroll in the study.

CONCLUSION

In the first interventional study of a strength training program for runners preparing for a marathon, the self-directed strength training program did not result in a significant decrease in the incidence of injury or improvement in average finishing time. Nevertheless, most participants in the strength training group found the program to be beneficial and intended to continue it. The similarities between the strength training and observation groups may be due to the design and timing of the program as well as the proportion of runners already participating in regular strength training. Given the high incidence of both minor and major injuries within this population of first-time marathon runners, further research is needed to better define modifiable risk factors and refine strength training interventions so that the positive health effects of running can be better achieved and maintained by reducing the associated risk of injury.

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