CHAPTER THREE

Skating quickness:

speed, acceleration, agility

Chapter Overview:

1 Players and coaches of U.S. teams have seen that Europeans are extremely fast skaters, especially adept at cornering and performing skills at high speed.

It is no wonder Soviet scientists communicate to their coaches the importance of testing and training for speed (on and off-ice) in comparison to all other physiological tests:
"Factor analysis, including tests of physical development showed the greatest factor loads go to tests describing speed capabilities ... especially speed, acceleration, and high speed turns. This is particularly important since that component of fitness is most successfully open to development at a young age" (Deryabin, USSR 1981).

2 Our research with over 2000 hockey players and 60 teams of various age and skill levels shows that teams at a higher designated level of play are faster at top speed and accelerate more quickly.

3 Attempting corners at over-speed requires greater knee bend, a fact which does not apply to over-speed skating in a straight line. Simple physics of cornering forces shows us that strength training must supplement on-ice learning in order to develop this skill correctly:

Cornering skill might be learned and performed perfectly at a slow speed, but while the technique does not change at higher speeds, it becomes increasingly difficult to corner as we attempt faster speeds. The player must lower his center of gravity more using greater knee bend, and this must be done against extremely high centrifugal forces. Without strong legs, players will revert to some form of compensation which develops poor technique if repeated often.

These facts imply that we must start training at a very young age for a low center of gravity by bending our knees in off-ice drills as well as when we skate.

Picture a sports car competing against a jeep in a race around corners.

Skating quickness: speed, acceleration, and agility

Hockey: a game of short sprints and explosive turns

Biomechanists at the Olympic Training Center used high speed film and computers to analyze movement patterns during a training game for the U.S. Olympic Team (Dillman, Stockholm, and Greer, 1984). They found that a typical shift was characterized by short, 2.0 second accelerations followed by coasting and deceleration of about 2.1 seconds. Other scientists have found similar results with Canadian junior players (Green, 1976), and the Czechoslavakian National Team (Seliger, 1972).

A test of 'top speed'

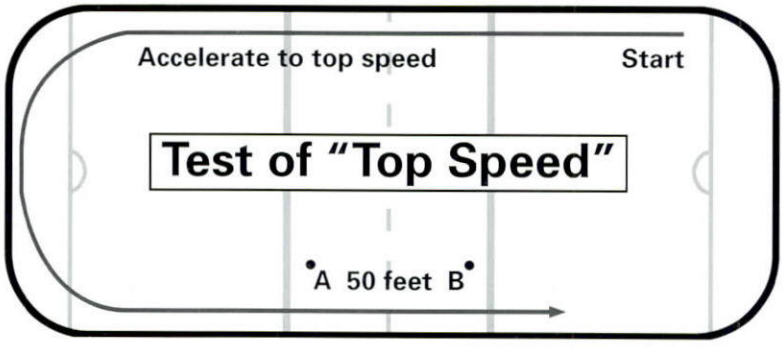
A test of 'top speed' was developed, in which players skate through photocells for a distance of 50 feet after a considerable run-up. In preliminary studies, skaters took more time than they would have guessed to accelerate to full speed and decelerate to a stop. It was necessary to include a run-up along one length of the rink, around one end, and up to the neutral zone, where they were timed for 50 feet.

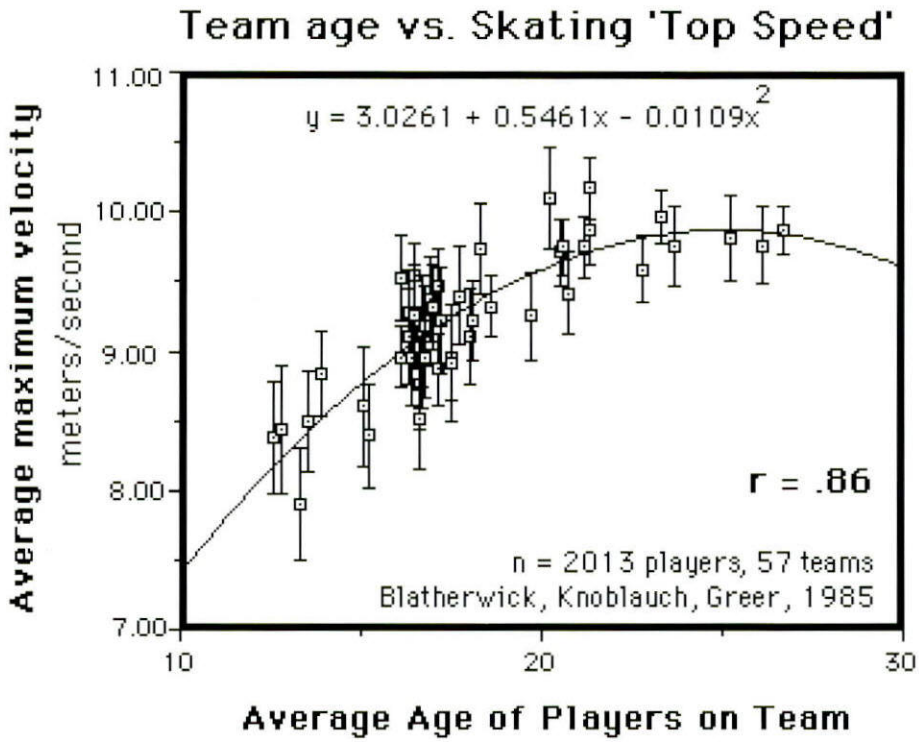
The results of the top speed test were highly reliable (repeatable) and showed clearly that players at higher designated levels of play were faster.

The top 80 amateur players in the country tried out for the 1980 Olympic Team, and the ones who eventually won the Gold Medal at Lake Placid were significantly faster than the players who tried out but didn't make the team. In testing 60 teams since that time, we have found similar results . Teams at higher levels of play are faster. Obviously, there are exceptions in which fast players can't compete at higher levels because they either lack other qualities or aren't given the chance, as in the case where scouts ignore small players regardless of their abilities.

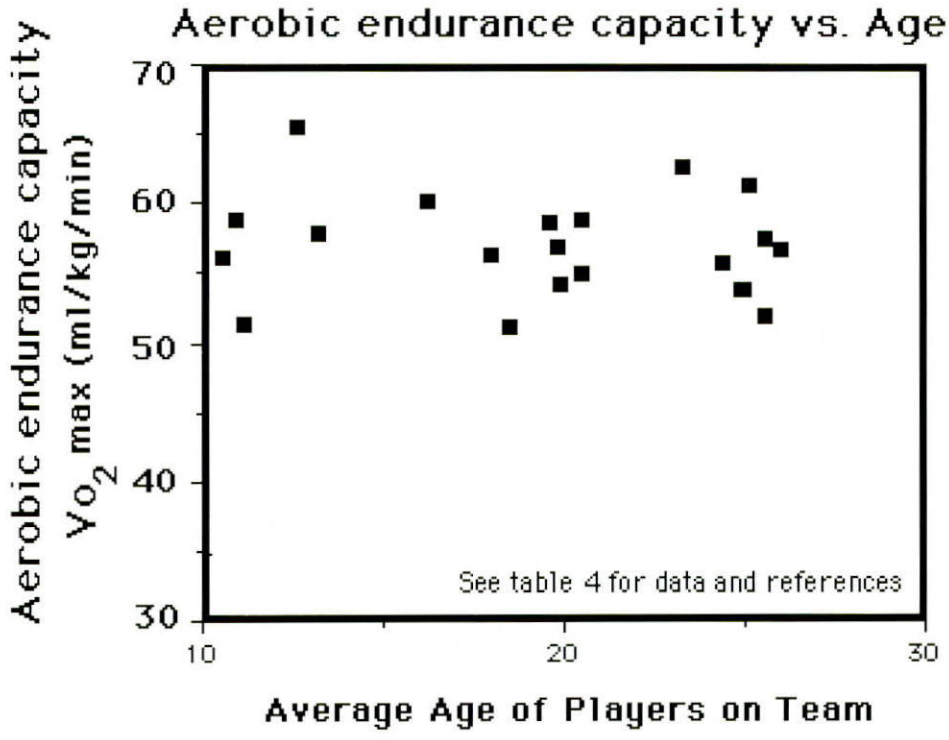
Skating tests showed clearly that players at higher designated levels of play were faster.

Skating speed is also highly related to age: notice in the following graph that older teams are faster. The curve peaks at 25 years, however, because older professional players have stopped training for speed and have spent too much practice time hooking and interfering. It is obvious that age is not the reason for the drop-off in speed, because we all witnessed some aging track athletes who ran the best times of their lives in the last Olympics after what they called their best training years: Florence Griffith Joyner, age 28; Edwin Moses, age 32.





We would not be surprised to see that as players get older they become faster skaters. However, the graph below summarizes data from a review of literature presented in a later chapter: Older teams do not have a greater aerobic endurance capacity, Vo2 max.



Team average maximum skating velocities

Test of "top speed"

Teams of same age and different level of competition.

OVER AGE 20		
U.S. OLYMPIC TEAM	>	UNSUCCESSFUL CANDIDATES
U.S. OLYMPIC TEAM	=	NCAA DIV.I UNIVERSITY CHAMPION
NCAA DIV.I UNIVERSITY CHAMPION	>	NCAA DIV.II COLLEGE CHAMPION
NCAA DIV.II COLLEGE CHAMPION	>	DIV.II COLLEGE TEAM (SAME LEAGUE)
18-19 YEAR OLDS		
U.S. NATIONAL JUNIORS	>	USHL JUNIOR A TEAM
JUNIOR A TEAM	>	JUNIOR B TEAM
15-18 YEAR OLDS		
U.S. NATIONAL MIDGETS	>	HIGH SCHOOL VARSITY
HIGH SCHOOL VARSITY	>	UNSUCCESSFUL CANDIDATES
HIGH SCHOOL VARSITY	>	HIGH SCHOOL JUNIOR VARSITY
13-14 YEAR OLDS		
A BANTAM TEAM	>	B BANTAM TEAM

STATISTICAL T-TEST RESULTS

> means faster; significant at the .01 level

= means not significantly different

Representative of 57 teams (n = 2013 players)

Test-retest ***reliability*** for "top speed" varies between r=.997 and r=.920 depending on age and homogeneity of team.

Table 1 has some interesting comparisons. It shows that when teams are grouped by age, the teams that play at a higher designated level are faster at 'top speed.' The exception is with NHL teams, which are not faster than their minor league affiliates, nor Olympic or Div. 1 University teams.

Acceleration capabilitlies

Quick short bursts of acceleration are a top priority of the training by U.S. Olympic teams, because we've seen the superior quickness of European teams on the larger Olympic sized rinks.

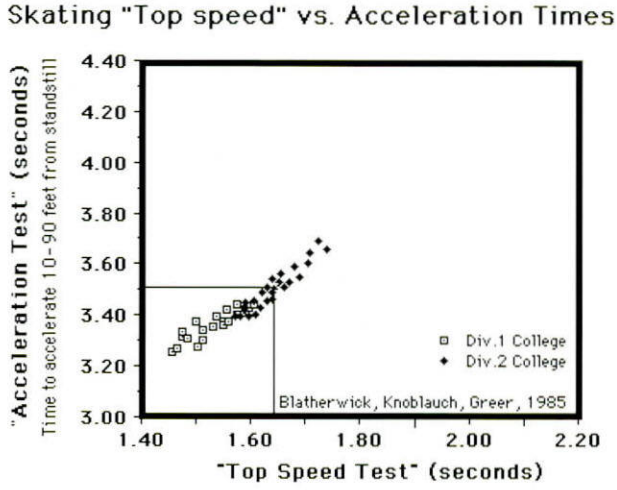
In 1979, we began testing the acceleration capabilities of 41 hockey teams (n=1886) over a 90 foot test in which the players were given a 10 foot "running start" and timed from 10 to 90 feet using photo-electric cells. The test was found to be reliable (r=.92 to r=.98) during test-retest measurements and correlated with the high speed film/computer analysis of acceleration in the first 20 feet (Greer, 1984).

Even the slowest players on a pro or college team are very fast.

Acceleration, like 'top speed,' was an important predictor of achievement level. For example, a Division I university hockey team was three standard deviations quicker ($p<.0005$) on the skating acceleration test than a Division II college team with players of similar age, height, weight, and body composition. These two teams are compared in the next graph showing times for both the "top speed" and "acceleration" tests.

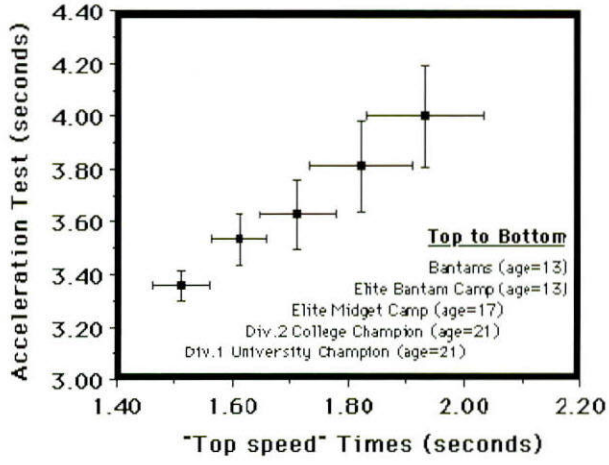
Note: the following graphs show the times to perform both the top speed and acceleration tests, not velocities and accelerations. Therefore, the lower a player's point is on the graph, the quicker is his acceleleration, and the farther to the left, the faster is his top speed.

Of the 1886 players tested for both "top speed" and "acceleration" times there were 8 professional, National, or Division I University teams tested. Not one player from these "elite" teams had results which fell outside the rectangle in the lower left corner of the graph. Even the slowest players on a pro or college team are very fast.

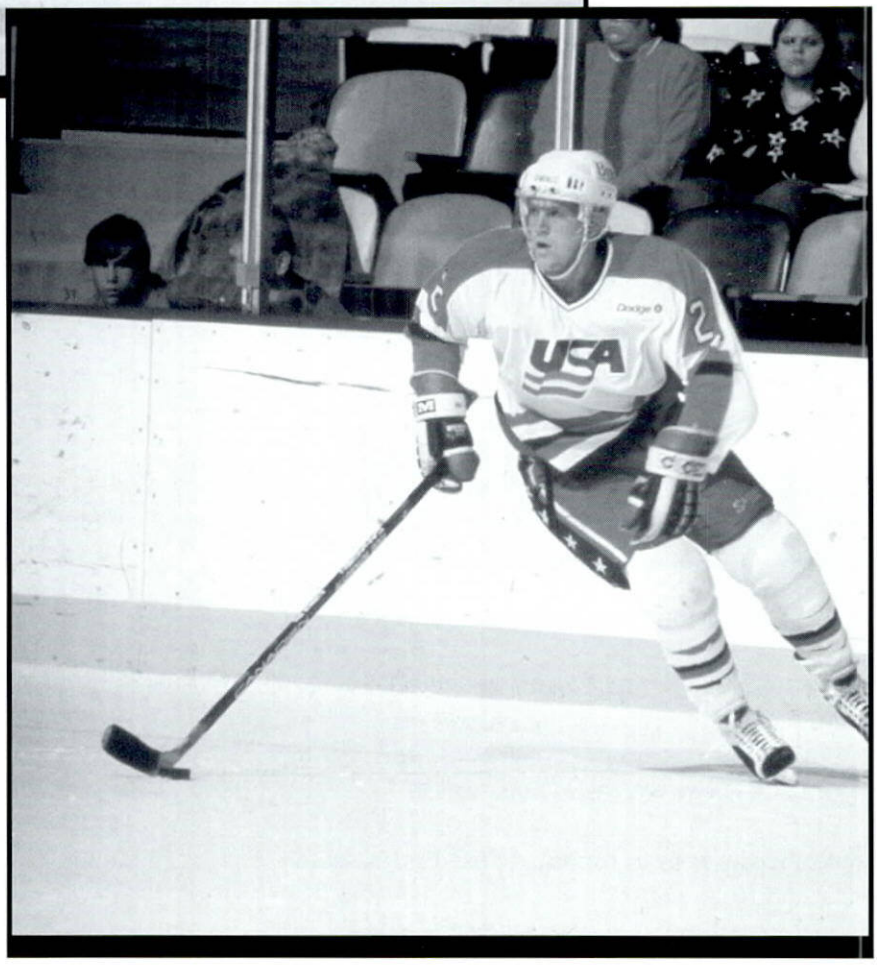


Above: times for each player from two teams the same age.

Below: means ±1 s.d. of five teams timed on both tests. Notice that teams the same age, but different classifications have very different speed and acceleration capabilities.



USA
"Famous
Hamburg


USA

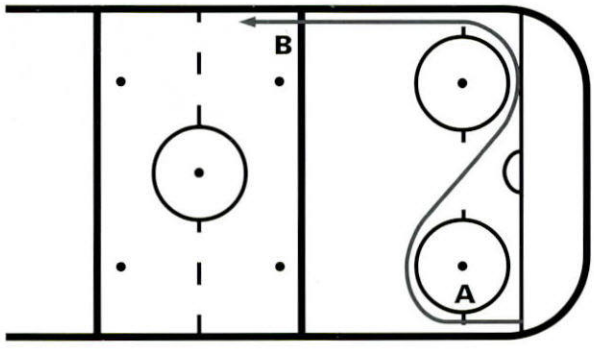
Agility and cornering ability is more difficult to test

Agility would probably be best defined as the ability to change directions quickly, and is perhaps the most important of all skating attributes. It is difficult to quantify, because the test protocol would require (almost random) quick changes in direction, and if players were able to follow the same course exactly, the ice would be cut up at each corner. Our attention shifted to a simple 'S-test' with two turns, where it was necessary to spray water to avoid cutting deep ruts in the ice.

The ability to skate corners is highly trainable on and off the ice

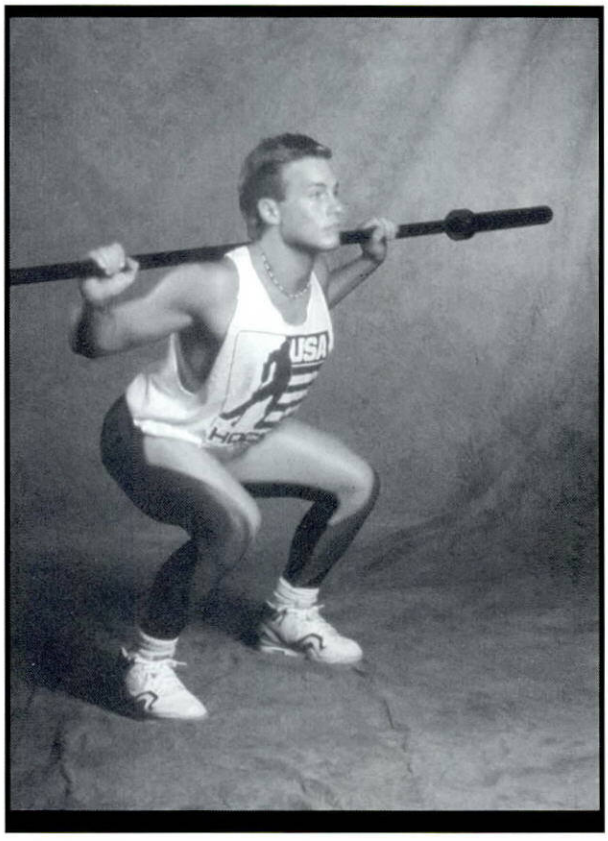
Two groups of 15 year old hockey players served as subjects for a summer training study with on and off-ice tests before and after the 7 weeks. One group played in a summer league and trained as they normally would (control group, n=12). Another group trained three times per week for up to 2 hours on-ice followed by an hour of lower body weight training (training group, n=16).

The on-ice workouts consisted of short sprint intervals with and without pucks for an hour at the beginning of the summer and 2 hours at the end. The last 15-20 minutes of each skating session consisted of skating corners wearing weight vests representing about 15% of body weight.

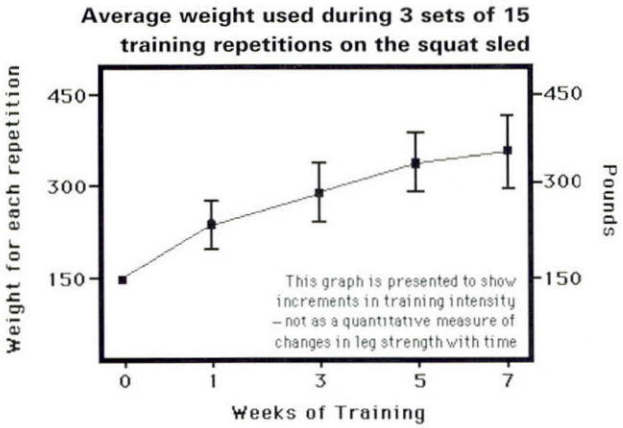


S-Test using photocells and high speed film

Lower body strength training started with squats using an unloaded bar for the first three weeks, but gradually small amounts of weight were added.



The heavier resistance training was done more safely on a plyometric squat sled (Owatonna Engineering; Medford, MN) designed to simulate the position of bar-bell squats. Players worked out with at least 3 sets of 15 repetitions, and over the seven weeks, the average training weight increased from 150 pounds to 360 pounds.



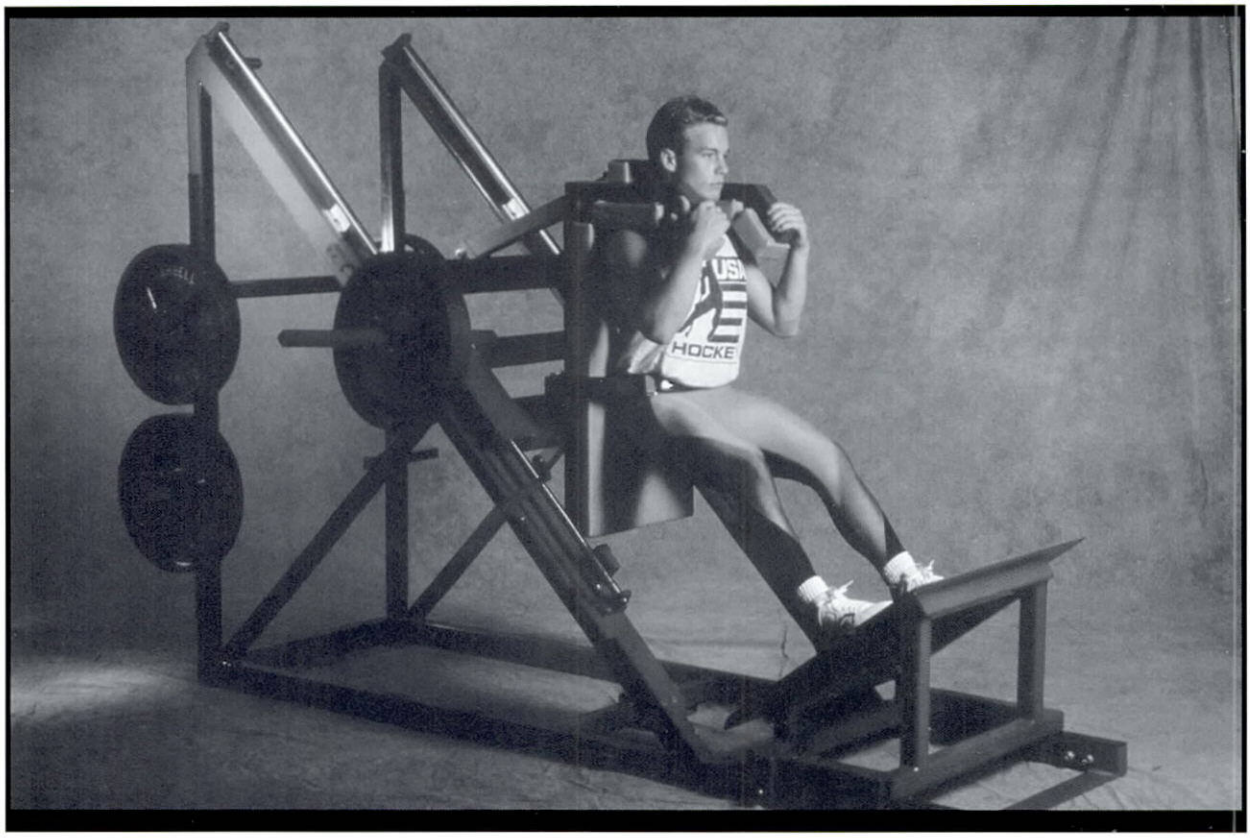
The results of seven weeks of training compared to seven weeks of games are shown graphically on the next pages.

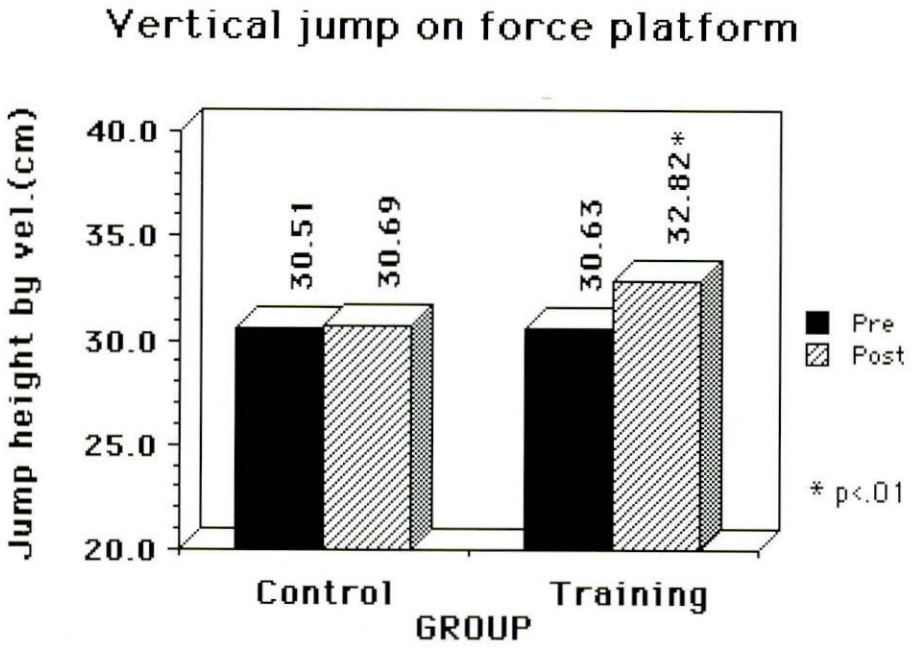
1) Both groups reduced body fat and increased lean body weight significantly ($p<.01$).

2) The training group (but not the controls) improved performance times on all skating tests, especially the cornering test (5.2%) and the top speed test (4.5%), which includes a high speed corner before starting the electronic timer.

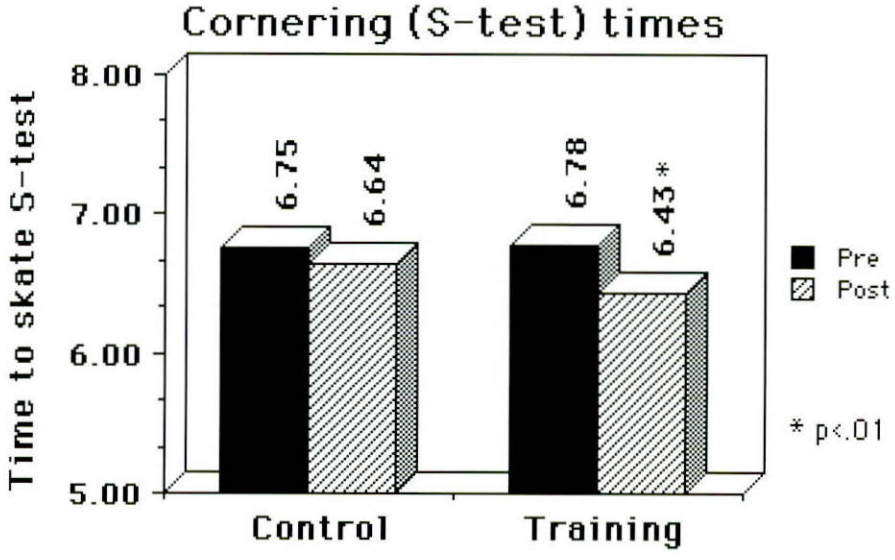
3) The training group (but not the controls) increased the ratio of thigh girth to fat, a measure used to monitor relative muscle mass in the thigh.

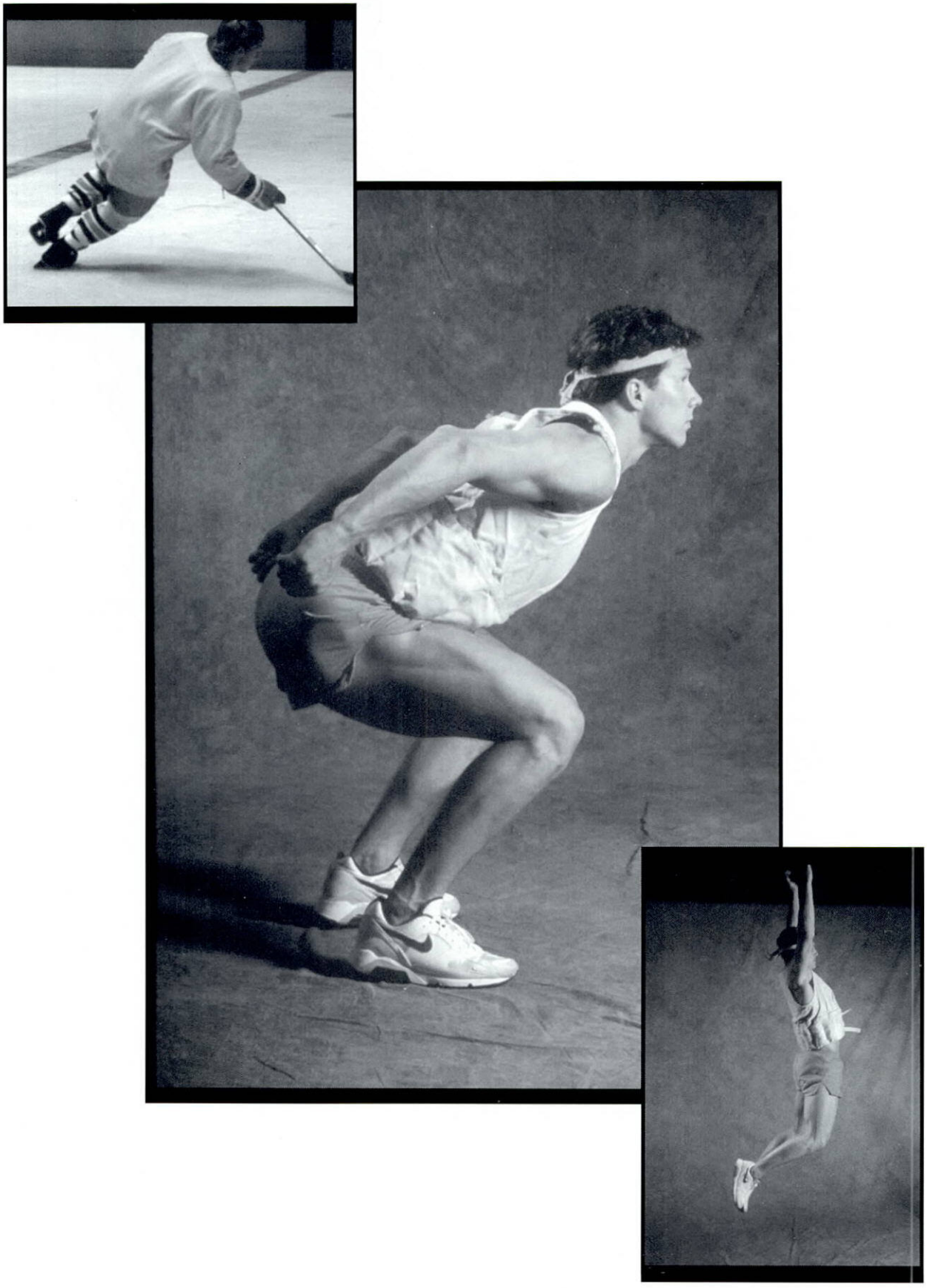
4) The training group (but not the controls) increased vertical jump measured on the force platform.





In skating corners and jumping ability, the training group improved more than those who had skated in a summer league for the same weeks.

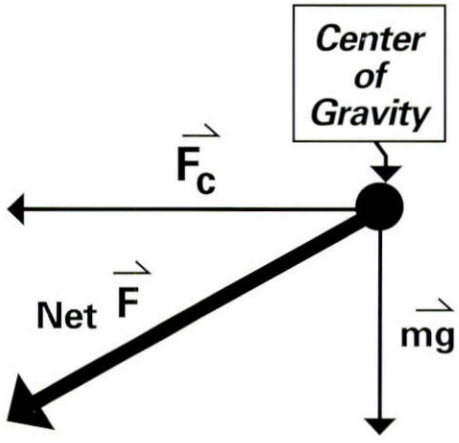




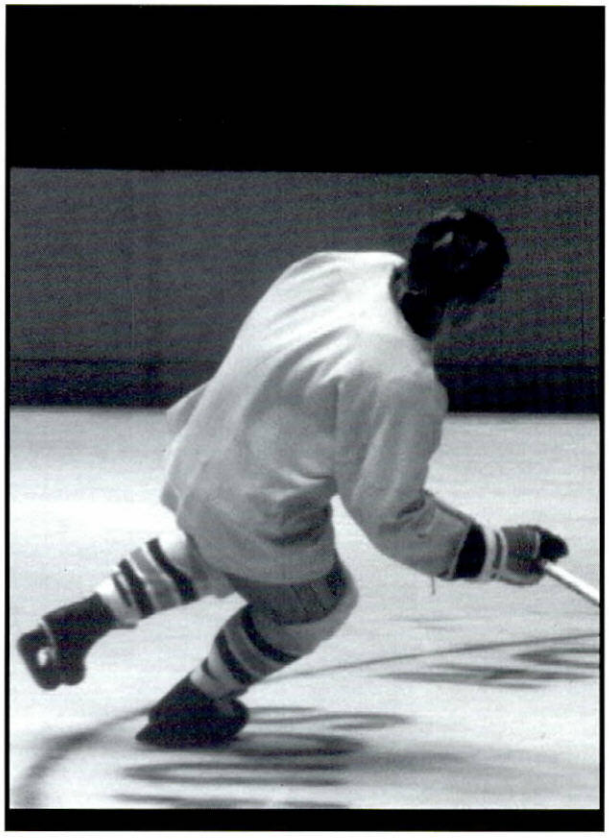
Velocity and cornering forces

One of the consequences of the high velocities attainable by hockey players is increased centrifugal force on corners. Using one of the 1984 U.S. Olympic players as an example, maximum skating velocity was 10.7 meters/second (35.0 feet/s or 23.8 miles per hour) and weight with equipment was 100 kg (220 pounds). If this player were to skate a corner as wide as half the rink (42.5 feet) at full speed, the resultant force (centrifugal force and body weight) would be 450 pounds as shown below. This is not only possible but one of the sprint interval drills in the daily training program of U.S. Olympic Teams.

Centrifugal force, $Fc = mv^2/r$



Note: Net force, F, is the vector sum of weight (vertical force, mg) and centrifugal force (Fc, horizontal), and must be 'summed' using the Pythagorean theorem.



.... a net force of 450 pounds on one leg as he crosses over !!!

The double-edged sword: To compound the problem of a large force on the legs, the player must bend his knees more as the forces get bigger, because ...

... a *torque* is created by the outward (centrifugal), and inward (centripetal) forces. To reduce the torque, a skater must lower his center of gravity. This is the advantage a sports car has over a jeep in a cornering race.

Extra credit physics and trigonometry: One effect of centrifugal force felt by the skater is called a moment (or torque) that would tip the skater over to the outside of the circle if he didn't lean into the corner. Centrifugal force acts on each point-mass of the body as if all the force is concentrated at the center of gravity, pushing the skater out of the circular path. The (equal and opposite) inward or centripetal force, keeping the skater on the circle is supplied at the interface between the ice and skateblade. From the following diagram, moment or torque is the product of the lever arm, X, times the component (FcSinØ) of centrifugal force which is perpendicular to the line, X.

Note: the centrifugal torque (X•FcSinØ) is offset by an equal and opposite torque (X•mg CosØ) due to the downward force of body weight (mg, shown above but omitted from the next diagram for simplicity.

Study the following equation and you'll see that, with a given speed and centrifugal force, Fc, to reduce the outward torque, either X has to be reduced by bending your knees, or you have to lean more, reducing angle Ø.

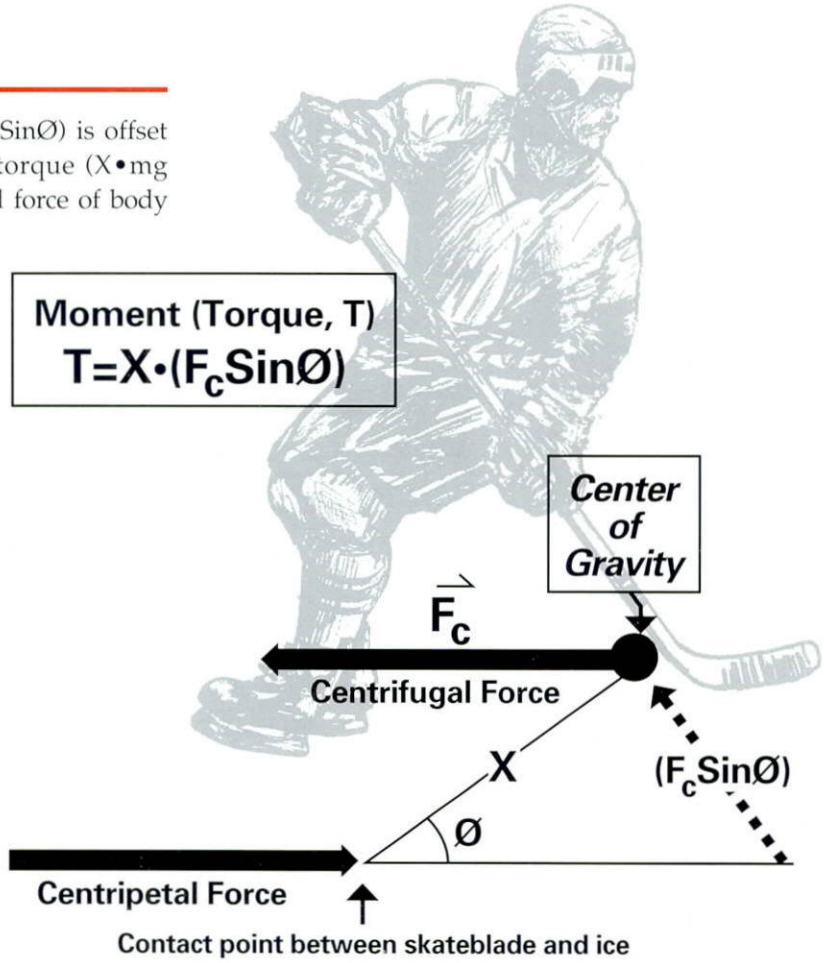
The efficient way to accommodate the increasing torque due to greater velocities, is to bend the knees, thereby reducing the lever arm, X.

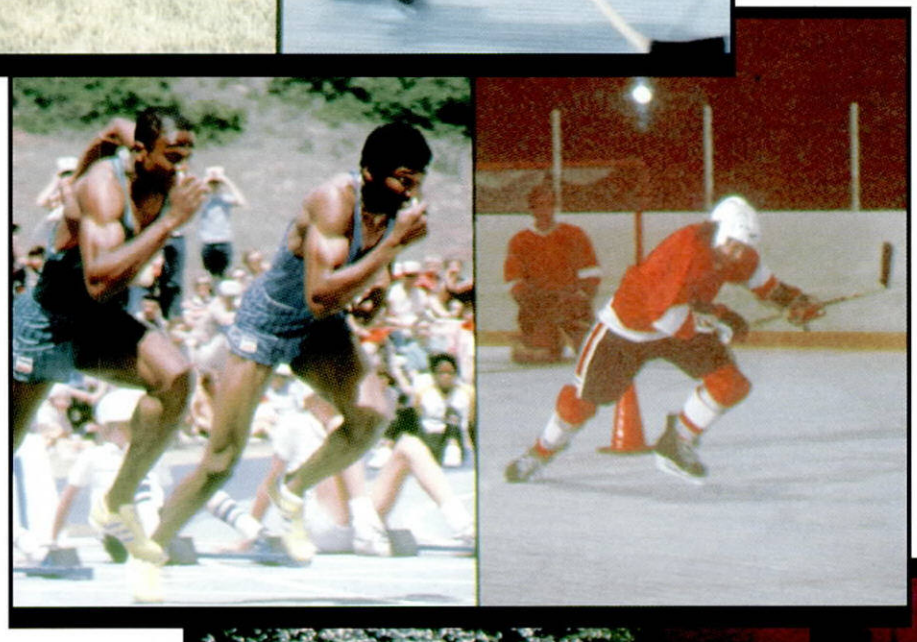
However, for every player there is a velocity at which the net force becomes too great to be met with enough knee bend. At this point the player must lean into the center of the circle more (reducing angle Ø). This is sensed as the velocity at which the edges of the skates will no longer hold, and the normal reaction is to slow down.

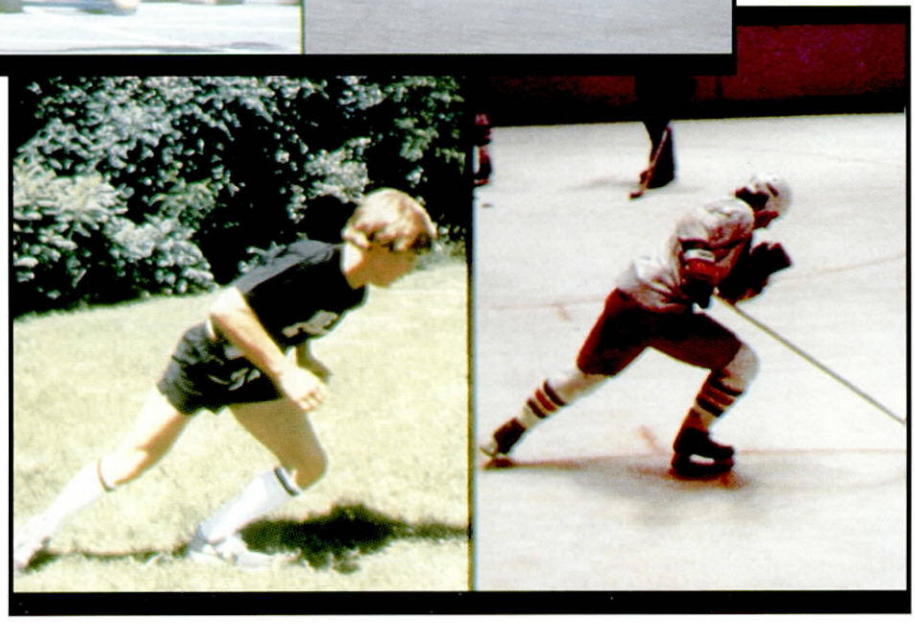
As a result of the physics and not because the technique of cornering is difficult, players are reluctant to attempt uncomfortably fast speeds around corners. This is not true skating straight lines. Coaches must be aware of this reluctance, and encourage young players to risk falling during overspeed intervals in order to improve cornering ability.

Conclusion from the physics:

Leg strengthening is an essential part of the process of learning to skate corners faster. We must train for a low center of gravity at a young age.



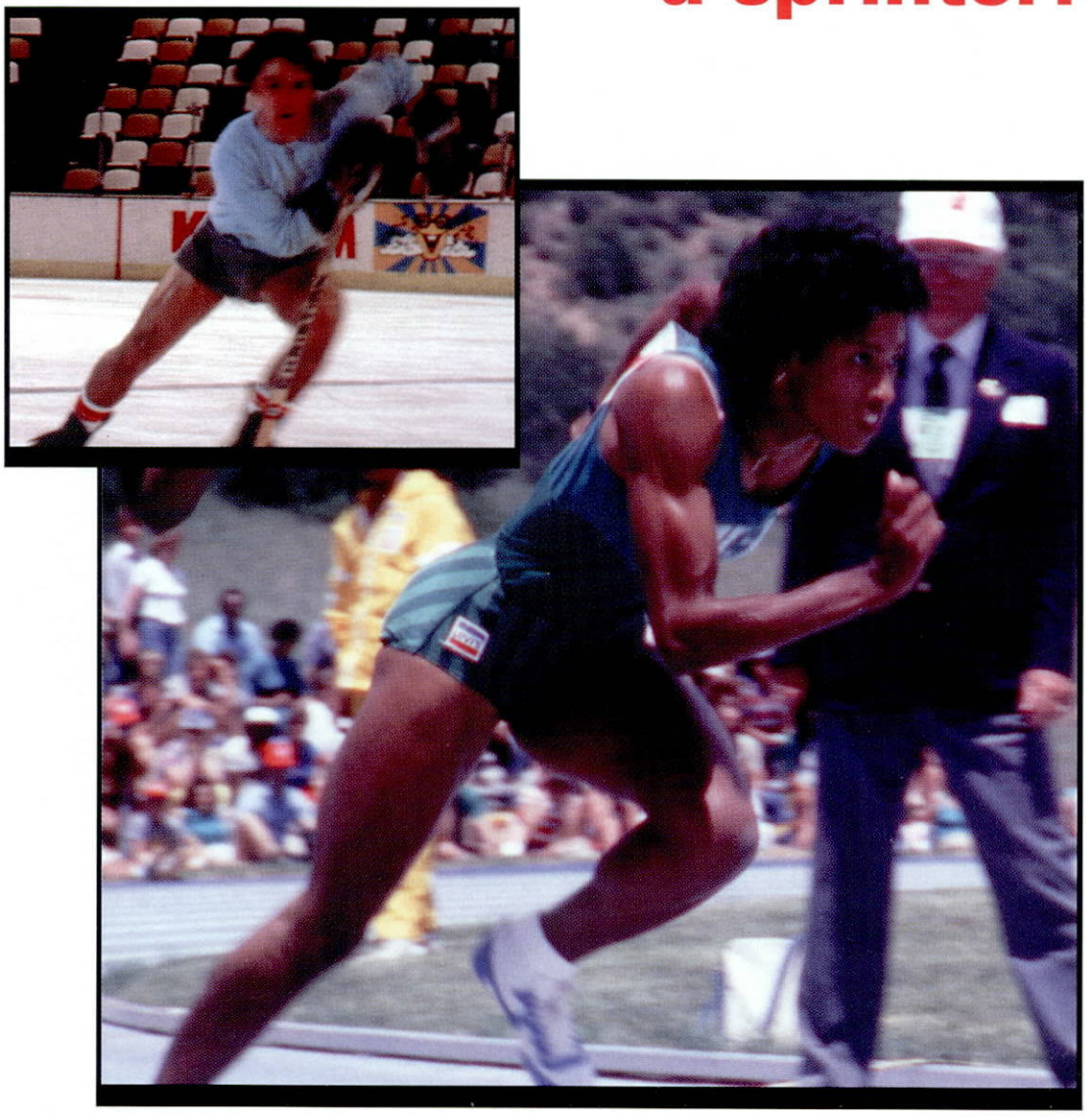




CHAPTER FOUR

To skate faster...

train like a sprinter!



Chapter Overview:

1 Our research with more than 2000 hockey players has shown that the ability to skate fast is highly related to off-ice sprinting and jumping.

2 This tells us that hockey players should train like track sprinters, hurdlers, or high jumpers. ***Whatever makes us faster sprinters or higher jumpers is likely to improve skating quickness and cornering ability.***

3 Off-ice sprint training — quality sprints with plenty of rest — can help us become quicker skaters. This should include some uphill sprints for overload, and some sprints down a slight hill (~5%) for overspeed.
Sprint training is one of the best ways to improve skating speed at any age.

We should not under-estimate the value of quality sprints. Just because there isn't a lot of pain in the muscles (like after lifting weights) doesn't mean there hasn't been a lot of development. We are training the nervous system. Sprinting uses every attribute of athleticism and teaches the intricate neuromuscular patterns required to move our legs quickly, summing up forces in a very coordinated, consecutive manner from our trunk, down through hip extensors, to knee extensors, to the final pushoff from the ankle and foot extensors.

To sprint fast, you must learn to increase power output while remaining relaxed. This is a valuable lesson for a hockey player trying to skate faster. Both movements utilize quickness and power, but are most efficiently done in a relaxed, coordinated, rhythmical, smooth manner.

The recovery phase of running and skating is equally as important. An added benefit of doing sprints (especially uphill sprints) is to help avoid strains to the hip flexors that are so common when we first skate all-out in the fall. Relatively slow strength training, even in the correct range of motion may not prepare us as well as sprints for the explosive movements in skating that cause injuries.

Young hockey players should consider sprinting on the track team. Track coaches know how to make you faster. We can learn a lot from their training methods.

4 Lower body strength training is essential for a powerful skating stride. We have previously discussed the need for strength training to corner properly against high centrifugal forces. This is almost an isometric or static strength. For skating quickness we need to develop power: the ability to combine strength with speed.

5 Plyometrics or jump training use strength in an explosive way, improving power. These should be done on a soft surface and only following months of strength training, in order to reduce the chance of injury.

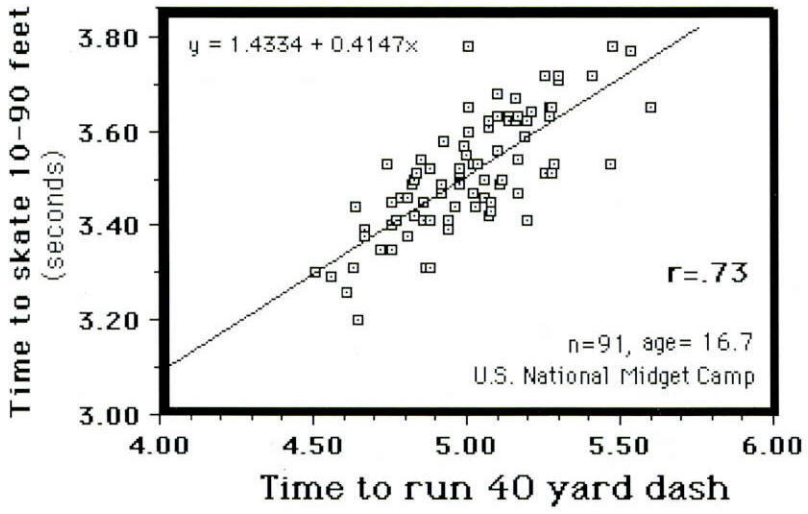
6 Overload plyometrics, such as one-legged or two-legged jumps with or without a weight vest can help us form correct habits of skating with greater knee bend. These should be modified to approximate the skating range of motion.

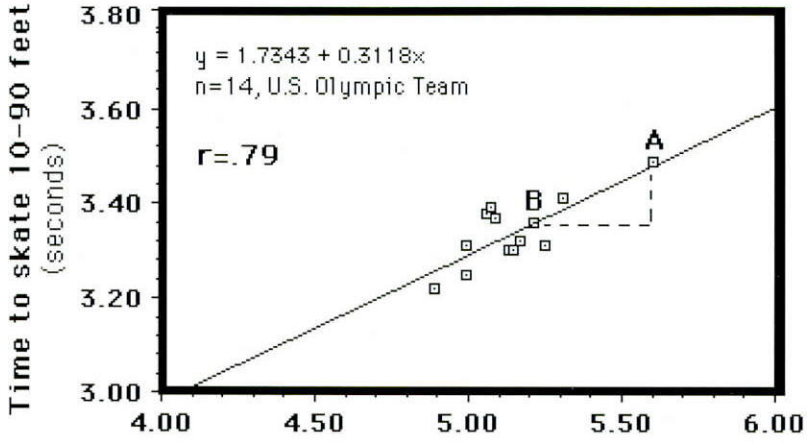
The fastest skaters are likely to be the fastest sprinters!

With every one of the 50 teams tested, there was a consistently high correlation between times on the skating acceleration test and a running forty yard dash (r values between 0.7 and 0.9). Even on professional and Olympic teams, where skating times are so homogeneous, this relationship is still very strong (r≈0.8).

These graphs show the relationship between running and skating sprint times. The fastest skaters and sprinters are found in the lower left region of the graph.

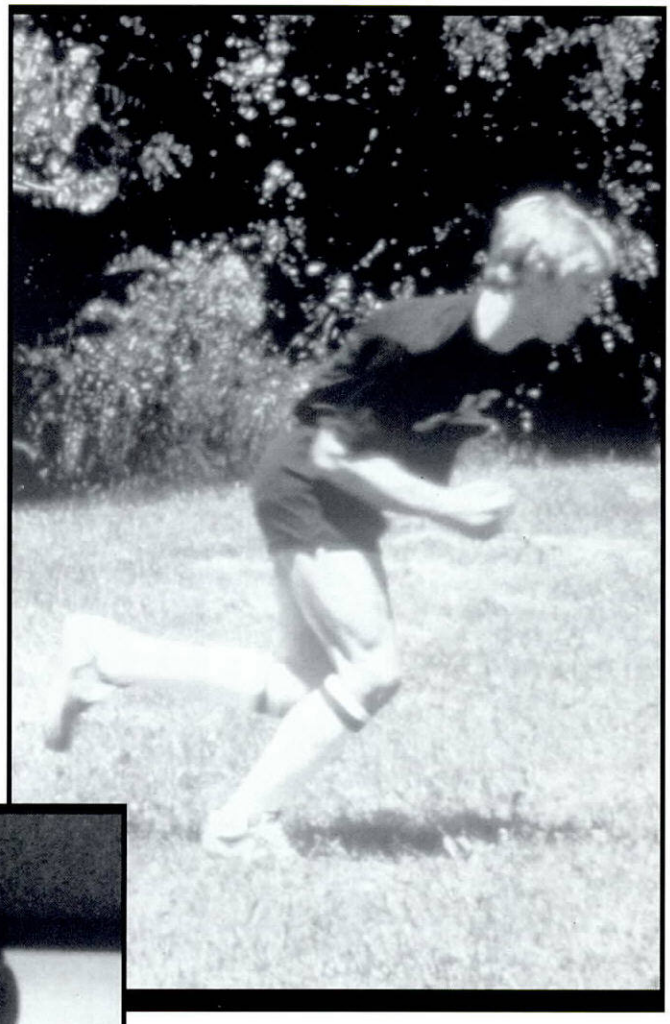
The importance of these graphs is they show that if a player were to improve off-ice sprinting ability, his point on the graph would be likely to move downward and to the left (such as from point A to point B).

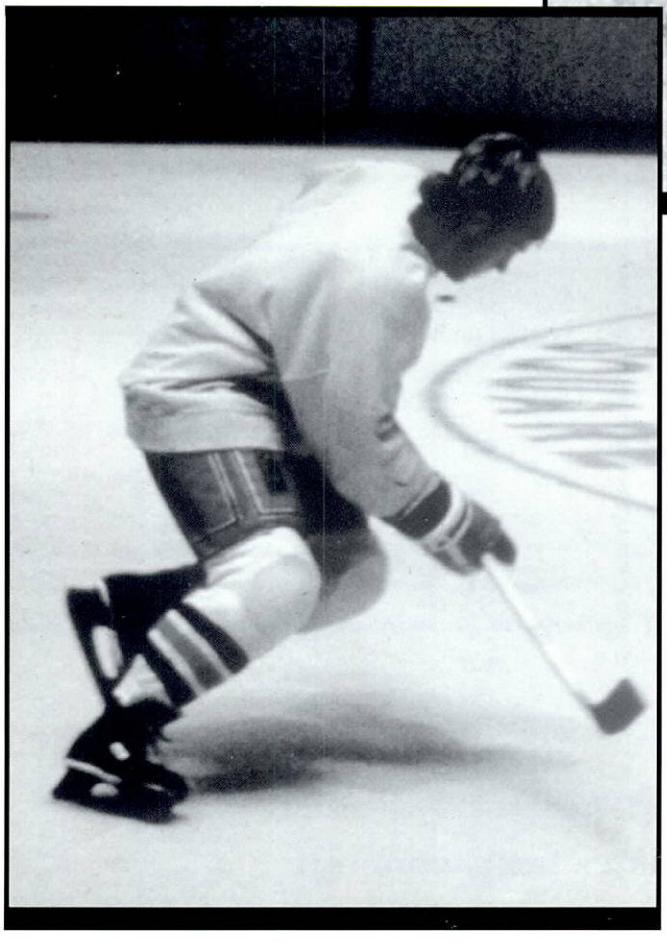




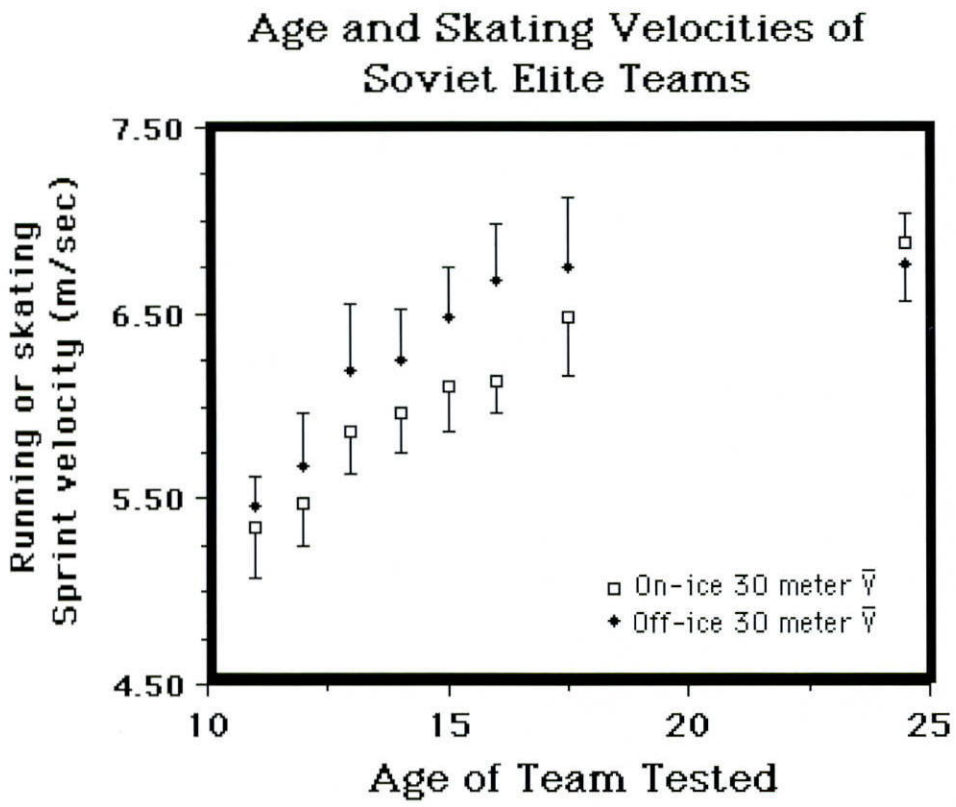
This represents an improvement in skating just by becoming a faster sprinter!

Whatever
training
makes you
a faster
sprinter, ...





will
make you
a faster
skater.



Soviet scientists and coaches have seen the value in sprinting.

The graph above represents data from different Elite Soviet hockey teams. Team averages and standard deviations are shown. Notice the graph shows velocities, not times for the sprint. So, the higher on the graph, the faster.

It is interesting that for every team but the Soviet National Team (age≈25 years) the average running speed (for 30 m) is faster than the average skating speed. Perhaps this shows that the older players spent less time sprinting than they did as youngsters.

So, how do you become a faster sprinter?

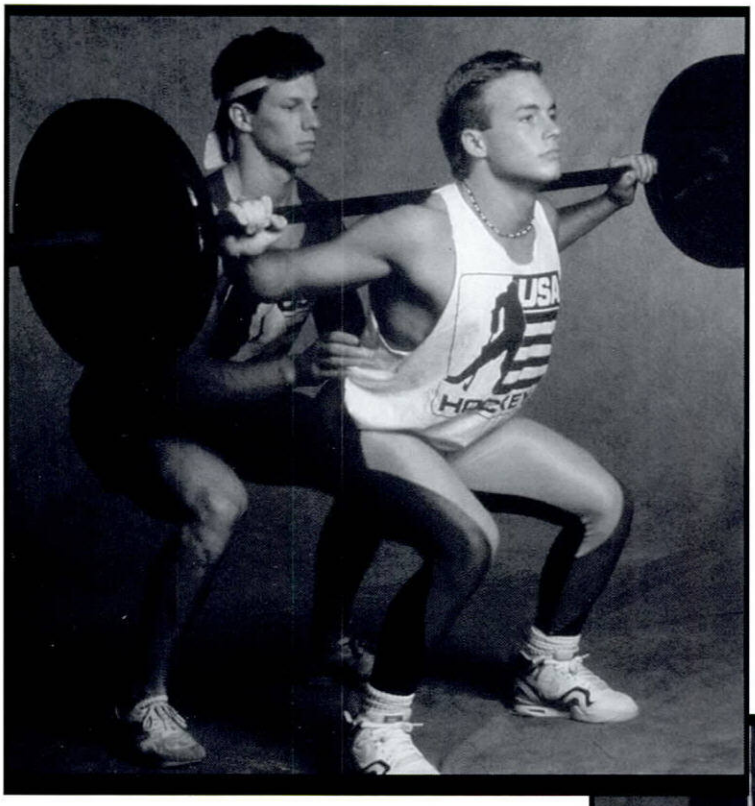
The preceding graphs give us an important clue to help prioritize our off-ice training: *whatever you do to become a faster sprinter will probably make you a faster skater.*

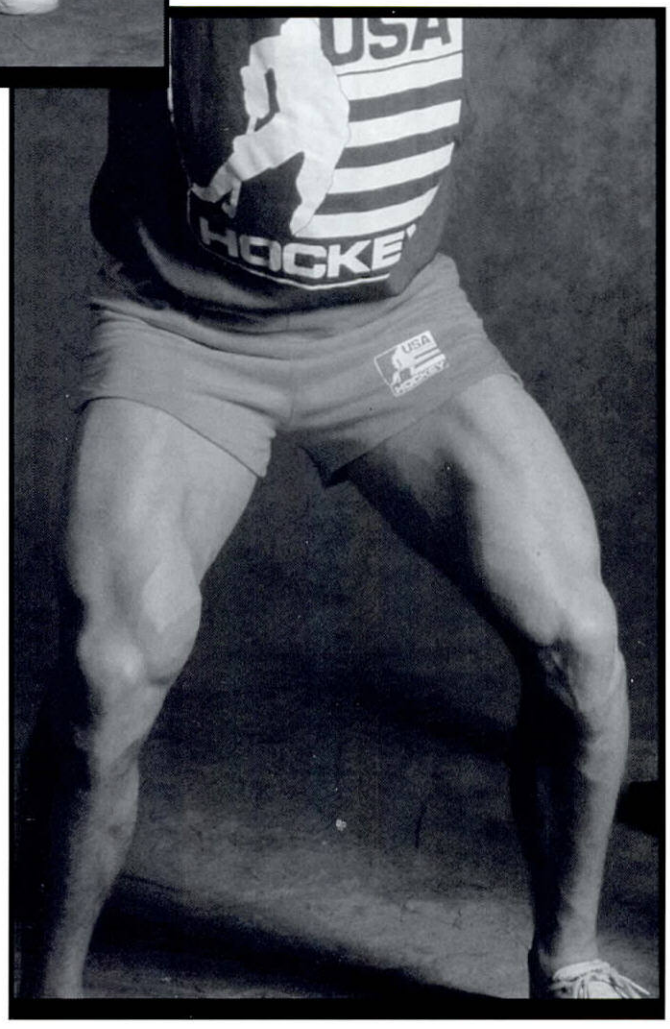
Soviet scientists and coaches have seen the value in sprinting.

Track coaches, scientists, and strength coaches have worked together for more than two decades to help sprinters become faster. They've found innovative training techniques to incorporate speed with strength, coordination, agility, and flexibility. If we want to become faster skaters, we should adapt some of their training to skating — both on and off-ice. The best choice is to go out for track and work with the sprinters.

The importance of leg strength

Sprinters have been competing for thousands of years, yet winning times continue to drop at every level. One of the biggest changes in track over the last forty years is the evolution of strength training. In the fifties, few great sprinters (or football players, for that matter) trained with weights. One common concern was the worry that bulky muscles would be slower.

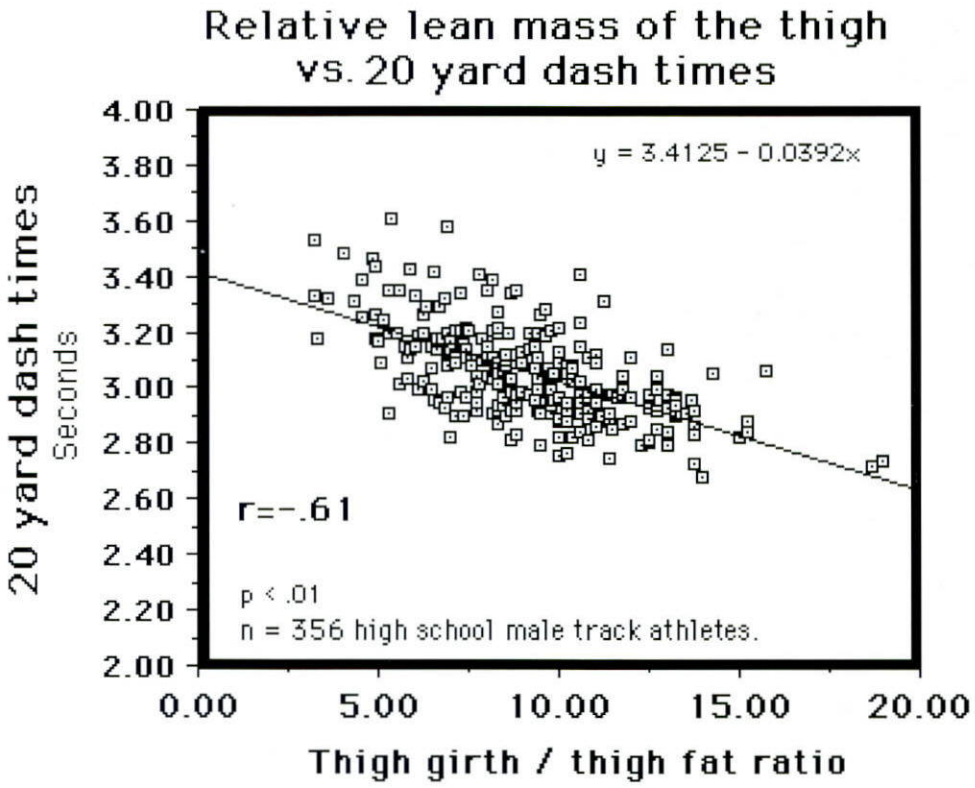




Leg strength is a critical factor to develop quickness in skating.

Football players and sprinters have demonstrated that strengthening the legs with weight training helps make them quicker — even when they've gotten extremely bulky, in the case of football players. The graph below demonstrates the relationship between sprinting 20 yards, and relative muscle mass in the thighs. High school track sprinters (n=356) were tested while attending a clinic on speed development. Thigh girth was divided by the sum of three ultrasound readings of fat in the legs, yielding a number which is used to determine which athletes had the biggest legs with the least fat. The farther to the right on the horizontal axis, the more thigh muscle an athlete had compared to thigh fat.

Athletes with the biggest thigh muscles (compared to fat) were likely to be the quickest sprinters in the 20 yard dash. A similar result was found for skating.



Thigh girth in cm, measured at mid thigh.
Thigh fat in mm is the sum of 3 sites by ultrasound.

Can we learn from Flo Jo and Ben Johnson?

In the 1988 Summer Olympics, both the male and female winners of the sprint events attributed their recent dramatic improvement to intense weight training (Bock, 1988). At 28 years old, Florence Griffith Joyner shattered existing world records, and ran 100 meter times comparable to elite male sprinters of a few years ago — better than O.J. Simpson!!!

In previous years, Joyner's weakness had been her starts, so she studied the techniques and training of the fastest men. "It's leg strength that makes the difference," said Joyner, and she supplemented her sprint training with weight training, including sets of squats with 320 pounds. The model for her training program was Ben Johnson, who also attributes his world record performances to squat workouts with 600 pounds and more. The fact that his accomplishments have been clouded by steroid use doesn't mean we can't steal some ideas from his workouts. Strength training helped him become the most explosive runner ever, out of the blocks, where sprinting and skating are very similar.

Force • Speed = Power: Using strength explosively.

The goal in track and hockey is to transfer increased strength to quickness.

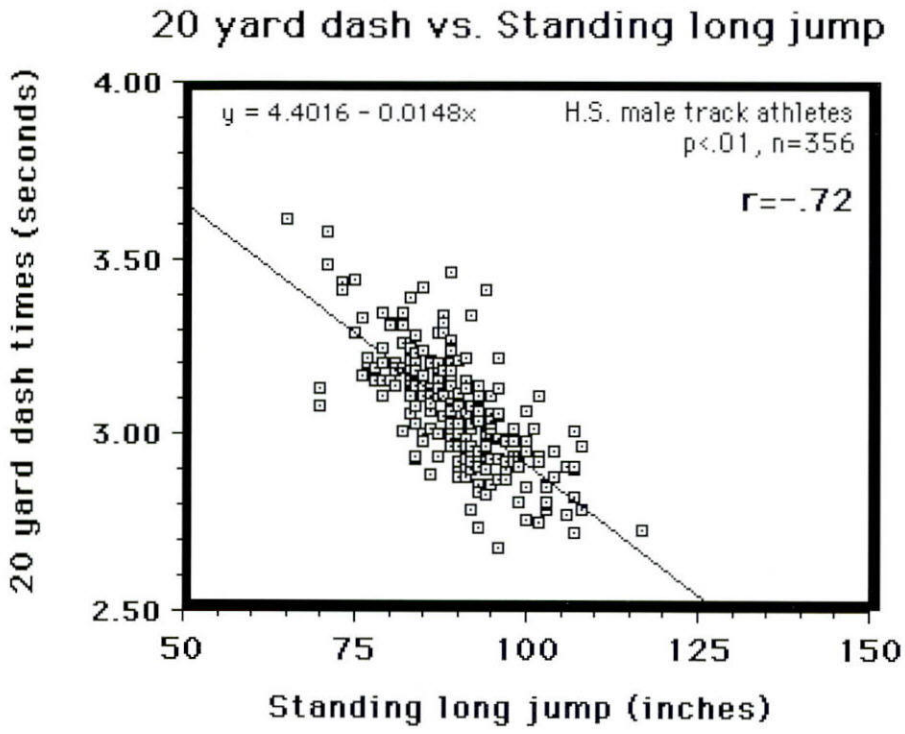
Sprinters have used plyometrics effectively, training the neuromuscular system to apply great forces in an explosive, fast movement. Jumping, hopping, or bounding exercises that resemble the triple jump are done for maximum speed, height, and distance. With high school track athletes we found a strong relationship between speed and jumping ability (long jump: r=-.72, shown below; and vertical jump: r=-.64, not shown).

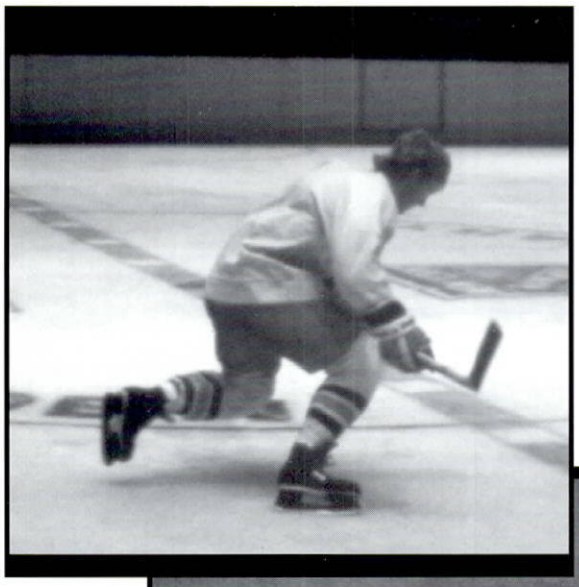
The same relationship exists between jumping ability and skating quickness.

The goal in track and hockey is to transfer increased strength to quickness.

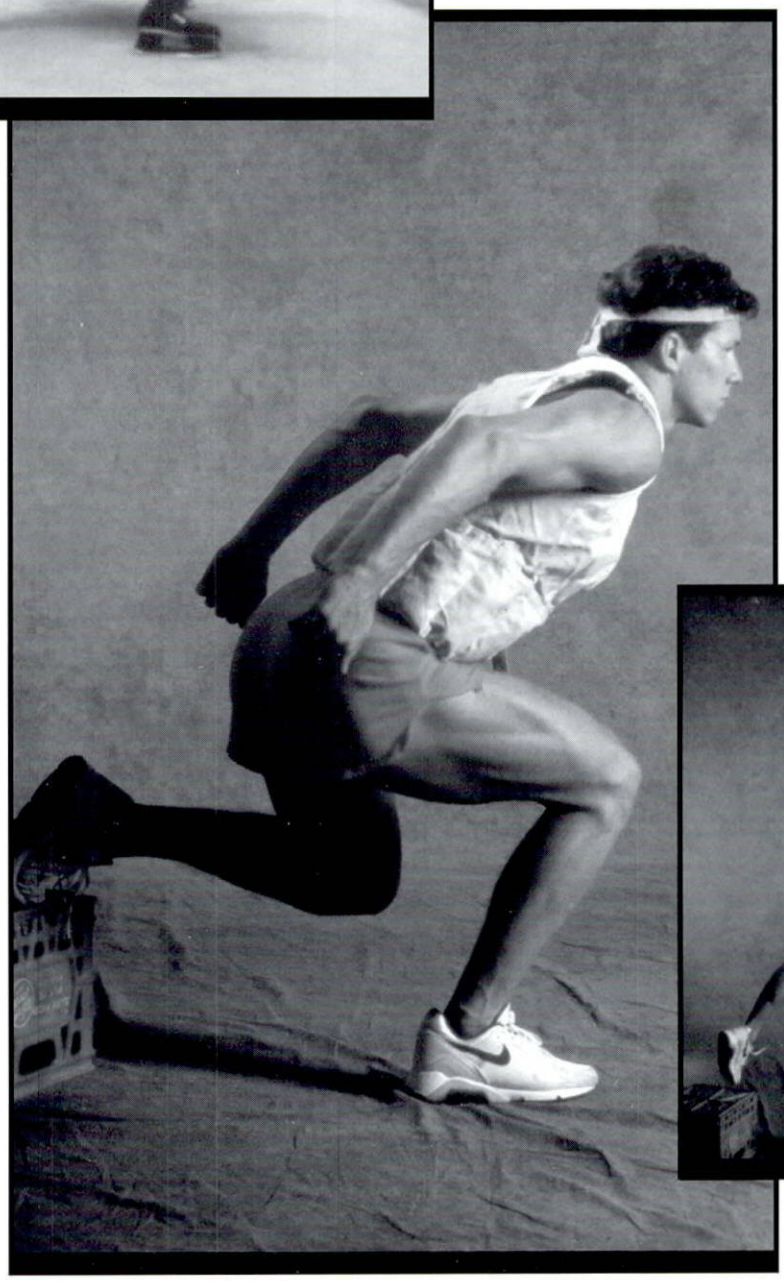
For every one of 50 teams we tested in this manner, the fastest skaters were likely to jump the highest or longest (r values between .6 and .8). We can look at the following graph in the same way as the relationship between on- and off-ice sprint speed...

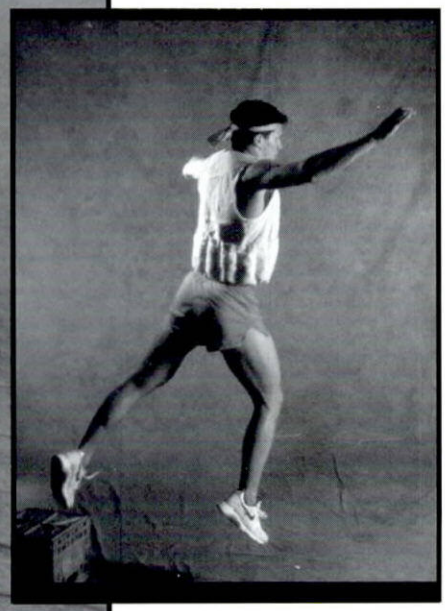
..whatever training helps you jump higher should make you a quicker skater!

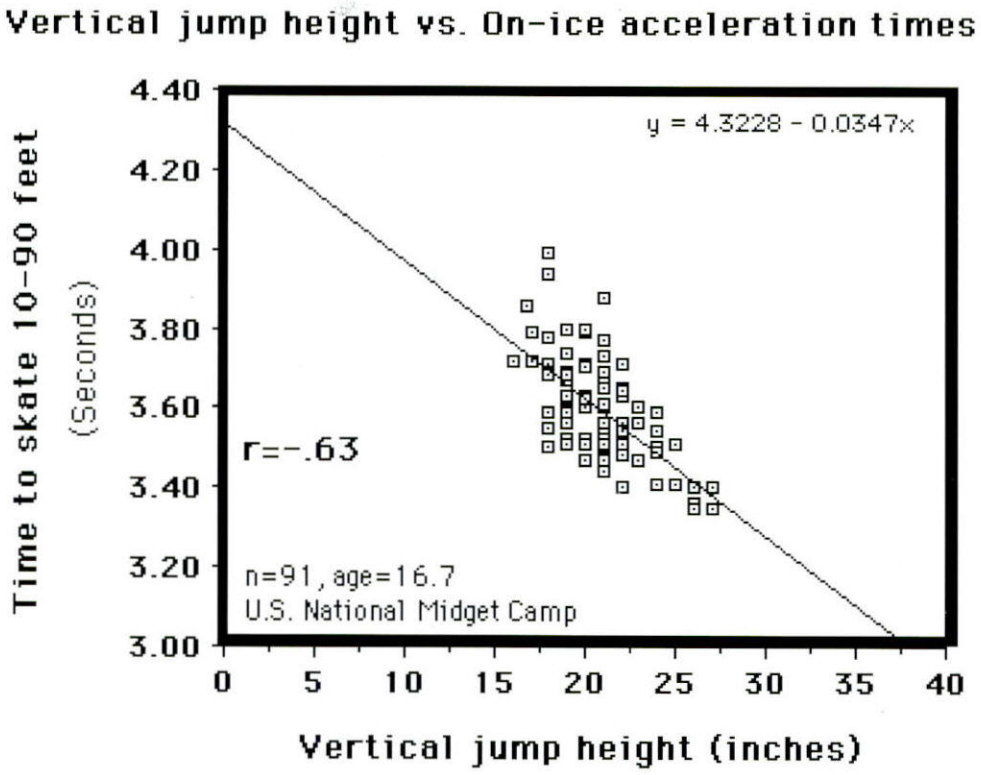




Plyometrics should be modified to approximate the skating stride.







Plyometrics should be modified specifically for hockey

Side-to side jumps and one-legged squat jumps should emphasize knee bend and explosive power. As seen in these pictures, the jumper and skater are using the same muscle groups in a similar range of motion. These jumps incorporate balance and coordination, and can be used to improve in these areas.

During any workout the one-legged jumps should be followed by two-legged squat jumps (with or without a weight vest). At this point, when fatigue has become a factor, concentration can be focused on the effort, not balance and technique.

Forming a habit of bent knees:

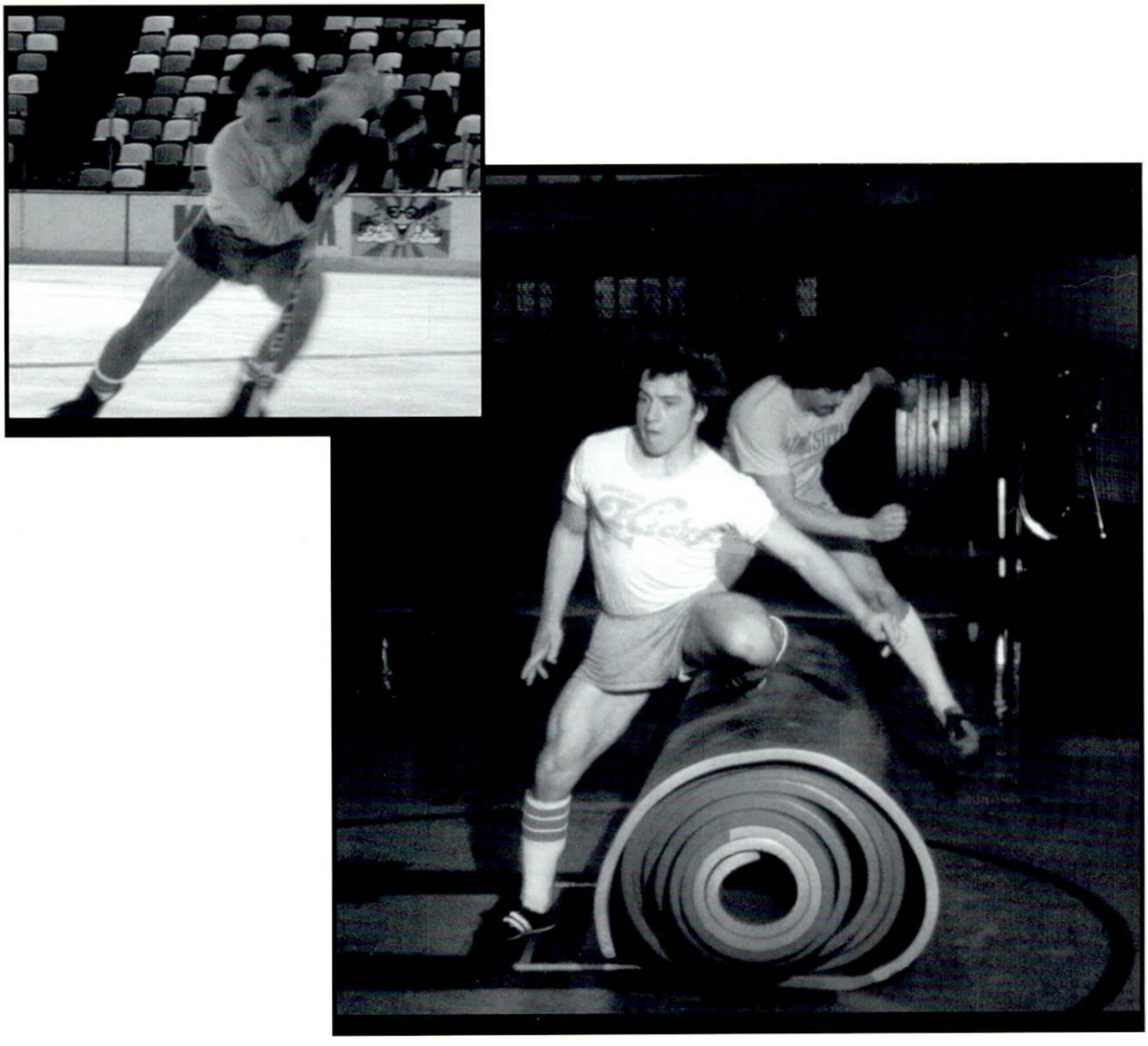
There are two important factors in developing a habit of good knee bend during skating or off-ice workouts:

1) The intricate neuromuscular patterns must be repeated perfectly in order to make the movement become reflex — eventually requiring no conscious thought.

2) Muscular endurance must be developed in this range of motion, so that a player doesn't return to previous habits as soon as there is a little fatigue.

Plyometrics, or jumping activities, can improve skating in several ways:

1) We are training to use strength very explosively; this amounts to training for power, rather than static strength.

2) We are practicing a rapid recoil (eccentric or lengthening phase), followed immediately by an explosive shortening of the muscles (concentric phase). This movement is common to all sports, certainly skating and checking.

3) With some modified jumps we can develop muscular endurance in a range of motion in which our knees are bent more than usual during skating.