Kristel Ngariem shows how to vary resistance in squats by using lifting chains. Ngariem represented Canada in the 2012 Junior World Championships, where she placed 12th with an 83-kilo snatch and 104-kilo clean and jerk in the 69-kilo class. Spotting her are Paul Dumais, a Canadian weightlifter who has also competed in the Junior Worlds, and coach Pierre Roy.

The Science of Strength Curves

The evolution of variable resistance training

BY **KIM GOSS, MS**

When you see young women cleaning bodyweight and young men squatting double bodyweight, you are looking at powerful athletes who are less likely to become injured. At BFS, for more than three decades we have seen firsthand the power of free-weight training on athletic performance. However, there are other tools athletes can use to give themselves an edge, such as resistance training machines.

The majority of equipment in commercial gyms today is in fact machines rather than free weights. That's fine, because the average trainee who lifts weights wants to lose fat and build muscle to look good and improve the quality of their life. Machines or free weights can accomplish both these goals. In contrast to

the average trainee, athletes and their coaches have a different agenda, which is to go beyond general physical fitness and develop athletic fitness for their sports. For them, the focus must be on free weights, with adjunct exercises on machines providing additional variety as needed or desired.

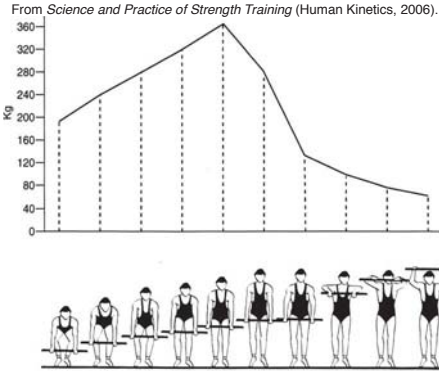
Resistance machines have built-in limitations, so let's see how we can make this equipment better. To do that requires an understanding of strength curves and resistance curves.

The theory of variable resistance is that exercise equipment should be designed to increase the resistance at the points at which the lifter is strongest. A strength curve is a mathematical model that represents how much force a muscle can produce at specific joint angles. There are several types of strength curves. The type most trainees are familiar with is an "ascending" strength curve, which exists when you can display more force as you extend the joints. Exercises such as deadlifts, squats, bench presses and military presses have ascending strength curves. Let's say an athlete has a personal best in the bench press of 300 pounds. If measured in a power rack with short movements, this athlete might be able to press 375 pounds at the midpoint of the exercise and 500 pounds at the finish.

With a descending stretch curve, the muscle appears to be displaying less force as a muscle is flexed. For example, when performing a leg curl or a dumbbell lateral raise, a lifter is stronger at the start of the movement than at the middle or the end.

Finally, there is an ascending-descending strength curve, which describes an exercise in which the midpoint of the exercise is the strongest. A standing biceps curl is an example of such an exercise.

From *Science and Practice of Strength Training* (Human Kinetics, 2006).



A strength curve is a mathematical model that represents how much force a muscle can produce at specific joint angles.

A resistance curve describes how an exercise applies force to a muscle. In a regular bench press, the strength curve is such that the movement appears easier as the arms are extended. However, if you want to make the muscle work harder on a bench press to match the strength curve, the machine would have to be designed so that the resistance is heavier towards the top of the exercise. This could be accomplished with lifting chains, because the chains exert more force downward as they are lifted off the floor.

The Nautilus Generation

Nearly a half century ago the late Nautilus inventor Arthur Jones experimented with chains to vary the strength curves of exercise machines. Ultimately, Jones decided that the best way to match the resistance curve of an exercise machine to the strength curve of a muscle was by using cams rather than circular pulleys. The cams were shaped like seashells, so Nautilus was a perfect name for Jones's company. I should mention, however, that although Jones is rightly credited for popularizing the use of these types of cams, the first patent for such a shell-shaped pulley was awarded in 1901 to Max Herz of Vienna.

The design of the pulleys on machines affects the resistance curve of an exercise.

Herz explained in his patent how his pulley accomplished the goal of increasing resistance at the points of an exercise at which the lifter is strongest: " …in working with such apparatus, during the whole movement, the muscles shall be exerted in accordance with their momentary tension or pulling force." In other words, there would be no sticking points during the exercise – the muscles would work with the same degree of effort throughout the entire exercise.

In one gym where I trained figure skaters in the '90s, the owner had four of Jones's medical machines, two for the torso and two for the neck. I was told the total cost of these machines was approximately $200,000. Despite their cost, the machines were popular among insurance companies because the equipment provided data about how an individual with a back or neck injury was progressing. As such, insurance companies had no objection to paying $150 for a 10-minute, one-set-per-exercise workout.

Even so, the therapeutic value was controversial because an individual with a neck or back injury who becomes stronger is not necessarily having less pain. In fact, back pain experts such as Stuart McGill, who has published more than 200 peer-reviewed research studies on lower back pain, has found that muscular endurance is probably more important than absolute strength in helping those with back pain.

About the cam design of the Nautilus machines, it was a good idea for sets involving low repetitions, but not for higher repetitions, such as the 10-15 reps a bodybuilder often performs. This is because fatigue changes the strength curve, an idea I was introduced to in the early 1990s by personal trainer Jerry Telle of Colorado.

Again using the example of the bench press, an athlete performing a single repetition can lift more weight as the arms are extended. As such, using chains or bands would be practical ways for the resistance curve of the exercise to match the strength curve – although I should mention that due to the instability of the bands, BFS does not recommend them in the high school environment. But what happens when a 10-repetition (10RM) maximum is performed? After grinding out that last rep, if the athlete tries one more repetition, they will probably be able to get the weight a few inches off their chest before failing – in effect, the athlete is stronger at the start of the movement. Using bands or chains for higher repetitions (10-15) would not be appropriate, because during the last few reps the athlete will be increasing the resistance at the weaker part of the movement.

Leverage machines, such as these three built in the USA by Bigger Faster Stronger, provide a type of variable resistance to increase the stress on the muscles.

There are many ways to get around this problem. For one, if you were designing a machine to work an ascending strength curve for an exercise, a round pulley would be better than a cam for overloading all points of the strength curve – if the primary goal is building as much muscle as possible. The ideal solution would be to design a machine that would adjust the resistance curve during the exercise, and in fact Telle has a patent for an exercise machine that does exactly that.

Another practical option is to vary the resistance curve manually during the exercise. For example, if an athlete performs 15 reps in a bench press, the first 10 reps could be performed with chains, and then (with the help of two training partners) the chains would be taken off mid-set and the athlete would perform the remaining 5 reps. In effect, the weight would feel "smooth" throughout the entire movement during those last few reps. You could also perform partial movements in a set. For example, with bench presses, an athlete could perform the first 10 reps just to the sticking point, and then perform the remaining reps throughout a full range of motion. Another option is to combine exercises, such as performing a set of preacher curls to focus on the lower range of the biceps, and then performing a set of incline dumbbell curls to focus on the upper range.

In his book *Tellekinetics*™ Telle describes in detail many such methods to vary a resistance curve during a set. For example, when performing a

dumbbell fly, an athlete could start with the arms straight and then, upon reaching failure, could bend the arms slightly to improve leverage and therefore be able to pump out a few more reps; upon reaching failure, the athlete could immediately perform a dumbbell bench press.

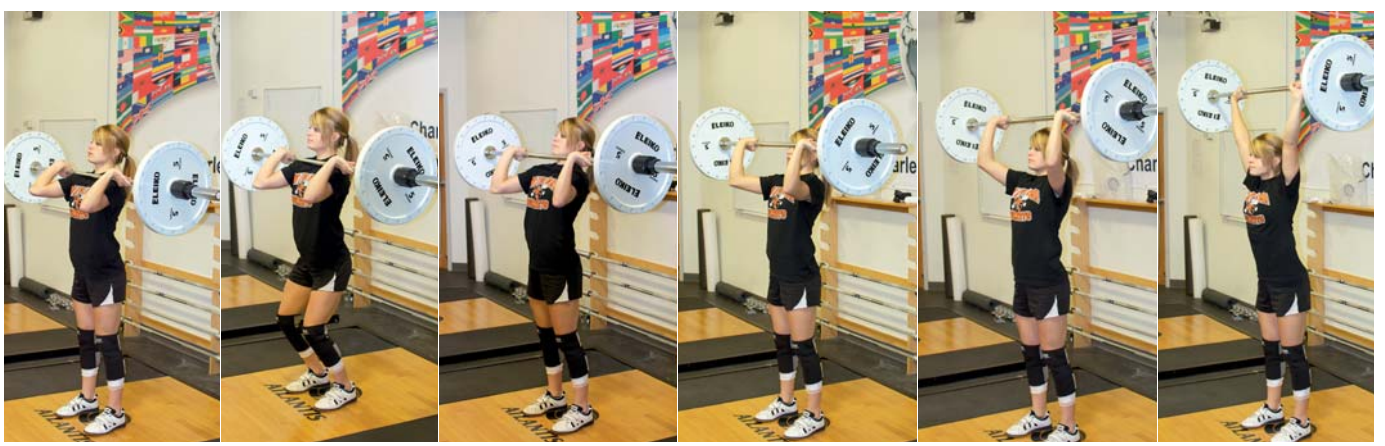
The resistance curve also may be varied by means of "cheating." Some athletes cheat by using poor form, such as by raising the hips during the bench press to grind out that last rep or swinging the weight in a standing barbell curl – both are techniques that can place harmful stress on the lower back. The type of cheating I'm talking about involves using other muscle groups to help the athlete perform additional repetitions without altering the technique of the basic exercise. Let's take the example of a military press.

Perform a set of strict military presses for as many reps as possible; then help yourself through the sticking point on a few additional reps by starting the exercise by driving the weight with the help of your legs – an exercise called a push press. This technique will enable you to overload the end portion of the movement where you are strongest. You could even go a step further by performing a push jerk, which entails driving the weight with your legs and then jumping your feet out to the side to move your hips lower under the bar. Finally, on the last rep you could lower the bar slowly, as you can lower more weight eccentrically than you can lift concentrically. Added up, such a set would start with reps done to concentric failure, followed by forced reps, and finishing off with heavy eccentric loading.

As for resistance curves when using free weights, one of the advantages of many Olympic weightlifting exercises is that the athlete can adjust to the "flat" resistance curve of a free weight by accelerating the bar. For example, a power clean is pulled slowly off the floor and then is performed rapidly at the finish.

Exercise machines are here to stay, and there are good reasons to use them along with free weights to achieve physical and even athletic fitness. In future issues of *BFS* we will talk more about using variable resistance to help anyone involved in athletic or physical fitness to optimize their training. BFS

After reaching concentric failure in a military press, athletes can use their legs to perform a few more reps and overload all areas of their strength curve for the exercise.



AMERICAN MADE AMERICAN QUALITY

ULTIMATE MULTI USE RACK ONLY $2,095

8 FOOT POWER RACK ONLY $995

IS YOUR PROGRAM READY FOR THE TOUGHEST RACKS

HEAVY DUTY SUPER CAGE JUST $1,475

Rings not included

Includes instructional DVD

ROTATIONAL BODY WEIGHT TRAINING

CrossCore 180

Expand Your Rack!
Add Body Weight, Rotational Training to your rack for only $249.99

BIGGER FASTER STRONGER

BFS

DEDICATED TO HELPING ATHLETES SUCCEED SINCE 1976

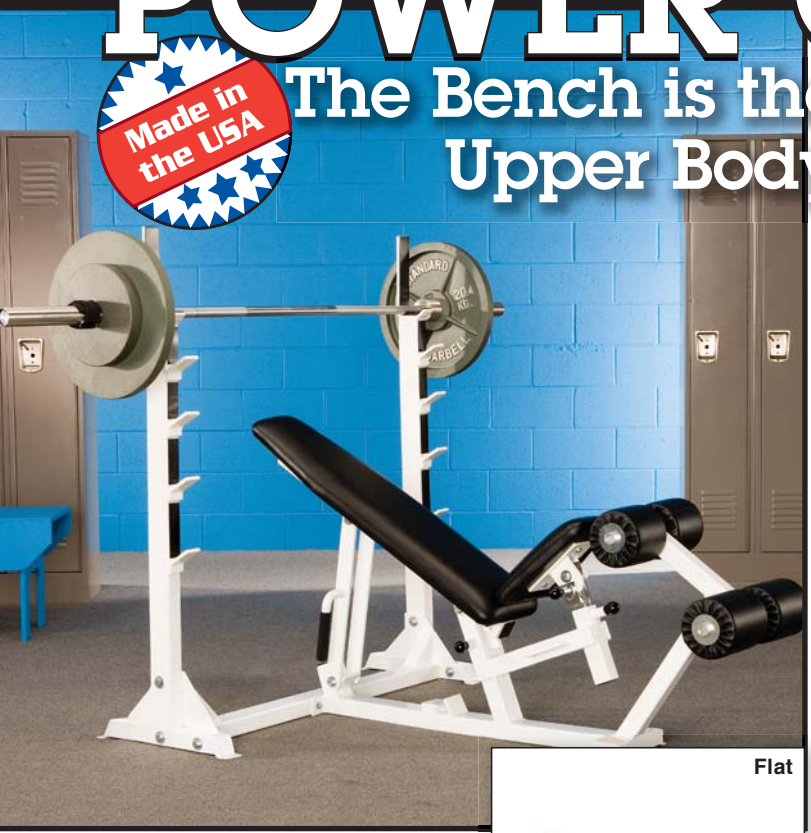
GET TOUGH 1-800-628-9737

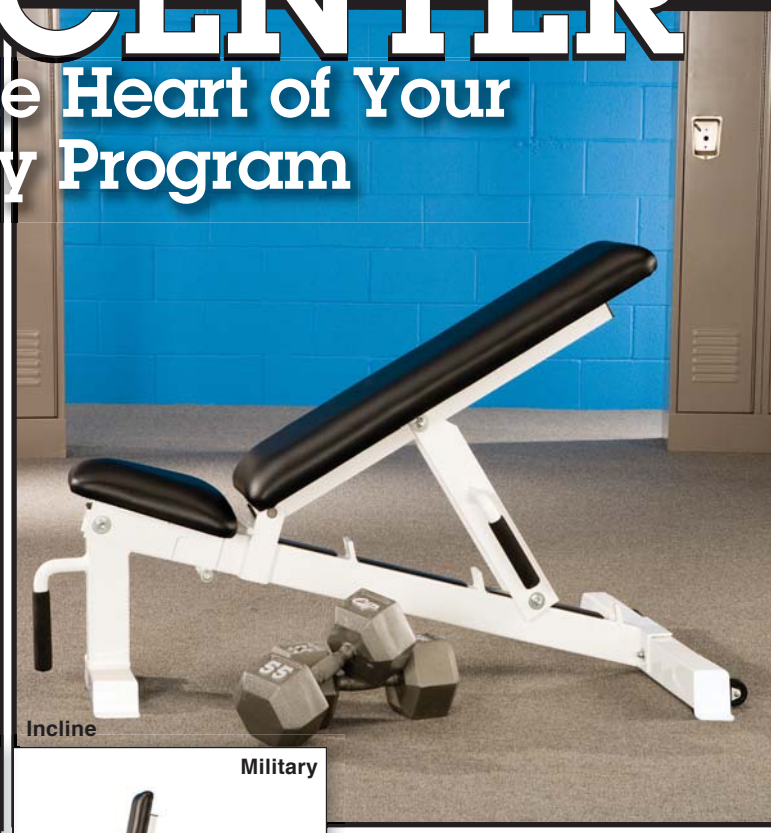
online at www.biggerfasterstronger.com • email us at info@bfsmail.com
843 West 2400 South, Salt Lake City, UT 84119 • Fax (801) 975-1159

POWER CENTER

Made in the USA

The Bench is the Heart of Your Upper Body Program





Incline

Olympic 4-in-1 Bench

- Highest quality construction - period
- Easily adjusts between Olympic decline, Olympic bench, Olympic Incline and Olympic military (-20, 0, 30, 85 degrees)
- Built sturdy for your strongest athletes

$645

- l-67" w-48" h-57"

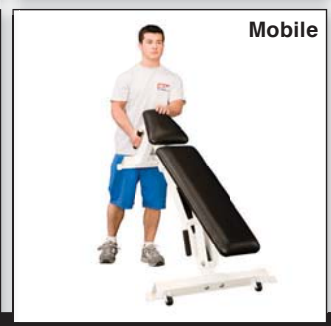
Flat

Military

Military (shoulder press)

Flat

Decline



Mobile

Flat Bench With Incline

- Easily adjusts from flat to military: 0, 30, 35, 45, 85 degrees
- Heavy-duty: Built to last
- Easy to move with handle and wheels

$415

- l-51" w-30" h-18"

BIGGER FASTER STRONGER

BFS steel equipment is proudly designed and manufactured in the USA

GET STARTED! 1-800-628-9737

online at www.biggerfasterstronger.com • email us at info@bfsmail.com

843 West 2400 South, Salt Lake City, UT 84119 • Fax (801) 975-1159