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.

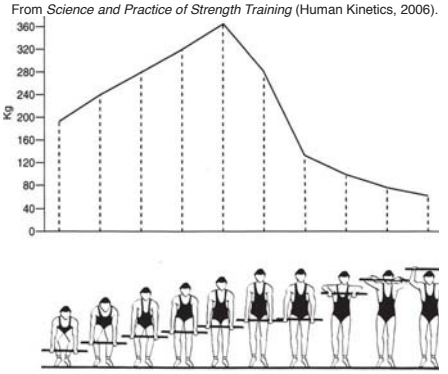
Resistance machines have built-in limitations, so let's see how we can make this equipment better. To do that requires an understanding of strength curves and resistance curves.

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.

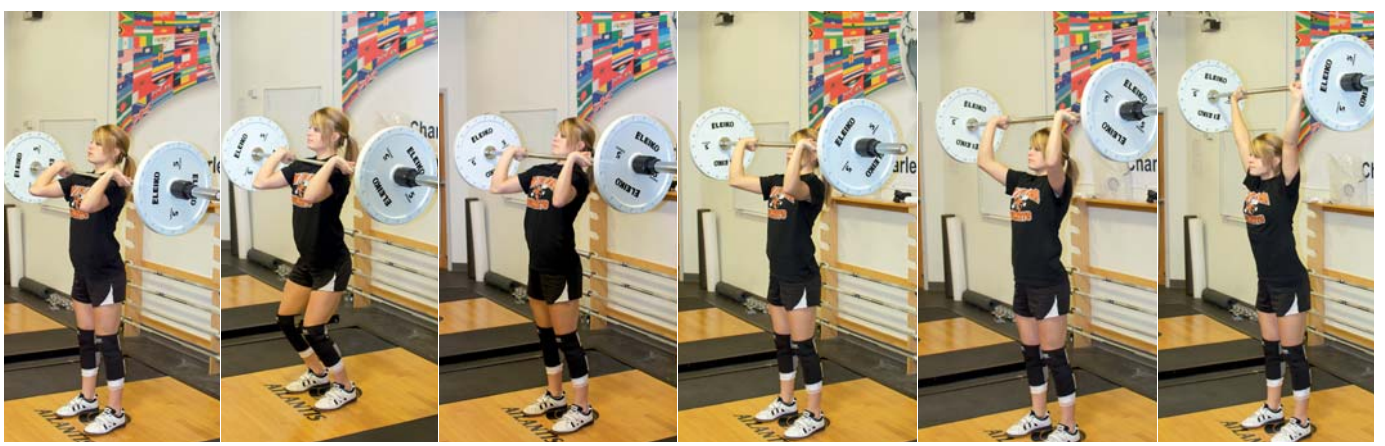
The resistance curve also may be varied by means of "cheating." Some athletes cheat by using poor form, such as by raising the hips during the bench press to grind out that last rep or swinging the weight in a standing barbell curl – both are techniques that can place harmful stress on the lower back. 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.



Lifting Chains REVISTED

A look at the ever increasing value of lifting chains in helping athletes achieve their physical potential

BY **KIM GOSS, MS**

During the squat exercise, chains increase the resistance at the top of the exercise, where the athlete is strongest.

If something works, there is really no reason to change it. The BFS program has been used to help create successful athletic programs for over three decades, so there would have to be an important reason to make a change to it. We found one: lifting chains.

Chains make athletes work harder throughout the entire set. After a few weeks of training athletes with chains, coaches often report not only increases in 1-maxes, but also more acceleration while lifting, which can translate into a more explosive athlete on the field or court.

The roots of lifting chains can be traced back over four decades to when Nautilus inventor Arthur Jones wrote about experimenting with chains to vary the strength curves of his machines. Jones eventually gave up on the idea of using chains, instead relying on shell-shaped cams to vary the resistance. It should be noted that although Jones popularized the use of these cams, the first patent for such cams was awarded in 1901 to Max Herz of Vienna.

Among the first group of athletes to rediscover lifting chains were powerlifters, including one of the most accomplished powerlifting coaches in the world, Louie Simmons. Later strength coaches also caught on to the idea, primarily to increase results with bench press and squat variations.

A Closer Look at Strength Curves

The theory of variable resistance is that exercise equipment should be designed to increase the resistance at the points at which you are strongest. Herz explained in his patent how his pulley accomplished this goal: " . . . in working with such apparatuses, 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.

A strength curve is a mathematical model that represents how much force can be produced at specific joint angles. An "ascending" strength curve 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. Chains would be valuable for these exercises because the increasing resistance during the strongest joint angles would make the exercise feel "smooth" through the entire movement.

A descending strength curve exists when you can display more force as you flex a joint. An adductor (inner thigh) pull with cables or a machine would have a descending strength curve, as you can display more force when the legs are closest together. And some exercises have an ascending-descending strength curve, which means that you can display more strength at the mid-range of the movement. Chin-ups and standing biceps curls are such exercises. Using chains for exercises with descending or ascending-descending strength curves would not be very useful, as the chains would apply the most resistance in the parts of the exercise where you would be weakest.

One important point to consider

BFS chains come in three sizes: 12 pounds, 19 pounds, and 28 pounds.

about strength curves concerns the effects of muscular fatigue. For a bench press, as the set progresses, fatigue would make the athlete less strong at the finish of the exercise than at the start. Let's say an athlete can bench press 200 pounds and is trying to perform as many reps as possible with 160 pounds. For the first five reps the weight feels lighter at the finish, for the next three to five reps the weight might feel the same through the entire movement, and at about the 12th rep the athlete might only be able to lift the barbell a few inches off the chest. The practical application of the fatigue factor is that chains would not be appropriate for bodybuilding protocols that require high repetitions, such as reps of 12-15, because the resistance would be too heavy at the end range of motion.

Because the BFS program emphasizes lower reps than do bodybuilding programs, chains would be a good training method, especially during the first week of the BFS training cycle, which uses set-rep protocols of 3x3. It would be less effective during the fourth week, in which sets of 10-8-6 are performed for many core lifts.

Incidentally, research has shown that the eccentric portion of an exercise is the most effective type of muscular contraction for developing strength, and eccentric strength is important for developing the ability to control the forces that occur in sports, such as landing during a jump in volleyball or basketball. Also, eccentric contraction is primarily responsible for developing muscle mass, which is why swimmers seldom display large muscle mass, as there is little intense eccentric contraction in most swimming strokes.

Explosive Advantages

Chains improve explosive strength, which is the ability to apply force at the beginning of an exercise or athletic movement. In squats, chain training will teach you to push harder throughout the entire exercise because the resistance increases. You can't slack off when there are chains on the bar!

In addition to adding resistance to squats and bench presses, chains are useful in quick lifts such as cleans, snatches and even jerks. One strong advocate of using chains for the quick lifts is Doug Briggs, a faculty member at New Mexico State University and president of the American Weightlifting Association. The idea to use chains occurred to him in May of 2002 when his team was training at Scott Warman's Pro-Gym in El Paso, Texas. "I was sitting on a bench looking at the chains hanging off of a bench press bar and the thought occurred to me that this might be something I could adapt to Olympic weightlifting," says Briggs.

Brigg's first thought was how to adapt the chains so that they wouldn't get in the way of the feet or interfere with the lift. He believed that to ensure safety it was important to have the chains attached as far away from the inside collars of a barbell as possible. (To do this with a BFS chain, you would attach the regular collars to the bar to secure the weight plates, and then slide the steel lock-down pin collar that holds the BFS chains to the far ends of the outside sleeve.)

As for length, the chains had to be long enough to remain on the floor during the entire lift or there would be a high risk of the chains swinging wildly and hitting the lifter. This is a problem especially with jerks and push presses, as the distance from the floor is several feet higher than it would be with a squat. (BFS chains can be lengthened by use of chain extenders, each of which adds two feet to the length of the chain.)

The next step was to determine the proper chain weight. "I found that some of the studies on chains were inconclusive or showed no promise for this method. It didn't take long to figure out that one of the problems with the studies was the fact that the chain weight was too great. Powerlifters often use very heavy chains for the exercises, and it would make sense for a powerlifter to train with heavier weights when using chains. But the movements of powerlifting and Olympic weightlifting are different. In fact, the only movement that is similar is the break off the floor, as in the deadlift or first pull of the clean."

For an Olympic weightlifter, using weights that are too heavy in pulling movements causes the barbell to decelerate too much and adversely affects the proper snap of the hips when the bar brushes the thighs. Says Briggs, "Technique is very important in the two Olympic lifts. When the additional weight of the chains is correct, the lifter can make the lift even exceed a previous max without a breakdown in form. The most important difference in my method is that by using a lighter chain weight, I am 'tweaking'

or 'fine-tuning' the lift, not destroying the movement or trying to build brute strength or power."

Briggs says the correct chain weight can help teach a lifter to finish their pull by using the upper body muscles more aggressively. And if a lifter doesn't finish the second pull, they will not be able to get under the weight. "The force plate is measuring the amount of force the athlete is applying to the ground with their feet, and what you're finding with the chain is that the force is applied longer, which means the upper body is more active. We've also found that there's actually more acceleration on the bar — it's tapping onto the potential we all have."

Briggs says the Olympic lifts, particularly the snatch, require a high level of shoulder stability. "Chains work these muscles because the lifter has to control and stop the sway of the chains at the completion of the snatch or jerk. When using the chains at 100 percent of maximum and then removing the chains, there will be a noticeable difference in bar speed and ease of movement." Says Matt Rich, one of Briggs' lifters, "Completing a full snatch is one thing, but completing a full snatch with a set of chains attached adds a new dimension to training. Since the chains sway a bit during the lift, it forces you to adjust and become more stable in the bottom position."

Soviet research suggests that most jerks are missed not due to lack of strength, but due to the bar moving forward excessively. Briggs says chains help this problem by making certain the bar is pushed straight up. "Also, when you do the dip and drive in the jerk, the chains force the athlete to get under the bar faster because you have that additional weight that's trying to bring that bar down. You have to exert more force on the bar to get the bar up, and you have to get under the bar quicker."

Exercises that Briggs has used chains with include the snatch, clean, jerk out of the rack, front squats, back squats, deadlifts, high step-ups, and of course bench presses and incline bench presses. Briggs says, "I encourage anyone involved in Olympic weightlifting to try this method. While it might not work for everyone, I assure you that it will work for the majority of lifters."

BFS Perfects the Chain

In the past, athletes wanting to try lifting chains in their workouts were in for a challenge. When BFS Vice President John Rowbotham set out to produce chains, he discovered they were difficult to find. "About the only places where an athlete could find suitable chains for lifting were marine supply stores, which sell the type of chains that attach to anchors. These are very, very expensive."

Kristel Ngariem is a 14-year-old Olympic lifter who uses chains in her workouts to develop explosiveness. This year she will represent Canada in the Junior World Championships, and her best lifts are a 154-pound snatch and a 191-pound clean and jerk in the 139-pound bodyweight class.

Rowbotham, along with Eric Snowden, who runs the manufacturing department, and BFS President Dr. Greg Shepard, designed a strong chain with a galvanized non-flaking finish and devised a way to make the chain easy to use. They accomplished this by attaching the chain to a collar that easily slides on the end of an Olympic bar sleeve. They also attached a steel lock-down pin to ensure that the collar doesn't slip when the bar is lifted, although Rowbotham says it's best to attach a regular collar on the outside of the barbell sleeve.

Finally, thanks to efficient manufacturing processes, BFS was able to produce three different weights of a quality barbell chain at the lowest price. As for how to store the chains so they don't become obstacles on the floor, Rowbotham says his practice is to simply hang them on the BFS weight belt rack. The rack will hold three pairs of chains, which is perfect because the chains come in three weights (12 pounds, 19 pounds, and 28 pounds). The rack also has a security bar that locks them in place to prevent theft. Says Rowbotham, "If the demand is there, we can certainly design and build a special chain rack, but our belt rack works just fine."

Chains are now affordable and have received the rare endorsement of BFS, but there is another reason to add chains to your workout: motivation. "Athletes love chains!" says Briggs. "The kids see the chains, they hear them banging down on the floor, they hear them coming up — they really like it. There's just something cool about chains!" BFS