# The Saga of the Seated Leg Curl

*by Ken Hutchins*

This article was originally published in 1994. It contains valuable history and fundamentals required by all exercise instructors. Updated references are included at various points in this reproduction. I have edited some of the details for clarity.

---

In 1982, Arthur Jones assigned three of us to the Nautilus-funded Osteoporosis Study at the University of Florida Medical School in Gainesville, Florida. Among this group was Keith Johnson, M.D.

Each of us had made a two-year commitment to the study. Although I stayed for nearly four years, and later learned the contract between Nautlus and the University of Florida was for nine years, Keith exited the study at his two-year anniversary. The study was terminated by Arthur Jones at about the five-year point.

Keith remained in Gainesville for several months while awaiting admittance to a residency program. Meanwhile, he became absorbed in the development of some new exercise machine designs. He visited the osteoporosis research center regularly to discuss with me ideas on several subjects.

On one such day in 1984, Keith proposed a seated leg curl (knee flexion) design. I exploded into my usual tirade against seated leg curl designs. I demanded to know how anyone could be so stupid as to design an exercise wherein the subject attempted to contract a muscle on which he was sitting. I also told Keith that he, as an M.D., should know better than to stoop to such defective design principles.

Keith had heard all of this before. He patiently let me finish my abusive criticism. Then he calmly explained that in this design the subject was not going to sit on his hamstrings—that he would sit only on his ischium, superior to the belly of the hamstrings. Provided as the "seat" was a small shelf on which to accommodate the subject's ischium.

I then complained, "The problem of sitting on your hamstrings is solved, but how do you propose to hold the knees upward and concentric with the movement-arm axis?"

Keith explained that the self-centering movement arm incorporated in the then-current Nautilus On-the-Side Leg Curl machine had many untapped applications. Before he could finish, I knew that he was correct and where he was headed with this idea. The nature of the coupled movement arm is to drive the axis of the knee to the axis of the movement arm and keep it there. Keith had made a great intellectual leap in leg curl design, and I felt foolish for not seeing it before that day.

A viable seated leg curl design was needed. The vintage prone design could be a productive tool when outfitted with low-friction articulations and a Super Slow Cam retrofit. However, user problems remained. It is difficult to teach subjects to protect their knees during entry/exit. The hips must flex as the knees flex. (Please note photos on next page.)

The arms and hands must arrest the reactionary force as the movement arm tends to pull the body, and thus, the knees inferiorly and off the axis of the machine (and off the rear end of the machine's bed pad. With his face plastered into the bed of the machine, the subject cannot see what he is doing with his legs. In short, it is a complex mess for most subjects to control. Full-term pregnant women are not able to use it at all.

The Nautilus On-the-Side Leg Curl made its debut in 1982 or thereabouts. It solved many of the aforementioned problems, but it introduced a few new problems. Lying on her side (Please note photos on page 3.), the subject pulled harder with her right hamstrings than the left. Also contributing to the uneven hamstring contraction—as well as an independent problem—was the misalignment of the spine, shoulders, and head that occurred when the subject lay on her side.

If Keith had, indeed, struck pay dirt with his seated design, he had solved all of the problems associated with direct resistance for the hamstrings. It was extremely important that I take his idea seriously.

Keith's insistence of other applications for the self-centering movement arm led to other possibilities. In general, it underscored that the first requirement of Full-Range Exercise—rotary resistance—needed further elaboration and definition.

First of all, there is no such thing as *rotary resistance.* There exists torque, but torque is a product of straight-line force and lever length. Force and resistance are, in general, the same thing. I do admit, however, that torque is a foreign concept to most laymen and that the idea of *twisting force* or so-called *rotary resistance* is a loose way to get the idea

of torque across. But this loosey-goosey language leads to conceptual mis-steps (illogic) that preys on our subsequent conclusions.

Second, a rotary-form Nautilus machine such as a Pullover does not impose torque about the joint (shoulder). It merely provides torque and rotary-form movement about its (the Pullover's) axis. Instantaneous force applied to the upper arm bones is in a straight line, orthogonal to the bones. This overall reactionary force on the body changes (The arms produce *actionary force* during the exercise.), dependent upon the instantaneous position of the body and the movement arm.

For example:

> Force (machine force or reactionary force) in a Pullover is posteriorly directed when the elbows are directly superior to the shoulders. This force is levered over a point on the seatback at about the level of the subject's shoulder blades to redirect the force forward at the pelvis, thus requiring a belt to contrain the subject's butt from being forced forward and out of the seat.
>
> Force is upwardly directed when the elbows are directly anterior to the shoulders. This requires a belt to anchor the subject into the seat to prevent him from being lifted upwards out of the seat.
>
> Force is anteriorly directed when the elbows are directly inferior to the shoulders. This requires a belt to prevent the machine from launching the entire subject forward and out of the machne.
>
> Therefore, efforts to arrest reactionary force are in constant flux in so accord.
>
> A coupled movement arm for the Pullover—if this was possible—would render a constantly directed reactionary force.

In the non-coupled, prone Nautilus Leg Curl, the force when the leg is straight tends to drive the lower end of the thigh downward on the rear edge of the upholstery, thus tending to pry the upper thigh and pelvis upward. When the knee is flexed to 90 degrees the force tends to drag the entire body off the rear end of the machine. At the completion of flexion—of course, depending on the subject's flexional limit—the force tends to lift the entire lower leg upward (a minor effect).

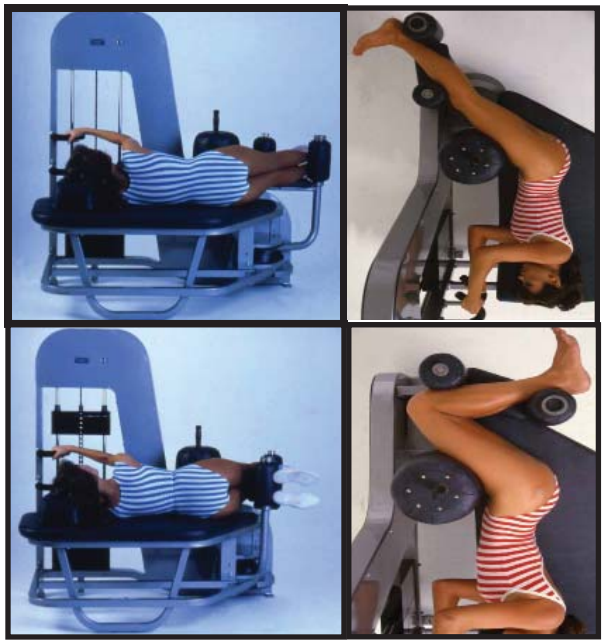
However, the self-centering movement arm is designed to facilitate the principle of the mechanical couple. A couple contacts the body part in two places distal to the involved joint. These two contacts receive equal and opposite force from the rotating limb. In so doing, the limb is forced to EITHER rotate its proximal end—the knee, in the case of the Leg Curl—concentrically with the machine axis OR to encounter opposition to rotation from the couple contacts.

During rotation, the general reactionary force on the body does not change. [Note that this is an improper use of the formal meaning of *reactionary force*, since we are really discussing a *reactionary torque*.]. It tends to force the body to counter-rotate, regardless of the joint/movement arm angular position.

For example, in a Seated Leg Curl untilizing a coupled movement arm (Several companies have long sold seated leg curl machines with a non-coupled movement arm—of course, stupidly having the subject trying to contract the very muscle they are sitting on!), your body is pulled by the movement arm into the seat bottom. This direction of force is unchanging, although the force magnitude does vary with cam effect and bodytorque.

In essence, the application of the couple marks the advent of a truly rotational exercise. It does not merely permit rotation at the joint axis. It *imposes* rotation.

**The Vintage Nautlus Prone Leg Curl. This machine is re-engineered by Ken Hutchins to provide maximum resistance decrease at full knee flexion. To accomplish this, part of the frame has been cut away to provide a pass for the drive belt. Please read the text on page 1 to visualize the performance issues encountered with this device.**



**The Vintage Nautilus On-the-Side Leg Curl. Upper Left and Right: The bottomout (start of positive) position. Lower Left and Right: The topout (finish of positive) position. Photos taken by Ken Hutchins circa 1984. Note the increased lordosis and hip flexion that occurs during the excursion. Some instructors have advocated performing this exercise while delimiting this action...bad idea. Lumbar extension and hip flexion must occur as the knees flex to stabilize the pelvis for hamstring tendon mooring and to provide active sufficiency for the hamstrings and passive sufficiency for the quadriceps.**

Before the advent of the couple, rotation at the joint was imposed internally by the static and dynamic stabilizers of the joint—not the machine, not any machiine, including Nautilus. If not, the limb immediately distal to the joint would be sheared off in some instantaneous direction of force by the corresponding instantaneous position of the movement arm.

In the case of the couple, however, your internal stabilizers can be deficient—even missing (in theory)—yet the couple will permit (enforce) movement only at that rotational axis.

Potentially, Keith had caused me to discover the couple as the mechanical design of choice when applied to the management of early-stage rehabilitation of grossly deranged joints. I could predict many problems with prototyping such applications, but I believed that it had tremendous potential value.

[For an updated (~2014) discussion on the couple please read *Exercise for The Human Knee.* This four-part treatise explains so-called *shear force* and the fundamentals regarding *closed-chain* and *open-chain* movements. I placed the links at the end of this article.]

I wanted Arthur Jones to recognize Keith's idea. I also realized the difficulty of making such a presentation to Arthur. He could be a brilliant man, but he often behaved emotionally when his ego was confronted in exercise equipment design. I knew that I had slight chance of winning his support by verbal explanation, and I recognized the imperative to get a prototype built to show him instead of to tell him.

I phoned Gary Jones in Mexia, Texas. Gary was always happy to build almost anything we needed. Unfortunately, Gary was presently involved in a mad rush to prototype leverage equipment for the Midwest distributor. He suggested that I ask Clay Steffe—manager of the Lake Helen Nautilus prototype deparrtment—to prototype Keith's idea.

Clay was working his staff 18 hours/ day prototyping the medical testing machines that were later to become MedX® testing machines. He listened to my request, but he did not yet appreciate the concept. He agreed to investigate any idea I proposed once he could block off some time.

My last resort was to phone Greg Webb, the Nautilus engineer in Virginia. Although I already knew most of what he explained about the mechanical couple, Greg provided me one new item of information: The forces between the two couple contacts increase on the limb as they are positioned progressively closer. Therefore, for comfort reasons, it is desirable to distance such contacts as much as possible.

I believed that Greg had listened to my explanation of Keith's design. He said that he would try to build a working prototype. Although I waited several months for Greg's prototype, it never came.

I had one last resort: Take the idea to Arthur. As stated already, doing so ran a high risk of permanent shutdown by Arthur. It was likely that I could not make him listen at all. I knew that I needed a brief statement to grab his attention. This technique had worked in the past. I planned such a statement that would sound as though I had simultaneously criticized his beloved Ten Requirement of Full-Range Exercise AND praised his mechanical ingenuity for the miraculous application of the couple.

I saw my opportunity one afternoon in 1984 as Arthur and I walked together across the parking lot at Nautilus. I said, "Arthur, your On-the-Side Leg Curl is the first machine ever to provide truly rotary resistance."

This jolted Arthur. He was uncertain of my meaning and became momentarily very agitated and impatient for me to explain. But as he was about to cross-examine me, another employee confronted him with a major business emergency. He rushed into the studios to take the phone at the security desk. He avoided me from then on, probably because he believed I merely wanted to plead with him to transfer me out of the Osteoporosis Study. My only chance had failed.

In 1986, I returned to work in Lake Helen. Clay Steffee and his staff were still at work on the medical machines. Clay had an on-the-side back testing machine displayed on the CADD monitor when I entered his office. Seeing this, I began to ridicule Arthur's on-the-side designs. I also chided Clay for acquiescing to such expensive tangents of nonsense. They were a design fetish Arthur just could not get out of his system.

[Arthur's worst tangents of his Nautilus era were the Duo-Poly Pullover, the on-the-side craze, and the Duo Squat. Of course, Arthur erroneously believed these two to be his all-time best designs of Nautilus vintage. And many of his old guard still stupidly swear by them.]

In explaining this, I detailed the neck, shoulder, thoracic, lumbar, pelvis, and knee misalignments and their unnecessary problems encountered in the On-the-Side Leg Curl. I also pointed out that, if we are intent on ideal medical treatment of any part of the spine, we desire an attitude so that the spine is aligned—thereby excluding on-the-side complications.

As I was speaking, Clay pulled up the CADD file for the On-the-Side Leg Curl to visualize my meaning. He then visually rotated the machine drawing to a vertical body attitude. Understanding some of my complaints, Clay hedged regarding how to keep the knees on the axis and how to support the body without sitting on the hamstrings. I recanted Keith's idea, and Clay exclaimed, "Damn, this is incredible. I will have George [Johns] prototype this, beginning Monday." Within a week, the prototype was built, but I did not get to see it because Arthur fired me. This had nothing to do with the Seated Leg Curl design.

Arthur was involved in negotiations to sell Nautilus and as part of the sales job he was doing on Travis Ward and any other prospects, Arthur wanted to present all of the potential products that were forthcoming from his various prototype departments. In June of 1986, Arthur walked through the Lake Helen prototype department and made mental notes of each project. He studied Joe Thibodeau's work on the medical rotary torso—later to become the MedX Rotary Torso. He expressed reserved excitement with an abdominal machine incorporating a moving axis. His eyes then focused on George's (really Keith Johnson's) Seated Leg Curl. It appeared so strange that Arthur gruffly asked, "What the hell is this?"

Clay calmly explained its concept, and George demonstrated its function. Arthur excitedly remarked that it was the most important Nautilus development in years. As I expected he would, Arthur grasped most of its value instantly.

Arthur and the prototype staff lingered around this prototype for another 15 minutes or so. Amidst this excitement, Ell Darden entered. Overhearing Arthur's remark, Ell blurted, "Arthur, Ken Hutchins has been trying to get someone to build this idea for almost three years."

Arthur quipped, "Well why the hell didn't he come talk to me about it?"

[I have told this story to several of Arthur's long-time employees—many of which still worked for him at the time. The most common reply after hearing the story came from Dick Wall, Nautlus employee and delivery expert. Laughing, Dick said, "Yep, that is exactly the way it is to work with Arthur."]

### Design Flaws

Before George built the prototype, I sternly asserted that it must include a translating seat. But George refused to include it. He stated that it would overly complicate the first prototype and that we might include a floating seat in a second prototype..

George's prototype worked exceptionally well. In fact, it held knee alignment too well in one respect, and this led to the possibility of minor knee irritation. He nor anyone else got around to including the translating seat. But as I had insisted, it was not dispensible.

We imagine the joints of the body to rotate in a circular arc. This assumption more precisely stated: the end of a bone that articulates about a joint proscribes a circle. This, in fact, is not the case. Any joint, particularly the knee, proscribes an ovoid (egg shaped) arc with the end of its corresponding limb.

For example: as your knee straightens, the radius of the condylar surfaces increases, and this effectively lengthens your leg. This effectively-added length is in the femur.

Ideally, the Seated Leg Curl must be designed so that you (all of your body above the knees) are permitted to move forward as the knees flex and then backward as they extend. This fore/aft translation is possible only if the seat is on a linear bearing system.

Such a linear bearing system is expensive. Nautilus balked at producing a Seated Leg Curl until 1987. It was first incorporated as one of the exercises in the first version of the Nautilus Multi-Station. (I helped Tim Tew photograph this machine in Dallas for marketing materials.) This seated curl incorporated pads that were too soft, thus permitting yet greater forward travel of the torso and thigh during flexion and causing greater knee irritation as the femurs were driven backwards during extension. No allowance was made for the seat to move during the exercise.

In 1988, George Johns prototyped a cammed plateloading machine that fared much better because its pads were stiffer. Slightly different couple contacts and seat positioning also

may have contributed to it success. It was not sold back then. However, as of circa 1998 Nautilus was marketing a cammed plateloader line—Power Plus—that probably includes George's 1988 work. The seat was stationary during the exercise.

Nautilus eventually developed a Seated Leg Curl to sell with its Next Generation line. Again, it irritated the knees because of too-soft pads and the lack of a moving seat. I condemned everyone's designs up to this time for their refusal to include the required moving seat bottom.

Eventually, Gary Jones produced and sold the Hammer Seated Leg Curl. Using Keith's same general concept, the Hammer version possessed the easiest and safest entry/exit, but its cam was grossly incorrect and could not be altered with after-market retrofits since it was a leverage machine. Still, it was devoid of a moving seat. It *seemed* that this machine was better tolerated by the knees than those of Nautilus.

In 1992, Clay Steffe's staff at MedX released its Seated Leg Curl. At first, I was so pleased that I advised Lincoln Fitness to purchase two of them. I also remarked to several associates that perhaps this machine did not require a moving seat after all.

The MedX incorporated stiff pads that did not seem to permit excess body translation at light loads. What I call wobble effect—the body's ability to move a few millimeters on the rolling of its flesh—seemed to adequately accommodate any fore/aft translation that occurs as a function of load, changing instant knee axes, and pad compression.

For awhile, I noticed few complaints of knee irritation from the MedX. Only exceptional subjects with extreme joint derangement lodged complaints; and I expected almost anything to irritate their knees. However, as time passed additional subjects encountered irritation.

Furthermore, I noticed that my knees were mildly irritated as they approached extension using heavy loads. Meanwhile, appreciate that no one used the machine's full extensional range. All subjects were carefully pinned a conservative distance from complete straightening, much more from hyperextension.

I eventually found that extension was more acceptable to my knees if I reduced the extension range yet further. Ellington Darden recommended that subjects be positioned somewhat further away from the movement arm. This seemed to help some subjects, but my knees seemed better if I moved closer to the movement arm. This seemed also to help some of the other subjects. However, I came to believe that only a moving seat design could make this machine live up to its full potential and once accomplished, would be a boon to so-called problems of shear effect.

Since knee excursion is ovoid, its instant axis demands not only a fore-aft, horizontal freedom, but also a simultaneous vertical freedom—upward-downward movement of the knee. Fortunately, I found that the knees automactically ride upwards a little during flexion. This accommodated this last concerrn.

[In the early 2000s, Nautilus manufactured a seated leg curl in its Nautilus One line in which the movement-arm axis moved—not the seat—to accommodate my requirement. It works better than a stationary axis like that in the MedX Seated Leg Curl, but its movement distance was fixed—with the assumption that all knees are the same and that distortion due to uphostlery compression, etc. wiould be constant. THE SEAT MUST BE ALLOWED MOVE ! NO EXCEPTIONS !]

If all the aforementioned problems of the prone Leg Curl were not enough to justify a coupled, seated design, note this subtlety: there is a crossover point during positive flexion of the prone design. Here, the subject is indecisive regarding exactly where he should commence flexing the hips. This can be adversely irritative, especially to subjects suffering from back complaints and especially if the subject flexes one hip before the other. This *should* cause back problems. And the reason I'm dropping this paragraph in now is that MedX—even with the advent of its Seated Leg Curl—continued to sell a prone Leg Curl...!!

The coupled, Seated Leg Curl maintains the hip at a moderately flexed position and also supports the torso, pelvis and thigh so that they cannot weave around. This indecision (crossover point) is removed from the exercise

Shortly after this article was written, I designed and sold many seated leg curls with a coupled movement arm and a floating seat. This design solved all of the inherent problems long-sufffered with this exercise. (See Photos)

For more current information on the couple please read my *Shear Forces? or Sheer Nonsense?* It can easily be found online. Also:

**http://www.ren-ex.com/exercise-for-the-human-knee-part-i/**

**http://www.ren-ex.com/exercise-for-the-human-knee-part-ii/**

**http://www.ren-ex.com/exercise-for-the-human-knee-part-iii/**

**http://www.ren-ex.com/exercise-for-the-**

**My initial attempt to provide a translating seat on a seated leg curl machine was to put a linear bearing table into the frame of a MedX Seated Leg Curl machine. It worked very well, but it also brought out two new deficiencies. Although I had radically increased resistance fall-off at complete knee flexion, it remained inadequate fall-off. Also, the timing of the such radical fall-out that I intended to provide had to be perfectly timed to the exact point of maximum knee flexion for each subject's joint delimitation. This could not be solved until I built the SuperSlow Systems Seated Leg Curl.**

**The Vintage SuperSlow Systems Seated Leg Curl. This device provided a coupled movement arm with a floating seat and a radical cam profile that could be perfectly timed with a crank to place minimum load exactly at the point of each subject's maximum knee flexion. Also, the crank provided a readout for perfect reproducibility of cam position. Photo taken in 2002.**


**The Nautilus One Seated Leg Curl. Instead of providing a moving seat, this machine accommodates the ovoid shape of the knee with a movement-arm axis that moves. This works considerably better than the vintage MedX counterpart, but still does not provide for the needed resistance fall-off or cam timing requirement. Also, the axis moved too much for some subjects and not enough for others.**